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OekoRess II: Country Case Study III

U.S.: Beryllium Mining (Spor Mountain)

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Abstract

The project "Further development of policy options for an ecological raw materials policy" (OekoRess II) builds on the results of two preceding research projects, UmSoRess and OekoRess I. It links experiences gained in the analysis of environmental and social standards with the assessment of environmental risks in the mineral resources sector. The project team conducts 10 case studies to evaluate and refine the method to assess site-related environmental hazard potentials posed by mining operations, which was developed in the OekoRess I project. The focus is on improving the indicator for environmental sector governance, by comparing the assessed environmental hazard potentials, the observed environmental impacts and the governance analysis with existing governance indicators. The aim is to answer the questions whether existing governance indices and indicators are able to adequately reflect the capacity of governments, companies and civil society to manage potential environmental hazards and avoid or reduce environmental impacts of mining.

This case study analyses the environmental hazard potentials and the environmental impacts of the the Spor Mountain mine in Utah, United States of America (U.S.), which is the largest beryllium producer in the world. Based on the available data, the environmental impacts of beryllium mining in Spor Mountain seem to be quite low. The main environmental impact are the large land footprint and potential health impacts, since beryllium is hazardous to humans. The mining company implements high health and safety standards that reflect today's best practices. The site-related environmental hazard potentials, identified by the OekoRess methodology, overestimated the hazardous potential of the use of auxiliary substances, mining waste management, the role of radioactive components and potential water stress.

The U.S.' overall strong sector governance is well captured by key governance and development indices. The Fraser Investment Attractiveness Index reflects the conditions at Spor Mountain particularly well. Environmental governance indices such as the Environmental Performance Index and the Environmental Democracy Index capture the strong environmental legislation well, but are not able to reflect specific regional challenges.

Kurzbeschreibung

Das Vorhaben „Weiterentwicklung von Handlungsoptionen einer ökologischen Rohstoffpolitik" (ÖkoRess II), welches auf den Ergebnissen zweier vorangegangener Forschungsprojekte (UmSoRess und ÖkoRess I) aufbaut, verbindet Erfahrungen aus der Analyse von Umwelt- und Sozialstandards mit der Bewertung von Umweltrisiken im Rohstoffsektor. Das Projektteam führte 10 Fallstudien durch, um die im Rahmen des ÖkoRess-I-Projekts entwickelte Methode zur Bewertung standortspezifischer Umweltgefährdungspotenziale im Bergbau zu evaluieren und weiterzuentwickeln. Der Fokus liegt auf der Verbesserung des Indikators für Umwelt-Governance, indem die bewerteten Umweltgefährdungspotenziale, die tatsächlichen Umweltauswirkungen und die Governance-Analyse mit vorhandenen Governance-Indikatoren verglichen werden. Ziel ist es, die Frage zu beantworten, ob die Governance-Indikatoren in der Lage sind widerzuspiegeln, inwiefern relevante Akteure (Regierungen, Unternehmen und Zivilgesellschaft) potentielle Umweltgefährdungen bewältigen und Umweltauswirkungen des Bergbaus vermeiden oder reduzieren können.

In dieser Fallstudie werden die Umweltgefährdungspotenziale und die Umweltauswirkungen der Spor-Mountain-Mine in Utah, USA, dem größten Berylliumproduzenten der Welt, analysiert. Auf Basis der vorhandenen Daten scheinen die Umweltauswirkungen des Berylliumabbaus im Spor-Gebirge gering zu sein. Die Hauptauswirkungen auf die Umwelt entstehen durch den großen Landverbrauch beim Abbau. Außerdem bestehen mögliche Auswirkungen auf die menschliche Gesundheit. Das Bergbauunternehmen hat jedoch hohe Gesundheits- und Sicherheitsstandards, die den heutigen Best Prac-

tices entsprechen. Die mit der ÖkoRess-Methode identifizierten standortbezogenen Umweltgefährdungspotentiale haben das Gefährdungspotential des Einsatzes von Hilfsstoffen, das Management von Bergbaureststoffen, die Rolle radioaktiver Komponenten und den potenziellen Wasserstress überschätzt.

Die insgesamt starke Bergbau-Governance der USA wird von wichtigen Governance- und Entwicklungsindizes gut erfasst. Der Fraser Investment Attractiveness Index erfasst die Situation der Spor-Mountain-Mine besonders gut. Umwelt-Governance-Indizes wie der Environmental Performance Index und der Environmental Democracy Index erfassen die strengen Umweltgesetze gut, können jedoch keine spezifischen regionalen Merkmale abbilden.

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List of Abbreviations

ASM	Acid Mine Drainage
AZE	Alliance for Zero Extinction
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
BLS	Bureau of Labor Statistics
CEQ	Council on Environmental Quality
DEQ	Department of Environmental Quality
DOI	Department of the Interior
EDI	Environmental Democracy Index
EITI	Extractive Industries Transparency Initiative
EPA	Environmental Protection Agency
EIS	Environmental Impact Statement
EPI	Environmental Performance Index
FLPMA	Federal Land Policy and Management Act of 1976
GDP	Gross Domestic Product
GML	General Mining Law of 1872
GPI	Global Peace Index
ha	Hectare (equal to 10,000 square meters)
HDI	Human Development Index
IEA	International Energy Agency
IRA	Indian Reorganization Act of 1934
Mt	Megatons (equal to million metric tons)
NEPA	National Environmental Policy Act of 1969
NGO	Non-Governmental Organization
NMA	National Mining Association
OSHA	Occupational Safety and Health Administration
OSMRE	U.S. Office of Surface Mining Reclamation and Enforcement
RAMS	Restoration of Abandoned Mine Sites
REEs	Rare Earth Elements
UN	United Nations
U.S. (USA)	United States (United States of America)
USACE	U.S. Army Corps of Engineers
USFS	U.S. Forest Service
USGS	U.S. Geological Survey

USORC	Utah Surface Owner Protection Act of 2012
WGI	Worldwide Governance Indicators

1 Focus of the study and relevance

The following case study is the third of ten case studies that are being prepared as part of the project "Further development of policy options for an ecological raw materials policy" (OekoRess II) commissioned by the German Federal Environment Agency. The case studies build on the results of two research projects, the UmSoRess[1] project and the OekoRess I[2] project. In UmSoRess, the impacts of raw material production on the environment, society and the economy were analyzed in 13 case studies.[3] The goal of the case studies was to gain a better understanding of the connections between the environmental and social impacts of mining in the context of various countries with different problems and governance contexts. In OekoRess I, a method was developed to evaluate the ecological availability of raw materials and the site-related potential for environmental hazards posed by mining operations with the aim of further developing the criticality concept.

As part of the follow-up project OekoRess II, 10 additional case studies will be conducted combining the analytical approaches of UmSoRess and OekoRess I in order to evaluate and further develop the method to assess the site-related potential for environmental hazards posed by mining operations, which was developed in the OekoRess I project. This effort will focus on improving the indicator for environmental sector governance used in the methodology, by comparing the assessed potential for environmental hazards, the observed environmental impacts and the governance analysis with existing governance indicators. The aim is to answer the question if existing governance indices and indicators are able to adequately reflect the capability of governments, companies and civil society to manage potential environmental hazards and avoid or reduce environmental impacts of mining. The results of the 10 case studies will be compared and a set of governance indicators will be identified that can be used to improve the raw-material-specific assessment approach developed as part of the OekoRess I project.

This case study analyses the potential for environmental hazards and the environmental impacts of the Spor Mountain mine in Utah, United States of America (U.S.), and the country's mining governance. The mine is the only developed source of beryllium in the country and the largest beryllium producer in the world. Beryllium metal has very specific characteristics that make it an important component of a number of applications. It is used in air- and spacecrafts, industrial components, consumer electronics or telecommunication infrastructure or military devices (USGS 2016). The metal is one of the lightest structural metals and is almost seven times more durable than steel. It also offers a high heat absorption capacity and is an excellent thermal conductor (Wagner 2006).

The case study is structured in four parts: First, the structure of the U.S. mining sector and its contribution to the national economy is analysed (chapter 2). Second, a brief overview of the Spor mine is given. The geographic and geologic context is analysed followed by an overview of the applied mining and processing methods (chapter 3). Third, the potential for environmental hazards posed by the mining operation is discussed using the OekoRess I methodology and selected environmental impacts and reactions to these are described using the DPSIR framework that was also used in the UmSoRess case studies (chapter 4).[4] Fourth, the governance of the U.S.' mining sector is analysed (chapter 5) and finally, the findings of the assessment of the potentials for environmental hazards and environmental

[1] Approaches to reducing negative environmental and social impacts in the production of metal raw materials. For more information see https://www.umweltbundesamt.de/umweltfragen-umsoress

[2] Discussion of ecological limits of raw materials production and development of a method to evaluate the ecological availability of raw materials with the aim of further developing the criticality concept. For more information see https://www.umweltbundesamt.de/umweltfragen-oekoress

[3] The case studies and fact sheets on the standards and approaches analysed can be accessed here: https://www.umweltbundesamt.de/umweltfragen-umsoress

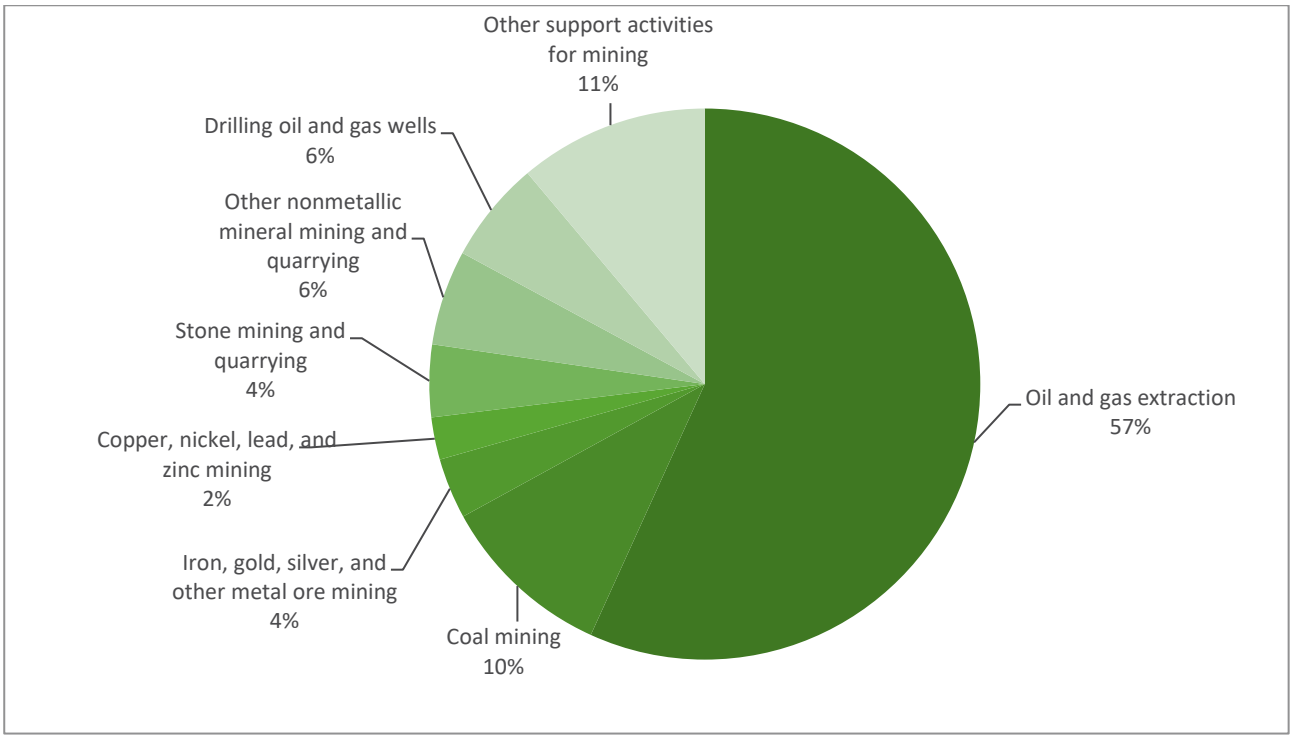
[4] The DPSIR framework comprehensively accounts and visualizes the causal connection between environmental issues, their origin, their impacts and the responses taken. The model consists of driving forces, pressures, State, impacts and responses. For further information, see e.g. Kristensen (2004).

impacts and the governance analysis are compared to existing governance indicators and indices, and first conclusions for the methodology development are drawn (chapter 6).

2 Structure and macroeconomic relevance of U.S. mining sector

The mining sector is of particular importance for the U.S. economy. The sector contributed (directly and indirectly) $220.4 billion to the Gross Domestic Product (GDP) in 2015 (direct contributions were around $100 billion), which was around 1.2 % of total GDP, according to the World Bank (2016; NMA 2016, data for 2015). This contribution was made up of a coal[5] sector share of $65.6 billion, a metal ore[6] sector share of $54.5 billion and non-metallic[7] mineral sector share of $100.3 billion (NMA 2016). In 2015, non-fuel raw materials produced by the mining sector in the country had an estimated value of $78 billion[8], which, after processing and handling, resulted in processed mineral materials worth $630 billion (NMA 2016d). Figure 2-1 illustrates the shares of the various sub-sectors of the U.S. mining and minerals manufacturing. Oil and gas extraction accounted for the major part of mining sector's contribution (57 %); coal mining took a share of 10 %.

Figure 2-1: Sub sector contribution to the GDP of mining and mineral manufacturing in 2015



Source: BEA (2017).

[5] "Mining of bituminous coal, anthracite, lignite by all types of mining; development of coal mine sites; beneficiating (preparing) coal" (NMA 2016:21)

[6] "Establishments engaged in developing mine sites or mining metallic minerals; ore dressing and beneficiating operations, such as crushing, grinding, washing, etc. Beneficiating may be performed at mills operated in conjunction with the mines served or at mills operated separately" (NMA 2016:21)

[7] "Establishments engaged in developing mine sites, mining or quarrying non-metallic minerals (except fuels (i.e. oil and gas)). Also included are certain well and brine operations, and preparation plants primarily engaged in beneficiating non-metallic minerals" (NMA 2016:21)

[8] An estimated number, might be changed to a greater or lesser side by NMA

There are a number of U.S. states that significantly contribute to the economy of the country due to mining activities. According to the U.S. Department of the Commerce (BEA 2017a), the largest contributor to the GDP from mining activities[9] in 2015 was Texas ($150,631 million), followed by Oklahoma ($23,114 million) and Pennsylvania ($17,408 million). In 2015, the greatest value of non-fuel mineral products was produced in Nevada ($6,940 million; gold, copper, silver, diatomite), followed by Arizona ($6,800 million; copper, molybdenum, cement) and Texas (over $5,000 million; stone, cement, sand and gravel, salt) (USGS 2016a). In Utah, the value of produced non-fuel minerals amounted to $2,930 million (molybdenum, copper, potash, beryllium) (USGS 2016a).

The exports of mining products (export of all oil, gas, minerals and ores) contributed $34,829 million to the U.S. economy in 2015, which was a 2.3 % share of the country's overall export revenues (ITA 2017). Oil and gas[10] export had a value of $20,333 million, and export of minerals and ores[11] had a value of $14,496 million. According to the estimations of NMA (2016), in 2015, the U.S. mining activities generated $18,000 million of total direct taxes and $26,000 million of indirect tax payments. Four of the top 40 mining companies of the world belong to or have major shares in the U.S. (PwC 2016; MINING.com 2017).

The U.S. mining sector is not only an important contributor to the economy, but also a large job provider. In 2015, the mining industry both directly and indirectly employed around 1.7 million people (1.1 % of total labour force in 2015) (based on BLS 2017 and NMA 2016a, data for 2015). Of this, the minerals mining sector directly employed 415,000 people and indirectly employed 734,000 (NMA 2016a).

The U.S. is a minerals-rich country, holding 24.5 % of global molybdenum, 5.6 % of lead, 5.5 % of zinc; 5.4 % of gold, 4.6 % of copper; 4.4 % of silver and 4.1 % of iron ore reserves (NMA 2016e). Ten of twenty critical raw materials are produced in the U.S. (European Commission 2014). It was the second largest producer of minerals (incl. mineral fuels) and the third largest producer of rare-earth (REEs) concentrates (following China and Australia) globally in 2014 (BMWFW 2016). Table 2-1 outlines information on the U.S. production of minerals[12] and their importance for the global market.

The country is the world's leading producer of beryllium and the second largest producer of molybdenum after China (BGS 2017, INN 2016a). In 2015, the U.S. produced 275 tons of beryllium, but production decreased in 2016 to 190 tons, resulting in a drop in the U.S. share of global beryllium production from 92 % in 2015 to 86 % in 2016 (NMA 2016f; 2017). This decrease in beryllium's sales was due to the falling demand from the energy sector, as oil and gas production widely use beryllium (USGS 2017; Materion Corporation 2017b).

[9] In this case – SIC (Standard Industrial Classification) definition. Mining in broad sense: extraction of all solid, liquid and gaseous minerals; quarrying; well operations; milling; other preparations at the mine site or as a part of mining activity (BEA 2017b).

[10] Oil and gas, category 211 in NAICS, includes crude petroleum, oil (incl. from oil shale and sands), natural gas, sulfur recovery from natural gas, recovery of hydrocarbon liquids (NAICS 2017).

[11] Minerals and ores, category 212 in NAICS, all metallic and non-metallic minerals, incl. coal (NAICS 2017).

[12] Oil and natural gas production is excluded

Table 2-1: U.S. Mineral Production

Mineral [*= critical according to EC 2014]	Production 2015 (unless otherwise noted)		
	Volume [t] (unless otherwise noted)	% of ∑ World	Rank
Beryllium*	275	92	1
Borates*	1,300,000	21.5	2
Cobalt*	760	0.5	16
Coking Coal[13]*	57,400,000	5.2	4
Copper	1,380,000	7	4
Germanium*	3	2	4
Gold	212	7	4
Lead	385,000	7	3
Molybdenum	56,300	19.3	2
Nickel	27,167	1	14
Palladium*	12.5	6	4
Phosphate Rock*	27,600,000	10.4	2
Platinum* (2016)	3.7	2	5
Potash (K_2O equivalent)	770,000	2	9
REE*	2,460	1.6	3
Silver	1,100,000	4	9
Titanium (mineral concentrates)	100,000	2	15
Uranium (metal content)	1,287	2.1	10
Zinc	780,000	7	4

Source: BGS (2017); NMA (2016f[14]); IEA (2016).

The private sector dominates the mining industry in the US. The sector is furthermore characterised by mining companies of all sizes, ranging from small companies with less than 100 employees and medium sized companies to some of the world largest mining companies, which are headquartered in the U.S:, like Newmont Mining, Peabody Energy and Freeport-McMoRan (PWC 2012; Baker and McCulloch 2013).

Beryllium extraction and processing in the U.S. is mainly done by the multinational company Materion, which is headquartered in Ohio and is the only fully integrated beryllium products supplier globally. The company is also the owner of the Spor Mountain mine (BeST 2016).

[13] Data from IEA 2016

[14] NMA (2016f) source is used only for beryllium, number is consistent with Statista 2017

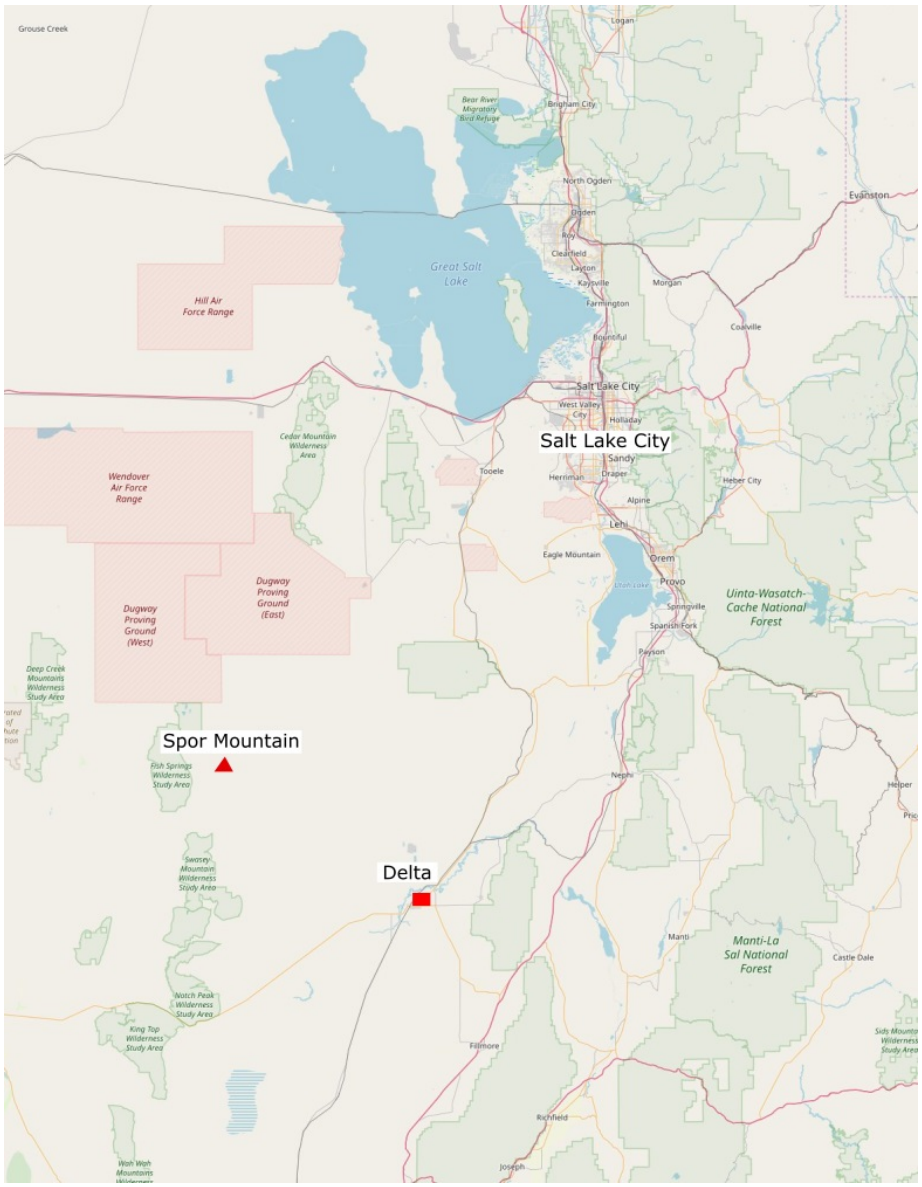
3 Overview of the Spor Mountain geology and the mining operation

Currently, the majority of world Beryllium supply is produced by the Spor Mountain Mine in the United States. The deposit was discovered in 1959, the first pit opened in 1968 and production at the mill started one year later (Wagner 2006). The operator of the mine Materion Resources is the largest beryllium producer in the world (Gwynn et al. 2011).

3.1 Geography

The beryllium deposit at the Spor Mountain is located in the Juab County in northwestern Utah (U.S.) (compare Figure 3-1). The mine is situated in the west of the Thomas Mountains. The mining properties are located approximately 47 miles north-west of Delta, where the company's mill is situated (compare Figure 3-1and Figure 3-2). Before the beryllium mining project started, the region had already been commercially mining fluorspar and uranium (Wagner 2006). The Yellow Chief mine northeast of the Spor Mountain Deposits was the largest uranium mine in the county until its closure in 1962 (Ege 2005) (compare Figure 3-2).

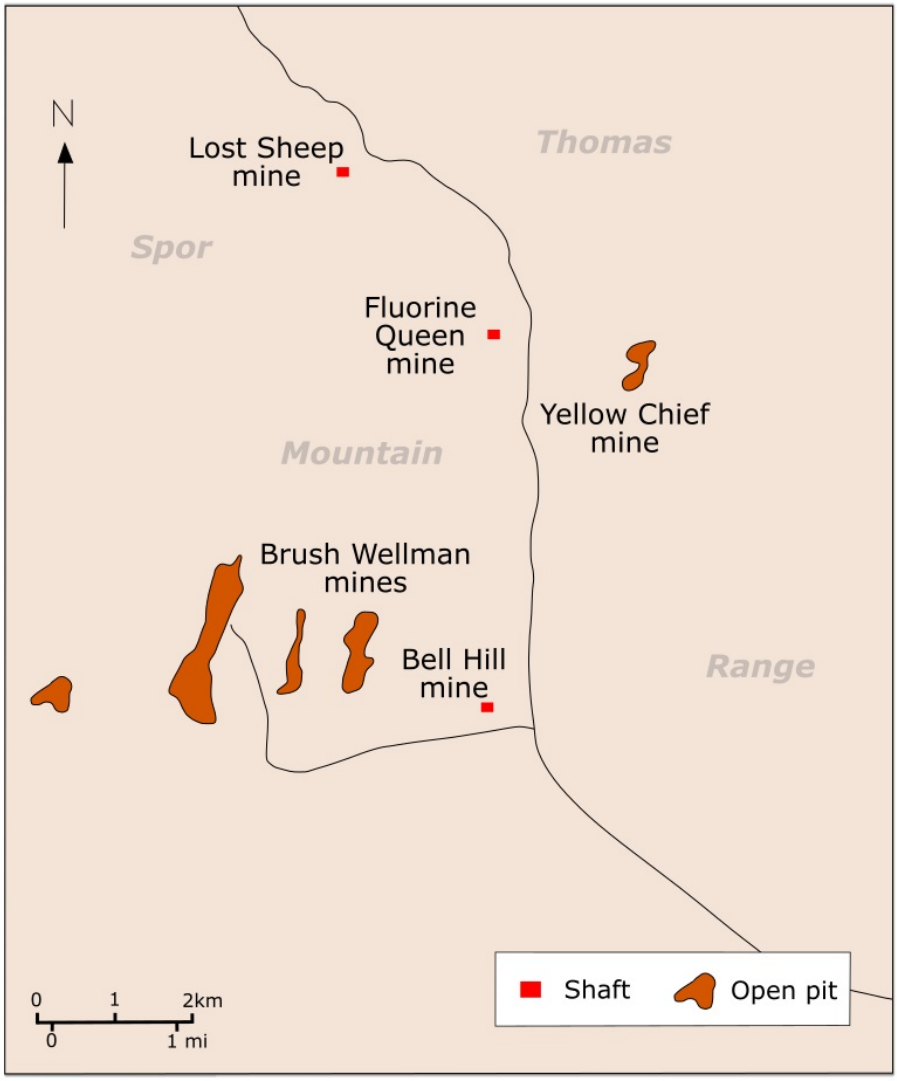
Figure 3-1: Location of selected mines and mining districts in Utah



Based on Open Street Maps.

The climate of the region is arid to semi-arid and represents a cold desert or cold semi-arid climate, according to the Köppen climate classification. The summers are hot with average maximum temperatures of 34° C in July, and winters are cold with average minimum temperatures of 11° C in January. The average annual precipitation is 219 mm (U.S. Climate Data 2017; Foley et al. 2012).

Figure 3-2: Location of the beryllium deposits



Source: Based on Ege (2005).

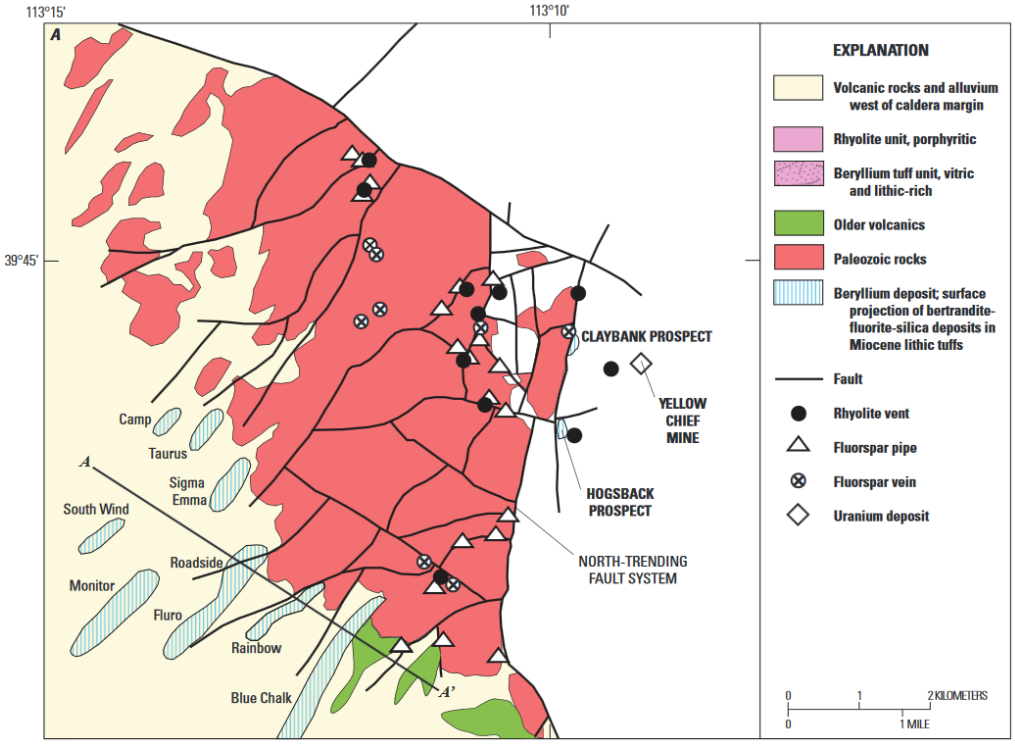
Prior to mineral extraction, the region was used for grazing. Today, the surrounding properties of the mine are still used for cattle and sheep. Wildlife in the area consists of small mammals, birds and antelopes (Wagner 2006).

3.2 Geological context and ore deposit formation

The deposits are made up of westward tilted and faulted marine sedimentary rocks from the Palaeozoic era, which are covered by volcanic tuffs and flows from the Tertiary era. The Spor Mountain formation was deposited approximately 21 million years ago, through volcanic eruptions and erosion of older volcanic material. The latter is composed of tuff, rhyolite, sandstone and conglomerates. Hydrothermal processes let to the deposition of the beryllium bearing ore through faults in the host rock: the strongly porous and carbonate bearing tuff reacted with the mineralized hot fluids and precipitated after cooling down (Ege 2005; Lederer et al. 2016; Barton and Young 2002) (compare Figure 3-3). The

mined ore is bertrandite, which is a hydrous beryllium silicate (BE4Si2O7 (OH2)). The betrandite occurs as stratiform tuff varying in thickness and grade (Wagner 2006). The Spor Mountain deposit is currently the only known example of this deposit type, which is economically feasible to mine (Lederer et al. 2016).

Figure 3-3: Geologic map of Spor Mountain



Source: Lindsey (2001) modified by Foley et al. (2012).

3.3 Mining and Processing

The company Materion is mining bertrandite ore from eight open pit mines at the Spor Mountain. Earlier plans for an underground mine to extract the ore failed due to poor ground conditions (Trueman and Sabey 2014). The removal of overburden and waste rock is referred to as open-pit pre-stripping. Earth moving machines are used to move overburden and waste rock to expose a three to five year supply of bertrandite ore. The mine uses a modified bench system, where the ore body's strike is followed (Wagner 2006). The deposits are mined to shallow depths of 30 to 50 meters due to the stripping costs of the hard rhyolite cap rock (Ecclestone 2014; Lindsey 1978).

There is no visual difference between the beryllium rich bertrandite ore and the surrounding material (Wagner 2006). The beryllium mineralization is colorless and the crystal structure is too small to be visually distinguished (Ecclestone 2014). The company therefore carefully samples the ore to determine its grade. Drill samples are tested in the laboratory; afterwards, cutoff points in the field are determined using a portable neutron-activated beryllium analyzer (berylometer) (Trueman and Sabey 2014; Wagner 2006). The orebody is then mined by loaders guided by in-pit assaying with a berylometer. After the extraction, the ore is stockpiled in thin layers, creating a homogenous blend that is suitable for the mill to process. There is no concentration process at the mine site; the ore, which is ready for transport has an average beryllium grade of 0.265 %. The ore is then transported by trucks to the mill (Trueman and Sabey 2014).

The milling operations of the mine occur in Delta, where the bertrandite ore from the mine and imported beryl ore are processed (Wagner 2006; Ecclestone 2014). The bertrandite ore is first crushed and wet grinded followed by a wet screening process. Afterwards, the ore is leached with a sulfuric

acid solution at temperatures of 95°C to extract the beryllium and form a beryllium sulfate solution. A solvent extraction process is then used to remove impurities from other elements that were extracted with the ore. The waste slurry is stored in a tailings dam facility (Trueman and Sabey 2014).

The finished product at the mill in Delta is beryllium hydroxide, which is then either shipped to facilities in Elmore (Ohio) where it is converted to metal or sold to other producers of beryllium products (Lederer et al. 2016; Mc Lemore 2010).

4 Overview of environmental hazard potentials and environmental impacts

4.1 Environmental hazard potentials

As part of the OekoRess I research project an evaluation scheme for assessing the environmental hazard potentials (EHPs) of the extraction of primary abiotic raw materials was developed. This evaluation scheme is based on indicators, which are assigned to three levels of consideration. These levels are geology, technology and site surroundings. The level "Geology" comprises five indicators, which include environmental factors inherent to the geology on site. These key influencing factors are "precondition for acid mine drainage (AMD)", "paragenesis with heavy metals", "paragenesis with radioactive components", "deposit size" and "specific ore grade". The second level is "Technology" and includes the indicators "mine type", "use of auxiliary substances", "mine waste management" and "remediation measures". The third level "Site (surroundings)" comprises the indicators "natural accident hazard due to floods, earthquakes, storms, landslides", "Water Stress Index (WSI) and desert areas", and "protected areas and Alliance for Zero Extinction (AZE) sites". Furthermore, the indicator "conflict potential with local population" focusses on the social context. The latter indicator is further developed by analysing ten case studies of which the present case study is one.

The environmental hazard potential for each indicator can be rated as low (green), medium (yellow) or high (red) (for detailed information on the method see Dehoust et al. 2017b). Table 4 1 shows the evaluation of the EHPs of the Spor Mountain beryllium mine, which are described in detail below.

The assessment of the EHPs of the Spor Mountain beryllium mine is followed by an analysis of the actual situation and impacts of the mining activities on the environment as well as the responses from the mine site operator, the responsible authorities as well as the local communities, using the DPSIR framework (Chapter 4.2).

Table 4-1: Site-related OekoRess assessment

Thematic Cluster	Indicator	Potential for environmental hazards		
		low	medium	high
Geology	Preconditions for acid mine drainage (AMD)	X		
	Paragenesis with heavy metals		X	
	Paragenesis with radioactive components			X
	Deposit size			X
	Specific ore grade	X		
Technology	Mine type			X
	Use of auxiliary substances			X
	Mining waste management			X
	Remediation measures	X		

Thematic Cluster	Indicator	Potential for environmental hazards		
		low	medium	high
Site (surroundings)	Natural accident hazard due to floods, earthquakes, storms, landslides	X		
	Water Stress Index (WSI) and desert areas			X
	Protected areas and Alliance for Zerto Extinction (AZE) sites	X		
	Conflict potential with local population	X		

4.1.1 Geology

Preconditions for acid mine drainage (AMD)

According to Foley et al. (2012) data on acid-base accounting for the Spor Mountain mine are not available. Nonetheless, the composition of minerals, which includes carbonate minerals as clasts and a lack of sulfide minerals, indicates that waste material should be overall alkaline. Moreover, beryllium is a litholphile element that usually mineralized in oxidic deposits. Accordingly, the potential for acid mine drainage is low (*low potential for environmental hazards*).

Paragenesis with heavy metals

An analysis of the chemical composition of the mineralized tuff at the Spor Mountain shows the presence of lead and zinc. A median of 42 mg/kg of lead (Pb) and a maximum of 1600 mg/kg of zinc were detected (Foley et al. 2012). Due to the low AMD potential, heavy metals forming a solution is rather improbable. Nonetheless, the presence of lead and zinc poses a certain risk for contamination with heavy metals (*medium potential for environmental hazards*).

Paragenesis with radioactive components

The region has been commercially mining uranium for the past few decades (Wagner 2006). The deposit Spor Mountain itself is associated with uranium enrichments, which creates a high risk for radioactive contamination (Foley et al. 2012). In the past, the applied processing method involved the extraction of uranium from the ore (Stonehouse 1985) (*high potential for environmental hazards*).

Deposit size

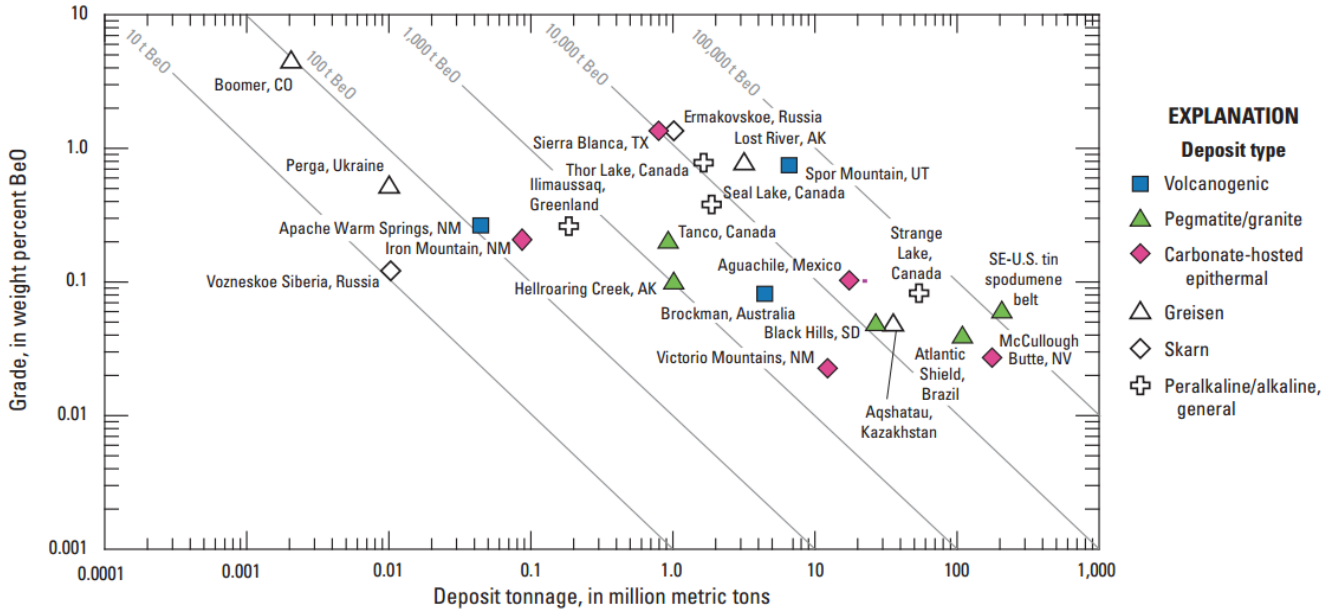
The Spor Mountain is the largest mine extracting beryllium ore globally (compare Figure 4-1). According to Materion's annual report, there are approximately 8 million tons of beryllium ore in Utah (Spor Mountain) that contain roughly 20,000 tons of beryllium, which could last at least 75 more years (Materion Corporation 2017). In 2015, around 73,500 tons of bertrandite ore were mined. Accordingly, the deposit is large and poses a high risk for ecological damage. A larger deposit usually affects a larger surface area, especially if it is an open pit mine (*high potential for environmental hazards*).

Specific ore grade

According to Barton and Young, the average ore grade is 0.72 % Beryllium Oxide, Ecclestone assumes an average ore grade of ca. 1 % Beryllium Oxide (Barton and Young 2002; Ecclestone 2014). No other large mines extracting beryllium ore currently exist. The deposit is the only economically important one of this kind. Hence, the ore grade can be interpreted as rather high. In comparison with other known deposits, the ore grade at the Spor Mountain mine ranks among the richest (compare Figure

4-1). A low ore grade would result in the production of larger waste material volumes. As the ore grade can be interpreted as high, it poses no significant ecological hazard potential (*low potential for environmental hazards*).

Figure 4-1: Overview of grade and tonnage of the most important beryllium ore deposits in the world. Diagonal lines show equal value of contained metal in metric tons



Source: USGS (2016).

4.1.2 Technology

Mine type

Currently, Materion extracts ore from 8 pits applying an open-pit pre-stripping method. The method involves the removal of large amounts of overburden and waste rock (Wagner 2006; Ecclestone 2014; Trueman and Sabey 2014) (*high environmental hazard potential*).

Use of auxiliary substances

The crushed ore is leached with sulfuric acid. The use of chemical reagents such as sulfuric acid, as well as the application of a solvent extraction process poses a high environmental risk (*high environmental hazard potential*).

Mining waste management

Concentration activities are not taking place at the mine site but at the mill. After separating the beryllium sulfate solution from the waste material, the slurry is stored in a tailings storage facility. The total size of all basins combined adds up to ca. 80 ha containing all tailings accumulated since the opening of the plant in 1969 (compare Figure 4-2). Materion has a number of monitoring wells around the tailings pond to control ground water quality and to stay in line with Water Quality Permit regulations from the Utah Department of Environmental Quality (DEQ Utah 2014). The area has a dry climate and clay horizons, which significantly lower the risk of a breach of the tailings. However, the storage of slurry in a tailings dam facility has a very high environmental damage potential in case a breach occurs. Potential deterioration includes contamination of ground waters in the area, pollution of the Sevier River (approx. 1.5 km away from the tailings pond) and the Yuba Reservoir downstream and the chemical pollution of the soils(*high environmental hazard potential*).

Figure 4-2: Satellite image of the processing plant northeast of Delta

Source: Screenshot from Zoom Earth 2017 (NASA Satellite Images)

Remediation measures

Materion acts in compliance with the Utah Mined Land Reclamation Act of 1975. In 1977, the company filed a reclamation plan. Revised plans were submitted in 1981 and 1988 (Wagner 2006). Topsoil is often used to cover dumps and waste rock is used for backfilling. Some mines have already been back-filled and reseeded with native plants (Mining Focus 2011; Materion Corporation 2017c).

The company had a program that tested the best possible techniques for revegetating the dumps. Subsequently, the company was awarded the Utah Divison of Oil, Gas and Mining's 2000 Earth Day Award for its remediation measures (Wagner 2006) *(low environmental hazard potential).*

4.1.3 Site (surroundings)

Natural accident hazard due to floods, earthquakes, storms, landslides

The total natural disaster risk is assessed by analyzing four individual sub-indicators. The evaluation is carried out in acordance with the measurement instructions, which suggest to use georeferenced data from publicly available risk maps. The results are taken directly from the given risk assessment:

- The risk for earthquakes is low according to the risk maps used, even though earthquakes in Utah occur rather often.Up to several hundreds of small earthquakes are registered every week in the area of Thomas Range (earthquakes with a magnitude between 1 and 3.5 on different depths are registered weekly (Earthquaketrack 2017)).
- The risk for floods is low;
- The risk for tropical storms is low;
- The risk for landslides is medium.

The indicator total is derived by the highest hazard potential of the sub-indicators.

Moreover, environmental disasters happen frequently in Utah that are not part of the evaluation but should be mentioned here nevertheless: Tornados hit the region occasionally; however, they occur less frequently than in some other U.S. states. The volcano index for Utah also oversteps the U.S. average by 8.3 times, though the last known volcanic eruption happened over 5 centuries ago (USA.com 2017).

Although these risks exist, the potential that they seriously affect the operation and induce environmental damage is low (*low environmental hazard potential*).

Water Stress Index (WSI) and desert areas

The WSI by Pfister et al. (2009) provides characterization factors on the relative water availability at watershed level. The indicator combines this information with an evaluation whether the site is located in a desert area. Mining operations often need large amounts of water for the operation. Depending on the hydrological situation, a competition for water between the different users can occur. The evaluation was carried out in accordance with the procedure described in the measurement instructions (Dehoust et al. 2017a). According to the World Resources Institute (WRI 2013), the U.S. has a medium water stress score of 2.9 (score from 0 to 5), with Utah being the second driest state of the U.S. (Utah Natural Hazards Handbook 2008). The region "remains in moderate drought," facing drinking water shortage in some cities (Desert News Utah 2014a) (*high environmental hazard potential*).

Protected areas and Alliance for Zero Extinction (AZE) sites

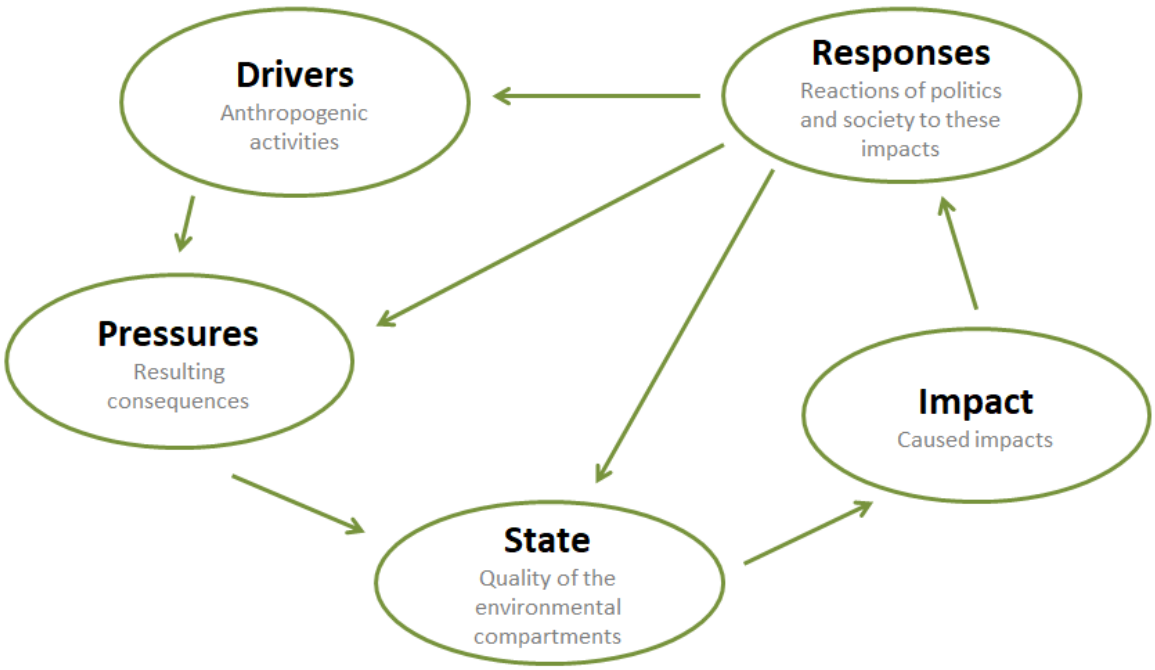
Georeferenced data for designated protected areas are used to assess hazards posed by mining extraction. The metric to evaluate EHPs corresponds to the method first described in the draft standard of the Initiative for Responsible Mining Assurance (IRMA 2014). The evaluation shows that there are no protected areas close to the beryllium mines of the Spor Mountain (*low environmental hazard potential*).

Conflict potential with local population

The governance indicators "Voice and Accountability" and "Control of Corruption" are both over 80 % (World Bank 2016a) If both indicator values are ≥ 65 %, conditions for peaceful negotiations environment-induced conflicts can be supposed (*low environmental hazard potential*).

4.2 Environmental impacts

Figure 4-3: DPSIR-Framework



Source: Own preparation, based on Kristensen (2004).

The DPSIR framework is a systemic analytical approach to better understand the interaction of humans and their environment in order to derive adequate policy measures. It comprehensively accounts for and visualizes the causal connections between human activities, the resulting consequences for the environment and the responses of humans. The model consists of driving forces, pressures, state, impacts and responses[15].

Due to the lack of information about the Spor Mountain beryllium mine and its environmental impacts, the following chapter focuses on common impacts of beryllium on the environment and human health and refers to specific mine sites whenever possible. This information was mainly gathered from the operating company reports, company web sites and company information. Furthermore, documents from the Utah Department of Environmental Quality (DEQ) and the U.S. Geological Survey (USGS) data were used. There is a notable lack of information concerning the mine from Non-Governmental Organizations (NGOs), public organization or local communities.

4.2.1 Pressure

Beryllium mining at the Spor Mountain started in 1968. The processing plant (mill) is situated 16 kilometres from the closest city, Delta, and the mine itself is around 80 kilometres away (CLUI 2017). The mining operation and processing has directly and indirectly affected an area of 3,000 ha and another 89 ha is affected by a tailings pond in Delta. There is only limited information on specific pressures

[15] For further information on the DPSIR framework and its elements see Kristensen (2004).

generated from the Spor beryllium mine as well as from the mill in Delta city. This might be due to the fact that Materion is a major global beryllium producer, with strict standards in place for each of its processes. However, as with any mining activities, the beryllium mine at the Spor Mountain has a number of impacts on the environment and human wellbeing, including land usage and negative effects on both water bodies and human health. The major impacts will be outlined in the following paragraphs.

4.2.2 State and Impacts

Surface disturbance and wildlife

Spor Mountain is situated in a desert area, where flatlands are covered by sparse vegetation that reaches only 0.3 meters high (or 0.6-1 meters along water bodies) due to a lack of moisture. The mountain sides have more developed flora; however, since the mountain is of relatively low elevation, no concrete vegetation zones can be distinguished in the area (Staatz & Carr 1964). Before the demand for beryllium increased in the 1960s, the mountain slopes, currently allocated to mining pits, used to be grazing areas for livestock and wild animals. Some sheep and cattle are still grazing on territories belonging to the mining company (Whitley 2006). Wildlife is also observed in the area (Materion Corporation 2017a).

Water pollution

Beryllium is insoluble in water and, therefore, accumulates in sludge. It is unlikely to affect fish if the mineral dust reaches water bodies or if other animals drink such water (Lenntech n.d.). According to the water survey of 2016, which was published by DEQ Utah, concentration of beryllium in drinking water in the state of Utah was far below the allowable limit (DEQ Utah 2016).

Air pollution

Beryllium dust might remain in the air for several days, but is easily removed by rain or snow. Beryllium concentration in the air in the U.S. has an average value of 0.03 ng/m^2; the number is higher for cities (reaches 0.2 ng/m^2), where beryllium is released into the air through coal and fuel burning processes (Cooper & Harrison 2009). In 2012, Materion, in cooperation with the United Steelworkers, addressed the United States Occupational Safety and Health Administration (OSHA) with a joint suggestion to make the beryllium airborne standard 200 ng/m^2 instead of the previous standard of 2000 ng/m^2 (The New York Times 2015a): "Materion Brush Inc. recommends that users of beryllium containing materials maintain worker exposures to airborne beryllium to levels reliably below its recommended exposure guideline (REG) of 0.0002 milligrams (equal to 200 ng) beryllium per cubic meter of air" (Materion Corporation 2011).

Health impacts

If the concentration of beryllium exceeds the set limits in dust, mist or fume, its small particles enter human lungs and provoke lung granulomas[16]. This can lead to a chronic beryllium disease (CBD) or berylliosis (The Elements Unearthed 2010). Additionally, beryllium can cause allergic reactions and disturbance of the skin surface (Cooper & Harrison 2009). Beryllium was at one point considered to be a carcinogen; however, the latest research shows that this element rarely causes cancer (Lenntech n.d.; Gunn 2013). Nowadays, the risk of getting CBD during beryllium mining and processing activities is considered to be rather low due to higher safety standards and modern technologies that improve workers' protection (see section "Responses") (Gunn 2013).

[16] Small neoplasms, formed by white blood cells when they surround beryllium particles, stuck in mucous membrane or in lung alveoli.

The harmful effects of the contact between beryllium and the human body were not well-known until the mid-1960s; therefore, many employees working in the beryllium industry at that time fell sick. An increased number of diseases among workers were observed at the Brush Wellman (currently, Materion) processing plant in Ohio (The Elements Unearthed 2010). After a new plant was built in 1960s, safety and health standards were improved. There is no detailed data on the current situation in the Spor Mountain mine; however, the company provides information that the health and safety standards at the mine site are up to date and reflect today's best practices (see section "Responses").

4.2.3 Responses

A range of measures are being undertaken by both Materion and the government to minimize pressures and negative impacts of beryllium mining and processing activities.

In order to decrease stresses to soils and surface, Materion has a "life-on-mine" mining strategy, which includes reclamation activities on site and making sure that wild animals have access to the area. After topsoil is removed to get access to the ore, it is processed and moved nearby, for example, to dumps or old backfilled pits, which are then covered with the saved soil and reseeded. Materion also uses modern methods of dump construction and seedbed maintenance. Native plants' seeds are used to revegetate the areas in order to avoid the spread of invasive species (Materion Corporation 2017a). The company even received an award[17] for these innovative approaches (s. section "Mine closure plan" above).

With the aim of controlling water quality and staying in line with Water Quality Permit regulations from the Utah Department of Environmental Quality and the EPA's Clean Water Act, Materion has a number of monitoring wells around the tailings pond (DEQ Utah 2014). The company takes samples on a regular basis and monitors not only the content of beryllium, but also other potentially hazardous elements.

Air quality is regulated by the Clean Air Act from the EPA (beryllium is included in the EPA's list of dangerous air pollutants) and OSHA's requirements (i.e. Urban Air Toxics Strategy) (Report on Carcinogens 2016). Materion installed filters on exhaust ventilation to prevent beryllium particles from getting into the air around the mill. The workers of the company frequently handle ventilation equipment monitoring (Materion Corporation 2011a).

After recognizing the hazardous nature of beryllium, Materion introduced effective safety regulation measures for the employees. The company instituted safety practices for the work with beryllium, which include wet methods and exhaust ventilation (Materion Corporation 2011a). Furthermore, the company provides respirators and special clothing for the workers in order to prevent beryllium contact with the skin and block beryllium from entering workers' lungs. Furthermore, air samples are taken in all places where beryllium processing is done, and tools and machinery parts are cleaned on a regular basis with special reagents and liquids. In 2003, Materion implemented an innovative Worker Protection Model (WPM), containing 8 levels of protection measures of the employees (Materion Corporation n.d.).

[17] Annual event, celebrated on a global scale and marking an anniversary of the appearance of the modern environmental movement.

5 Governance

Regulation of mining in the U.S. is complex – every mine has its own unique composition of stipulations, depending on, among other things, each state's individual legal statutes, the type of land where the mine is located (if it is private, state-owned, federal, tribal), the kind of natural resource that is being extracted, the type of mining operations and the individual environmental conditions in the area of mining operations. Control and regulation of mining processes include federal and state governments with various regulatory agencies and sometimes overlapping laws (United Nations 2010), which at times make some legal processes, like the permission process, complicated from a mining company's perspective (Minerals make Life 2014). This complexity prolongs the permission process on mining activities in the U.S. for up to 10 years, which is five times longer than in Australia or Canada (Minerals make Life 2014).

5.1 Sector governance, regulation and effectiveness of national institutions

Land ownership and licensing

In the U.S., land governance and management of natural resources has a multilevel structure. Most processes are tightly linked to the type of land and the type of activity that is being carried out.

Unlike most other countries, in the U.S., every person who owns the land also owns the resources beneath the surface (according to the General Mining Law (s. section "Federal laws and the role of states")). This is called a "fee simple estate," which is a combination of mineral rights and surface rights and means that full ownership of the property includes everything under and above the surface of the piece of land (Wall & Wall 2014). In order to start a mining operation or extraction on a piece of land, an individual (or a company) can acquire the permission to mine from the holder of surface ownership of the land by buying out the mineral rights, leasing the deposit or renting it (Find Law 2017).

However, conditions might differ from state to state; for example, in a number of the U.S. states with long oil and gas extraction histories (e.g. Colorado or Texas), mineral rights are different from surface ones. Additionally, in a number of states, mineral rights prevail over surface rights (Mineral Wise 2017). Furthermore, some states created additional protection for surface owners, like in Utah with the "Utah Surface Owner Protection Act of 2012" (USORC n.d.). This act requires mining companies to make a detailed description and a plan concerning the targets and intentions for land use, as well as calculate the surface damage, land owner crop loss and land value loss compensations. Additionally, the company has to provide the land owner with access to the land (Wall & Wall 2014).

Besides acquiring the mineral rights, there are various other permits that are needed to start any mining activity. These mining permits can differ from state to state. The process of obtaining a licence in order to open a new mine usually takes seven to ten years. To start a new project, all mining companies (or individuals) must have their projects approved by the local, country, state and federal government (SNL 2015; BLM 2016). At each stage, numerous actors are involved, including governmental organizations, NGOs, tribal governments and general public organizations (Investopedia 2015).The number and a type of the needed permits is determined by a range of factors, such as mining regulations on the state level, the type of land and the owner of the land targeted for mining activities, among other things. All in all, mining permits obtained by a claimant can be grouped into four categories:

- Environmental permits: mainly, to comply with the National Environmental Policy Act (NEPA): actors involved include the EPA, Bureau of Land Management (BLM), and U.S. Army Corps of Engineers (USACE) (BLM 2016; EPA 2017a)
- Development and operational permits: federal and state level permits for exploration activities, building of communication lines (e.g. roads, bridges, buildings, railway connection, energy supply lines, waste management regulation)) (SNL 2015; Idaho Mining Association 2017)

- Operation plan permits: permits for the type and method of mineral and its extraction; necessary additional activities, processing plan, pollution control facilities etc.). To get these permits, the plan must be coordinated with a number of Federal and state agencies, including BLM, U.S. Forest Service (USFS), EPA and others (GPO 2016; SNL 2015).
- Reclamation Bonding and reclamation related activities: this includes a plan, presented by the mining company (individual), concerning the clean-up of the mined area and its reclamation after a deposit is extracted, and cooperation with BLM is needed for the step of calculating of the reclamation costs (Surety 2017)

Federal laws and the role of states

Mining regulations in the U.S. are mainly based on the "General Mining Law" of 1872 (GML) (AGI 2017; Kalmiopsis Rivers Org 2016) and on the U.S: federal law. However, regulatory responsibilities have widely been delegated to state agencies, which have developed their own regulations and standards. While there are federal laws and agencies that oversee the implementation of regulations, each state in the U.S. has its own mining agencies and actors, and also usually has its own additional mining laws and environmental regulations (DOL 2017; SNL 2015). Both the federal and state levels are tightly interconnected when it comes to mining activities. Overall, the mining sector in the country is mainly regulated by the following major mining laws:

- The "General Mining Law" of 1872 (GML) regulates prospecting and mining on Federal lands. According to the GLM, each citizen or corporation of the U.S. has a right to carry out geological prospection, discover valuable minerals (incl. uranium, diamonds, zinc, gold, etc.), purchase the deposits and extract them if they are situated on Federal lands with open access[18] (GML 1993; PERC n.d.).
- The Federal Land Policy and Management Act of 1976 (FLPMA) regulates mining activities on public lands (DOI 2017; FLPMA 2001). The FLPMA was established by the Bureau of Land Management (BLM) and governs the implementation of GML on public lands (BLM 2017). The FLPMA emphasizes that mining permissions must not lead to inappropriate or needless degradation of public lands and soils (ICLG 2016).
- The National Environmental Policy Act (NEPA) of 1969 requires Federal agencies (incl. the U.S. department of Agriculture, U.S. Department of Energy; BLM) to complete an Environmental Impact Statement (EIS) for any Federal action significantly affecting the environment and human life (AGI 2017; EPA 2017). Each state's individual regulations define a particular Federal actor to be responsible for the EIS. The EIS can be carried out by a third-party contractor with a suitable qualification, chosen by the responsible Federal agency (USACE 2017c; U.S. Court of Appeals 2016).
- The Mineral Materials Act of 1947 (or the Common Varieties Act) applies to Federal onshore lands and regulates common[19] hard rock[20] minerals. The act regulates the sale of deposits of such materials and permissions in case they are located on public lands and the GML does not cover such deposits (EITI 2015; Materials Act of 1947 1980).

Within each U.S. state, there are a number of additional permits for mining activities that must be obtained by mining companies or individuals to start their activities. However, the amount and scope of the legislations varies and differing standards exist between the states. In Utah, for example, one of the

[18] Which means, the land does not belong to the territory of a protected zone, such as National Park or equal.

[19] Common hardrock minerals include sand, gravel, stone, pumice, cinders., timber and other forest products

[20] Hardrock minerals – valuable minerals described in the GML. Include precious metals (such as gold, silver) and industrial minerals (such as zinc, copper, molybdenum, lead) and uranium. Though exclude most of energy minerals, defined as leasable ones (Red Lodge 2010).

additional state-specific regulations is the Abandoned Mine Reclamation Program (Utah State Legislature 1997; DEQ Utah 2017). Likewise, Nevada has a range of mining regulations and reclamations, including one focusing on the protection of Lake Tahoe (Nevada Legislature 2016; NDEP 2016).

The GML in detail

The GML of 1872 attracts more attention than other legislations, since it causes dissatisfaction among environmental NGOs, think tanks and public organizations. The law is considered to be outdated and is believed to put additional indirect financial pressure on the U.S.' taxpayers:

First, the law is criticized for not containing any environmental protection measures (Earthworks n.d.; Red Lodge 2010). According to the GML, environmental regulation of mining operations, exploitation and exploration are under the jurisdiction of the state and Federal environmental regulations, such as the NEPA and the Clean Air Act (GML 1993; PERC n.d.). However, the requirements made by the federal and state actors are not mining-specific and are criticized for not being strict enough and for having gaps in areas such as groundwater protection (Earthworks 2011). Critics blame the GML for the existence of more than 500,000 abandoned mines all over the country, which have large negative environmental impacts (Reveal News 2014), in particular water pollution. Examples of this water pollution can be seen in all states in the western U.S. For example, after the closure of the uranium Atlas Mine in Utah in 1984, more than 170 ha were covered with waste and an additional 53 ha were under tailings. The tailings' liquid leaked into groundwater and reached the Colorado River, which caused uranium levels to exceed normal background levels by 1,660 %. Clean-up activities were not started until 2009 (Roulson et al. 2010; Live Science 2015). Another example is in Montana, where dozens of cyanide-containing solutions spilled from the Zortman – Landusky gold and silver mine, contaminating streams and ground water and leading to health problems in the Native American Gros Ventre and Assiniboine tribes that lived adjacent to the mine (Environmental Justice Atlas 2014; Roulson et al. 2010). The mine was abandoned in 1998 after the mining company filed bankruptcy and acidic tailings and waste were left on the site (Earthworks 2011a).

Secondly, the GML allows companies to turn public lands into private lands, as mining operations overrule other possible land-use activities. Extraction takes priority if a deposit of non-fuel minerals is found on a public land and is not directly inside a protected area (PEW 2011). To obtain a piece of public land, a citizen (or a company, including a foreign one), must carry out exploration activities and if a hard rock mineral deposit is found, a claim can be staked. According to the GML, the land is then given to the claimant for mining purposes, regardless of which other potential use the land had had before (Seymour 2004; Every CRS Report 2009). Thus, some valuable areas of the U.S. are heavily disturbed by mining works or are in danger of being mined (National Wildlife Federation n.d. a; Center for Biological Diversity 2015). For example, hard rock minerals, such as gold, copper, nickel are being found in the Great Lakes basin. In 2007, a sulphide mine permission for the area was given to the mining company, although this kind of mines is proven to have a highly negative impact on the environment and wildlife (National Wildlife Federation n.d. a). Another case can be found in the Grand Canyon area, where the Canyon uranium mine was closed in 1992 but reopened again after 2010 (Grand Canyon Trust 2015). Mining activities around his mine site and others around the National Park led to an increased uranium contamination of ground water and springs, which are located inside the National Park area.

Moreover, under the GLM, land is sold at very low prices, thus indirectly subsidizing the mining industry. The case of Carlota copper mine is one example of this. The deposit was discovered in 1990s and was first owned by a Canadian company until it was purchased by Polish KGHM International (KGHM 2017; Mining Atlas 2015). The copper deposit was estimated to be 478,000 tons, which, in 2001, had an estimated value of $728 million. Nevertheless, the approximately 1,234 ha of public land where the mine is situated was purchased for about $1,700 (SeattlePi 2001; USFS 1997).

Finally, the GML does not include provisions for royalties for mining on publicly owned lands at the federal level (Earthworks 2016). Annually, about $40 million is lost in US federal revenues through nonexistence of royalties for hard rock mining (PEW 2009). Additionally, the renaturation of abandoned mines is carried out by EPA, and thus, is financed by public taxes as federal reclamation standards in the GML are missing and companies are not called to account (Montana River Action n.d.). According to calculations, some $29 million are annually paid by taxpayers because of these standards (PEW 2009).

There are initiatives working on reforming the U.S. mining sector, mainly driven by environmental NGOs and organizations. In 2015, the Congressman Raúl Grijalva[21] proposed a new bill that aimed at changing the GML (Grijalva 2015). The Bill, among other things, included raising royalties up to 8 % for new mines and 4 % on existing ones[22]; stopping the sale of public lands for a price of $2.50 per acre; enforcing land managers to deflect proposed mines and mining claims in cases when public lands are supposed to get degraded due to mining works; and implementing fixed and clear standards for reclamation and clean-up activities (Phoenix New Times 2015). However, the bill did not pass Congress (E&E News 2016a).

Indigenous rights

There are more than 300 Native American[23] reservations and more than 200 Alaska Native villages in the U.S., which are inhabited by more than 567 tribes officially recognized by the State (HPAIED 2014). These tribal lands cover 2.3 % of all U.S. territory, amounting to nearly 234.7 million ha (95 million acres) of land (National Wildlife Federation n.d.).

Until the late 20th century, tribal lands were often mined under federal laws, providing larger rights to white populations and open access to any minerals on tribal lands. Today, the majority of Native American lands are "lands in trust," which means they belong to the federal government and while Indigenous people may use these lands, they do not own them; therefore, the State has still the right to extract natural resources from the land (Thought Co 2016). These lands are also under the coverage of the Leasing of Allotted Lands for Mining Purposes Act of 1909 and the Indian Mineral Leasing Act of 1938, which together state that both the lands given to and managed by Native Americans and the unallocated lands of Native American reservations can be used for mining activities under a lease (EITI 2015). However, the Indian Mineral Development Act of 1982 gives tribes the rights and abilities to cooperate with mining companies in the sphere of exploration and extraction of resources. If anyone intends to carry out activities, including mining, on tribal lands, they have to approach the Bureau of Indian Affairs (BIA) first, since it administrates the lands (BIA 2017). Afterwards, the process of permission and approval moves under the jurisdiction of BLM and OSMRE (s. section "Federal laws and institutions" for more details).

Under the regulations of federal laws and state laws compensation is normally not provided (BBC News 2014). However, cases exist where compensation was payed, for example: in 2014, after more than 50 years of a claiming process led by the Navajo tribe, the U.S. government finally made a decision to pay $554 million in compensation to the Navajo Nation for the lands taken from the tribe and used for mining purposes within these years (BBC News 2014).

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[21] The Congressman represents Arizona's Seventh Congressional District, he was also aware of the Oak Flat Campgroup (s. section "Indigenous People and the U.S. Mining")

[22] Current royalties are 2 – 5 % for metals and 12.5 % for extractive fuels (coal, oil and gas) (PwC 2012a).

[23] "American Indian or Alaska Native refers to a person having origins in any of the original peoples of North and South America (including Central America) and who maintains tribal affiliation or community attachment. The American Indian and Alaska Native population includes people who marked the "American Indian or Alaska Native" checkbox or reported entries such as Navajo, Blackfeet, Inupiat, Yup'ik, or Central American Indian groups or South American Indian groups" (Census 2010).

The compensation for environmental damages for Native American tribes is weakly regulated by the government. One of the examples is the Gold King mine spill. The Navajo tribe was severely affected by an accidental release of toxic waters by EPA and workers for environment restoration, which polluted a river with toxic tailings (Indian Country Today 2015). The EPA has still not compensated the Navajo people who were highly affected by the spill, even though the agency has accepted its fault and promised to pay for the losses (Navajo Times 2017).

The UN highlighted some major challenges and concerns regarding the rights of indigenous people in the U.S. and recommended that for any extractive resources project affecting Indigenous people a proper environmental impact assessment be carried out in order to assess the impacts of the mining project on the environment and on the livelihoods and rights of indigenous people (Tauli-Corpuz 2017). Furthermore, the UN advised the U.S. to adopt consistent practices when consulting with indigenous tribes (ibid.)

Responsible mining initiatives

As reported in the U.S. National Report to the UN's Commission of Sustainable Development in 2010 (United Nations 2010), the country made valuable steps towards more responsibility in the mining industry, involving Federal agencies as well as state level actors and citizens. There is a wide variety of programs, working towards responsible mining, better waste and brownfield management and a range of other relevant topics. For example:

- EPA's Brownfield Program which provides financial support to various actors in order clean and, possibly, reuse mining sites (EPA 2017b).
- USACE Restoration of Abandoned Mine Sites (RAMS) Program which focuses on the closure of non-coal mines and provision of restoration and protection of water bodies affected by the pollution (USACE 2017)
- EITI (Extractive Industries Transparency Initiative): The U.S. joined the EITI as a Candidate in 2014, having supported the Initiative since 2003 (U.S. Department of State 2017).

Particular legislation for beryllium

Beryllium is a critical mineral for both the EU (European Commission 2014) and the U.S., according to numerous studies (USGS 2016). The importance of beryllium and its toxic nature have led to the creation of additional legislation and government programs that regulate and manage beryllium extraction, processing and other related activities, for example:

- In 2008, the U.S. Department of Defence (DOD) began a partnership with Materion and invested in a beryllium processing plant in Ohio (Elmor city), which has been operating since 2012. The partnership stipulates that more than 50 % of the pure beryllium metal produced by the plant is provided for use by the U.S. government for defence while the rest can be sold to the U.S. private sector or abroad. (USGS 2017a).
- The Chronic Beryllium Disease prevention program (10 CFR Part 850), which was established by the U.S. Department of Energy in 1999, provides guidance for decreasing hazardous impacts of beryllium on workers. It outlines the necessity of medical control for employees that are at risk and manages the implementation of particular safety regulations and operations for minimizing beryllium containing dust, fumes or mists which might influence employees (Department of Energy 1999).
- The EPA identified beryllium powder (P015) as a dangerous waste (Resource Conservation and Recovery Act (RCRA)). This fact means that companies producing and using beryllium must recycle beryllium powder instead of dumping it (USGS 2017a; Materion Corporation 2011b).

5.2 Social context of mining and conflicts

There are frequent conflicts happening in the U.S. due to natural resources' extraction on Native American lands as well as due to abandoned mines on tribal lands. Abandoned uranium mines attract the most attention, as, for example, in the case of uranium mines at the Colorado Plateau. There, 90 % of uranium mills were situated directly in or on the borders of tribal lands and there are more than 520 abandoned uranium mines on Navajo lands (Environmental Health 2016). Tailings from the mines and toxic waste have caused heavy water and soil pollution, resulting in a high number of cases of cancer among local populations (Moore-Nall 2015). Due to the absence of clean-up activities, uranium still impacts the health conditions of the tribe, resulting in heightened contamination of uranium in the urine of nearly 30 % of tested Navajo members (an average level for the whole U.S. population is 5 %) (AzCentral 2017a).

Conflicts between non-native Americans and mining companies are much rarer, but incidents of disagreement with mining companies still occur. A conflict around tar-sand mines in Utah is one example. In 2012, the Canadian company U.S. Oil Sands developed the first in the U.S. tar sand mines. The mines were approved by the Utah Water Quality Board (Peaceful Uprising 2012). The Federal government allocated 53,459 ha (132,100 acres) of Utah public lands to tar sands extraction and additional territories to oil shale development (Alternet 2013). The projected extraction area crossed the borders of two Indian reservations and caused numerous protests among citizens living nearby, as well as a reaction from EPA concerning the necessity of clarification of the project's boundaries (Tar Sand Resist Org. 2014; DESMOG 2014). From the very beginning, there was a concern that waste from the mines would reach the Colorado River and pollute the waters, affecting not only inhabitants of Utah, but also Navajo people living downstream in other states (Peaceful Uprising 2012;). Numerous protests occured in the region after the project was announced; in 2014 some activists were arrested after crossing the fences of the U.S. Oil Sands property (DESMOG 2014; Desert News Utah 2014). The extraction activities were slowed down in 2016 due to the crash of oil prices.

Regarding the Spor Mountain mine, there is no information on any conflicts happening around it. The nearest Native American reservation, which is the Skull Valley Indian Reserve, is some 80 kilometres from the Spor Mountain, and not directly affected by the beryllium mining activities (Avalon 2011).

6 Comparison of the analysis with existing governance indices and conclusion

In this final chapter, the findings of chapter 4 (environmental hazard potentials and environmental impacts) and chapter 5 (governance analysis) are analysed to answer the following research questions:

- Does the assessment of the environmental hazard potentials adequately point to the actual environmental impacts?
- Are existing governance indices and indicators able to adequately reflect the governance capability to cope with the challenges arising around the environmental hazard potentials and environmental impacts of mining? In other words, are the identified governance gaps reflected in existing governance indices and indicators?

In order to answer the second question, a number of indices and indicators (see Table 6-1) were chosen based on a screening of a wide range of existing governance, environmental governance, and peace and conflict indices.

The results of this case study will be compared with the results of nine additional case studies that are conducted as part of this project as well as the case studies conducted in UmSoRess and OekoRess I. By comparing the findings of the case studies, a set of governance indicators will be identified that can be used to improve the assessment approach to analyse the potential for environmental hazards of the OekoRess I project.

Does the assessment of the potential for environmental hazards adequately point to the actual environmental impacts?

The data available regarding environmental impacts of the assessed mine was not sufficient to comprehensively analyse the actual environmental impacts. Based on the available data, the environmental impacts of beryllium mining in Spor Mountain seem to be quite low. The main environmental impact that was identified is the use of land, as mining and processing directly and indirectly affect an area of 3,000 ha. Furthermore, there are potential health impacts, since beryllium is hazardous to humans; however, the mining company implements high health and safety standards at the mine site that reflect today's best practices.

The indicators "deposit size" and "mining type" highlight a high potential for environmental hazards with regard to the extensive use and damage of land, which could be verified in the DPSIR assessment. However, the site-related OekoRess methodology points towards a higher number of environmental hazards potentials rated as "high" than the amount of actual impacts that could be identified. The indicators "use of auxiliary substances", "paragenesis with radioactive components", "mining waste management" and "Water Stress Index (WSI) and desert areas", which also show a high potential for environmental hazards, could not be verified.

Main findings of the governance analysis

In general, the governance analysis underlines the U.S.'s overall strong sector governance. Nevertheless, it also shows that the sector needs reform and stronger laws in terms of environmental protection and compensation for Native American communities. The major issue is the outdated federal mining law, dating back to 1872, which is still regulating major hard rock mineral mining activities and allows mining companies to privatize public lands. Furthermore, the law creates loopholes due to missing sector-specific legislation to protect the environment which led to abandoned mine sites followed by environmental pollution and negative effects for local communities. In addition, there are examples of violation of indigenous peoples' rights and disturbance of their territories and spiritual values, caused by mining activities and abandoned mines.

In case of the Spor Mountain beryllium mine, no human rights violations or conflicts could be identified. This might be due to the fact that the area is sparsely populated and mining activities as well as

beryllium processing activities do not disturb native people or other residents. Furthermore, the analysis of Materion's activity showed that the company is adhering to environmental regulations and laws, imposed by EPA and the Utah State authorities.

Do existing governance indicators reflect U.S.'s governance gaps and challenges?

The U.S.' overall strong sector governance is well reflected in key governance and development indices. The U.S.'s Human Development Index (HDI) is very high, showing the country's high level in key dimensions of human development (HDR 2017). The WGI-indicators "Rule of Law", "Government Effectiveness", "Regulatory Quality" and "Control of Corruption" reflect the country's overall strong sector governance. All of the Worldwide Governance Indicators (WGI) rank the U.S. around the 90th percentile, except of "Voice and Accountability," which is at a percentile of 81.28, and "Political Stability and Absence of Violence" Index, which is at a percentile of 69.52 (World Bank 2016a). This score reflects a medium likelihood of instability and of politically motivated violence and terrorism in the U.S.

The overall strong governance is also reflected in the U.S.'s high scores in the Environmental Performance Index (EPI), which displays the country's performance regarding the protection of human health and protection of ecosystems; the U.S. ranks 26 out of 178 (following Canada), scoring 84.72 out of 100 (Yale University n.d.). However, these indicators seem to not reflect the very specific challenges of the mining sector, such as the observed ecosystem disturbances through mining activities (e.g. Great Lakes and Grand Canyon cases) and the elevated levels of pollution around abandoned mines. Nevertheless, as the legislation on environmental protection improves, the mentioned environmental problems are mainly sector specific, and as the abandoned mines are often a relic from past decades, the EPI seems to reflect the U.S.'s currently and overall strong environmental governance well.

The Environmental Democracy Index (EDI) indicates the "degree to which countries have enacted legally binding rules that provide for environmental information collection and disclosure, public participation across a range of environmental decisions, and fair, affordable, and independent avenues for seeking justice and challenging decisions that impact the environment." The U.S. received a "good" EDI score, ranking 3 of 70. The U.S. received high scores on transparency, participation and justice, prompting a statement that "[The U.S.] could continue to promote environmental democracy by ensuring that the public is well informed, has ample opportunities to participate, and can access justice" (EDI 2017a). With regard to general environmental governance, this indicator accurately reflects the state of the U.S.; however, the index is not able to reflect the sector specific challenges in environmental democracy, which seem to be bigger and should result in a lower ranking. Furthermore, the EDI is only available for 70 countries and can therefore not be used for a global assessment methodology.

The same is true for the Investment Attractiveness Index surveyed yearly by the Fraser Institute. The index is based on a country's geologic attractiveness and measures the effects of government policy on attitudes towards exploration investment (Fraser Institute 2017b). The Investment Attractiveness Index ranks the U.S. as the third most attractive mining industry country for investments globally (only slightly behind Canada and Australia), reflecting the U.S.' overall strong governance in the mining sector (the country ranks second globally when only focusing on policy attractiveness) and the country's geological attractiveness. In contrast to the other indices and indicators, the Fraser Investment Attractiveness Index also provides data for the subnational level for the U.S.. While the subnational data also reflects the overall strong sector governance, it also shows significant differences between states. The states range from rank 4 of 104 (Nevada) of all countries and states assessed to 11 of 104 (Utah) and 84 of 104 (Washington). This fact reflects the challenges of varying legislations and differing standards between the states. The surveys were designed to capture the potential investors' uncertainties on issues such as administration, regulation or interpretation thereof, the level to which existing regulation is enforced, as well as legal and taxation systems, etc. (Fraser Institute 2017b).However, the Fraser In-

vestment Attractiveness Index provides only subnational data for the U.S., Canada, Argentina and Australia. Therefore, this very detailed information cannot be used for a global assessment methodology for which the overall project OekoRess II is aiming to develop.

The Global Peace Index (GPI) displays a country's level of peacefulness according to a ranking in three domains: ongoing and internal conflicts, levels of harmony or discord within a nation and a country's militarisation. The U.S. has a medium rank of 103 out of 162 (on a scale from very high to very low) within the Global Peace Index, due to the conflicts in which the country participates (IEP 2016). As the indicator is based on three domains (internal conflicts, discord within a nation and a country's militarisation), it cannot reflect only internal or only sector-specific conflicts.

Conclusion

The U.S.'s overall strong governance is well reflected in key governance and development indices like the HDI or the Worldwide Governance Indicators; however, the existing indices and indicators show a limited ability to reflect the specific and nuanced governance challenges of the mining sector. Only one index seems to be able to capture some of the more specific challenges, but has other limitations and problems. The significant differences between states in the Investment Attractiveness assessed by the Fraser Institute seem to reflect the challenges created by varying legislations and differing standards between states. However, subnational data is only available for four countries and can therefore not be used for a global assessment methodology.

The data basis for the environmental impact assessment was weak. Based on the available data, the challenges around missing environmental legislation in the U.S. and the potentially high environmental impacts of beryllium mining could not be identified for the Spor mountain mining site. Causes for this are not clear; however, it might be because of adequate mining regulations in the state, the strong internal standards of the mining company and the close strategic cooperation between the company and the state, the resource-specific regulations on beryllium in the U.S. as a hazardous substance or a combination of all these factors.

Table 6-1: Governance indicators U.S.

Index/Indicator	U.S.	Year	Index/Indicator	Applicability
Human Development Index (HDI)	0.920 (very high human development, rank 10)	2015	The HDI measures the "average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and have a decent standard of living. The HDI is the geometric mean of normalized indices for each of the three dimensions" (HDR 2017)	Reflects well the overall very high development and standard of living in the U.S.
Environmental Performance Index (EPI)	Rank 26 of 178, Score 84.72 of 100	2016	The EPI measures the performance of countries on high priority environmental issues in two areas: protection of human health and protection of ecosystems (EPI 2017, 2017a).	Reflects the overall good governance in the environmental sector. However, the indicator seems to not reflect the very specific challenges of the mining sector, such as the observed ecosystem disturbances through mining activities
Fraser Investment Attractiveness Index	Third most attractive region in the world for mining investment (rank 3), Second most attractive policy environment.	2016	The index rates countries "based on geologic attractiveness and the extent government policies encourage or deter exploration and investment" (Fraser Institute 2017a).	Reflects well the overall strong governance in the mining sector. The differences in ratings between the states seem to reflect the challenges created by varying legislations and standards between states, creating some uncertainty for mining investors. Sub-national data is only available for the U.S., Canada, Argentina and Australia.
Environmental Democracy Index (EDI)	Rank 3 of 70, Score 2.16 (good)	2016	EDI measures the degree to which countries have enacted legally binding	Reflects well the overall strong governance, however, , the index is not able

Index/Indicator	U.S.	Year	Index/Indicator	Applicability
			rules that provide for environmental information collection and disclosure, public participation across a range of environmental decisions, and fair, affordable, and independent avenues for seeking justice and challenging decisions that impact the environment. (EDI 2017; 2017a)	to reflect the sector specific challenges in environmental democracy, which seem to be bigger and should result in a lower ranking.
Voice and Accountability (WGI)	1.08 (estimate between -2.5 and 2.5); 81.28 (percentile rank terms from 0 to 100, with higher values corresponding to better outcomes)	2015	Voice and Accountability captures "perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media" (World Bank 2010).	Reflects well the overall strong governance. Does not reflect the specific challenges in terms of varying legislations across federal states and provinces and participation.
Political Stability and Absence of Violence (WGI)	0.7 (estimate between -2.5 and 2.5) 69.52 (percentile rank terms from 0 to 100, with higher values corresponding to better outcomes)	2015	Political Stability and Absence of Violence/Terrorism measures "perceptions of the likelihood of political instability and/or politically-motivated violence, including terrorism" (World Bank 2010).	According to the values of the index, the U.S. has a medium likelihood of political instability and politically-motivated violence. This reflects well the overall situation.
Government Effectiveness (WGI)	1.46 (estimate between -2.5 and 2.5) 89.9 (percentile rank terms from 0 to 100, with higher values corresponding to better outcomes)	2015	Government Effectiveness captures "perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies" (World Bank 2010).	The values of the index reflect higher than average quality of public services and high independency of civil services from political pressure. Reflects well the overall strong governance.

Index/Indicator	U.S.	Year	Index/Indicator	Applicability
Regulatory Quality (WGI)	1.30 (estimate between -2.5 and 2.5) 88.46 (percentile rank terms from 0 to 100, with higher values corresponding to better outcomes)	2015	Regulatory Quality captures "perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development" (World Bank 2010).	Reflects well the overall strong governance.
Rule of Law (WGI)	1.60 (estimate between -2.5 and 2.5) 90.38 (percentile rank terms from 0 to 100, with higher values corresponding to better outcomes)	2015	Rule of Law captures "perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence" (World Bank 2010).	Reflects well the overall strong governance.
Control of Corruption (WGI)	1.38 (estimate between -2.5 and 2.5); 89.90 (percentile rank terms from 0 to 100, with higher values corresponding to better outcomes)	2015	Control of Corruption captures "perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests" (World Bank 2010).	Reflects well the overall strong governance.
Global Peace Index (GPI)	2.154 (medium, scale of -1.5, overall rank 103)	2016	Countries' level of peacefulness (Institute for Economics & Peace 2016).	The indicator reflects the country's level of peacefulness well.

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