Environmental Research of the
Federal Ministry for the
Environment, Nature Conservation and Nuclear Safety

Project number: 3715 32 310 0

Report number: FB000275/ANH,5,6,ENG

OekoRess II: Country Case Study X

Peru: Base Metal Mining (Cerro de Pasco)

by

Becker, Fiona; Rüttinger, Lukas; van Ackern, Pia; adelphi

Rechlin, Aissa; Pablo, Pedro; Schöning, Noah; Projekt-Consult GmbH

On behalf of the German Environment Agency

Completion date November 2018

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 reported environmental impacts of the Cerro de Pasco zinc-lead production in Peru. The main environmental impacts identified are the large surface disturbance (open pits, processing plants, and mining waste), air pollution with fine particles of heavy metal, noise and vibration, and pollution of groundwater, lagoons and nearby rivers, leading to severe health impacts (in particular lead poisoning). The site-related environmental hazard potentials, identified by the OekoRess methodology, were mostly confirmed by the analysis of the actual environmental impacts at the mining site. However, the OekoRess assessment does not account for the high exposure to noise and the impacts of abandoned mines.

Overall, the analysed governance indicators reflect the mining governance of Peru quite well, except for the Fraser Policy Perception Index (PPI) and the Environmental Performance Index (EPI). Most Worldwide Governance Indicators (WGI) confirm Peru's overall average to weak sector governance. The Corruption Perception Index (CPI) reflects well the low governance performance in terms of corruption. The mostly average to low scores for governance indicators underline that there is no strong governance in place, which would be able to remedy the severe environmental impacts from mining.

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 führt 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.

Diese Fallstudie analysiert die Umweltgefährdungspotenziale und die tatsächlichen Umweltauswirkungen des Zink- und Bleiabbaus in der Cerro de Pasco-Mine in Peru. Die wichtigsten festgestellten Umweltauswirkungen sind ein großer Landverbrauch (Tagebau, Verarbeitungsanlagen und Bergbauabfälle), Luftverschmutzung, Lärm und Vibrationen sowie die Verschmutzung von Grundwasser, Bergseen und nahegelegenen Flüssen, die zu schweren gesundheitlichen Auswirkungen (insbesondere Bleivergiftungen) führen können. Die mit der ÖkoRess-Methodik identifizierten standortbezogenen

Umweltgefährdungspotenziale wurden größtenteils durch die Analyse der tatsächlichen Umweltauswirkungen im Abbaugebiet bestätigt. Die ÖkoRess-Bewertung berücksichtigt jedoch nicht die hohe Lärmbelastung sowie die Auswirkungen bereits stillgelegter Bergwerke.

Insgesamt spiegeln die analysierten Governance-Indikatoren die Situation des peruanischen Bergbausektors recht gut wider, mit Ausnahme des Fraser Policy Perception Index (PPI) und des Environmental Performance Index (EPI). Die meisten Worldwide Governance Indicators (WGI) bestätigen Perus allgemein durchschnittliche bis schwache Bergbau-Governance. Der Corruption Perception Index (CPI) spiegelt die geringe Governance-Leistung in Bezug auf Korruption gut wider. Die meist durchschnittlichen bis niedrigen Werte der Governance-Indikatoren unterstreichen, dass es keine starke Governance gibt, die in der Lage wäre, die gravierenden Umweltauswirkungen des Bergbaus zu adressieren.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

AMD	Acid Mine Drainage
ASGM	Artisanal and small-scale gold mining
ASM	Artisanal and small-scale mining
AZE	Alliance for Zero Extinction
CPI	Corruption Perception Index
DIA	Declaración de Impacto Ambiental (Environmental Impact Statement)
DPSIR	Driving forces, Pressures, States, Impacts and Responses
DIGESA	Dirección General de Salud Ambiental (General Directorate of Environmental Health)
EDI	Environmental Democracy Index
EHP	Environmental Hazard Potential
EIA	Environmental Impact Assessment
EIA-d	Estudio de Impacto Ambiental Detallado (Detailed Environmental Impact Assessment)
EIA-sd	Estudio de Impacto Ambiental Semi-detallado (Semi-detailed Environmental Impact Assessment)
EPA	Environment Protection Act
EITI	Extractive Industries Transparency Initiative
EPI	Environmental Performance Index
EU	European Union
FTA	Free Trade Agreement
GDP	Gross Domestic Product
GPI	Global Peace Index
ha	Hectare
HDI	Human Development Index
ILO	International Labour Organisation
INEI	Instituto Nacional de Estadística e Informática
Minsa	Ministerio de Salud (Ministry of Health)
MT	Metric tons
Mt	Mega ton
OEFA	Organismo de Evaluación y Fiscalización Ambiental (Agency for Environmental Evaluation and Enforcement)
OekoRess	Research Project "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"
PPI	Policy Perception Index
PPP	Purchasing Power Parities

SENACE	Servicio Nacional de Certificación Ambiental para las Inversiones Sostenibles (National Service for Environmental Certification for Sustainable Investments)
TDS	Total Dissolved Solids
TPD	Tons per day
UBA	Umweltbundesamt (German Environment Agency)
UmSoRess	Research Project “Approaches to reducing negative environmental and social impacts in the production of metal raw materials”
UN	United Nations
UNDP	United Nations Development Programme
USD	United States Dollars
WGI	Worldwide Governance Indicators
WHO	World Health Organization
WSI	Water Stress Index

1 Focus of the study and relevance

The following case study is the last 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 analysed 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 to evaluate the ecological availability of raw materials and the site-related environmental hazard potentials (EHP) posed by mining operations was developed with the aim to 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 environmental hazard potentials posed by mining operations, which was developed in the OekoRess I project. This effort will particularly focus on improving the indicator for environmental sector governance used in the methodology, 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 if existing governance indices and indicators are able to adequately reflect the capability of governments, companies and civil society to manage envrionmental hazard potentials 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-related assessment approach developed as part of the OekoRess I project.

This study analyses the environmental hazard potentials and the environmental impacts of the zinc-lead (and to a minor extend silver and copper) production at the Cerro de Pasco mine complex, and the country's mining governance. Despite its toxicity, lead is used in a wide range of applications – especially in electrical engineering (e.g., in rechargeable batteries) but also in mechanical engineering, plant construction and civil engineering. Zinc is nowadays especially used as corrosion protection, in batteries and in civil engineering.

The Pasco de Cerro is one of the most famous deposits in Peru and started in the 16th century as a silver mine site. Open-pit mining of lead and zinc became important in the 20th century. The impacts on the environment and health from the century's long mining activities, and especially the decades of lead extraction in open-pit mining, are severe. Mining at Cerro de Pasco has stopped in 2015 and measures to mitigate at least the gravest consequences have started recently.

The case study is divided into four parts: First, the structure of the mining sector of Peru and its contribution to the national economy is analysed (chapter 2). Second, a brief overview of the Cerro de Pasco mining complex is given. The geographic and geologic context is analysed, followed by an overview of the applied mining and processing methods (chapter 3). Third, the environmental hazard potential

[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.

posed by the mining operation are discussed using the site-related OekoRess 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 Peru's mining sector is analysed (chapter 5). Last, the findings of the assessment of the environmental hazard potentials and environmental impacts and the governance analysis are compared to existing governance indicators and indices and first conclusions for the methodology development are drawn (chapter 6).

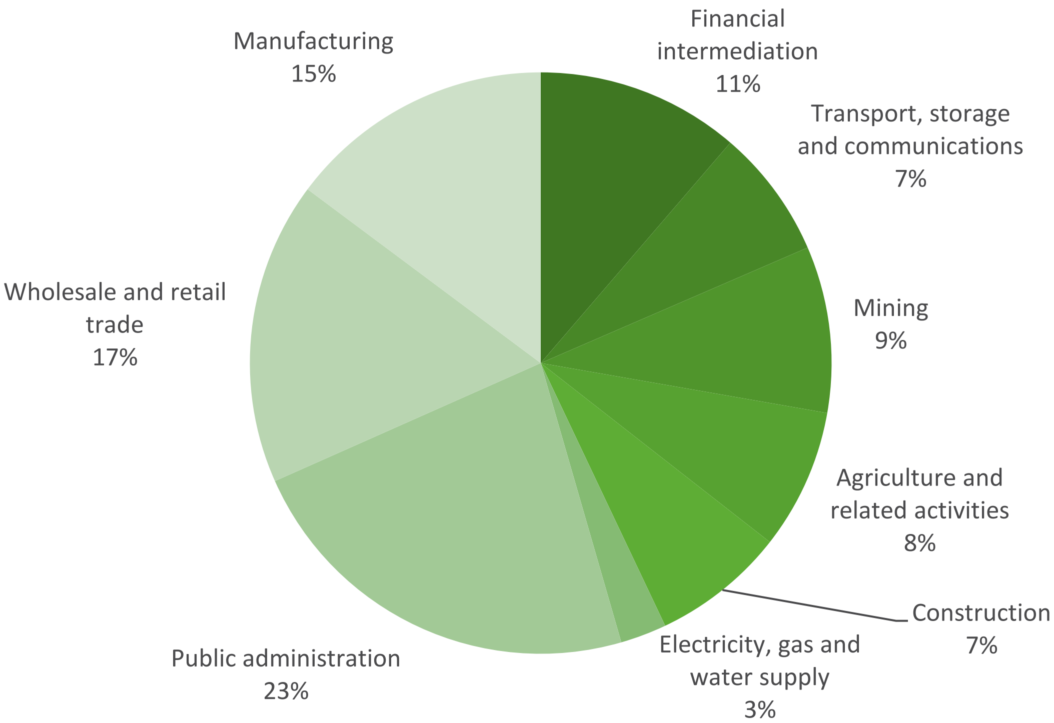
[4] The DPSIR framework comprehensively accounts and visualizes the causal connection between environmental issues, their origin, their impacts and the responses taken. The model consists of driving forces, pressures, state, impacts and responses. For further information see e.g. Kristensen (2004).

2 Structure and macroeconomic relevance of Peru mining sector

Peru is a country with a considerable potential for natural resources and mining, the importance of which has increased significantly in the past decade, contributing 9% to the country's gross domestic product (GDP) in 2017 (see Figure 2-1). Total GDP was USD 211,398 million in 2017, with a growth rate of 2.5%, which was significantly lower than the rate of 4% in the previous year (World Bank 2018). The economy is slowing down after years of rapid growth driven by copper, molybdenum, iron, zinc and silver production[5], due to a decline in hydrocarbon production (INEI 2018). This development comes in the context of a delay in infrastructure investments and Odebrecht's international corruption scandal[6], which started to spread to Peru in 2017 (MDNP 2018). Nonetheless, growth rates in metal mining remained positive. In November 2017, metal mining production was 5% higher than in November 2016 (Banco Central de Reserva del Peru 2018), while inflation remains low at an average of 2.9% (World Bank 2018).

The promotion of national and foreign investment in mining and the creation of mechanisms to facilitate access to investments are some of the priorities of the Peruvian government. In this context, it has been beneficial for Peru to become a member of the Pacific Alliance, to have negotiated bilateral treaties with the US, China and – jointly with Colombia and Ecuador – a FTA (Free Trade Agreement) with the European Union (EU) (MDNP 2018). In addition, the raw materials partnership between Germany and Peru came into force at the beginning of 2015 (BMWI 2015). The aim of this partnership is to foster cooperation "in the field of exploration, development, extraction, processing and utilisation of mineral resources" and "environmentally sound closure of mines and recultivation of mining regions" (BMWI 2015, own translation).

Figure 2-1: Total value added of GDP in 2017 by economic activity at current prices



Source: CEPALSTAT (2018).

[5] The contribution to the GDP of metal mining increased by 16.3 % in 2016, due to an increase in metal mining activity by 21.2 %. The start of production at Las Bambas copper mine was a major contribution to this development.

[6] Refer to chapter 5.1 section on "corruption and transparency" for more details on the Odebrecht scandal.

In 2017, according to the Ministerio de Energía y Minas (2018), mining exports (metal, non-metal) accounted for 61.8% of the total value of the country's exports, reaching USD 27,745 million.

With 30.7% of total export value in 2017, copper is the most important export product, followed by gold, lead, zinc and silver. The main export destinations for metallic products are China, the United States and Switzerland (see Table 2-1). China is also the largest foreign investor in Peru's mining sector, followed by the United States, Canada, and Australia (Saldarriaga 2017).

Table 2-1: Top five countries importing metallic raw materials from Peru in 2017

Export destination	USD $ mio.	% of shipments	Exported Metals
China	9,890	36%	copper, gold, zinc, lead, iron, tin
United States	2,451	9%	copper, gold, zinc, silver, lead, iron, tin, molybdenum
Switzerland	2,335	9%	silver, copper, gold
India	1,904	7%	copper, gold, zinc
South Korea	1,78	7%	copper, zinc, lead, tin, molybdenum

Source: Ministerio de Energía y Minas (2018).

The contribution of the mining industry to the Peruvian GDP makes it a sector of importance to the tax incomes of the state and regional authorities.

Peru has deposits of a large variety of metals and minerals and continuously increased its metal production over the past 10 years. It is the world's second largest copper, zinc and silver producer (see Table 2-2). In Latin America, it ranks first in the production of gold, zinc and lead (Ministerio de Energía y Minas 2018).

Table 2-2: Place of Peru in the Worldwide Ranking of Mining Production

Mineral	**Production 2016**			
	Volume [t]	**% of ∑ World**	**Rank in Latin America**	**Rank in World**
Gold	153.01	4.8	1	6
Copper	2.35 million	11.4	2	2
Silver	4,375	15.9	2	2
Zinc	1.34 million	2.5	1	2
Lead	314,422	6.7	1	4
Tin	18,789	6.1	3	6
Molybdenum	25,757	9.3	2	4

Source: Ministerio de Energía y Minas (2018).

Extractive sector activities are diversified along the value chain and life cycle of mines, involving academia as much as the private and public sector.

An estimated 200 mines are in operation in Peru, with many important projects currently awaiting development such as Quellaveco - Anglo American (USD 5,000 million), Mina Justa - Minsur (USD 1,300 million) and Pampa de Pongo - Zhongrong Xinda Group (USD 1,500 million). Most of the world's major mining companies are represented in the country, including Newmont (USA), Glencore (Switzerland), Gold Fields (South Africa), Freeport-McMoRan (USA), Rio Tinto (United Kingdom), Anglo American (United Kingdom), Southern Copper Corporation (Mexico), and Barrick (Canada). There are also dozens of local mining companies and collaborations with important mining companies (SES Professionals 2017).

Productive mining activity takes place in 23 of the 25 administrative regions of Peru (Ministerio de Energía y Minas 2016):

- Arequipa is leading the national copper production due to the expanded production of the Cerro Verde mine;
- La Libertad ranks as first national gold producer for the operations at Barríck Misquichilca and La Arena, among others;
- The Pasco region is the main producer of lead, mainly due to the contribution of its polymetallic mines, including Buenaventura, Milpo, and Volcan Compañía Minera, while
- Junín currently leads the production of silver.
- Ica has the main production of iron with the Marcona unit of Shougang, and
- In the Puno region, Minsur operates the only tin mine.
- Piura is leading in the production of phosphates and limestone ;
- Cajamarca is rich in gold and copper;
- Moquegua and Tacna are regions with a long mining tradition that exploit copper and molybdenum; and finally
  Lima region, with significant polymetallic and non-metallic diversity, occupies a high rank in the in the production of many raw materials.

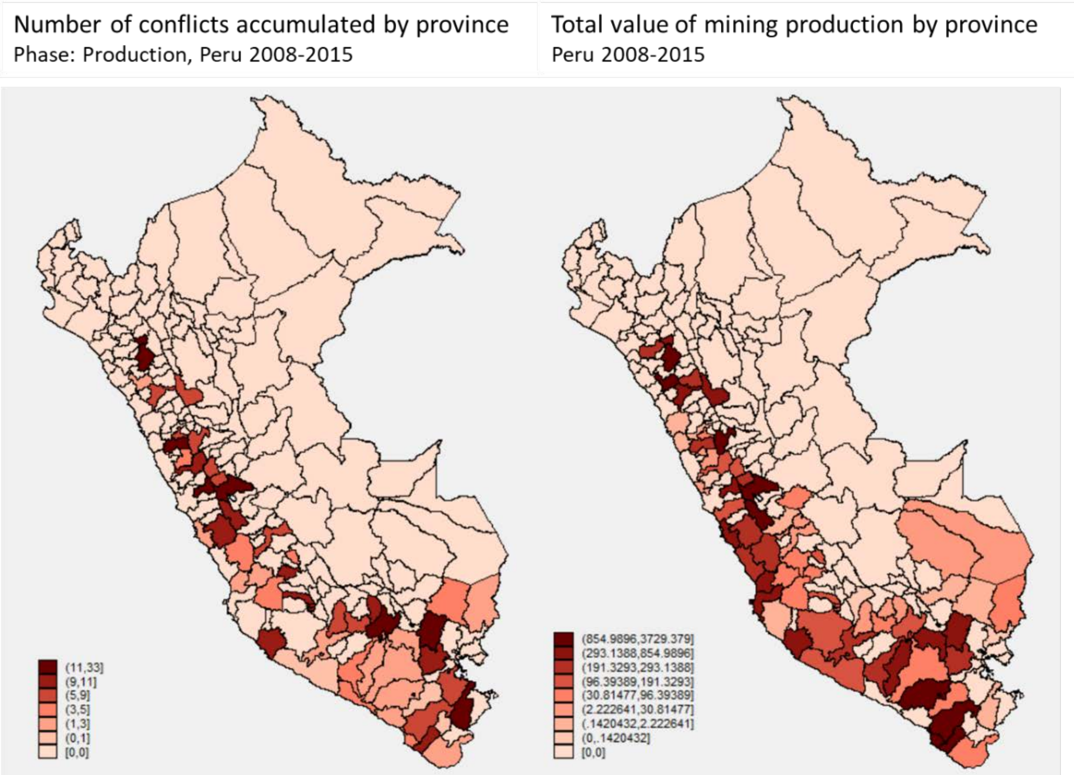
Employment and income growth have significantly reduced the poverty rate. The moderate poverty (USD 4 per day, 2005 PPP[7]) decreased from 45.5% in 2005 to 19.3% in 2015. This equals 6.5 million people who were lifted out of poverty during this period. Extreme poverty (USD 2.5 per day 2005 PPP) was also sharply reduced from 27.6% to 9% over the same time span (World Bank 2017).

1.2% of the economically active population is directly employed in mining. The number of workers almost doubled between 2005 and 2016, increasing from 98,703 to 174,126 (Ministerio de Energía y Minas 2016). In 2012, three million jobs were directly or indirectly dependent on the mining industry. Moreover, the illiteracy rate has fallen in small and medium-sized mining areas, and measurable progress has been made in health and education (Häntsche et al. 2014). Critical voices consider the multiplier effect estimated by the Ministry of Mines to be by far too favourable and point out that positive distribution effects to the lower social classes were not realized as indicated by increasing poverty figures in recent years in some mining districts, such as Puno, Casco and Cusco (Vargas Koch et al. 2018; Hinojosa 2011).

Peru is also a country with marked social conflicts related to mining (see Figure 2-2). There is a direct relationship between the zones reporting on active mining conflicts and mining production. Social protests delayed important mining projects worth USD 21.5 billion between 2010 and 2014 (Castellares and Fouché 2017).

[7] Purchasing Power Parities.

Figure 2-2: Mining conflicts and value of mining production by province



Source: Castellares and Fouché (2017).

3 Overview of the Cerro de Pasco mining operation and geology

The Cerro de Pasco deposit is not only one of the country's main zones of polymetallic mineralization but also one of the world's largest polymetallic (zinc, lead, copper and silver) resources (Mining Data Solutions 2018). The Cerro de Pasco mine is the oldest active mine in Peru with a history dating back to the 16th century (Cedron 2012).

The Cerro de Pasco mine has three different operations: the underground mine Paragsha, the Raúl Rojas open pit mine and the less important Vinchos mine (Cedron 2012). While the underground operation Paragsha has been active since the beginning of the 16th century, Raúl Rojas started operating in the early 20th century, after the US mining company Cerro de Pasco Corporation purchased most of the mining concessions in the region and expanded the mining activities. By then, the Cerro de Pasco mine did not solely produce silver but also copper, lead, and zinc. Especially in the open pit mine Raúl Rojas, located in the heart of the city, mainly zinc and lead is produced. After the Peruvian military regime nationalized the mines in 1974, the liberal government of President Fujimori privatized the Cerro de Pasco mine again in 1999 by selling it to Volcan Compañía Minera, a Peruvian company (Cedron 2012). The ore is processed mainly in the Paragasha processing plant and to a lesser extent in the San Expedito processing plant (S.R.L. 2012).

As the reserves within the confines of the concessions granted are depleted, an expansion plan (the Plan L) was presented, which covered 11.4 ha of the Chaupimarca district and would entail the relocation of the whole city Cerro de Pasco. The history of the Cerro de Pasco mine and the city of the same name have been inextricably linked as the city has been built due to the mining activities in the elsewise inhospitable landscape. The city has approximately 70,000 inhabitants (Cedron 2012). After a long process of negotiations with authorities and conflicts between proponents and opponents of the expansion, the company abandoned the further development of Plan L (S.R.L. 2012).

3.1 Geography

With a total surface of 1,285,215 km^2 and a population of 31,488,625 Peru is the third largest country in South America (MDNP 2018). While it is bordering the Pacific Ocean to the west, the country's neighbours are Colombia (north), Brazil (east), Bolivia (southeast) and Chile (south). Three main landscapes determine the image of the country from West to East: the Pacific, the central Andes and the Amazonian lowlands.

The Cerro de Pasco mine is located in the Pasco region on the Andean Plateau in Central Peru, at 10°40'39.38"S, and 76°15'34.09"W. The mining activities cover an area of approximately 2,734 ha at an altitude of 4,340 meters above sea level (see Figure 3-1) (Banco Central de Reserva del Peru n.d.; Hinojosa De La Sota 2014). Cerro de Pasco is accessible from Lima city via highway and railway. However, the railway is only used for the transport of cargo.

The mountainous landscape is characterized by a tundra-like climate and sparse vegetation that consists entirely of ichu (Peruvian feathergrass) and moss, which is typical for the Puna and Cordillera region. There are two well-marked seasons: a rainy season between November and March and a dry season between April and October. The annual average temperature is quite low (5.5°C) and does not vary significantly over the year. Even in December, the warmest month of the year, the average temperature only reaches 6.4°C, while June is the coldest month with 4.3°C. Daily variance, however, is high with cold nights in which the temperatures can drop to -18°C. Annual precipitation amounts to a total of more than 900 mm and a variance of only 139 mm between the wettest month (March) and the driest month (June) (Climate Data n.d.; Hinojosa De La Sota 2014).

Figure 3-1: Location Cerro de Pasco

Source: Based on Google Earth, with satellite images from Landsat/Copernicus (2016).

The Cerro de Pasco is situated in the basin of the rivers Huallaga and Mantar – in the Nudo de Pasco –, which constitute the continental divide of the surface waters in the Central Region of Peru (Banco Central de Reserva del Peru n.d.). The area has a smooth relief and is surrounded by hills that are interspersed with small valleys and ravines that lead to the river Huallaga in the east and the river Quebrada in the west. Those rivers lead to the riverbed of the San Juan that belongs to the hydrological system of the Mantaro River, which itself leads to the Atlantic ocean (Hinojosa De La Sota 2014; Ministerio de Energía y Minas 2011).

The Pasco region has several protected natural areas; however, they are not in the surroundings of the mine operation (Peru Routes 2015):

- National Park Yanachaga Chemillén (122,000 ha)
- National Reserve Junin (53,000 ha)
- National Sanctuary Huallay (6,815 ha)
- Protection Forest San Matias-San Carlos (145,818 ha)
- Communal Reserve Yanesha (34744.7 ha), El Sira (616,416.41 ha)
- Reserved Area Huayhuash (67,589.76 ha).

3.2 Geological context and ore deposit formation

The stratigraphy is comprised of sedimentary rocks aging from the Lower Paleozoic to the Quaternary. The oldest Paleozoic rocks crop out to the east, while marine sediments of the Mesozoic and continental sediments of the Tertiary are found around Cerro de Pasco. Small Miocene intrusions in these sediments are responsible for most of the mineralization in the area (Hinojosa De La Sota 2014).

In the mining district of Cerro de Pasco, low metamorphosed Devonian shales and sandstones (Excelsior Group) underlie red layers of Permian to Triassic sandstones and conglomerates (Mitu Group).

Overlying these rocks – towards the east of the district – a calcareous sequence of several hundred meters thickness corresponds to the Pucara Group of older Triassic – to lower Jurassic age. Multiple episodes of folding (Eocene and the Lower Miocene) in the district were followed by magmatic-volcanic activity in the late Miocene (Cabos 2005).

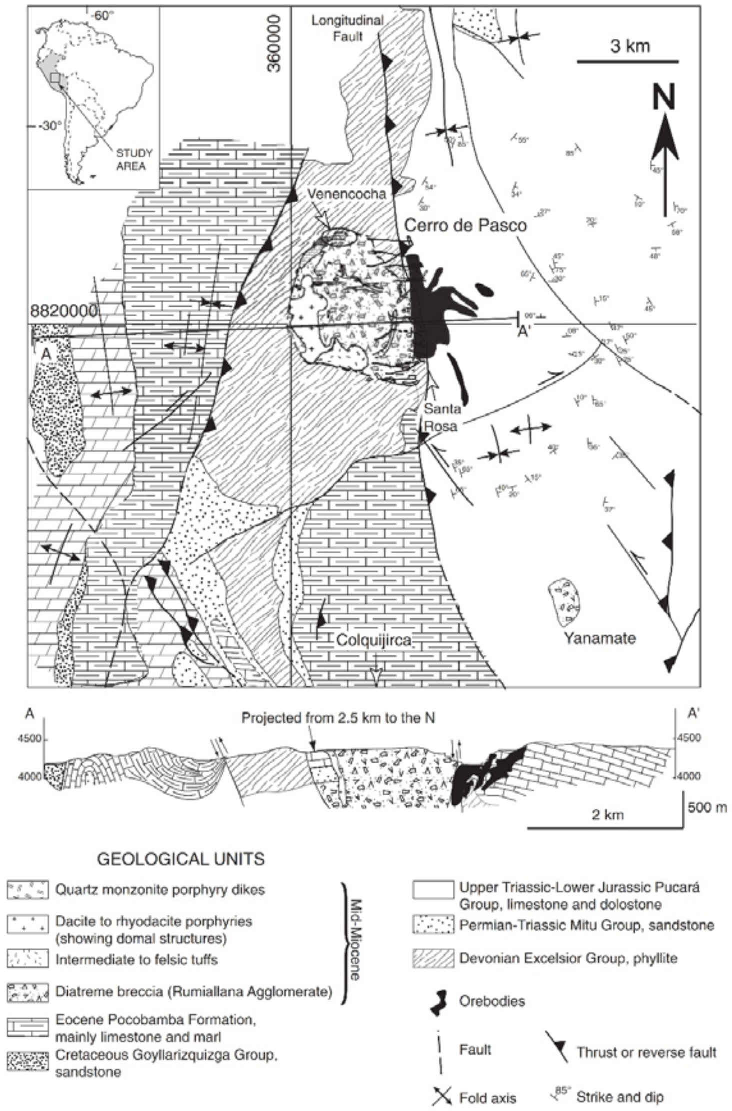
The Cerro de Pasco deposit of Zinc-lead-silver-bismuth-(copper) (Zn-Pb-Ag-Bi-(Cu)) is located east of a felsic, Miocene diatrema[8]-dome complex (see Figure 3-2). This circular shaped "Volcanic Neck" (see Figure 3-3) is located between two north-south trending reverse faults, along which Paleozoic rocks overthrust younger Miocene and Eocene rocks (Hinojosa De La Sota 2014). The large Zinc-lead-silver ores are situated at the southeast of the diatreme and represent a first phase of "low sulphuration" type mineralization associated with pyrite-silica along the around 1,800 m contact.

An acidic magmatism (quartz-monzonite) followed by a late phase of mineralization is superimposed on the first phase, forming other copper-silver deposits in veins, bodies, and veins of lead-zinc, fine pyrites (silver-bismuth) and residual deposits of silver-gold. This second phase of mineralization is strongly sulphidic.

The current exploitation is carried out in the east of the Raúl Rojas open pit in calcareous rocks where the zinc-lead-silver comes from blond sphalerite and galena, accompanied by pyrite. This mineralization with argillic hydrothermal alterations shows strong structural control as well as marked zoning. Copper-rich zones laterally adjoin pyrite-rich zones that exhibit minerals such as galena, sphalerite, matildite as well as hematite, magnetite and Manganese-iron-zinc carbonates (Einaudi 1977).

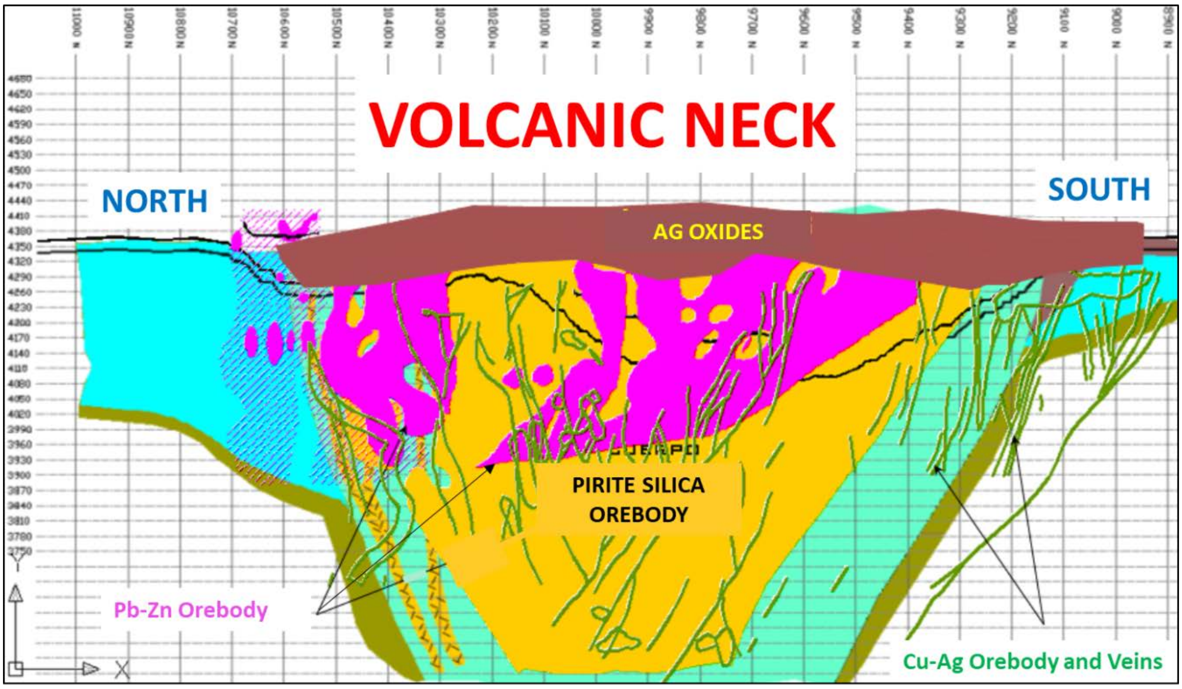
[8] A diatreme is a volcanic structure formed through gaseous explosion caused during contact of hot magma gets and shallow ground water. A crater (maar) is formed as well as a rock filled pipe or cone like structure below surface – the diatreme.

Figure 3-2: Regional geology of the Pasco region. Paleozoic metamorphic rocks overthrust Cenozoic rocks along N-S trending reverse faults



Source: Baumgartner et al. (2008).

Figure 3-3: N-S cross-section of the diatreme



Source: Hinojosa De La Sota (2014).

In the carbonate rocks, veins and bodies of zinc-lead developed, which are characterized by a poor iron sphalerite with FeS contents of 0.4 to 4%. The ferriferous-sphalerite-galena assembly is spatially associated with the pyrrhotite bodies and has been extensively exploited in the past – both in the underground and in the west of the open pit.

Table 3-1 displays the grades and the total amount in metric tons (MT) of zinc, lead, copper and silver resources and reserves of the Cerro de Pasco unit (Volcan Compañia Minera S.A.A. 2018). With resources over 3 Mt of zinc and more than 1.1 Mt Pb as well as silver resources exceeding 10 kt, the size of the deposit can be regarded as large (zinc and lead) to very large (in case of silver). Copper, on the other hand is less important in the international comparison with 0.1 kt copper content.

Table 3-1: Resources (measured, indicated and inferred during exploration) and reserves (proven and probable) of the Cerro de Pasco deposit

Resources	kt	Grades				Fines			
Measured, Indicated & Inferred		Zinc (Zn)	Lead (Pb)	Cop-per (Cu)	Silver (Ag)	Zinc (Zn)	Lead (Pb)	Copper (Cu)	Silver (Ag)
		%	%	%	oz/MT	Thou-sand t	Thou-sand t	Thou-sand t	Millions of oz
Cerro de Pasco re-sources	140,853	2.15	0.80	0.09	2.54	3,034	1,130	131	358
Measured	30,777	2.62	0.95	0.06	1.86	808	292	18	57
Indicated	84,604	2.24	0.83	0.10	2.46	1,899	705	84	208
Inferreds	25,472	1.28	0.52	0.12	3.63	327	133	30	92
Cerro de Pasco mineral reserves	15,490	1.25	0.44	0.07	4.94	193	69	11	77
Proven	1,696	1.23	0.44	0.13	5.44	21	7	2	9
Probable	13,794	1.25	0.44	0.06	4.88	172	61	9	67

Source: Volcan Compañia Minera S.A.A (2019).

3.3 Mining and Processing

Volcan Compañía Minera S.A.A. is a Peruvian mining company dedicated to the exploitation and production of zinc, copper, silver, gold, and lead in the region of the Central Sierra.

Volcan has five operating units: Yauli, Chungar, Alpamarca, Cerro de Pasco, and Oxidos de Pasco; with nine underground mines, three open pits, seven concentrator plants with a treatment capacity of 21,900 Tons per day (TPD), and a leaching plant of 2,500 TPD.

The Cerro de Pasco unit includes the Paragsha underground mine, the economically less important Vinchos mine, and the Raúl Rojas open pit mine, as well as the San Expedito/Paragsha plant. The Pasco Oxides Plant is another operation unit in Cerro de Pasco and started operations in April 2014 (Volcan Compañia Minera S.A.A. 2016).

Volcan acquired the company Minera Paragsha S.A.C in Cerro de Pasco in 1999. Between 2006 and 2008, plans were underway for a new expansion of the Paragsha mine, called Plan L (see also chapter 3). In April 2012, Volcán suspended Plan L, supposedly due to protests in the community (Cronología Histórica 2014).

Paragsha Mine

The production of this underground mine reached 264 thousand tons per annum, with average grades of 6.80% zinc, 2.22 % lead and 3.95 oz silver/Mt. Mining activities in the Paragsha mine stopped in 2015 (Volcan Compañia Minera S.A.A. 2015).

The underground mine was divided into six production levels, from Level 800 to Level 1800, forming four main exploitation areas. The used mining techniques were cut and fill[9], and sublevel stoping[10].

The transport of ore from the stopes (the excavated open space) to the ore bin in the different areas of exploitation was carried out with electric scooptrams. From this ore bin[11], the material was carted off with Locomotives and Mining Trolleys (Volcan Compañia Minera S.A.A. 2016).

Vinchos Mine

In the underground mine Vinchos, a polymetallic ore rich in silver was mined until December 2014. Compared to the other operations, the underground pit was small, with 90,000 MT production in 2014 and grades of 2.4% zinc, 1.7% lead and 3.3 silver oz/MT (Volcan Compañia Minera S.A.A. 2014).

Raúl Rojas Open Pit

The Raúl Rojas open pit is located in the middle of the city of Pasco and currently occupies 50% of the city's area (Latin America and the Caribbean Atlas of our Changing Environment n.d.).

The dimension of the open pit is 1.9 km (N-S), 1.6 km (W-E) and 380 m depth. Operations at the pit are currently suspended; the ore was processed until December 2012 (Volcan Compañia Minera S.A.A. 2016).

The open pit mining was arranged in descending banks with cross sections in conical trunk form (see Figure 3-4). Excavation took place by drill and blast method with a drilling mesh[12] of 12 m for all drills.

[9] Cut and fill: during mining, the bed rock (rocks that are not ore bearing) excavated is later filled back into the voids created underground. Consequently, less waste material is transported to the surface.

[10] Stoping: method that is used in cases where the host rock is strong enough to withstand collapsing into the excavated open space (the "stope"). Mining begins in steps from bottom to top along the roof. Excavation is usually carried out using drill and blast.

[11] Storage system, which receives ore intermittently from the mine.

[12] Drilling mesh: Order of the location of drilling points.

The blasting was performed in order to fragment the rock, by generating strong pressures confined inside the drilled holes and thus creating a high concentration of energy that leads to two dynamic effects: fragmentation and displacement. Raúl Rojas used explosives based on ammonium nitrate.

In order to avoid strong vibrations due to the mine's proximity to the city, blasting was carried out using the DECKS system[13]. Furthermore, blasting within the drill was used in combination with surface delays (delays of millisecond are used between charges in a blast).

The stripping ratio[14] was 3.41:1 and the waste material was classified according to its mineralogical characteristics in:

- Leachable low-grade mineral (copper and silver values) and
- oxidized minerals with silver values of 300 g/Mt on average.

Mining waste without economic interests was transported by trucks from the open pit to the waste dump Rumiallana[15]. According to Estudio de Impacto Ambiental Ampliación Paragsha/San Expedito, the Rumiallana waste dump will have physical and chemical stability for revegetation.

Figure 3-4: Raúl Rojas open pit

Source: Vanesao (2005), (CC BY 4.0).

San Expedito/Paragsha Processing Plant

The ore grade in the remaining reserves of the Cerro de Pasco mine decreased to a level that requires increasing the capacity of the Paragasha and San Expedito processing plant including a change in the processing methods (S.R.L. 2012).

The plant mainly processes complex minerals of lead-zinc-silver sulphides with pyrite as gangue using selective flotation of lead and zinc ores. The objective is to obtain separate lead and zinc concentrates. The stages correspond to a conventional selective flotation of lead and zinc sulphides and include

[13] The DECKS system consists of loading the drill with an intermediate plug that oscillates between 1-2 m, leaving also a 6 m collar that was filled with the debris of the perforation.

[14] Stripping ratio: volume of waste material that needs to be handled to extract a certain tonnage of ore.

[15] Rumiallana Dump covers an area of approximately 41 ha (Ground Water International 2006).

crushing, grinding, flotation, thickening, and filtering. Tailings from both plants, Paragsha/San Expedito and Pasco Oxides (see paragraph Pasco Oxides Plant) are transported to the tailing facilities located in the Ocroyoc ravine, 4.7 km away from the concentrator plant by use of gravity piping (Ministerio de Energía y Minas n.d.).

The runoff waters of the tailings of Ocroyoc from the Mining Unit of Cerro de Pasco, are cleaned and then discharge via the channel to the Quilcamachay lagoon that belongs to the catchment area of the San Juan River (Autoridad Nacional del Agua 2014).

Pasco Oxides Plant

According to Volcan Compañia Minera S.A.A. (2016), significant stockpiles of the company contain oxidic ores of silver and gold. Furthermore, resources of silver and gold bearing oxide ores are present in the southern part of the Raúl Rojas open pit. To benefit from this resource, the company has built a cyanidation plant that produces approximately four to five million ounces of silver per year.

Construction of this first leaching plant of Peru (see Figure 3-5) started in July 2012. With a capacity of 2,500 TPD and an approximate investment of USD 280 million, it is designed for future expansion to 4,000 TPD and certified by the International Cyanide Management Institute (Volcan Compañia Minera S.A.A. 2016).

Activities at the oxide plant begin with loading and transport of the oxides stored in the stockpiles to the beneficiation plant. The processing begins with the reduction of the size of the ore pieces (crushing and grinding) followed by leaching[16] and culminates with the melting of the precipitated material, obtaining metallic silver (Ministerio de Energía y Minas 2011).

The tailing material of the oxide plant is transported making use of gravity through pipes to Ocroyoc tailings facility. At Ocroyoc fine decanted and clarified water is pumped into the sedimentation ponds of the Ocroyoc water treatment plant (Ministerio de Energía y Minas 2011).

Figure 3-5: Distribution components of the Cerro de Pasco mine and Pasco Oxides Plant

Source: Own compilation based on Open Street map (n.y.) and information from Volcan Compañia Minera S.A.A (2013).

[16] Leaching is a metallurgy technique. In this case, diluted solutions of sodium cyanide are used to extract the desired metals from the crushed ore.

4 Overview of the environmental hazard potential and environmental impacts

4.1 Environmental hazard potential

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 Cerro de Pasco mining operations, which are described in detail below.

The assessment of the EHPs of the Cerro de Pasco mining operations 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 for Cerro de Pasco

Thematic Cluster	Indicator	Environmental hazard potential		
		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	
Site (surroundings)	Accident hazard due to floods, earthquakes, storms, landslides			X
	Water Stress Index (WSI) and desert areas	X		

Thematic Cluster	Indicator	Environmental hazard potential		
		low	medium	high
	Protected areas and Alliance for Zero Extinction (AZE) sites	X		
	Conflict potential with local population			X

4.1.1 Geology

Preconditions for acid mine drainage (AMD)

The chemical composition of the processing residues and the overburden is a major factor if the conditions favor AMD. In general, AMD requires the presence of sulphide minerals. If these are exposed to moisture and oxygen (air), a chain of chemical reactions leads to the formation of an oxidation and hydrolysis and thus to the formation of acid leachate. These acidic seepage waters can increase the removal of heavy metals from the rock and thus further push towards mobilization of heavy metals (Dehoust et al. 2017a).

In Cerro de Pasco, the largest part of the mined ore is of sulphidic nature. Moreover, the region is known for its cold, humid air. The environmental hazard potential for AMD is therefore high (*high environmental hazard potential*).

Paragenesis with heavy metals

At Cerro de Pasco mainly zinc and lead are mined as well as silver and copper. Consequently, three out of four mining products are categorized as heavy metals, having a high environmental hazard potential. Further potentially associated heavy metals include arsenic, cadmium and mercury (*high environmental hazard potential*).

Paragenesis with radioactive components

No information regarding possibly elevated uranium (U) or thorium (Th) concentrations are detected. The indicator paragenesis with radioactive elements is therefore low (*low environmental hazard potential*).

Deposit size

The metal content in the resources of zinc, lead and silver lead to a classification of the deposit of large to very large in the international comparison and, thus, a deposit of world rank. The environmental hazard potential is consequently high (*high environmental hazard potential*).

Specific ore grade

Average grades of resources are 2.15% Zinc, 0.8% lead, 0.09% copper, 2.78 Oz silver. The ore grade in the reserves is lower in comparison to the specifications for the resources for zinc (1.25%) and lead (0.44%) as well as copper (0.07%) and only increased for silver (4.94 oz/TM). The ore grades according to the site-related evaluation scheme lead to a classification of low (lead and copper) to average (zinc). As lead is one of the main products of the Cerro de Pasco mine, its poor grade leads to an overall high environmental hazard potential (*high environmental hazard potential*).

4.1.2 Technology

Mine type

Cerro de Pasco Mine has underground and surface operations. The Raúl Rojas open pit mine operates in solid rock, generating large earth movement and significant impact on the surface. In accordance with the site-related evaluation method, the environmental hazard potential is medium for solid rock open pit mining (*medium environmental hazard potential*).

Use of auxiliary substances

The plant mainly processes complex minerals of lead-zinc-silver sulphides with pyrite as gangue using selective flotation of lead and zinc ores. The objective is to obtain separate lead and zinc concentrates. The stages correspond to a conventional selective flotation of lead and zinc sulphides and include crushing, grinding, flotation, thickening, and filtering.

Due to the proximity of the Paragsha and Pasco Oxides Plant as well as the corresponding tailings, the processing steps undertaken at these palnts are included in the site-related evaluation. Silver, lead and zinc are recovered from the ore in several steps, including steps include crushing, grinding, flotation, thickening, and filtering using flotation. In addition, cyanide leaching takes place at the Pascos Oxides Plant. In the process of cyanide leaching, the material is first crushed and milled and then leached with diluted sodium cyanide solutions (Ministerio de Energía y Minas 2011). Flotation as much as leaching with cyanide solutions is classified as “use of toxic substances, leading to a high environmental hazard potential (*high environmental hazard potential*).

Mining waste management

Mining waste produced by the Cerro de Pasco mine was either used for backfilling in the Paragsha mine or stored above ground. From 1956 to 2000, the waste was transported to the Excelsior waste dump that is located in the Simon Bolivar district and contains 50 Mt of waste deposits with a structural height of 45-55 m. The deposited materials consist of fragments of angulated and strongly pyritized rock, matrix clayey sand with the presence of oxides. Furthermore, approximately 78 million tons of tailings produced by Paragsha/San Expedito Plant between 1943 and 1992 were deposited at the Quiulacocha tailings facility. The waste rock of the active oxide plant is stored in the Ocroyoc tailings facility. Due to the size and height of the tailings, the environmental hazard potential is high (*high environmental hazard potential*).

Remediation measures

Volcan Compañía Minera S.A.A. has its mine closure plan for Cerro de Pasco approved by the Peruvian Government. These plans include the use of best possible techniques for recultivation (Activos Mineros S.A.C. 2017). However, while mining galleries have been at least partly backfilled in the process, further in-process activities for renaturation on the surface do not seem to have taken place. The environmental hazard potential is consequently classified as medium (*medium environmental hazard potential)*.

4.1.3 Site (surroundings)

Accident hazard due to floods, earthquakes, storms, landslides

The total natural disaster risk is assessed by analyzing four individual sub-indicators. All sub-indicators (earthquakes, floods, tropical storms, landslides) show a low environmental hazard potential. The evaluation is carried out in accordance 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 indicator total is derived by the highest hazard potential of the sub-indicators. Most sub-indicators were rated with a low environmental hazard potential (storms, landslides, not located in arctic region) except the two sub-indicators earthquakes and landslides, which show a high environmental hazard potential. Rainfall in the summer season (December-March) is typical for the mountainous climate around Cerro de Pasco. During this period, heavy precipitation causes landslides and rock falls. Landslides and elevated water levels caused by those weather events can lead to the generation of AMD and physical instability in the waste dumps and tailings. The overall rating for this indicator is, consequently, high *(high 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. Cerro de Pasco is not located in a desert or semi-desert zone and the water stress is low (Water stress index, WSI 0 to < 0.15), which leads to a low environmental hazard potential *(low environmental hazard potential).*

Protected areas and Alliance for zero extinction (AZE) sites

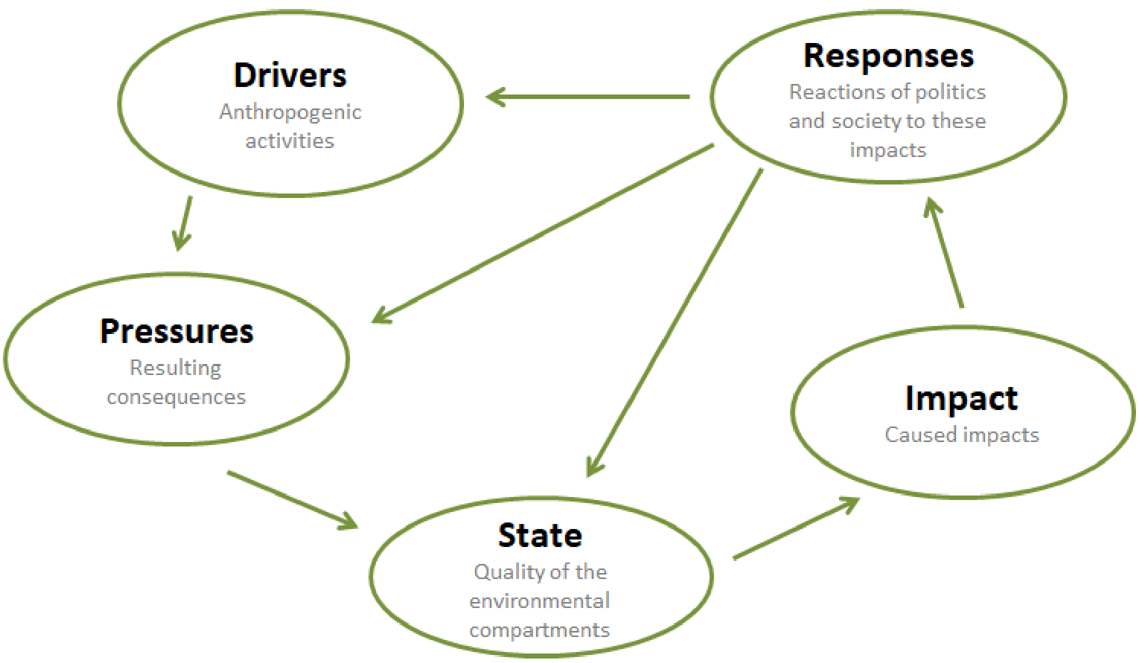
Georeferenced data for designated protected areas are used to assess hazards posed by mining extraction. The metric to evaluate EHPs corresponds to the method first described in the draft standard of the Initiative for Responsible Mining Assurance (IRMA 2014). There are no protected areas close to the mine. Therefore the environmental hazard potential for protected areas and AZE sites is rated as low *(low environmental hazard potential).*

Conflict potential with local population

The Worldwide Governance Indicator (WGI) "voice and accountability" shows a moderate percentile rank 55.67 for Peru, while the WGI indicator "control of corruption" shows a slightly lower percentile rank of 43.27. In accordance with the site-related evaluation method, if one of the two WGI indicator values is below 45, the environmental hazard potential is classified as high *(high environmental hazard potential).*

4.2 Environmental impacts

Figure 4-1: DPSIR framework



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

The DPSIR framework is a system analysis approach to help better understand the interaction of humans and their environment in order to derive adequate policy measures. It comprehensively accounts for and visualises 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.[17]

This chapter focuses on environmental impacts, human health, and surrounding areas. This information originates from websites of different media companies, reports, and closure plans.

4.2.1 Pressures

The mining operation began in 1901 and has affected, directly and indirectly, an area of 893 ha (8.93 km^2 measured based on Google Maps (n.d.)) involving land loss, reducing the habitable area in the city, and leading to degradation of water, air and soil quality. Some of the mining environmental liabilities have been transferred to the company Activos Mineros S.A.C. such as the Excelsior waste dump and Quiulacocha Tailings. The distribution of the mining components of Cerro de Pasco is shown in Figure 3-5.

4.2.2 State and Impacts

Surface disturbance

The operations of the Cerro de Pasco mine are located in the city of the same name. The city emerged as a mining settlement without planning, and has an irregular outline. The industrial zone (mainly mining-related) has an area of 171 ha (1.71 km^2). The waste "zone" comprises 136 ha (1.36 km^2) and the open pits 132 ha (1.32 km^2). This makes the mine itself occupy almost 50% of the city (Aramayo Bazzetti 2009).

Raúl Rojas open pit began in 1956, absorbing city areas and starting to entail re-settlements of parts of the city, eliminating the old center of Cerro de Pasco. In 1964, an agreement was reached that those inhabitants, whose houses were destroyed, would be moved to a "new city" built by the company in the Pampa de San Juan located 2 km from the old center. The pit constantly expanded through the 1970s, 1980s and 1990s. This led to the destruction of old neighborhoods, continuous reduction of urban space and to a deficiency of basic infrastructure in particular sanitation and electricity (Mendoza Carrasco 2016). In its last stage, the pit reached almost 1.5 km in diameter and 300 meters in depth (Mendoza Carrasco 2016).

In 2010, due to the depletion of reserves, the Plan L was proposed. This plan consisted in the further expansion of the open pit with the clearing of 4.7 ha (0.04 km^2) of the southeast wall (mining area), considering a safety area of 4 ha (0.04 km^2) and 2.7 ha (0.027 km^2) of green area. However, the expansion was stopped by the mining company (Ríos 2013).

Air pollution

Operations and diverse activities carried out by the mining company are sources of air pollution. This

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

includes emissions from the concentrators of the Paragsha/San Expedito Plant, as well as dust from the waste dumps and tailings that surround a large part of the city (Labor 2007). The high content of polluting particles in the air is caused by dust from tailings, which contain sulfur anhydride and fine particles of heavy metals such as sulfur dioxide, arsenic, and lead (Mendoza Carrasco 2016). It can be assumed that the mining activities in the Raúl Rojas open-pit mine in its time added to the air pollution.

Noise and vibration

The main noise pollution that the city suffered resulted from the vibrations and detonations carried out in the Raúl Rojas open pit mine and underground mine Paragsha as part of the mining operations. The detonations known as "tiro" were usually realized at 11 am and 3 pm and caused vibrations that affected the entire population. Progressive deterioration of the housing infrastructure and urban equipment of the city were reported (Mendoza Carrasco, 2016). Another, ongoing, significant environmental impact comes from the processing plants. Here, the noise originates from the different processing steps in the crushing and grinding sections (Astocaza Armacanqui 2008).

Groundwater pollution

A hydrogeological study conducted in 2006 concluded that a total of 25 l/s of water from dumps and stockpiles infiltrate the groundwater with estimated 6-8 l/s infiltrating the deeper groundwater. The groundwater flows towards the underground mine Paragsha and fills the old mining galleries (Ground Water International 2006).

Runoff and groundwater below and adjacent to dumps and stockpiles were strongly affected by AMD. The water's pH is between 0 – 6 and the measured dissolved solids content amounts to 260,000 mg/l. The solid contents in the acidic ground water include sulfate, fluoride, ammonia, arsenic, cadmium, iron, lead, manganese, nickel, and zinc. Contaminated groundwater verifiably reached a depth of 60 m, but is likely to extend to 100 m (a consequence of the hydraulic influence of the mine).

The Yanamate lagoon was used for mining wastewater discharge from 1981 onwards. The dumping of acid waters into the lagoon led to an increase of the water level and, in consequence, to a linkage of the Yanamate lagoon with the Laguna Huaygacocha (Golder Associates Perú S.A. 2000). The surface quality of the Yanamate lagoon has been improving slowly but the water is still acidic (pH between 1.9 and 2.2) and levels of arsenic, cadmium, copper, nickel, lead, and zinc exceed the General Water Law of Peru. The levels of ammonium, bismuth, chromium, phosphorus, manganese, thallium and vanadium are also high.

The groundwater downstream of the lagoons shows a neutral to slightly acidic pH values. Data indicates that present limestone has a neutralizing effect on the lagoons and thus counteracts the infiltrations. Salty water with total dissolved solids (TDS) in the range of 2,000 mg/l and concentrations of sulfates and ammonia exceeding the discharge limits of effluents have been measured (Ground Water International 2006).

Pollution of nearby rivers

The Quebrada Quiulacocha lagoon and the Quiulacocha Creek (not the tailings storage facility of the same name), which are tributaries of the San Juan river, are affected by contamination through mining, industrial water and domestic discharges. The lagoon contains heavy metals that exceed the limits determined by the World Health Organization (WHO). The heavy metal levels in the lagoon are: iron (3910.5 mg/l), manganese (30.57 mg/l), zinc (335.20 mg/l), and cooper (33.73 mg/l) (Wade et al. 2006). In consequence, the San Juan River is gradually deteriorating and becoming contaminated and changing its physical and chemical characteristics, with the presence of lead exceeding permitted limits (Paz Valenzuela 2016). The San Juan River has its source in the Pasco knot and is the main tributary of the Mantaro River (Paz Valenzuela 2016).

Results of the water quality monitoring of the Water Resources Quality Monitoring Program carried out by Dirección General de Salud Ambiental (DIGESA) in 2001 and 2008, and in 2010, 2011, and 2014 showed that the heavy metals Cadmium, copper, iron, manganese, lead, and zinc exceeded environmental quality standards. Heavy metal concentrations decreased significantly until 2014 in comparison to the quality monitoring results of 2001 to 2011. Concentrations of metals have been reduced by 70% compared to the values of 2001. With regard to arsenic, national standards where exceeded only during the dry seasons in the period 2001 to 2011 (Villarreal Huacachi 2016).

Another river near the city – the Tingo River that flows into the Huallaga River –is contaminated by runoff from the Rumiallana dump, located at the head of the river where the company Cerro Volcan/Cerro SAC currently deposits its debris (Helfgott 2012). Concentrations of metals are very high at the top of the sub-basin and lower at the bottom. At the top, metals such as manganese, aluminum, cadmium, and lead are found in concentrations more than 50 times higher than the values allowed by the WHO. In its basin, the Tingo River receives many tributaries that generate a dilution effect regarding the concentration of all the metals present in the river. However, metals such as lead, cadmium, and arsenic remain in concentrations above the limits of environmental quality standards[18] until their confluence with the Huallaga River, affecting people that live in this basin. The water is not drinkable nor can it be used for animals or crops. The metals present are residuals and moving along the food chain (Asociación Civil Centro de Cultura Popular Labor 2009).

Health

Available data shows chronic lead poisoning of children, and some cases of high contamination in several Cerro de Pasco's suburbs (Ministerio de Salud 2005). High lead levels can have a negative effect on blood formation, the nervous system, the digestive system, the kidneys, reproduction and children's' learning. Additionally, high levels of other metals in the blood such as caesium, thallium, arsenic, chromium, nickel, and aluminium have been detected. Nonetheless, no specific source of the contamination was determined and results from health specialist have not been published (Helfgott 2012).

4.2.1 Responses

Water treatment

In the 1980s, a treatment plant was built by the Peruvian government due to the Central Government's interest in using part of the Mantaro waters for Lima's water supply. This reduced the pollution of the San Juan River, but did not entirely eliminate it. Paz Valenzuela (2016) presents possible measures to mitigate impacts on the water bodies in the area. If these suggestions have led to actions by the ministry could not be determined based on the information at hand.

Health

In 2015, a dialogue between the population and the Peruvian government was started that has led to several actions by the government. In 2017, Minsa (The Ministerio de Salud – Ministry of Health) pub-

[18] Decreto Supremo N° 015-2015-MINAM - Environmental Quality Standards (ECA) for Water.

lished a press release to declare a formal 90 days health emergency declaration that included the districts of Chaupimarca and Simón Bolívar. The two districts are part of the Pasco Region. During this period, Minsa can carry out immediate actions to execute an emergency action plan for health problems caused by heavy metal contamination. The plan prioritized children under 12 and pregnant women (Ministerio de Salud 2017a and 2017b).

Furthermore, a comprehensive health plan was proposed for 2017 to 2021, which includes the construction of a Specialised Heavy Metal Attention Centre in Junín – a demand from the local population in Pasco. Minsa called on parents to allow immediate health care for children with heavy metal poisoning by traveling with them and that the parents should support the treatment financially. (Ministerio de Salud 2017b).

In the same year, the government started a program to provide drinking water to the population of Pasco as local water was classified to be too heavily contaminated for drinking purposes (Ministerio de Vivienda, Construcción y Saneamiento 2017).

In addition to addressing the causes for the heavy metal contamination of the area, Activos Mineros S.A.C. carried out the bidding process of the closure plan of the Excelsior waste dump. Furthermore, the terms of reference for the selection process to develop a closure plan for the Quiulacocha tailings are being prepared (Congreso de la Republica del Perú 2017).

5 Governance

5.1 Sector governance, regulation and effectiveness

As global metal prices rose significantly in the 1990s, mining investments experienced a sharp increase in Peru. Between 1990 and 1997, investments increased by 90 percent and mining operations expanded into areas that previously had not known industrial mining at that scale (Gil 2009). At that time, the government under the authoritarian rule of Alberto Fujimori created strong incentives for investments by implementing economic liberalisation policies: In 1991, the Fujimori government adopted three bills to promote and facilitate foreign direct investments, private investments and mining investments (Arellano-Yanguas 2011; Contreras Carranza 2016; Bury 2005). Theses legislative developments weakened the newly established environmental code, as it was considered too costly for companies (Gil 2009). In addition, the Fujimori government introduced a comprehensive mining law, the General Mining Law (Ley General de Minería) in 1992.

Institutional and administrative framework

The Ministry of Energy and Mines is the main regulating body for mining in Peru. The Ministry has several specialized agencies. The agency responsible for granting and registering mining concessions is the Geological, Mining and Metallurgical Institute (Instituto Geológico, Minero y Metalúrgico). The General Directorate of Mining (Dirección General de Minería) is the agency in charge of granting authorizations for exploration and exploitation projects. The Directorate of Mining Environmental Affairs grants environmental certifications for smaller mining sector projects while large-scale mining projects fall under the responsibility of the National Service for Environmental Certification for Sustainable Investments (Servicio Nacional de Certificación Ambiental para las Inversiones Sostenibles, SENACE), which is a body of the Ministry of Environment (KPMG 2016).

The institutional framework for environmental policy in Peru has been advanced over the last decade. Two developments were especially important: the relocation of most environmental responsibilities from sector authorities to the Ministry of the Environment (established in 2008) on the one hand and the transfer of environmental responsibilities from the national government to subnational and local authorities on the other hand (OECD 2016). In the past, the Ministry of Energy and Mines had not only the responsibility for promoting mining in general and granting mining concessions, but also for regulating its environmental and social impacts and approving the Environmental Impacts Statements prior to a mining project. This led to an evident conflict of interest between both the promotion of mining activities and environmental and social regulation of mining (Bebbington and Bury 2009). Since July 2015, the newly created SENACE at the Ministry of Environment is responsible for granting environmental certifications for large-scale mining and other bigger infrastructure projects, which need Detailed Environmental Impact Assessments (Estudio de Impacto Ambiental Detallado, EIA-d)[19] (KPMG 2016; OECD 2016). Prior to that date, the general Directorate of Mining Environmental Affairs was in charge of granting the environmental certifications for all mining projects (KPMG 2016). The establishment of SENACE was important to render environmental management more efficient and independent. However, the institution is still relatively young and the transfer of assessment functions from sector entities to SENACE is still in process (OECD 2016).

In contrast to these positive developments, a new law was passed in July 2014 to promote private investments in the country. Civil society and environmental organizations criticize that this law weakens environmental governance and the EIA process substantially (Environmental Investigation Agency

[19] There are three types of Environmental Impact Assessments in Peru: Environmental Impact Statements (Declaración de Impacto Ambiental, DIA) for projects that are not expected to have significant negative environmental impacts, the Semi-Detailed Environmental Impact Study (Estudio de Impacto Ambiental Semidetallado, EIA-sd) for projects that are expected to cause moderate negative environmental impacts, and the EIA-d for projects that are expected to cause significant negative environmental impacts (SENACE 2016). SENACE is only responsible for EIA-d.

2015). The new law "significantly reduces most fines for companies because of environmental damages, forces environmental studies to be done in just 45 days, and allows exploitation of fossil fuel and mining in any newly formed protected areas. [In addition], the Ministry of Environment no longer has the authority to set standards for air, soil, and water quantity" (KPMG 2016: 10).

The Agency for Environmental Evaluation and Enforcement (Organismo de Evaluación y Fiscalización Ambiental, OEFA) – also a body of the Ministry of the Environment – was established in 2008 and is responsible for auditing and supervising compliance with environmental regulations of medium and large-scale mining projects (KPMG 2016). The creation of OEFA strengthened environmental enforcement in Peru as regards the number and amount of fines levied for environmental damage (OECD 2016). In 2016, OEFA imposed 45 fines on mining companies (La República 2017). In general, however, "the fines levied bear no relation to the economic costs of the associated damage" (OECD 2016: 36).

Legal and regulatory framework

The General Mining Law regulates all mining activities, including small and medium-scale mining (OECD 2016; cf. General Mining Law). The Law covers mainly the terms and conditions under which mining activities are allowed and how mining rights can be obtained (EY 2017). It does not contain environmental regulations but refers to environmental laws (cf. General Mining Law). The General Mining Law stipulates that all subsurface land and mineral resources are property of the state, regulated through a concession system (cf. General Mining Law; EY 2017). Prospecting or mining companies need to acquire concessions from the Ministry of Energy and Mines, granted through the Geological, Mining, and Metallurgical Institute (KPMG 2016). Unclaimed or unoccupied lands can be accessed by the holder of a mining concession (ICLG 2018). When privately owned, access to the surface needs to be acquired separately from the surface (EY 2017). The General Mining Law establishes a clear administrative process which mining concession holders must comply with to gain access to privately owned land. The Law requires mining operators to have an agreement with the owners of the surface land (EY 2017). However, the granting of a mining concession does not require the prior consultation of local communities or regional governments. Residents or land users often only learn about the granting of a concession for their land when exploration activities take place or the mining company seeks access or wants to purchase the land (Bebbington et al. 2013). In cases in which the landowners refused to allow access to subsurface minerals, expropriation procedures have been considered in the past (EY 2017). This institutional setup bears a significant conflict potential.

Environmental legislation in the mining sector

In 1990, the Environment and Natural Resources Code (Código del Medio Ambiente y los Recursos Naturales) was established as the first environmental framework law. The current General Environmental Law was enacted in 2005 and superseded the Environment and Natural Resources Code (SPDA 2010). It refers to various sector-specific regulations. The General Environmental Law and other laws (in particular the National Environmental Management System Law (Ley del Sistema Nacional de Gestión Ambiental) and the National Environmental Impact Assessments System Law (Ley del Sistema Nacional de Evaluación de Impacto Ambiental)) constitute the legislative framework for EIA (Ministry of the Environment n.d.). The environmental regulation for mineral exploration activities (Reglamento Ambiental para las Actividades de Exploración Minera) was established in 2008 and renewed in 2017, aiming at promoting mineral exploration activities (OECD 2016; El Comercio 2017). The regulation lays down that studies and investigations prior to actual exploration activities do not require environmental certification. Further, it stipulates that exploration activities with up to 40 perforation platforms require an Environmental Impact Statements (DIA), while exploration activities with more than 40 perforation platforms require a Semi-Detailed Environmental Impact Study (EIA-sd) (El Comercio 2017).

Informal Mining

In addition to industrial large-scale mining, Peru also has an artisanal and small-scale mining (ASM) sector. ASM miners in Peru extract almost exclusively gold (IIED 2002). Lead and zinc mining is usually not mined by ASM operators (IGF 2017). Artisanal and small-scale gold mining (ASGM) occurs in the Madre de Dios region, is mostly informal and comes at a high environmental and social cost. It leads to deforestation, mercury pollution and resulting environmental and health issues. Other problems linked to ASGM are hazardous working conditions, tax evasion as well as crime and sexual exploitation in the neighbouring communities (Salo et al. 2016). ASM is an important governance issue (see Rüttinger et al. 2015). In 2002, the Peruvian government started a nationwide formalization process to gain control over the ASM sector. In addition, the regional government of Madre de Dios approved a Formalization and Restructuring Plan for region's ASM sector, which included six mandatory steps (Salo et al. 2016). However, it became evident that only the minority of miners has the capacity to implement these steps. As a result, as of June 2016, no mining operator in Madre de Dios has fulfilled all six requirements to become formalized (Salo et al. 2016).

The reaction of the central government to the stalemate in the formalization process has been twofold: interdiction involving military force and the promotion of formalization through financial help. However, those incentives have mostly failed, due to lacking organization, capacities, and financial means (Salo et al. 2016; O'Faircheallaigh and Corbett 2016).

Corruption and transparency

Corruption in Peru is widespread among government officials, in the judicial system and public service (GAN 2016). Several corruption scandals have had sweeping impacts, reaching the highest levels of government and the judiciary. President Pedro Pablo Kuczynski resigned in March 2018 after several cases of corruption became evident, including vote-buying, abuse of presidential clemency and bribery in exchange for public contracts (Odebrecht case) (BBC 2018; Transparency International 2018a; Transparency International, 2018b). Three of Kuczynski's presidential predecessors and the main opposition party are also under investigation in the Odebrecht corruption case (Cervantes 2018).

In its 2017 report on combatting corruption in mining approvals, Transparency International finds that Peru's mining sector is prone to corruption as public service contracts in the mining licencing authority are mostly short-term and low-paid. This gives incentives to contracted officers to work for the industry while issuing mining licences (Caripis 2017).

Peru is a compliant country of the Extractives Industries Transparency Initiative (EITI) under which all industry payments and government revenues related to oil, gas and mining have to be publicly disclosed (GAN 2016). However, at the moment, EITI is only covering payments and revenues transparency but does not account for the implementation of human rights in the mining sector. Therefore EITI has limited transformative power in Peru (Romero et al. n.d.).

Indigenous and minority rights

Peru ratified ILO Convention 169, the Indigenous and Tribal Peoples Convention, in 1994. It was incorporated into national law in 2011 through the Prior Consultation Law (Ley del derecho a la Consulta Previa a los Pueblos Indígenas u Originarios) (Sanborn et al. 2016). The ILO Convention stipulates that "indigenous people have the right to prior consultation and to free, prior, and informed consent before any relocation from their lands" (Bebbington and Bury 2009: 17297). The Prior Consultation Law lays down that indigenous people need to be consulted through a public participation process prior to the approval of a mining project that might impact indigenous communities (KPMG 2016).

However, the effectiveness of the Prior Consultation Law is limited. First of all, not all indigenous groups are recognized by the state and registered in the official data base on indigenous peoples (Datos Oficial de Pueblos Indígenas u Originarios), which makes it difficult to trigger a prior consultation in the first place (Caripis 2017; Leyva 2018). Other limiting factors are: the consultation process is defined by the state without indigenous participation; the approval of a mining concession is not subject to consultation; consultations are focused on operational decisions and not on consent (Bebbington et al. 2013; Flemmer & Schilling-Vacaflor 2016; Leyva 2018).

5.2 Social context of mining and conflicts

Mining conflicts

Conflicts between rural communities on the one hand and large mining companies and the state on the other hand increased since the beginning of the 21st century. The Defensoría del Pueblo (Ombudsman's Office) publishes monthly reports of social conflicts in Peru. In its most current report, the Defensoría del Pueblo recorded a total of 198 ongoing social conflicts of which 84 were mining-related (Defensoría del Pueblo 2018).

Conflicts between communities and large-scale mines are linked to disputes over land use and land rights, indigenous consultations, negative environmental impacts of mining operations, high community expectations for economic development in mining regions and the inadequate redistribution of resource rents both through the state and companies (Paredes 2016).

Over the past years, mining-related conflicts were highly contentious and often ended in violence. For example, five people lost their lives in police confrontations while protesting against the Conga gold mining project in Cajamarca in 2012 and seven people died during protests opposing the proposed Tia Maria copper mine in Arequipa in 2015 (Echave and Diez 2013; Hill 2015). In addition, the extraction of oil claimed many lives: protests against the extraction of oil in the Amazon escalated in 2009, leaving 23 policemen and 10 civilians dead (Andreucci and Kallis 2017; Amnesty International 2010).

The United Nations Working Group on Business and Human Rights reported after a visit to Peru in July 2017 that mining operations in different parts of the country are associated with severe human rights concerns. The Working Group "observed the limited presence of state institutions in the areas of mining operations, undermining governance and the rule of law, hampering dialogue with communities and contributing to an environment of mistrust, discontent and social unrest" (OCHA 2017).

Conflict Management

The Peruvian state has developed several instruments and institutions for conflict prevention and management (Orellana 2015; Damonte 2016). The introduction of the Environment and Natural Resources Code (Código de Medio Ambiente y de los Recursos Naturales, Legislative Decree 163) stipulated the concept of EIAs already in 1990 (OECD 2016). It was enhanced by the creation of SENACE.

In 1992, the government introduced the so called 'canon minero' law that "allocated 20 per cent of the income tax paid by mining companies to the territory in which the profits were generated" (Arellano-Yanguas 2011: 662). The legislature increased the share of revenues transferred back to the mining region from 20 to 50 per cent of the income tax in 2001 (Arellano-Yanguas 2011). Although the 'canon minero' is well-intentioned, it also created new problems and conflicts: Local authorities do often not have the capacity to distribute the fiscal transfers efficiently; different levels of governments dispute over the allocation of money; and subnational governments argue over their territorial boundaries (Arellano-Yanguas 2011).

The Defensoría del Pueblo was established in 1993 as an independent organ reporting to the congress. Its function is to monitor and protect the constitutional rights and freedoms of the individual and the community. The Defensoría also publishes monthly reports on social conflicts in the country, which serve as early warning system (Damonte 2016).

The Prior Consultation Law, introduced in 2011, is another conflict prevention mechanism (see paragraph on indigenous and minority rights) (Sandborn et al. 2016).

In addition to the Prior Consultation Law, the National Office for Dialogue and Sustainability (Oficina Nacinal de Diálogo y Sostenibilidad) was created in 2012. It is a state-run mediation body and forms part of the Presidency of the Council of Ministers (Presidencia del Consejo de Ministros) (Orellana 2015).

Mining conflicts in Cerro de Pasco

Conflicts in Cerro de Pasco are related to the expansion of the mine in the city and to health problems stemming from mining pollution.

Open-pit mining within the city limits of Cerro de Pasco began already in 1956 (Environmental Justice Atlas 2018; Dajer 2015). Many buildings and city infrastructure had to give way for the expanding mining pit, mining infrastructure and tailings.

The Municipality declared residential and commercial zones as well as monuments a cultural heritage (Environmental Justice Atlas 2018). Nevertheless, the company managed to expand the mining pit further and plans to resettle the whole city emerged. In 2008, the national congress (Congreso de la República) adopted a law for the resettlement of the city. However, it remains unclear who will finance the resettlement. The mine changed ownership several times, which complicates the distribution of responsibilities. The current owner Volcan claims it is not responsible for resettlement and that the state should be in charge (Dajer 2015).

In June 2017, several families from Cerro de Pasco protested in Lima and camped outside the Ministry of Health to demand support to deal with the health impacts of mining pollution, notably to construct a regional hospital, which specialises in exposure to heavy metals, a health plan and to ensure the quality of drinking water (Reuters 2017; SPDA 2017). The Defensoría del Pueblo intervened and tried to facilitate the dialogue not only with the Ministry of Health but also with the Ministries of the Environment, Energy and Mining and Housing (SPDA 2017). As a reaction to the protests, the Ministry of Health declared a health emergency[20] in two districts of Pasco. The Ministry of Health acknowledged the contamination of water with heavy metals and other pollutants and announced an action plan, prioritizing children younger than 12 years and expectant mothers (SPDA 2017). As the action plan was not fully implemented, affected residents from Cerro de Pasco returned to the Ministry of Health in February 2018 to continue protesting. The protests led to a new declaration of health emergency and a new action plan for twelve districts in the Cerro de Pasco region in March 2018 (Paucar Albino 2018). However, it is not clear whether these new measures have been implemented.

The United Nations Working Group on Business and Human Rights highlights in its 2017 report water contamination, depletion of water and the presences of heavy metals in the mine workers' and local populations' blood in Cerro de Pasco and other mining places. The Working Groups comments that a transparent assessment and mitigation of mining impacts on health and the environment and the reparation of affected people is lacking (OCHA 2017).

[20] In 2012, the Ministry of Health has already declared a health emergency in the region, but residents' report that several announced actions were not implemented (SPDA 2017).

6 Conclusion and comparison of the analysis with existing governance indices

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 are compared to 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 is identified that can be used to improve the assessment approach to analyse the environmental hazard potential of the OekoRess I project.

Does the assessment of the environmental hazard potentials adequately point to the actual environmental impacts?

The main environmental impacts outlined in this study are the large surface disturbance (open pits, processing plants, and mining waste), air pollution, noise and vibration, and pollution of groundwater and nearby rivers, leading to severe health impacts.

For most indicators, the assessment of the environmental hazard potentials adequately pointed to the identified environmental impacts. For example, the large land footprint of the mine is reflected by the high environmental hazard potential for the indicators “deposit size” and “specific ore grade”.

In addition, the high environmental hazard potential for the indicators “preconditions for acid mine drainage (AMD)”, “paragenesis with heavy metals” and “use of auxiliary substances” adequately reflected the actual environmental impacts at the site: air pollution with fine particles of heavy metal, pollution of groundwater, nearby lagoons and rivers linked to AMD and heavy metals, and the resulting health impacts (in particular lead poisoning).

The discontent of the local population with the governance situation at Cerro de Pasco is well reflected in the indicator “conflict potential with local population”, which shows a high environmental hazard potential.

The low environmental hazard potentials for the indicators “paragenesis with radioactive components”, “Water Stress Index (WSI) and desert area” and “protected areas and Alliance for Zero Extinction (AZE) sites” also adequately reflected the realities at the mining site as no reports of related environmental impacts were found.

A high environmental hazard potential was indicated for “mining waste management” and for “accident hazard due to floods, earthquakes, storms and landslides”, which are plausible potential environmental hazards. Luckily, actual incidents and related environmental impacts have not been reported yet.

The indicator “mine type”, which stands for the extent of the intervention at the earth's surface and the associated impacts on landscape, has a medium environmental hazard potential at Cerro de Pasco as it is a solid rock open pit mine. However, this does not reflect the specific location of the mining area, which spreads over large parts of the city and the high exposure to noise. The extreme closeness of the inhabited area and the increased exposure of the population to negative impacts of the mining site were not reflected in the site-related evaluation method.

The indicator "remediation measures" shows a medium environmental hazard potential. This reflects that Volcan Compañía Minera S.A.A. has an approved mine closure plan in place and that its implementation is lacking. However, it does not fully reflect the actual situation, again linked to the fact that Cerro de Pasco is a historic mining region with its first mining activities dating back to the 16th century. It has a legacy of abandoned mining sites and it is very difficult to separate the environmental impacts of the abandoned and the active mine. The site-related evaluation assesses EHPs for specific mines and does not take into account mining heritage.

Main findings of the governance analysis

In general, the governance analysis underlines Peru's average sector governance with relatively well-developed policy formulation. Corruption is widespread in the public sector and Peru's mining sector is also prone to corruption. State institutions have a limited presence in mining areas, leading to weak governance performance and "undermining governance and the rule of law"(OCHA 2017).

Over the past decade, the institutional framework for environmental policy in Peru has advanced. Environmental responsibilities were shifted from sector authorities – including the Ministry of Energy and Mines – to specialised institutions (SENACE and OEFA) at the Ministry of the Environment to render environmental management more efficient and independent. Before that, overlapping responsibilities for promoting mining in general, granting mining concessions and for environmental and social impacts had caused conflicts of interests. At the same time, a new law for the promotion of investments, amongst others in the mining sector, has weakened the environmental code and its implementation.

Numerous mining-related conflicts have occurred in the past, are still prevalent and often ended in violence. Conflicts between communities and large-scale mines are linked amongst other issues to land use and rights (particularly regarding mining concessions, which can be granted without prior consultation), inadequate consultations of indigenous communities, negative environmental impacts of mining operations and the inadequate redistribution of resource rents both through the state and companies.

Do existing governance indicators reflect Peru's governance gaps and challenges?

Peru's overall average to low sector governance is well reflected in the set of Worldwide Governance Indicators (WGI). Within this set of indicators, Peru has the highest score for WGI Regulatory Quality (0.42 and a percentile rank of 67.31), which reflects the relatively well-developed policy formulation and in particular the investment friendly policies in the mining sector (World Bank 2017). Peru's second highest WGI score is the indicator Voice and Accountability (0.27 and a percentile rank of 55.17), which reflects well the average governance performance in this specific area in Peru and in the mining sector.

For all other WGI indices Peru shows negative scores with its lowest value in Rule of Law (-0.50 and a percentile rank of 33.17) and Control of Corruption (-0.50 with a percentile rank of 38.94). This reflects very well the overall weak governance performance and the mining sector governance. Property rights are still a crucial point of conflict and the likelihood of violence in mining related conflicts is high. The limited presence of state institutions in mining regions weakens the rule of law. Widespread corruption, including top-level government officials, is a general governance problem. The mining sector is also prone to corruption.

Lastly, the country receives a -0.13 for WGI indicator Government Effectiveness (percentile rank of 48.56) and a -0.26 score for WGI indicator Political Stability and Absence of Violence (percentile rank of 36.19). The Government Effectiveness score reflects well the average governance effectiveness regarding policy formulation and weaknesses in implementation in the mining sector. The credibility of the government's commitment to implement the existing policies for the mining sector is rather low, which is exemplified by the inadequate redistribution of resources and reparations as well as a lack of a transparent assessment and mitigation of mining impacts on people's health and the environment. Against this background, the score for Government Effectiveness could be expected to be even lower.

The Political Stability and Absence of Violence score represents well Peru's low to average overall political stability as well as the mining sector's governance. The analysis revealed a significant number of social conflicts related to mining and protests leading to casualties. The high number of mining-related violent incidents suggests that the score could be even lower.

The Fraser Policy Perception Index (PPI), which shows an average rank and score for Peru (Rank 43 of 91, Score 68.99), reflects very well the mining sector's relatively high policy attractiveness in particular the existing laws promoting private investment and suggests an average general sector governance (Fraser Institute 2017). However, it does not reflect the environmental governance at Cerro de Pasco very well. The score should be lower.

An index specifically capturing the country's performance regarding the protection of human health and of ecosystems is the Environmental Performance Index (EPI). The EPI does not measure the quality of environmental legislations in place, but rather a country's actual environmental performance. Peru ranks 64 out of 118, scoring 61.92 (Yale University n.d.), which are average values. Based on this case study and the available data, this indicator's value seems appropriately reflecting the overall average to strong environmental performance but does not completely reflect the environmental performance in the mining sector. Due to the severe environmental impacts at Cerro de Pasco one could expect an even lower score.

The Corruption Perception Index (CPI) rates countries on how corrupt their public sector is seen by experts. Peru ranks 96 out of 180 countries assessed with a score of 37, which reflects the results of the governance analysis well which showed private investment interests are still placed before environmental regulations and corruption is common (Transparency International 2017).

Conclusion

Overall, the analysed indices and indicators show a good ability to also reflect the specific governance situation in the mining sector of Peru, except for the PPI and the EPI. Peru's overall to average to weak sector governance is well reflected in key governance indices of the WGI. However, for some of WGI indicators the values seem higher than the results of the governance analysis would suggest. The CPI reflects well the low governance performance regarding corruption.

The PPI and the EPI reflect the overall governance situation well but do not seem to reflect the severe situation at the area around Cerro de Pasco. Although mining is often very contentious in Peru and entails negative impacts in various cases, the health impacts in Cerro de Pasco stand out in severity. However, Cerro de Pasco is also an extreme case due to the long-standing mining activities, taking place in the middle of the city. This shows the difficulty of estimating to what degree a single case (the respective focus of the case studies is on a specific mining site) is representative for the assessment of the national mining sector governance as a whole.

For the case of Cerro de Pasco, the indicators for environmental hazard potentials are quite accurate in reflecting the actual environmental impacts. The mostly average to low scores for governance indicators underline that there is no strong governance in place, which would be able to remedy the severe environmental impacts from mining.

Table 6-1: Overview of governance indicators

Indicator	Peru	Year	Indicator measures…	Applicability
Voice and Accountability (WGI)	0.27 (estimate between -2.5 and 2.5) 55.17 (percentile rank terms from 0 to 100, with higher values corresponding to better outcomes)	2017	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.	Reflects well the average governance performance in this specific area in Peru and in the mining sector. +
Political Stability and Absence of Violence (WGI)	-0.26 (estimate between -2.5 and 2.5) 36.19 (percentile rank terms from 0 to 100, with higher values corresponding to better outcomes)	2017	Political Stability and Absence of Violence/Terrorism measures perceptions of the likelihood of political instability and/or politically-motivated violence, including terrorism.	Reflects well Peru's low overall political stability as well as the mining sector's governance. The analysis revealed a significant number of social conflicts related to mining and protests leading to casualties. However, the high number of mining-related violent incidents would indicate an even lower value. +
Government Effectiveness (WGI)	-0.13 (estimate between -2.5 and 2.5) 48.56 (percentile rank terms from 0 to 100, with higher values corresponding to better outcomes)	2017	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.	Reflects well the average governance e.g. as regards policy formulation and weaknesses in implementation in the mining sector. The credibility of the government's commitment to implement the existing policies for the mining sector is rather low for which examples are the inadequate redistribution of resources and reparations as well as a lack of a transparent assessment and mitigation of mining impacts on people's health and the environment. Against this background the score could also be expected lower in the particular case of Cerro de Pasco. +

Regulatory Quality (WGI)	0.42 (estimate between -2.5 and 2.5) 67.31 (percentile rank terms from 0 to 100, with higher values corresponding to better outcomes)	2017	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.	Reflects well the relatively well-developed policy formulation and in particular the investment friendly policies in the mining sector. As regards the overall governance one would even except a lower value. +
Rule of Law (WGI)	-0.50 (estimate between -2.5 and 2.5) 33.17 (percentile rank terms from 0 to 100, with higher values corresponding to better outcomes)	2017	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.	Reflects the overall weak governance performance and the mining sector governance very well. Property rights are still a crucial point of conflict and the likelihood of violence in mining related conflicts is high. The limited presence of state institutions in the areas of mining operations weakens the rule of law. ++
Control of Corruption (WGI)	-0.50 (estimate between -2.5 and 2.5) 38.94 (percentile rank terms from 0 to 100, with higher values corresponding to better outcomes)	2017	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.	Reflects well the governance in this area and the mining sector in which private investment interests are still placed before environmental regulations and corruption is common. +
Environmental Performance Index (EPI)	Rank 64 of 180, Score 61.92 (out of 100)	2018	The protection of human health and protection of ecosystems.	Reflects well the overall average to strong governance in the environmental sector but does not completely reflect the mining sector governance. The responsibilities for EIA's were recently separated from the granting of concessions which should reduce conflicts of interest between the promotion of mining and environmental regulations. It should thus strengthen the appropriate conduction of EIAs. How-

				ever, based on the environmental impacts in the area around Cerro de Pasco one would expect an even lower score. -
Fraser Policy Perception Index	Rank 43 of 91, Score 68.99 (out of 100)	2017	The index measures the overall policy attractiveness and the country's government policy on attitudes towards exploration investment.	Reflects very well the mining sector's relatively high policy attractiveness in particular the existing laws promoting private investment. ++
Corruption Perception Index (CPI)	37 (rank 96/180; scale 0 -100)	2017	Describes the perception of the corruption in the public sector by experts	Reflects well the governance in this area and the mining sector in which private investment interests are still placed before environmental regulations and corruption is common. +

7 References

Activos Mineros S.A.C. (2017): Activos Mineros Convocó La Licitación Pública Para La Ejecución De La Obra De Remediación Del Pasivo Ambiental "Excelsior" En Pasco. Online: http://www.amsac.pe/index.php/noticias/item/592-activos-mineros-convoco-la-licitacion-publica-para-ejecucion-de-la-obra-de-remediacion-de-pasivo-ambiental-excelsior-en-pasco (27.11.2017).

Amnesty International (2010): Demonstrationen gegen Bergbauunternehmen endeten blutig. Online: https://www.amnesty.de/2010/8/13/demonstrationen-gegen-bergbauunternehmen-endeten-blutig (22.11.2018).

Andreucci, D., & Kallis, G. (2017): Governmentality, Development and the Violence of Natural Resource Extraction in Peru. In: Ecological Economics 134, 95–103.

Aramayo Bazzetti, A. (2009): Análisis Del Conflicto Socioambiental En Cerro De Pasco Mediante La Ecología Política Y Los Ciclos Adaptativos (Master of Science). Universidad Nacional Agraria La Molina.

Arellano-Yanguas, J. (2011): Aggravating the Resource Curse: Decentralisation, Mining and Conflict in Peru. In: Journal of Development Studies, Vol. 47, No. 4, 617–638.

Asociación Civil Centro de Cultura Popular Labor (2009): Evaluación de la Calidad de los Recursos Hídricos en la Provincia de Pasco y de la Salud en el Centro Poblado de Paragsha. Cerro de Pasco: 84.

Astocaza Armacanqui, P. (2008): Planeamiento De Minado Del Tajo Abierto Raul Rojas UEA De Cerro De Pasco De Volcan Compañía Minera S.S.A (Título De Ingeniero De Minas). Universidad Nacional De San Cristóbal De Huamanga.

Autoridad Nacional del Agua (2014): Autorización Vertimiento de Aguas residuales tratadas Empresa Administradora Cerro S.A.C(pp. 1-3) (Perú, Ministerio de Agricultura y Riego). Lima. RD 118-2014-ana-DGCRH.

Banco Central de Reserva del Perú (2017): “Exportaciones Por Grupo De Productos Desde 1950.” Online: http://www.bcrp.gob.pe/docs/Estadisticas/Cuadros-Anuales/ACuadro_13.xls (12.10.2017).

Banco Central de Reserva del Perú (2018): Minería Metálica Creció 5 % en Noviembre 2017. Notas Informativas. Online: http://www.bcrp.gob.pe/docs/Transparencia/Notas-Informativas/2018/nota-informativa-2018-01-18.pdf (23.01.2019).

Banco Central de Reserva del Perú (n.d.): CARACTERIZACIÓN DEL DEPARTAMENTO DE PASCO [PDF]. Online: http://www.bcrp.gob.pe/docs/Sucursales/Huancayo/Pasco-Caracterizacion.pdf (12.10.2017).

Baumgartner, R., Fontbote, L., & Vennemann, T. (2008): Mineral Zoning and Geochemistry of Epithermal Polymetallic Zn-Pb-Ag-Cu-Bi Mineralization at Cerro de Pasco, Peru. Economic Geology, 103(3), 493-537. doi:10.2113/gsecongeo.103.3.493.

Bazzetti, A. A., & Infantas, E. S. (2010) : Determinación De Las Fases De Colapso En Las Diferentes Etapas De La Evolución Histórico-Ambiental De Cerro De Pasco (1901- 2008). Ecología Aplicada, 9(1-2), 113-124. Online: http://dx.doi.org/10.21704/rea.v9i1-2.401 (11.11.2017).

BBC (2018): Pedro Pablo Kuczynski: Under fire Peru president resigns. Online: https://www.bbc.com/news/world-latin-america-43492421 (22.11.2018).

Bebbington, A. J. aund Bury, J.T. (2009): Institutional challenges for mining and sustainability in Peru. In: Proceedings of the National Academy of Sciences of the United States of America 106(41), 17296–17301.

Bebbington, Anthony; Jeffrey Bury and Emily Gallagher (2013): Chapter 11 Conclusions. In: Bebbington, Anthony and Jeffrey Bury (eds.): Subterranean Struggles: New Dynamics of Mining, Oil, and Gas in Latin America. University of Texas Press, 267-288.

BMWI (2015): Bekanntmachung des deutsch-peruanischen Abkommens über Zusammenarbeit im Rohstoff-, Industrie-, und technoogiebereich. Vom 15.Mai 2015. Bundesgesetzblatt Jahrgang 2015 Teil II Nr. 18, ausgegeben zu Bonn am 25. Juni 2015. Online: https://www.bmwi.de/Redaktion/DE/Downloads/A/abkommen-zwischen-brd-und-peru-partnerschaft-rohstoff-industrie-und-technologiebereich.pdf?__blob=publicationFile&v=6 (23.01.2019).

Bury, J. (2005): Mining Mountains: Neoliberalism, Land Tenure, Livelihoods, and the New Peruvian Mining Industry in Cajamarca. In: Environment and Planning A 37(2), 221–239.

Cabos, R. (2005): Potencial Minero En La Region Pasco, .31-35, Rep.

Caripis, L. (2017): Combatting Corruption in Mining Approvals. Assessing the risks in 18 resource-rich countries. Study on behalf of Transparency International Australia. Online: https://www.transparency.org/whatwedo/publication/combatting_corruption_in_mining_approvals (22.11.2018).

Castellares, R., & Fouché, M. (2017): Determinantes de los Conflictos Sociales en Zonas de Producción Minera (pp. 1-27, Publication No. DT. N°. 2017-005). Banco Central de Reserva del Perú.

Cedron, M. (2012): Historic mines in Peru - a new tourist attraction Cerro de Pasco Case. Acta Geoturistica, 3(2), 42-47.

CEPALSTAT (2017): Peru: NATIONAL NATIONAL ECONOMIC PROFILE. Online: http://interwp.cepal.org/cepalstat/Perfil_Nacional_Economico.html?pais=PER&idioma=english (30.10.2017).

Cervantes, M. (2018) : Peruvians march against corruption as head of judiciary resigns. Online: https://www.reuters.com/article/us-peru-corruption/peruvians-march-against-corruption-as-head-of-judiciary-resigns-idUSKBN1KA051 (22.11.2018).

Climate data (n.d.): Klima Cerro de Pasco. Online: https://de.climate-data.org/suedamerika/peru/pasco/cerro-de-pasco-28094/ (22.11.2018).

Congreso de la Republica del Perú (2017) Boletín de Indicadores y Prevención de Conflictos Nro. 162.

Congreso de la República, Humala Tasso, O., Presidente Constitucional de la República, Castilla Rubio, L. M., Ministro de Economía y Finanzas, De Habich Rospigliosi, M., Ministra de Salud, & Albán PERALTA, W., Ministro del Interior (2013): Decreto Legislativo Que Dicta Medidas Destinadas A Garantizar El Servicio Público De Salud En Los Casos En Que Exista Un Riesgo Elevado O Daño A La Salud Y La Vida De Las Poblaciones [PDF]. Lima: El Peruano.

Contreras Carranza, C. (2016): Die peruanische Wirtschaft zu Beginn des 21. Jahrhunderts. In: Iken Paap, Friedhelm Schmidt-Welle (Hrsg.): Peru heute: Politik, Wirtschaft, Kultur. Frankfurt am Main: Vervuert (Bibliotheca Ibero-Americana, 166), 93–115.

Cronología Hhistórica (2014): Online: https://laultimareina.wordpress.com/cerro-de-pasco/cronologia-historica/ (11.11.2017).

Dajer, T. (2015): High in the Andes, A Mine Eats a 400-Year-Old City. Online: https://news.nationalgeographic.com/2015/12/151202-Cerro-de-Pasco-Peru-Volcan-mine-eats-city-environment/ (22.11.2018).

Damonte, G. (2016): Minería, Estado y comunidades: cambios institucionales en el último ciclo de expansión extractiva en el Perú. Un balance de investigación. In: Miguel Jaramillo (Hrsg.): Investigación para el desarrollo en el Perú: Once balances. México: GRADE, 403–444.

Defensoría del Pueblo (2018): Reporte de conflictos sociales N.° 173. Online: https://www.defensoria.gob.pe/wp-content/uploads/2018/08/Reporte-Mensual-de-Conflictos-Sociales-N%C2%B0-173-Julio-2018.pdf (22.11.2018).

Dehoust, G.; Manhart, A.; Möck, A.; Kießling, L.; Vogt, R.; Kämper, C.; Giegrich, J.; Auberger, A.; Priester, M.; Rechlin, A.; Dolega, P. (2017a): Erörterung ökologischer Grenzen der Primärrohstoffgewinnung und Entwicklung einer Methode zur Bewertung der ökologischen Rohstoffverfügbarkeit zur Weiterentwicklung des Kritikalitätskonzeptes (OekoRess I) - Methode für einen standortbezogenen Ansatz. Umweltbundesamt, Dessau-Roßlau.

Dehoust, G.; Manhart, A.; Möck, A.; Kießling, L.; Vogt, R.; Kämper, C.; Giegrich, J.; Auberger, A.; Priester, M.; Rechlin, A.; Dolega, P. (2017b): Discussion of the environmental limits of primary raw material extraction and development of a method for assessing the environmental availability of raw materials to further develop the criticality concept (OekoRess I). Umweltbundesamt. Dessau-Roßlau.

Dirección General de Minería (2017): Modificación Concesión de Beneficio Paragsha - Ocroyoc(pp. 3-9) (Perú, Ministerio de Energía y Minas). Lima.

Dold, B., Wade, C. & Fontboté, L. (2007): Water Management for Acid Mine Drainage Control at the polymetallic Deposit of Cerro de Pasco, Peru. - In: Cidu, R. & Frau, F.: Water in Mining Environments. - p. 423-426, 2 fig.; Cagliari (Mako Edizioni).

Echave, J., & Diez, A. (2013): Más allá de Conga. Lima: Red Peruana por una Globalización con Equidad/CooperAcción.

Einaudi, M. T. (1977): Environment of ore deposition at Cerro de Pasco, Peru. Online: http://econgeol.geoscienceworld.org/content/72/6/893 (10.11.2017).

El Comercio (2017): MEM aprobó nuevo reglamento para la exploración minera. Online: https://elcomercio.pe/economia/peru/mem-aprobo-nuevo-reglamento-exploracion-minera-noticia-483714 (22.11.2018).

Empresa Editora el Comercio (2008): Cerro de Pasco: El Exodo. Online: https://elcomercio.pe/EdicionOnline/especiales/cerrodepasco/index.html (15.11.2017).

Environmental Investigation Agency (2015): Peruvian Environment Under Attack from Government, EIA Comments. Online: https://eia-global.org/press-releases/peruvian-environment-under-attack-from-government-eia-comments (22.11.2018).

Environmental Justice Atlas (2018): Online: https://ejatlas.org/conflict/cerro-de-pasco-peru (22.11.2018).

EY (2017): Peru’s mining & metals investment guide – 2017/2018.

Flemmer, R., & Schilling-Vacaflor, A. (2016): Unfulfilled promises of the consultation approach: the limits to effective indigenous participation in Bolivia’s and Peru’s extractive industries, in: Third World Quarterly. Volume 37, 2016 - Issue 1.

Fraser Institute (2017): Annual survey of mining companies 2017. Online: https://www.fraserinstitute.org/sites/default/files/survey-of-mining-companies-2017.pdf (23.01.2019).

GAN – Business Anti-Corruption Portal (2016): Peru Corruption Report. Online: https://www.business-anti-corruption.com/country-profiles/peru/ (22.11.2018).

General Mining Law. Online: http://www2.congreso.gob.pe/sicr/cendocbib/con3_uibd.nsf/89E200B65DCF6DE9052578C30077AC47/$FILE/DS_014-92-EM.pdf (22.11.2018).

Gil, V. (2009): Aterrizaje minero : Cultura, conflicto, negociaciones y lecciones para el desarrollo desde la minería en Ancash, Perú. (Primera edición ed.). Lima: Instituto de Estudios Peruanos.

Golder Associates Perú S.A. (2000): Plan De Manejo Ambiental De La Laguna Yanamate.

Google Earth (2016) based on Landsat Copernicus. Online: https://www.google.com/earth/ (01.10.2019)

Google Maps (n.d.): [Cerro de Pasco, Perú]. Online: https://www.google.com/maps/@-10.6791665,-76.2591363,8216m/data=!3m1!1e3 (15.11.2017).

Ground Water International (2006): Investigación Hidrológica de la mina subterránea y de las facilidades superficiales de la unidad minera Cerro de Pasco (Vol. 4301, pp. 1-17, Rep.).

Häntsche, Patrick (AHK Peru); Eidam, Frank (DERA); Schmitz, Martin (DERA); Winkelmann, Lothar (BGR), Ellermann, Siegfried (GTAI) (2014): Peru - Herausforderungen und Chancen für eine nachhaltige Entwicklung im Rohstoffsektor. Pp 129. ISBN-Nr. 3-86643-582-7. Herausgeber: Germany Trade and Invest. Online: https://www.deutsche-rohstoffagentur.de/DERA/DE/Downloads/studie_peru_gtai.pdf?__blob=publicationFile&v=8 (23.01.2019).

Helfgott, F. (2012): Cerro de Pasco: Historia y Espacio Urbano. Online:http://marcosaldana.com/wp-content/uploads/2012/11/Federico-Helfgott-Texto-para-Proyecto-Afuera2.pdf (17.11.2017).

Hill, D. (2015): What is Peru's biggest environmental conflict right now?. Online: https://www.theguardian.com/environment/andes-to-the-amazon/2015/jun/08/tia-maria-perus-biggest-environmental-conflict-right-now (22.11.2018).

Hinojosa De La Sota, J. (2014): Reconocimiento Geologico En Los Alrededores Del Yacimiento De Cerro De Pasco -Cerro Sac [pdf file]. Online: https://www.scribd.com/doc/315905104/Informe-de-La-Geologia-Local-de-Cerro-de-Pasco (18.11.2017).

Hinojosa, L. (2011): Riqueza Mineral y Pobreza en Los Andes. European Journal of Development Research 23: 488-499.

Historia - Revista Minería. (n.d.): Instituto de Ingenieros de Minas de Peru. Online: http://www.mineriaonline.com.pe/mineria-en-el-peru/historia (28.10.2017).

ICLG (2018): Mining Law 2019 – Peru. Online: https://iclg.com/practice-areas/mining-laws-and-regulations/peru#chaptercontent1 (22.11.2018).

IGF (2017): Global Trends in Artisanal and Small-scale Mining (ASM). A Review of Key Numbers and Issues. Online: https://www.iisd.org/sites/default/files/publications/igf-asm-global-trends.pdf (22.11.2018).

IIED (2002): No title. Online: http://pubs.iied.org/pdfs/9084IIED.pdf (22.11.2018).

INEI - Instituto Nacional de Estadística e Informática (2012): Perú: Estimaciones y Proyecciones de Población Total por Sexo de las Principales Ciudades, 2000-2015 (pp. 1-49, Rep. No. 23). Lima: Dirección Técnica de Demografía e Indicadores Sociales del Instituto Nacional de Estadística e Informática (INEI).

INEI - Instituto Nacional de Estadística e Informática (2018): Producción Nacional, Diciembre 2017. Informe Técnico No. 02 – Febrero 2018. Online: https://www.inei.gob.pe/media/MenuRecursivo/boletines/03-informe-tecnico-n02_produccion-nacional-dic2017.pdf (23.01.2019).

IRMA – Initiative for Responsible Mining Assurance (2014): Standard for Responsible Mining Draft v1.0. Online: https://responsible-mining.net/wp-content/uploads/2018/09/IRMA_Standard_Draft_v1.007-14.pdf (09.12.2019).

KPMG (2016): Peru Country Mining Guide. Online: https://assets.kpmg.com/content/dam/kpmg/pdf/2016/03/peru-mining-country-guide.pdf (22.11.2018).

Kristensen, P. (2004): The DPSIR Framework. - National Environmental Research Institute, Department of Policy Analysis European Topic Centre on Water, European Environment Agency. By: Kirstensen, P. Paper presented at the 27-29th September 2004 workshop on a comprehensive/detailed assessment of the vulnerability of water resources to environmental change in Africa using river basin approach. UNEP Headquarters, Nairobi, Kenya. Online: https://greenresistance.files.wordpress.com/2008/10/dpsir-1.pdf (22.10.2017).

La República (2017): Sector minería es el más sancionado en el sur por daños al medio ambiente. Online: https://larepublica.pe/politica/1041655-sector-mineria-es-el-mas-sancionado-en-el-sur-por-danos-al-medio-ambiente (22.11.2018).

Labor (2007): Participación. Boletin 11. Asociación Civil Centro de Cultura Popular Labor.

Latin America and the Caribbean Atlas of our Changing Environment (n.d.): Cerro de Pasco, Peru. Online: http://www.cathalac.org/lac_atlas/index.php?option=com_content&view=article&id=59%3Acerro-de-pasco-peru&catid=1%3Acasos&Itemid=5 (07.11.17).

Leyva Valera, A. (2018): Consúltame de verdad. Aproximación a un balance sobre consulta previa en el Perú en los sectores minero e hidrocarburífico, Online: http://cooperaccion.org.pe/wp-content/uploads/2018/07/17072-Consultame-la-verdad-web.pdf (22.11.2018).

Matos del Pozo, L. A. (2014): Enlace Regional Especial Pasco [PDF]. Oficina Técnica de Apoyo a la Mesa Directiva y de Enlace con los Gobiernos Regionales y Locales.

MDNP - Mineral Development Network Platform (2018): SCOT analysis Peru. Online: https://www.mineralplatform.eu/, retrieved (19.09.2018).

Mendoza Carrasco, M. S. (2016): Cerro De Pasco De Campamento A Ciudad (Master's thesis, Escuela Técnica Superior De Arquitectura La Salle, 2016) (pp. 1-87). Barcelona: España.

Mining Data Solutions (2018): Online: https://miningdataonline.com/property/1117/Raul-Rojas-Mine.aspx#Geology (25.09.2018).

Ministerio de Energía y Minas (2011): Estudio de lmpacto Ambiental Excepcional (EIAE) del Proyecto 'Planta Complemenlaria para el Beneficio de Minerales Oxidados". Online: http://intranet2.minem.gob.pe/web/archivos/dgaam/certificado/RD_236_2011_MEM_AAM.PDF (08.11.2017).

Ministerio de Energía y Minas (2016): Annual Mining Report. Online: http://www.minem.gob.pe/minem/archivos/file/Mineria/PUBLICACIONES/ANUARIOS/2016/anuario2016.pdf (28.10.2017).

Ministerio de Energía y Minas (2018): Anuario Minero 2017. Ministerio de Energía y Minas. pp. 138. Online: https://gobpe-production.s3.amazonaws.com/uploads/document/file/98805/ANUARIO_MINERO_2017_1_.pdf (23.01.2019).

Ministerio de Energía y Minas (n.d.): Ampliación Paragsha - San Expedito. Online: http://www.minem.gob.pe/descripcion.php?idSector=4&idTitular=1193 (08.11.2017).

Ministerio de Salud (2005): Determinación De Plomo En Sangre y Factores Asociados En Niños Y Mujeres Gestantes De Las Poblaciones Quiulacocha y Champamarca Cerro De Pasco. Online: https://www.yumpu.com/es/document/read/50494473/determinacion-de-plomo-en-sangre-y-factores-asociados-bvs-ins (20.12.2018).

Ministerio de Salud (2016): Monitoreo Calidad de Aire en la Ciudad de Cerro de Pasco. [online] Lima: Ministerio de Salud. Online: http://www.munisimonbolivar.gob.pe/sites/default/files/RESULTADOS%20CALIDAD%20AIRE%202015-NUEVO606.pdf (02.01.2018).

Ministerio de Salud (2017a): Declaran Emergencia Sanitaria por 90 días en distritos Simón Bolívar y Chaupimarca de Pasco. Online: http://www.minsa.gob.pe/?op=51&nota=24027 (20.11.2017).

Ministerio de Salud (2017b): COMUNICADO N° 008-2017/MINSA (Press release). Online: https://www.gob.pe/institucion/minsa/noticias/13666-comunicado-n-008-2017-minsa (08.11-2018).

Ministerio de Vivienda, Construcción y Saneamiento (2017): Ministerio de Vivienda distribuirá agua a localidades de Chaupimarca y Simón Bolívar (Press release). Online: https://www.gob.pe/institucion/vivienda/noticias/7423-ministerio-de-vivienda-distribuira-agua-a-localidades-de-chaupimarca-y-simon-bolivar (08.11.2018).

Ministerio del Ambiente - MINAM (2001): *Reglamento de Estándares Nacionales de Calidad Ambiental del Aire.* Lima, Peru.

Ministry of the Environment (n.d.): Sistema Nacional de Evaluación de Impacto AmbientalSistema Nacional de Evaluación de Impacto AmbientalSistema Nacional de Evaluación de Impacto Ambiental. Online: http://www.minam.gob.pe/legislaciones/sistema-nacional-de-evaluacion-de-impacto-ambiental/ (22.11.2018).

Molina, O., Olivari, J., & Pietrobelli, C. (2016): Global Value Chains in the Peruvian Mining Sector (IDB-TN-1114, pp. 1-40, Publication). Inter-American Development Bank. Online: http://dx.doi.org/10.18235/0000468 (19.12.2017).

O'Faircheallaigh, Ciaran and Tony Corbett (2016): Understanding and improving policy and regulatory responses to artisanal and small scale mining. In: The Extractive Industries and Society, 3(4), 961–971

OCHA (2017): Statement at the end of visit to Peru by the United Nations Working Group on Business and Human Rights. Online: https://www.ohchr.org/en/NewsEvents/Pages/DisplayNews.aspx?NewsID=21888&LangID=E (22.11.2018).

OECD (2016): Environmental Performance Reviews: PERU. Online: https://www.oecd.org/environment/country-reviews/16-00312-environmental%20performance%20review-peru-web.pdf (08.01.2020)

Online:WHO (2018): Envrionmental Noise Guidelines for the European Region. Online: http://www.euro.who.int/__data/assets/pdf_file/0009/383922/noise-guidelines-exec-sum-eng.pdf?ua=1 (20.12.2018).

Orellana, A. (2015): Preservando la gobernabilidad democrática: un análisis de las Oficinas de Resolución de Conflictos 2000-2014. In: Revista de Ciencia Política y Gobierno 2(4), 67–97.

Paredes, M. (2016): The globalization of mining conflict: Cases from Peru. In: The Extractive Industries and Society Volume 3, Issue 4, November 2016, 1046-1057.

Paucar Albino, J. (2018): Alerta en Pasco: decretan emergencia sanitaria por metales tóxicos en 12 distritos. Online: https://redaccion.lamula.pe/2018/03/26/mineria-pasco-emergencia-sanitaria-metales-toxicos-distritos-simon-bolivar-yanacancha-chaupimarca/jorgepaucar/?platform=hootsuite (22.11.2018).

Paz Valenzuela, E. (2016): Impacto geoambiental generado por la minería en el área circunscrita al Rio San Juan- Provincia De Pasco Departamento De Pasco. Tesis para optar el Título Profesional de Ingeniero Geólogo. Universidad Nacional De San Agustín Arequipa Facultad De Geología, Geofísica y Minas Escuela Profesional de Ingeniería Geológica.

Peru Routes (2015): Protected Natural Areas of Peru. Online: http://peruroutes.com/peru_ing_reserves.html (27.11.2017).

Pfister, S., A. Koehler, S. Hellweg (2009): Assessing the Environmental Impacts of Freshwater Consumption in LCA. In: Environmental science & technology. Vol. 43, No.11, 4098–104.

Red Muqui - Minería, Ambiente y Comunidades (2017): MINSA se compromete buscar convenios con mineras para atención de personas contaminadas en Pasco. Online: http://www.muqui.org/comunicaciones/noticias/item/610-minsa-se-compromete-buscar-convenios-con-mineras-para-atencion-de-personas-contaminadas-en-pasco (15.12.2017).

Reuters (2017): Chained to health ministry, Peruvians protest mining pollution. Online: https://www.reuters.com/article/us-peru-mining-pollution/chained-to-health-ministry-peruvians-protest-mining-pollution-idUSKBN19E0AN (22.11.2018).

Ríos, E. (2013): Bitácora de un cerreño. Online: http://ambiente-eliot.blogspot.pe/2013/02/alrededor-del-tajo-abierto.html (06.11.2017).

Romero, A.; Mello Neiva, J.; Hudlet, K. (n.d.): Accountability is needed before transparency in the extractive industries resonates with communities in Latin America. Online: https://www.business-humanrights.org/en/accountability-is-needed-before-transparency-in-the-extractive-industries-resonates-with-communities-in-latin-america (22.11.2018).

Rostworowski, M. (2013): Historia del Tahuantinsuyo [PDF]. IEP Instituto de Estudios Peruanos.

Rüttinger, L.; Treimer, R.; Tiess, G., Griestop, L. (2015): Umwelt- und Sozialauswirkungen der Goldgewinnung in Madre de Dios, Peru. Berlin. adelphiSaldarriaga, J. (2017, September 18). Perumin 2017: Los proyectos mineros en el 'miniboom' de precios. Online: https://elcomercio.pe/economia/dia-1/perumin-2017-proyectos-mineros-miniboom-precios-noticia-458905 (28.10.2017).

S.R.L. (2012): Evaluación del Plan de Cierre del Pasivo Ambiental “Deposito de Desmonte Excelsior”. Online: http://intranet2.minem.gob.pe/web/archivos/dgaam/certificado/RD_236_2011_MEM_AAM.PDF (08.11.17).

Salo et al. (2016): Local perspectives on the formalization of artisanal and small-scale mining in the Madre de Dios gold fields, Peru. In: The Extractive Industries and Society 3 (2016), 1058–1066.

Sanborn, C. A.; Hurtado, V.; Ramirez, T. (2016): La consulta previa en el Perú. Avances y retos. Online: http://repositorio.up.edu.pe/bitstream/handle/11354/1195/DI6.pdf?sequence=6 (22.11.2018).

SENACE (2016): El Senace y la Clasifición de Proyectos de Inversión. SENACE, Lima. Online: http://www.senace.gob.pe/wp-content/uploads/2016/10/dossier-evap2.pdf (21.01.2019).

SES Professionals (2017) : Overview of Peru’s Mining Industry. Updated 23.02.2017. Online: http://sesprofessionals.com/overview-of-perus-mining-industry/, (28.10.2017).

Smuda, J.et al. (2007): “Mineralogical and Geochemical Study of Element Mobility at the Sulfide-Rich Excelsior Waste Rock Dump from the Polymetallic Zn–Pb–(Ag–Bi–Cu) Deposit, Cerro De Pasco, Peru.” Journal of Geochemical Exploration, vol. 9, 2007, 97–110.

SPDA – Actualidad Ambiental (2017): Minsa declarará emergencia sanitaria en beneficio de afectados por contaminación en Pasco. Online: http://www.actualidadambiental.pe/?p=45145 (22.11.2018).

SPDA (2010): Manual de Legislación Ambiental - Vol. 1. Online: https://spda.org.pe/wpfb-file/pioner-01-pdf/ (22.11.2018).

Transparency International (2017): Corruption Perception Index 2017. Online: https://www.transparency.org/news/feature/corruption_perceptions_index_2017 (23.01.2019).

Transparency International (2018a): Pardon me? Presidential clemency and impunity for grand corruption. Online: https://www.transparency.org/news/feature/pardon_me_presidential_clemency_and_impunity_for_grand_corruption (22.11.2018).

Transparency International (2018b): Perceptions remain unchanged despite progress in the Americas. Online: https://www.transparency.org/news/feature/perceptions_remain_unchanged_despite_progress_in_the_americas (22.11.2018).

Van Outryve, T. (2015): Raul Rojas Open Pit [Digital image]. Online: https://news.nationalgeographic.com/content/dam/news/2015/11/30/perumine/01perumine.adapt.1900.1.jpg (10.10.2017).

Vanesao (2005): Unidad de Cerro de Pasco de Volcan. CC BY-SA 4.0. Online: https://commons.wikimedia.org/wiki/File:Unidad-de-Cerro-de-Pasco-de-Volcan.jpg (09.10.2019).

Vargas Koch, Camilo; Bittner, Constantin; Dreier, Vanessa; Fichtl, Moritz; Gottmann, Annika; Thomas, Wiebke (2017): Entwicklungsalternativen in Bergbauregionen Perus – Umweltauswirkungen des Bergbaus und Einkommensalternativen in der Landwirtschaft in Junín und Cajamarca. Centre for Rural Development (SLE) Berlin. SLE Publications Series.

Villarreal Huacachi, M. (2016): Calidad De Agua Del Río San Juan, en el Departamento De Pasco. Tesis para optar el Título Profesional de Ingeniero Ambiental. Universidad Nacional Federico Villareal - Facultad de Ingeniería Geográfica, Ambiental Y Ecoturismo.

Volcan Compañia Minera S.A.A. (2013): Junta Obligatoria Anual de Accionistas [PPT].

Volcan Compañia Minera S.A.A. (2014): Volcan Annual Report 2014. Online: https://www.miningdataonline.com/reports/annual/Volcan_Annual_Report_2014.pdf (22.10.2017).

Volcan Compañia Minera S.A.A. (2015): Volcan Annual Report 2015. Online: http://www.volcan.com.pe/inversionistas/Memoria%20Anual/Memoria%20Anual%202015.pdf (22.10.2017).

Volcan Compañia Minera S.A.A. (2016): Volcan Annual Report 2016. Online: http://www.volcan.com.pe/inversionistas/Memoria%20Anual/Memoria%20Anual%202016.pdf (22.10.2017).

Volcan Compañia Minera S.A.A. (2018): Consoldidated Reserves and Resources. Online: https://www.volcan.com.pe/centro-de-descargas/?cat_id=29 (06.11.2018).

Wade, C., Dold, B., & Fontboté, L. (2006): Geochemistry and Mineralogy of The Quiulacocha Tailings Impoundment from The Polymetallic Zn-Pb-(Ag-Bi-Cu) Deposit Cerro De Pasco, Peru. Journal American Society of Mining and Reclamation, 2006(2), 2198-2206. doi:10.21000/jasmr06022198.

World Bank (2017): Worldwide Governance Indicators. Online: http://info.worldbank.org/governance/wgi/#reports (15.11.2017).

World Bank (2018): The World Bank in Peru. Online: http://www.worldbank.org/en/country/peru (19.09.2018).

Yale University (n.d.): Environmental Performance Index – Peru. Online: https://epi.envirocenter.yale.edu/epi-country-report/PER (23.01.2019).