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OekoRess II: Country Case Study VI

Morocco/Western Sahara: Phosphate (Bou Craa)

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Abstract

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

This case study analyses the environmental hazard potentials and the environmental impacts of the Bou Craa phosphate mine in Western Sahara (annexed and administered by Morocco). The main environmental impacts were the contamination of air, water and soil in the surrounding area by the release of dust, phosphate, fluorine, cadmium, uranium and phosphogypsum, all of which can cause health problems. Overall, the OekoRess indicators adequately pointed to some of the actual environmental impacts of the mining at Bou Craa. However, the indicators are unable to reflect the overfertilization of ecosystems around Bou Craa caused by phosphate leakages, which is one of the main environmental impacts at the site.

Existing governance indicators reflect Morocco's average sector governance well. Yet, they do not capture the specific governance challenges in Western Sahara, which is a disputed area largely controlled by Morocco.

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 das Umweltgefährdungspotenzial und die tatsächlichen Umweltauswirkungen der Phosphatmine Bou Craa in der Westsahara (von Marokko annektiert und verwaltet). Die wichtigsten Umweltauswirkungen waren die Verunreinigung von Luft, Wasser und Boden in der Umgebung durch die Freisetzung von Staub, Phosphat, Fluor, Cadmium, Uran und Phosphogips, die allesamt gesundheitliche Probleme verursachen können. Die ÖkoRess-Indikatoren haben zwar einige der tatsächlichen Umweltauswirkungen des Bergbaus in Bou Craa angemessen dargestellt, sind jedoch nicht in der Lage, die Überdüngung der Ökosysteme im Bergbaugebiet durch Phosphataustritte, die eine der wichtigsten Umweltauswirkungen an diesem Standort darstellen, wiederzugeben.

Die bestehenden Governance-Indikatoren spiegeln die durchschnittliche Governance in Marokko wider. Sie erfassen jedoch nicht die spezifischen Governance-Herausforderungen in der Westsahara, die ein umstrittenes Gebiet ist, das weitgehend von Marokko kontrolliert wird.

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List of Abbreviations

AMD	Acid Mine Drainage
AZE	Alliance for Zero Extinction
CADETAF	Central d'Achat et de Développement de la Région Minière du Tafilalet et Figuig
CPI	Corruption Perception Index
DoE	Department of Environment
DPSIR	Driving forces, Pressures, States, Impacts and Responses
DRC	Directorate of Regulations and Control
EEP	Environmental Excellence Program
EIA	Environmental Impact Assessments
EPI	Environment Performance Index
GDP	Gross Domestic Product
GSHAP	Global Seismic Hazard Assessment Program
HSE	Health, Safety and Environment
IFDC	International Fertilizer Development Center
INI	National Institute for Industry of Morocco
MAD	Moroccan Dirham (currency of Morocco)
MEM	Ministry of Energy, Mines and Sustainable Development
MINURSO	United Nations Mission for the Referendum in Western Sahara
NACC	National Anti-corruption Commission
OCP	Office Chérifien des Phosphates
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'
ONHYM	Office National des Hydrocarbures et des Mines
ppm	Parts per million
SADR	Saharan
SRF	Schweizer Radio und Fernsehen
UmSoRess	Research Project 'Approaches to reducing negative environmental and social impacts in the production of metal raw materials'
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USGS	United States Geological Survey
WGI	Worldwide Governance Indicators

WSI	Water Stress Index
WWF	World Wildlife Fund for Nature

1 Focus of the study and relevance

The following is the sixth 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 previous 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 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 environmental hazards and avoid or reduce environmental impacts of mining. The results of the 10 case studies will be compared and a set of governance indicators will be identified that can be used to improve the raw-material-specific assessment approach developed as part of the OekoRess I project.

This case study analyses the environmental hazard potentials and the environmental impacts of the Bou Craa phosphate mine in Western Sahara (annexed and administered by Morocco). The mining sector in general and especially the phosphate industry plays a significant role in Morocco's economy. The case study is of particular interest to the project, as phosphate is an essential plant nutrient, not substitutable, a key component of fertilizers and therefore indispensable for global food production. At the same time, phosphate is a non-renewable finite resource whose availability decreases over time and requires sustainable management. Furthermore, the Bou Craa mine is located in Western Sahara and thus in a politically unstable area that has been occupied and administered by Morocco since the withdrawal of the Spanish colonial power in 1975. Together with the deposits in Western Sahara, Morocco holds approximately 74% (USGS 2017b) of the global phosphate reserves and thus has a significant position on the phosphate market. Within Morocco, the entire phosphate industry is controlled by a single company, the state-owned OCP (Office Chérifien des Phosphates). Besides social and political challenges, the Bou Craa[4] mine has to deal with a high water demand for mining and processing. It is particularly challenging in the very arid environment of Western Sahara. Additionally, the eutrophica-

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

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

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

[4] The French spelling is „Boucraâ" or „Bouckraa". In the literature used in this study the name of the town was mostly spelled „Bou Craa" (e.g. by OCP) which the study will therefore refer to for the town as well as for the „Bou Craa mine". Other literature also uses Bu Craa, Boucraa, or Boukra.

tion of ocean water by phosphate is a serious issue in terms of environmental impact of the mining operation.

The case study is divided into four parts: First, the structure of the mining sector of Morocco and its contribution to the national economy is analysed (chapter 2). Second, a brief overview of the Bou Craa mine is given. The geographic and geologic context is analysed followed by an overview of the applied mining and processing methods (chapter 3). Third, the environmental hazard potentials posed by the mining operation is discussed using the site-related OekoRess methodology, and selected environmental impacts and responses to these are described using the DPSIR framework that was also used in the UmSoRess case studies (chapter 4)[5]. Fourth, the governance of Morocco's mining sector is analysed (chapter 5) and last, both the findings of the assessment of the environmental hazard potentials and environmental impacts, as well asthe governance analysis are compared to existing governance indicators and indices and first conclusions for the methodology development are drawn (chapter 6).

[5] 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 Morocco's mining sector

Morocco's mining sector contributes significantly to the country's economy. Mining contributes 10% to the national gross domestic product (GDP) and products from this sector account for 22% of revenues from national exports (44.6 billion Moroccan Dirham, MAD) (MEM 2017). According to the USGS (2015), the Moroccan mining sector generates the highest foreign exchange revenues for the Government. The GDP generated by Morocco's mining sector increased since 2006 until the financial and economic crisis caused a collapse in 2009. In 2009, total sales from mining were 29.5 billion MAD. After 2009, the sales in the mining sector recovered, reaching maximum high in 2011 (74.1 billion MAD). Since 2010, Morocco's GDP from mining has stayed at approximately the same level, with a recent slight decrease of exports (MEM 2017).

Phosphate rock - used as a raw material for phosphoric acid and fertilizer - is the most important mineral commodity for Morocco in terms of export value and quantity. In 2015, the production figures of phosphate far exceeded those of metals and other non-metallic minerals extracted in Morocco (HCP 2017a; see Table 2-1). In 2014, exports of phosphate rock and phosphate-based products (rock mining and phosphate fertilizer manufacturing) amounted to 4.6 billion USD (37.79 billion MAD[6]), which was 4.3% of Morocco's GDP in the same year (110.1 billion USD) (USGS 2015; USGS, 2017c). In 2010, phosphates and its compounds accounted for approximately 3.5% of the Moroccan GDP (Agrimaroc 2016).

Table 2-1: Sales from Mining in Morocco, 2009-2014

Years	2009	2010	2011	2012	2013	2014	Variation 2014/2013 (%)
Total Sales (in billions of DH)	29.50	60	74,10	64,50	52,83	51,57	-2.39
Exports	20	40	53,7	53,8	42,19	41,02	-4.1
Local Sales	9,5	20	20,4	10,7	10,64	10,55	-0.84

Source of information: MEM (2017).

Including the phosphate deposits located in the occupied region of Western Sahara, about 74% (50 billion tons) of the world's phosphate reserves of 68 billion tons are owned and controlled by Morocco (USGS 2017b). In comparison: China follows with only 3.1 billion tons and Algeria in third place with 2.2 billion tons of phosphate rock reserves. In 2015, Morocco and Western Sahara produced around 36 million tons of phosphate (OCP 2015).

The largest phosphate producer by far is China, producing 138 million tons in 2016, followed by Morocco including Western Sahara (36 million tons), and the USA (27.8 million tons) (USGS 2017b). Although global consumption of phosphate is estimated to increase to approximately 48.9 million tons by 2020 (from 44.5 million tons in 2016), no imminent shortage of phosphate is expected. The world's known reserves will be sufficient for the next 300-400 years if the growth in consumption remains

[6] Converted from USD to MAD using the exchange rate of July 1, 2014.

constant. Global resources[7] of phosphate rock are estimated at more than 300 billion tons and could therefore meet demand even longer (USGS 2017b; IPNI 2013).

Besides phosphate, Morocco also produces lead, chemical manganese, iron, copper, barytine, fluorite, smectite clays, salt, silver and zinc. The second and third most produced commodities after phosphates are barytine and salt (Table 2-2). However, in 2014 only 42% of Morocco was mapped using geophysical methods, 35% using geological methods and 8% using geochemical methods. Hence, Morocco's mineral resources, mining production and the economic growth through mining might further increase in the future (USGS 2015).

Table 2-2: Mining Production in Morocco, 2014

Mineral [*= critical according to EC 2014]	Production 2014		
	Volume [t] (unless otherwise noted)	% of ∑ World	Rank
Arsenic trioxide	8,200	24	2
Barite	1,006,600	15	2
Fluorspar*	75,000	1.2	9
Phosphate rock*	27,390,000	14	2
Silver AG content in kg	276,000	n/a	15
Strontium	70,000	0.8	4

Source: USGS (2016; 2017c).

The global financial and economic crisis of 2009 impacted mining investments heavily. For research and the exploitation and valorization, investments halved one year after the crisis: In 2009, 404,000 MAD were spent on research in the mining sector in Morocco, in 2010 only 102,398 MAD were spent. The investments for exploitation and valorization simultaneously decreased from 7.8 million MAD (2009) to 3.7 million MAD (2010). However, after the global financial and economic crisis the investments for exploitation and valorization grew steadily and multiplied by ten in four years (2014: 31.21 MAD) (MEM 2017).

In Morocco, artisanal mining mainly takes place in the regions of Tafilalet and Figuig near Meknès in the northern part of the country, where barite, lead and zinc ores are extracted. No artisanal or small-scale mining of phosphate was mentioned in the literature. Since 1960, artisanal mining is legal in northern Morocco, but miners have to be organized within the Central d'Achat et de Développement de la Région Minière du Tafilalet et Figuig (CADETAF), a public institution with civil status and financial autonomy under the technical supervision of the Ministry of Energy, Mines and Sustainable Development (Ministère de l'Energie, des Mines et du Développement Durable, MEM).

In Morocco, phosphate extraction is carried out by only one company: the state-owned corporation

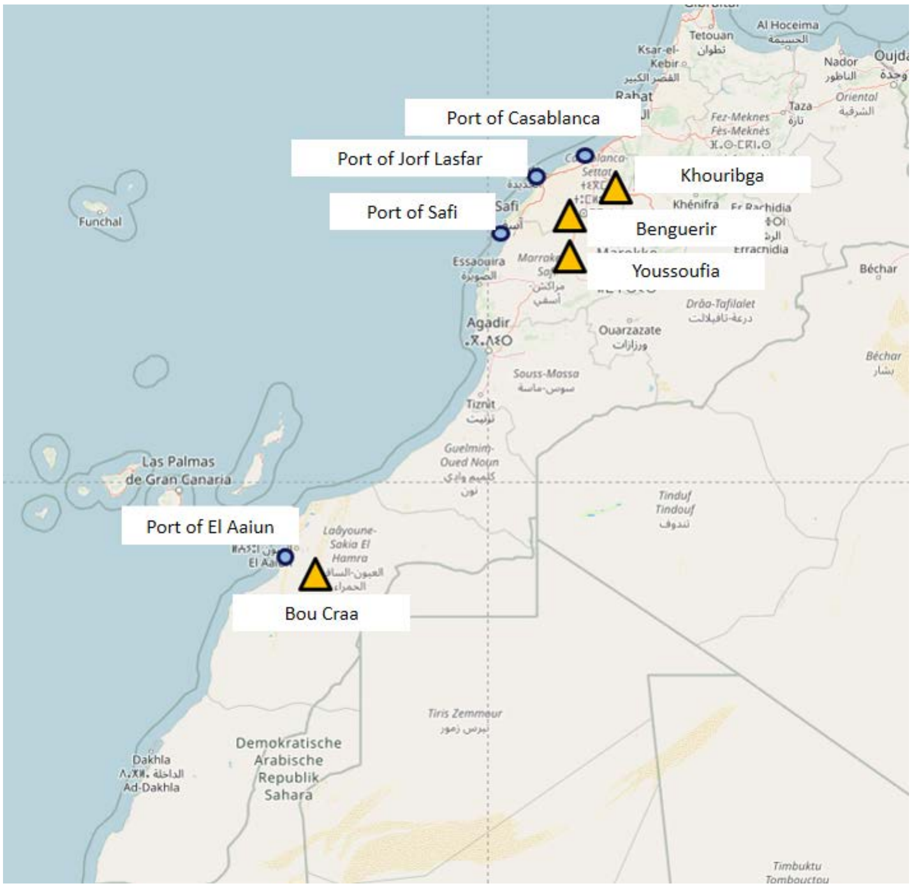
[7] Reserves are deposits that are economically exploitable according to the current state of technology. Resources, on the other hand, are deposits that are proven to exist but cannot be economically exploited at present.

Office Chérifien des Phosphates (OCP) (USGS 2017c). As a world leader in phosphate mining and fertilizer production, OCP supplies 30% of all global imports of phosphate and phosphate-derived products (OCP 2017a). The company plans to increase its phosphate rock capacity to more than 60 million tons per year by 2025 and to invest more than 5 billion USD in new mines and infrastructure (USGS 2017c; USGS 2015). In 2014, OCP produced "27.4 million tons of phosphate rock [...], about 5 million tons of phosphoric acid and 7.4 million tons of phosphate-based fertilizers"(USGS 2017c). On the phosphate rock trade market, OCP held a share of 47% for phosphoric acid, 33% for phosphate and 17 % for phosphate-based fertilizers in 2014 (ibid.).

Figure 2-1 shows the OCP sites in Morocco and Western Sahara. According to OCP, the Khouribga mining district in the north-east of Morocco holds the world's largest phosphate reserve. Based on the latest information from the OCP website, phosphate extraction at Khouribga amounts to 20 million tons per year and thus contributes the largest share (75%) of total annual extraction by OCP in Morocco. In Youssoufia and Benguèrir, both sites belonging to the Gantour mining basin in the south-west of Khouribga, production is 5 million tons per year (18.1% of total annual extraction) and in Bou Craa, the mine analysed in this case study, production is 2.6 million tons per year (9.4% total annual extraction (OCP 2017a).

The unemployment rate in Morocco and Western Sahara is around 9.7% (HCP 2017b). In general, the unemployment rate is much higher in urban areas than in rural areas (14.6% vs. 4.1%) (HCP 2017b). The mining industry provides around 41,000 jobs in Morocco and Western Sahara, with OCP alone employing 21,000 people (ONHYM 2016; USGS 2015). At the Bou Craa mine, 2,200 people are employed (USGS 2015). Information on indirect jobs created by mining sector related activities was not available.

Figure 2-1: OCP sites in Morocco and Western Sahara



Source: modified after Open Street Map (n.d.).

3 Overview of the mining operation and geology of Bou Craa

The Bou Craa phosphate deposit is located in the north of Western Sahara (see Figure 3-1 below). The Bou Craa mine and the processing plants in El Aaiun[8] are operated since 2002 by Phosboucraa, a corporation registered under Moroccan law and a wholly owned subsidiary of OCP. OCP in turn belongs to the Moroccan state (WSRW 2016; BAMF 2014). The main activities of Phosboucraa are "[...]the extraction, beneficiation, transportation and marketing of phosphate ore of the Bou Craa mine, including operation of a loading dock and treatment plant located on the Atlantic coast at El Aaiun" (WSRW 2016, p. 4).

In 1945, the Spanish geologist Manuel Alia Medina discovered the phosphate deposits in Bou Craa (BAMF 2014). Phosboucraa (at that time Empresa Nacional Minera del Sahara) was founded in 1962 by the National Institute for Industry (INI), a Spanish state-owned financing and industrial holding company. In 1972, Spain started to operate the mine. Since the annexation of the Western Sahara after the end of the colonial power of Spain in 1975, Spain retained a 35% share of the Bou Craa mine, while OCP received the remaining 65 %. In 2002, Spain then sold its 35% ownership of Bou Craa to OCP (Phosboucraa 2016a; WSRW 2016; OCP 2013b).

The Bou Craa mine is an open-pit mine with an extension of about 250 km^2 and is one of the largest phosphate deposits in the world (BAMF 2014) with reserves of 800 million tons (USGS 2017c). Bou Craa produced 1.6 Mt phosphate rock in 2015 and has an annual capacity of 2 Mt (USGS 2017c). OCP estimates a projected mine life cycle of more than 300 years, if the output of the mine stays constant (OCP 2013b).

Phosboucraa is a major job provider in the region with more than 2,194 employees (Phosboucraa 2016e). According to Western Sahara Resource Watch, most of the mine workers pertaining to the local population of Sahrawis[9] have to date been replaced by Moroccans who have settled in the occupied area. Sahrawi employees are reported to have experienced discrimination and being put at disadvantages to their fellow Moroccan workers (WSRW 2011).

3.1 Geography

The phosphate open-pit mine Bou Craa is located in the geographic region Saguia el-Hamra, which is located in the northern third of Western Sahara (Besenyo 2009). This contested territory lies on the northwest coast of Africa. After Spain withdrew from its former colony, Western Sahara was largely claimed and annexed by Morocco (CIA 2017). The annexed part was separated from the rest of the territory by a 2,000-km-long barrier -the Moroccan Wall, also called the "berm"- built by Morocco (BAMF 2014). The territory west of the berm is controlled by Morocco, and called the "Southern Provinces". The territory east of the berm is controlled by the liberation movement Polisario Front[10]. Bou Craa is located in the Moroccan controlled Southern Provinces and approximately 100 km south-east of El Aaiun, the capital of the El-Aaiun-Saguia el-Hamra region (Figure 3-1).

[8] The French name for the town is "Laâyoune". The majority of literature sources referred to in this study, used the spelling El Aaiun which is therefore used in this study. Other spellings are e.g. El Aaiún (Spanish) or El-Aaiún French.

[9] Native population of Western Sahara.

[10] Sahrawi liberation movement aiming to end Moroccan presence in Western Sahara.

Figure 3-1: Map of Western Sahara

Source: MINURSO (2014, Rev.88, September 2019).

The state of Western Sahara is largely a highly arid desert region (Worldatlas 2017). The landscape is mostly composed of low (mean elevation 256 m), shallow deserts alternating with small-partly rocky hills in the south and northeast of the country (CIA 2017). The Saguia el-Hamra region, which is named after the Saguia el-Hamra wadi (the Red River), is characterised by temporary rivers (wadis). During the rainy season, water can accumulate in this area. Due to high temperatures, however, the water evaporates very quickly and the wadis only remain temporarily humid (Besenyo 2009). The Saguia el-Hamra wadi is joining with the intermittent Wadi el Khatt just south of El Aaiun. The Bou Craa mine intersects some of the upper valleys of the catchment area of the Wadi el Khatt.

Some oases are located in the region as well, where palm trees, vegetables and further crops are grown (Besenyo 2009). According to satellite images the vegetation in the surrounding of the Bou Craa mine is sparse and mainly restricted to the wadis.

Despite the inhospitable conditions, different animal species can be found in the Saguia el-Hamra region. Besenyo (2009) describes the Houbara bustard, which can be seen frequently in the river valleys, different insects, scorpions, snakes and small mammals (Jerboa, Fennec fox, desert fox). Although the berm built by Morocco makes the migration of larger animals impossible, some larger mammals (antelopes, jackals, hyenas) can be observed.

According to the World Database on Protected Areas[11], operated by the United Nations Environment Programme (UNEP) World Conservation Monitoring Centre, the Bou Craa mine is not located in or adjacent to a protected area (UNEP 2017). This is consistent with the information provided by the United Nations Educational, Scientific and Cultural Organization (UNESCO) according to which no biosphere reserve exists in Western Sahara (UNESCO 2017). Furthermore, according to the Haut Commissariat aux Eaux et Forêts et à la Lutte contre la Désertification (2009), there are no national parks or "Sites d'intérêt Ecologique et Biologique (SIBE)"[12] near the Bou Craa mine or the processing plants in El Aaiun.

Bou Craa has a desert climate with virtually no rainfall. The Köppen-Geiger climate classification system classifies the climate as BWh – a hot desert climate. The average annual temperature is 20.7 °C with an average annual precipitation of 31 mm. The driest month is May, with 0 mm of rain. Most of the precipitation in Bou Craa falls in December, averaging 8 mm. The climate in El Aaiun corresponds to that in Bou Craa (Climate-Data.org 2017). Despite the low annual rainfall, at both sites, an environmental risk due to heavy rainfall events cannot be excluded. Rainfall data from Western Sahara from 1991 to 2015 illustrates the occurrences of heavy rainfall events every three to ten years. The latest heavy rainfall event occurred in January 2011 with an average precipitation of 23 mm (WB 2017a).

In El Aaiun, it is windy all year-round. The prevailing wind direction is north-especially in the summer. In December and January wind from the east is prevalent. The summer months represent the windier part of the year with average wind speeds of more than 13.8 mph (22.2 km/h) (Cedar Lake Ventures 2017).

Until the middle of the 20th century, the Western Sahara was mainly inhabited by Sahrawi shepherd nomads. Their nomadic lifestyle was not bound to national borders or territories. In recent decades, the majority of Sahrawis has been obliged to adopt a sedentary lifestyle. The majority of the population now lives in urban areas, over 40% of them in El Aaiun (CIA 2017). There is no information if nomadic tribes are still active in the area around the Bou Craa mine. Except the settlements west of the mine, which are related to the mining activities, satellite images suggest no further settlements in the surrounding area.

3.2 Geological context and ore deposit formation

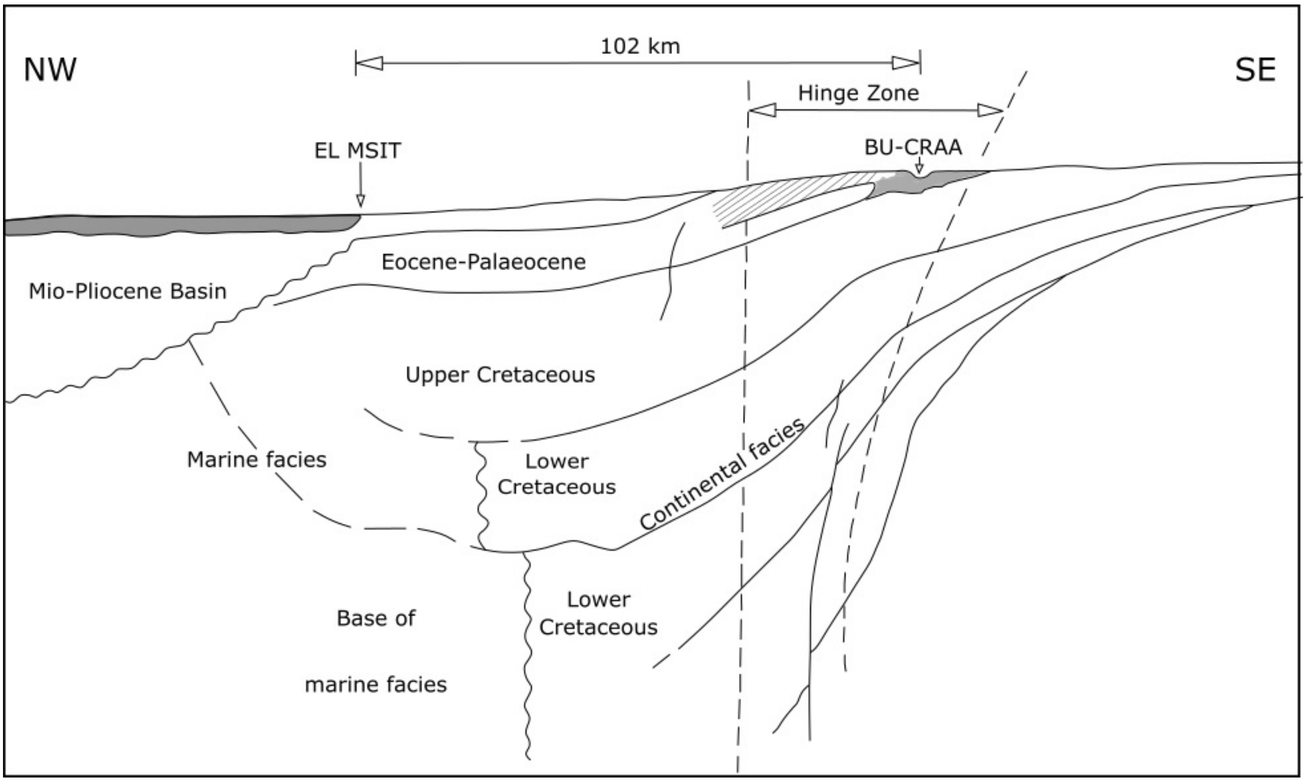
Phosphates can develop from marine-sedimentary, magmatic or from Guano-deposits. Globally, marine-sedimentary formed deposits are dominant. They make up around 90% of all deposits and originate from chemical-biological processes in the sea (BGR 2013). They generally form along continental shelves in shallow marginal marine settings such as lagoons and deltas. Here, upwelling cold ocean waters containing above-normal concentrations of phosphate precipitate and build phosphorites. Another form of building phosphorites is the building of calcium phosphate compounds, released from rotting organisms, which settle on the seabed and form the basis for mineralization of apatites or collophanes. Warm water with relatively alkaline conditions encourages this formation (Robb 2007).

[11] The World Database on Protected Areas (WDPA) is the most comprehensive global spatial dataset on terrestrial and marine protected areas.

[12] A network of biological and ecological sites, representative on the bio-ecological zones remarkable on ecosystems, with a high concentration of plant species and/or animal endemic rare or threatened, or index of high biodiversity.

The Bou Craa Phosphates are marine-sedimentary deposits, which formed in the early Cenozoic (see Figure 3-2) (USGS 2017a). Phosphate deposits in Morocco are imbedded in a spacious Mediterranean Tethyan phosphogenic province expands from western North Africa to Syria. The deposits are located in a platform of a passive margin accompanying the emergence of the Central Atlantic and the Alpine Tethys oceans (Porter Geoconsultancy 2011).

Figure 3-2: Structural relationships of main sedimentary basins of north-west Africa



Source: Own graphic based on information from Notholt, Sheldon and Davidson (1989).

The Bou Craa Phosphate mine is located in the so called Wadi Eddahab Basin (Notholt, Sheldon and Davidson 1989) and is part of the Mining district Aaiun Basin (USGS 2017a). Within the Basin, three main phosphate zones have been delineated. One of them is the central and southern Itgui zone which includes the Bou Craa sector. The Bou Craa Sector is the richest in phosphate with average grades ranging from 28 to 32% P_2O_5 and phosphate series (with two main phosphate beds) of an average thickness of 13.5 m under a relatively thin siliceous overburden (Notholt, Sheldon and Davidson 1989).

According to the U.S. Geological Survey (USGS 2017a) the deposit of the Bou Craa mine has a thickness of 5.5 m and covers an area of 23,100 ha (231 km^2). The depth from land surface to the tabular shaped deposit is approximately 18 m.

Phosphates occur in nature almost exclusively in apatite minerals, which is a collective name for a variety of natural calcium phosphates (BGR 2013). In the Bou Craa mine, phosphate is present in the apatite mineral Francolite (Carbonate-rich Fluorapatite ($Ca_5(PO_4, CO_3)_3(F,O)$)) (USGS 2017a; Mindat.org 2017). The gangue – the commercially worthless material that surrounds the apatite minerals – is a clay marl matrix with siliceous modules (USGS 2017a).

In addition to phosphate apatite minerals can contain calcium and other elements like fluorine, chlorine, thorium, uranium, vanadium or rare earth elements (BGR 2013). Due to trace amounts of uranium and thorium, the specific activity in the ores can reach 0.9-1.8 Bq/g (Ragheb 2017).

In general, phosphate deposits are known to contain uranium, even in high concentrations (WNA 2015). The uranium amount in phosphorites can be sufficiently high to recover uranium as a by-product of phosphate production. Phosphate deposits in Morocco are estimated to contain 6.5 million tons of uranium (NEA & IAEA 2016; IAEA 2009). They show uranium values of around 150 ppm and in some layers local enrichment up to 500-600 ppm (IAEA 2009). Consequently, it can be assumed, that the Bou Craa phosphorites contain a certain amount of uranium, however no exact data was found during literature review.

The heavy metal cadmium can also naturally be found in phosphate rocks (PhosphorusFutures 2017). According to Greenpeace 54-58% of the cadmium found in the environment in Western countries comes from the application of mineral phosphate fertilizers to agricultural land (Tirado and Allsopp 2012). The Moroccan phosphates are heavily contaminated with cadmium, which is carcinogenic (SRF 2015). Appleton (2002) indicates the occurrence of the heavy metal cadmium in the Bou Craa phosphates and names a cadmium content of 35 mg Cd/kg rock for the phosphate rocks in Bou Craa (average is a range of 5–300 mg Cd kg $rock^{-1}$ in sedimentary rocks) (Soler and Rovira 1996).

3.3 Mining and Processing

The Moroccan phosphate deposits are unfolded and practically horizontal. Therefore, the exploitation does not pose any particular challenges and is mostly carried out in open-pit mines (Bär 2017). When deposit geometry is favorable, open-pit mining is by far the most utilized and typically less costly method for mining phosphate deposits (IFDC 2010).

Open pit mining in Bou Craa is carried out by means of two walking draglines, and shovels to load trucks. In order to exploit the phosphorus layer, first, the hard siliceous overburden of the deposit is removed. The deposit is divided into several panels of a width of approximately 800 m and a length of around 3,000 m. Each panel is cut out in 40-meter wide trenches. Currently, only the upper of the two main phosphate beds is mined (Phosboucraa 2010; Brenneisen 2017).

Generally, in phosphate rock beneficiation, the availability of water is of major importance. In areas where water availability is severely restricted, dry screening (a separation process) is an effective way to produce pre-concentrates. Seawater can be used for washing, size classification and flotation. However, when seawater is used a final rinse with freshwater is needed (IFDC 2010). Beneficiation (or concentration) methods enable to increase the phosphate content by removing contaminants before further processing step (UNEP and IFA 2001).

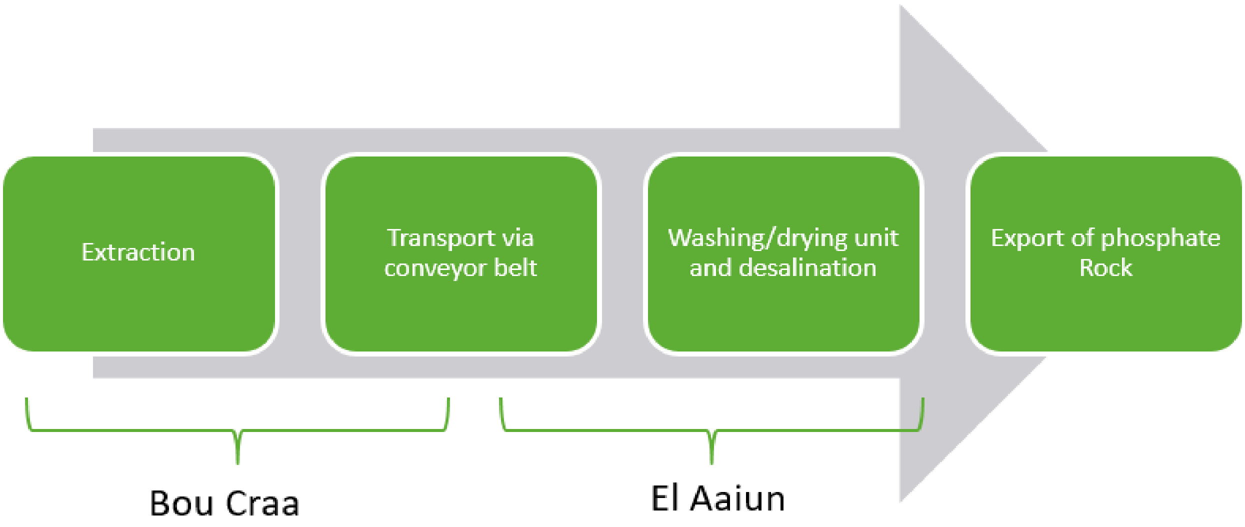
In Bou Craa, water shortage is a severe problem. Therefore, a two-phase system with a local separation of the production process was installed. The first phase in this process is accomplished at the Bou Craa mine site and comprises the exploitation of the mineral and the transport of the material to a primary enrichment plant (crushing and dry screening) which operates without water (Brenneisen 2017). In other phosphate mines operated by OCP (Khouribga, Benguerir) this step is carried out for the separation and disposal of the oversize low-grade material (UNEP and IFA 2001). It can be assumed that the same is true for the Bou Craa mine. After the dry screening, the phosphate rock is transported on a 100-km long conveyor belt from Bou Craa to the treatment plants located at El Aaiun (Phosboucraa 2010). The conveyor belt can be seen on satellite images (see Figure 3-3).

Figure 3-3: Satellite image of the conveyor belt from Bou Craa to El Aaiun

Source: Google Earth (2016), Images: Landsat/Copernicus

In El Aaiun the second - water dependent - phase of the beneficiation process is accomplished. Since El Aaiun is located on the coast, sea water can be used for most of this second phase. In a first step, the material is washed with sea water (Phosboucraa 2010). In general, washing is applied to remove impurities and barren material (e.g. organic matter, clay and other fines) from the phosphate (UNEP and IFA 2001; 911Metallurgist 2017). In a second step, the material is rinsed with fresh water produced by a desalination plant (Phosboucraa 2010). Rinsing removes the chloride originating from the sea water and is important to avoid severe corrosion by high chloride contents in further processing (IFDC 2010). In a last step, the phosphate rock is dried to reduce its water content. The whole process is mainly intended to increase the phosphate content of the product ,which is then carried to the ship loading dock and exported all over the world (Phosboucraa 2010). Figure 3-4 shows the value chain of phosphate from Bou Craa.

Figure 3-4: Value chain Bou Craa – El Aaiun



Source: Own graphic based on information from Phosboucraa (2016a).

No specific information about the waste material management in Bou Craa/El Aaiun could be found. However, due to the processes used it can be assumed, that in Bou Craa mainly overburden and barren material from dry screening and in El Aaiun primarily waste water and tailings from washing arise.

During the phosphate rock beneficiation, waste streams include products such as sand tailings and clay fines. Furthermore, huge quantities of water are discharged into water bodies or storage dams. A recovery of the process water is possible (UNEP and IFA 2001). Information on whether the process water in El Aaiun is recovered and whether the waste water is fed into dams or the sea could not be found.

A further treatment is required to convert the phosphate to water-soluble or plant-available forms in order to use the phosphate as a fertilizer (IFDC 2010). These production steps are not yet accomplished in Bou Craa/El Aaiun. However, by pursuing an industrial development program, Phosboucraa aims to create locally higher value through both - its mining operations and the processing of phosphate in the El Aaiun area. This includes the transformation of phosphate rock into intermediate products (phosphoric acid) and finished products (fertilizers). The future value chain of Phosboucraa will foreseeably comprise, among others, a new washing and floatation unit as well as a new fertilizers processing plant (Phosboucraa 2016b). Therefore, it has to be taken into account that the environmental hazard potential in Bou Craa/El Aaiun may change within the next years due to new processes used. Consequently, a reassessment of the processing specific indicator in the OekoRess Assessment might be required in the future.

4 Overview of environmental hazard potentials and environmental impacts

4.1 Environmental hazard potentials

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

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

The assessment of the EHPs of the Bou Craa mining site 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

Level of consideration	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

Level of consideration	Indicator	Environmental Hazard Potential		
		low	medium	high
Site (surroundings)	Natural accident hazard due to floods, earthquakes, storms, landslides	X		
	Water Stress Index (WSI) and desert areas			X
	Protected areas and Alliance for Zero Extinction (AZE) sites	X		
	Conflict potential with local population			X

4.1.1 Geology

Preconditions for acid mine drainage (AMD)

Phosphorus can occur as a lithophile or moderately siderophile element. In most cases it exists in calcium phosphate, referred to as apatite, and in this regard is lithophile. In the Bou Craa mine, the phosphate is extracted from apatite, quartz and calcite minerals. Thus, it occurs here in its lithophile form. Hence, the potential for acid mine drainage is low (*low environmental hazard potential*).

Paragenesis with heavy metals

Sedimentary formed phosphate can occur in combination with heavy metals (Mar and Okazaki 2012). The occurrence of Cadmium concentrations of 35 mg per kg rock (Appleton 2002) indicates a high environmental hazard potential in this regard at the Bou Craa mine (*high environmental hazard potential*).

Paragenesis with radioactive components

Although there is no specific data regarding radioactivity in the Bou Craa mine, the average uranium content in phosphate rocks ranges from 50 to 200 ppm (Feynman 1985). There is a high probability that phosphate at the Bou Craa mine is associated with uranium. According to the site-related OekoRess assessment, this indicates a high environmental hazard potential due (*high environmental hazard potential*).

Deposit size

According to estimates of the US Geological Survey, Morocco and the Western Sahara represent around 75% of the global deposits (USGS 2015). The Bou Craa mine has a phosphate deposit of 1.6 billion tons and is one of the largest and most important phosphate resources worldwide (Bouabdellah and Slack 2016). According to OCP calculations, the mine can reach a lifetime of 300 years at an annual mining volume of maximally 3 million m^3. In consideration of the site-related OekoRess assessment system for deposit size, the mine poses a high environmental hazard potential (*high environmental hazard potential*).

Specific ore grade

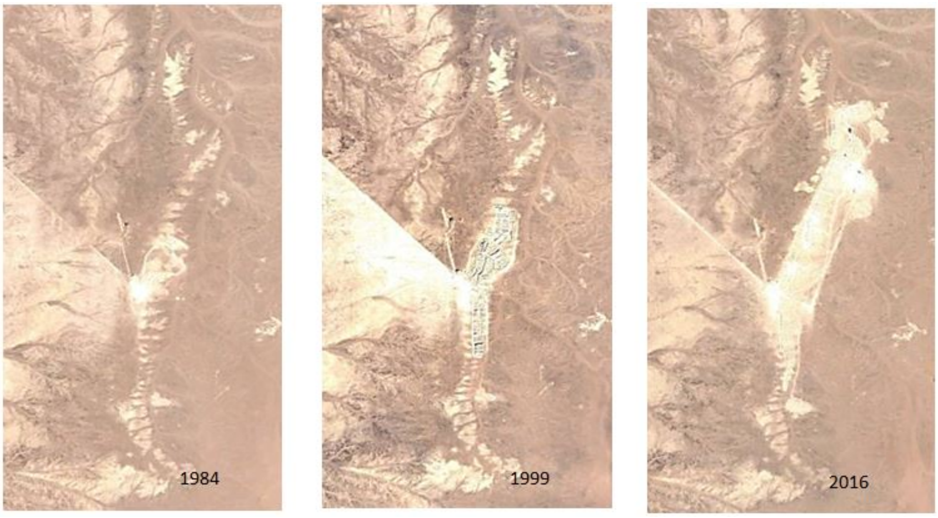
The phosphate content is indicated as phosphorous pentoxide, P_2O_5. Bou Craa is characterized for its high phosphate concentrations that exceed 37.5 wt % P_2O_5 (Bouabdellah and Slack 2016). According to IFDC (2010), phosphate content grades higher than 35 wt % can be defined as high grade. Phosphates of this type have a low environmental hazard potential according to the site-related OekoRess assessment methodology (*low environmental hazard potential*).

4.1.2 Technology

Mine type

The Bou Craa mine is an open-pit mine of sedimentary deposits. The land surface disturbance due to open-pit mining activities is high and permanently increasing (see Figure 4-1). Hard rock open pit mining disturbs the surface to a much larger extent than underground mining. In contrast to open pit mining in alluvial or unconsolidated sediment, the disturbance only extents to the size of the ore body. Hence, the indicator is evaluated with a medium EHP (high environmental hazard potential).

Figure 4-1: Transformation of the Bou Craa mining area since 1984



Source: Google Earth (2017), Images: Landsat/Copernicus

Use of auxiliary substances

In the Bou Craa mine mechanical processing without any toxic or other additives is used. Due to this reason, the environmental hazard potential of the indicator processing is determined as being low (*low environmental hazard potential*).

Mining waste management

For this indicator, both, the mine in Bou Craa and the processing in El Aaiun, will be considered. The processing steps carried out near the harbour include the separation by washing and drying of the phosphate. Tailing dams can be identified on Google Earth. However, the structural height of the identified tailings dam on Google Earth is below the threshold of 15m. Based on this information and without any further specific data, the waste material management is assessed as having a medium environmental hazard potential (*medium environmental hazard potential*).

Remediation measures

In 2014, OCP published a consolidated financial statement with the indication that the OCP group has developed an agricultural rehabilitation plan for exhausted mines, containing mines in Khouribga, Ben Guérir, and Youssoufia in Morocco. The Bou Craa mine in Western Sahara was not mentioned and there is no further information about any financial provisions. Thus, a high environmental hazard potential exists (*high environmental hazard potential*).

4.1.3 Site (surroundings)

Natural accident hazard due to floods, earthquake, 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 acordance with the measurment 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. The risk for earthquakes is low since Bou Craa is not located in a seismic active area (GSHAP world MAP). Due to the extreme aridity, no floods or landslides can be expected. The risk of tropical storms is low. In general, there is a low environmental hazard potential (*low environmental hazard potential*).

Water Stress Index (WSI) and desert areas

The WSI by Pfister et al. (2009) provides characterization factors on the relative water availability at watershed level. The indicator combines this information with an evaluation whether the site is located in a desert area. Mining operations often need large amounts of water for the operation. Depending on the hydrological situation, a competition for water between the different users can occur. The evaluation was carried out in accordance with the procedure described in the measurement instructions (Dehoust et al. 2017a). Even though the water stress index is low, the Western Sahara is – according to the WWF - a desert region and therefore, a high environmental hazard potential is assigned to the indicator (*high environmental hazard potential*).

Protected areas and AZE (Alliance for zero extinction) sites

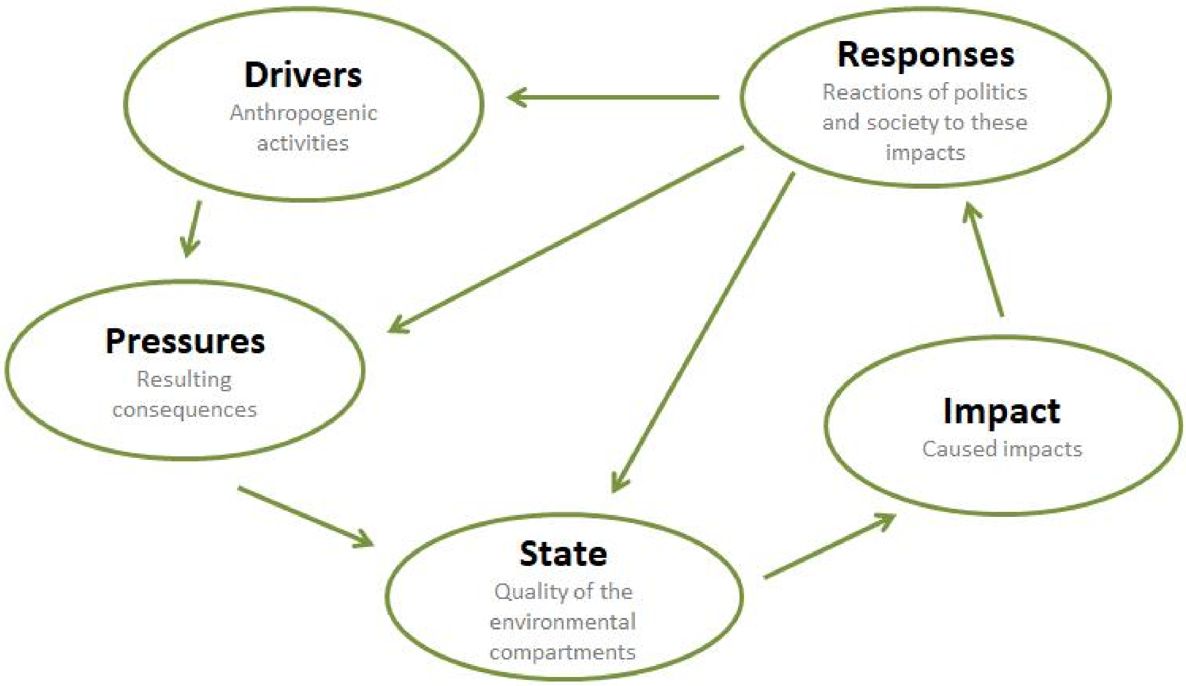
Georeferenced data for designated protected areas are used to assess hazards posed by mining extraction. The metric to evaluate EHPs corresponds to the method first described in the draft standard of the Initiative for Responsible Mining Assurance (IRMA 2014). There are no protected areas in the near and far surroundings of the Bou Craa mine and the processing plants in El Aaiun. Therefore, the environmental hazard potential is low *(low environmental hazard potential)*.

Conflict potential with local population

The governance indicators "Control of Corruption" and "Voice and Accountability" indicate a percentile rank of 52.88% and 29.06%, respectively (WB 2017b). Consequently, the environmental hazard potential is assessed as high (*high environmental hazard potential*).

4.2 Environmental impacts

Figure 4-2: DPSIR-Framework



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

The DPSIR framework is a systemic analytical approach to better understand the interaction of humans and their environment in order to derive adequate policy measures. It comprehensively accounts for and visualizes the causal connections between human activities, the resulting consequences for the environment and the responses of humans. The model consists of driving forces, pressures, state, impacts and responses.[13]

This chapter focuses on environmental impacts of mining activities in the area of the Bou Craa mine and the processing plants in El Aaiun. The focus lies mainly on water consumption and water contamination, air pollution and the negative impacts of phosphate mining on human health.

Due to the lack of specific information about the Bou Craa phosphate mine and its environmental impacts, the following chapter focuses mainly on common impacts of phosphate mining on the environment and human health and refers to specific examples whenever possible. In addition, satellite images were used to explore the surrounding area of the mine in Bou Craa.

4.2.1 Pressures

In Bou Craa the environment has been affected since the year of first production in 1973 (USGS 2017a). Given the size of the phosphate deposit, the mining activities and the associated pressures on

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

the environment will foreseeably continue for many more decades[14]. The Bou Craa mine has an extension of about 250 km^2 (BAMF 2014). In addition, there is the company site with the processing plants in El Aaiun, which is estimated to cover an area of 6.3 km^2 (Google Maps 2017). The industrial program that Phosboucraa is pursuing (e.g. new washing and flotation unit, new fertilizers processing plant) will lead to additional alterations and increases of the pressures in the future.

Phosphate mining in general and in Bou Craa in particular leads to a change in land use and affects the landscape. The landscape is disturbed through "clearing of vegetation, removal of topsoil, excavation of overburden and ore and the construction of overburden dumps" (UNEP and IFA 2001). Furthermore, the treatment plants in El Aaiun take up space along the coast. Figure 4-1 shows the extent of land use by mining activities in Bou Craa since 1984. As the Bou Craa mine's ore body takes over an area of 23,100 ha (231 km^2) (USGS 2017a) and global demand for phosphate is not expected to decrease, it can be assumed that the Bou Craa mine will continue to expand in the future.

In addition to land use, a major pressure of phosphate mining is the use of large quantities of (sea-) water to wash the phosphate ore, and of fresh water for the last step of processing.

There is only limited information on the very specific pressures and impacts generated from the Bou Craa phosphate mine as well as from the processing plants in El Aaiun available. However, based in parts on general literature on environmental hazards and impacts of phosphate, information provided by the mine operator and the analysis of google earth images, the main impacts of Bou Craa on the environment and human wellbeing can be identified, including the impacts through surface disturbance, emissions to air and water, generation of noise and vibration and radiation. These will be outlined in the following paragraphs.

4.2.2 State and Impact

Surface disturbance and wildlife

The Bou Craa mine is located in a desert environment with sparse vegetation. The land use for agriculture in Western Sahara is limited to permanent pasture (18.8% of total land). There is nearly no arable land and the permanent cultivation of crops is rare and limited to banks of rivers and oasis (CIA 2017; Besenyo 2009). Therefore, it can be assumed that the mining activities in Bou Craa do not affect any agricultural activities.

As mentioned in chapter 3.1, the living conditions for flora and fauna in Western Sahara are very unfavorable and the appearance of e.g. larger mammals is rare. The Bou Craa mine is not located close to any protected area, national park or biosphere reserve (cf. Section 3.1). Hence, no indication was found that a particular threat to biodiversity may exist.

The Bou Craa mine intersects some of the upper valleys of the catchment area of the Saguia el Hamra wadi and therefore interacts with these surface structures and the drainage system. However, since rain is very rare in this area, the influence of this disturbance is likely to be very small. These rainfalls that occur every three to ten years may lead to transport of materials relocated through mining processes (e.g. wind transport, tailings) into the drainage system. However, no data was obtained that verify this assumption.

[14] OCP names the phosphate's stock in Bou Craa at more than 1.1 billion m^3 and the annual extraction of phosphate at up to 3 million m^3, which would give the mine a lifetime of more than 300 years (OCP 2013b).

Noise and vibration

In general, noise and vibration may occur in phosphate rock mining activities during extraction, handling and beneficiation. Noise and vibration may arise due to blasting, the operation of equipment, the movement of heavy vehicles and the activities inside the processing plants (rock breakers, crushers and grinding mills) (UNEP & IFA 2001).

No evidence could be found that the overburden or phosphate rock in Bou Craa is broken by blasting. However, it cannot be excluded that this noisy and vibration-generating mining method is used. Noise is generated in the Bou Craa mine by the operation of walking draglines, shovels and trucks as well as the primary enrichment plant (crushing and screening). Noise is also likely to be generated during transport via the conveyor belt and further processing in El Aaiun.

Noise primarily affects the quality of people’s life living near the source of noise. Since few people live in the desert surrounding the mine and processing plants, it can be assumed that the effects of mining noise are minimal. The workers' settlement in Bou Craa is about 1.8 km (own calculation based on Google maps) away from the mine. The nearest buildings in the north of the processing plants in El Aaiun are about 1.5 km (own calculation based on Google maps) away.

Air pollution

The mining activities cause emissions to the air which are induced by the generation and emission of dust. This development of dust is caused in particular by excavation processes, equipment movements and treatment processes (UNEP and IFA 2001).

For Bou Craa it can be assumed that dust is the main source of emissions into the air. Many processes along the value chain of phosphate generate dust in Bou Craa and El Aaiun: e.g. the removal of overburden, the extraction of the phosphate rock itself, the movement of mining machines on unpaved roads, the dry screening on the mine site, the transport via conveyor belt, beneficiation processes, drying and the loading on ships (Othman and Al-Masri 2006). There are some indications suggesting wind erosion in the area: On Google Earth images (see Figure 4-1), there is a sand drift visible starting from the facility which can be related with dust originating from the phosphate industry. Furthermore, satellite pictures illustrate sediment formations along the 100 km long conveyor belt, which underlines the possibility that the fine particle fraction of the transported material is subject to wind erosion.

The extraction of phosphates in Bou Craa also releases a huge quantity of fluorine, which contaminates air, water and soil in the surrounding area and leads to health problems such as breathing, heart and muscle problems in both cattle and humans (SRF 2015; see section on health impacts). The fluorine originates from the fluorapatite that is mined in Bou Craa (see chapter 3.2). In Bou Craa, dust could affect the people who live in the mining settlement. In addition, the people working in the mine and in the processing plants are highly exposed to dust and the associated fluorine. Southwest of the mining complexes are no settlements, so the dust is mainly deposited in uninhabited areas and the marine environment. This is also indicated by satellite images showing whitish accumulations to the southwest. This can be seen particularly well along the conveyor belt (see Figure 3-3).

The city of El Aaiun is located north of the conveyor belt and the processing plants. Due to the prevailing wind direction in El Aaiun (north and east, see chapter 3.1) and the fact that there are constant winds in this area, the dust drifts to the southwest. Therefore, the people living there are probably not influenced by the dust. Nevertheless, the use of furnaces to dry phosphate in El Aaiun is an additional dust-generating factor (see “health impacts”).

Water consumption and water contamination

Large volumes of water are typically required by phosphate mining and beneficiation activities (UNEP & IFA 2001). However, the work in the Bou Craa mine (extraction and dry screening) does not require water. In the processing plants in El Aaiun larger quantities of water are used to wash the phosphate rock. The water used comes from the sea and is partially desalinated by a desalination plant before use (see chapter 3.3). Information on the environmental impacts of the desalination plant in El Aaiun could not be found. On the one hand, the desalination plant protects local groundwater resources. On the other hand, however, the process of desalination is not per se environmentally friendly. In general, the effluent from desalination plants is a multi-component waste (highly saline brine, which may be increased in temperature and contain contaminants), with potential negative effects on water, sediment and marine organisms (Lattemann 2005) and desalination of seawater uses significant amounts of energy.

Whether the process water in El Aaiun is recovered (see page 25) and whether the waste water is directed into dams or the sea could not be found out based on the available documents. From other OCP sites, however, it is known that the waste water is, at least partially, discharged directly into the sea (SRF 2015; White 2015).

When waste water is discharged directly, it can be assumed that cadmium (see chapter 3.2) and phosphate are introduced into the coastal waters off El Aaiun. Furthermore, it can be expected that these two components are deposited via dust (see above) into the sea off El Aaiun. A 2006 study by Morocco's national fisheries research institute found significant contamination of cadmium in shellfish around OCP's discharge points (White 2015). Another source describes that local fishing in the area of an OCP site has collapsed since the phosphate industry settled nearby (SRF 2015).

Although phosphorus is a vital element, an excess of this nutrient leads to eutrophication of water bodies. This process unnaturally increases the production and degradation of organic material. A biomass overproduction can cause different ecosystemic problems, such as anoxic waters (through decomposition), toxic algal blooms and decreases in diversity along with the destruction of habitats (Water Research Center 2014; World Ocean Review 2017). No information on eutrophication processes in the marine environment at El Aaiun is available but a study by Kateb et al. (2017) on the consequences of phosphate discharge into the Gulf of Gabes (Tunisia) shows that serious consequences for the marine environments can occur.

Contamination of groundwater and soil

Dust from mining activities is deposited on the ground in the vicinity of the mine, the conveyor belt and the processing plants. The extent to which the constituents of the dust (e. g. phosphate, cadmium or fluorine) are introduced into the soil and groundwater could not be determined. However, as there is hardly any rain in the area around Bou Craa (see chapter 3.1), it can be assumed that the vertical mobilization of the dust constituents is very low and limited to the rare, heavier rainfall events.

Health impacts

Phosphorus is an essential element for all living beings. However, excessive phosphate uptake can lead to the development of osteoporosis and a reduction in kidney function (centrosan 2017).

During the mining of phosphate rock, large amounts of dust are produced. This is critical because Moroccan phosphate is particularly high in cadmium and has appreciable quantities of uranium (see Chapter 3.2), two heavy metals associated with cancer, kidney failure and bone disease (White 2015). Without adequate occupational safety, dust exposure can therefore lead to serious health problems.

High dust exposure in and around the mines can lead to respiratory diseases, lung problems and allergies (SRF 2015).

Furthermore, phosphate rock extraction releases fluorine. In humans and animals working in or living close to a mine, black corroded teeth can be observed. This is a visible sign of high fluorine concentration in air and water (SRF 2015). Long-term intake of too much fluorine can lead to chronic fluoride poisoning and cause dental, bone and joint problems (SRF 2015; FIPR 2017).

The plants in El Aaiun are also subject to increased dust pollution due to the handling of the material and drying in ovens. The health risks caused by dust are comparable to those in the mines and might increase in the future as Phosboucraa is planning to expand its activities and to include the production of phosphoric acid and fertilizers. The occurrence of gases of sulfuric acid, phosphoric acid and ammonia can affect the workers' health during the chemical preparation of phosphate. During the fertilizer production, a radioactive byproduct called phosphogypsum might endanger the health of workers too (White 2015; FIPR 2017).

There are only a few recent studies publicly available on work-related illnesses in the Moroccan phosphate industry (White 2015). A lung study at one of the sites of OCP (Safi) showed that 80% of those examined suffered from pulmonary emphysema. OCP doubted the scientific correctness of the study (SRF 2015). In general, OCP sees no connection between mining or fertilizer production and the health problems of its workers or local residents (SRF 2015). The ministry of the environment set up air quality analysis stations at OCP sites (Safi, El Jadida and Jorf Lasfar). According to the ministry, no alarming results are found. However, the documents detailing these results are confidential according to Natasha White (2015). On the other hand, there are statements by OCP employees and residents in which the clinical pictures and suffering stories are remarkably similar (SRF 2015; White 2015).

The health problems caused by phosphate fertilizers are not limited to Morocco and the production process. Toxic components, such as cadmium, are delivered with the fertilizer to the importing countries, where they are brought into the soils and thus enter the food chain (Tirado and Allsopp 2012).

Radioactivity

As already mentioned, phosphate rocks can naturally contain high concentrations of radioactive compounds. During the production, transport and use of phosphate and phosphate fertilizer, workers and their environment may be exposed to increased radioactivity (see also chapter 3.2) (Othman and Al-Masri 2006)

It can be assumed that the miners in Bou Craa and the workers in El Aaiun are exposed to a certain amount of radiation. However, there is no information available on the specific quantity and quality of radiation at Bou Craa. Furthermore, the potentially radioactively contaminated material does not remain on the site, but is partially discharged into the environment with the dust.

It is very likely that the dangers of radioactive material in El Aaiun will increase as Phosboucraa expands its production. The reason for this is the occurrence of phosphogypsum, a radioactive waste by-product generated during fertilizer production. Phosphogypsum contains appreciable quantities of uranium and its decay products. During the fertilizer production, radionuclides present in the phosphate rock are selectively separated and concentrated (U.S. EPA 2017).

Because of its toxicity and its radioactivity uranium can cause kidney damages, lung infections, cardiac insufficiency, genetic damage, cancer and leukaemia (Umweltinstitut München e.V. 2012).

Climate

The excessive growth of algae due to eutrophication (see above) becomes a problem, as dead algae sink to the seabed and decompose there under oxygen degradation - resulting in so-called dead zones[15]. Climate change is intensified by dead zones, as coastal waters with a shortage of oxygen emit nitrous oxide (N_2O) in a significant amount on global scale (Naqvi et al. 2010) A cycle seems to be developing: Dead zones expand increasingly when the temperature rises and global warming is intensified by dead zones (UBA 2017; NOAA 2017).

4.2.3 Responses

Very little information has been found on what is done in response to the environmental impacts of the phosphate industry in Bou Craa. First and foremost, mainly information from Phosboucraa itself and from OCP had to be used for this section of the report. Since these are not independent sources, the statements must be considered critically.

The State Secretariat to the Minister of Energy, Mines and Sustainable Development[16] makes very general statements on measures concerning the mining industry in Morocco. For example, a study was carried out to assess the environmental and health impacts of mining operations in three pilot mine sites and resulted in the development of action plans for improving environmental management at these sites (Secrétariat d'Etat 2015a). Furthermore, the State Secretariat states that thresholds for emissions for certain industries, including the phosphates industry, are currently being developed (Secrétariat d'Etat 2015b).

OCP names "Environmental performance, resource optimization and environmental protection [...]" as clear goals in any activities or programs conducted by OCP (OCP 2015). In order to meet these aspirations, OCP has launched a series of measures and programmes aiming at reducing the environmental impact of the phosphate industry. These include amongst others a water strategy (e.g. desalination of seawater, recycling of wastewater), an energy strategy (e.g. capturing energy generated by chemical processes, use of renewable energy) and a waste-management strategy (e.g. reducing waste, re-using waste) (OCP 2017b). In 2013, OCP launched an Environmental Excellence Program (EEP) at all mining sites, which aims to transform environmental risks into opportunities to achieve a positive footprint over time (OCP 2013a). Also in 2013, all drying ovens in OCP's mining Sites were equipped with special filters for dust retention. In this way, dust emissions from all processing facilities can be monitored by OCP (OCP 2013a).

Even if Phosboucraa is a subsidiary of OCP, it cannot be assumed that all the strategies and programmes of OCP also apply to the facilities in Bou Craa and El Aaiun. In the following, measures are described that are primarily related to Bou Craa and El Aaiun.

Phosphate deposits are non-renewable resources. In order to conserve this resource, Phosboucraa relies on enhancing the mining process. This includes increasing the lifespan of the mine and optimizing its beneficiation process by building a flotation unit (Phosboucraa 2016d). In addition, by the help of new enrichment technologies low-grade layers become exploitable (OCP 2015).

[15] Dead zones are low-oxygen or oxygen-free zones in the oceans, which make life there impossible for many living beings.

[16] Secrétariat d'Etat auprès du Ministre de l'Energie, des Mines et du Développement Durable, chargé du Développement Durable

Within the framework of the EEP of OCP 1,200 shrubs and 3,000 m^2 of green space in Bou Craa were planted in 2015 (OCP 2015). Phosboucraa names furthermore the planting of more than 13,000 trees across the Region as an ongoing project to strengthen the vegetation cover (Phosboucraa 2016d).

Concerning air quality, OCP states in its annual report of 2015 that liquid and airborne waste assessment campaigns in Bou Craa were completed (OCP 2015). However, the results do not appear to be published. OCP stated on SRF[17] that they have the most modern air filters and comply with the specified thresholds for air pollution (SRF 2015).

Phosboucraa relies on renewable energies for its energy supply. Over 95% of the energy consumed by Phosboucraa is provided by the Foum El Wadi wind farm (Phosboucraa 2016d), saving more than 80,000 tons of CO_2 equivalent per year (Phosboucraa 2016e). Furthermore, as part of the EEP of OCP, 88 photovoltaic headlights were installed at the Bou Craa mine along a 3 km long track (OCP 2015). With the expansion of its production processes, Phosboucraa is also planning to use cogeneration[18] to meet the industrial site's energy needs (OCP 2015). The Heat Recovery System of the fertilizer production lines (completed and operational by 2020) will generate electric power in excess of 150 Gw/h, which will be added to the grid and will allow for additional seawater desalination capacity (Phosboucraa 2016e).

As mentioned above, beneficiation of phosphate rock requires a large amount of water. Mostly sea water is used for the washing process in El Aaiun, however the last step of processing requires freshwater. In order to meet this freshwater demand and to protect the local groundwater, a desalination plant has been operating in El Aaiun since 2015 (OCP 2013a). It is part of OCP Group's underground fresh water preservation program (financed by 2 leading international development institutions), produces up to 1.5 million m^3/year and all excess water is redistributed to the Region (Phosboucraa 2016d). However, as described above, desalination is not per se environmentally friendly. With the commissioning of the new floatation unit in El Aaiun, OCP expects to reduce water consumption by 20%. The washing by flotation enrichment process helps to collect a major part of water sludge and in a next step, to bring it back to the processing cycle (OCP 2013a).

With regard to the health and safety of its employees, Phosboucraa states to pursue "world-class health and safety policies" (Phosboucraa 2016d). An HSE (Health, Safety and Environment) Task Force was acquired by Phosboucraa, and a one-month mobilization campaign was carried out to sensitize employees to safety issues and appropriate safety behavior (OCP 2015). Furthermore, OCP stated on SRF that it owns the best medical facilities and regularly monitors its employees and former employees. At this point it should again be stressed that there are statements of workers who criticize the working conditions at OCP. They speak of inadequate protective measures at the workplace (e.g. just a disposable face mask for the dust, chemical-containers labelled in languages the workers do not understand) and missing education regarding the risks related to working in the factories[19] (SRF 2015; White 2015).

Through the Phosboucraa Foundation created in 2014, Phosboucraa, contributes to the development of society and economy in Western Sahara. The Foundation has established a number of agricultural, health and education programmes to enhance culture in Western Sahara (OCP 2015). Furthermore, the Environmental Preservation Program of the foundation supports environmental projects as well as the protection of natural areas and contributes to research and development for environmental protection (Phosboucraa Foundation 2016).

[17] Swiss channel ("Schweizer Radio und Fernsehen").

[18] Heat from the chemical processes is used to generate electricity through combined heat and power generation.

[19] These examples are not from Bou Craa/El Aaiun but from OCP fertilizer factories in Jorf Lasfar and Safi.

5 Governance

5.1 Sector governance, regulation and effectiveness of national institutions

Despite new laws, the progress of implementation of and compliance with legislation – in particular environmental legislation – in Morocco is weak. For example, an environmental impact assessment (EIA) and an "abandonment plan"[20] (de Richoufftz and Coune 2016; Major 2015) which are required by law could not be found for the Bou Craa site. Furthermore, secondary laws on details of environmental legislation are incomplete. The Moroccan government does not make enforcement a priority. The responsible Department for Environment within the MEM has a limited budget, which hampers it from fulfilling its tasks. Non-compliance with the law is rarely penalised and corruption in the sector occurs. The king and associated elites enjoy advantages in the mining sector including the phosphate industry such as non-prosecution in cases of corruption.

Institutional and administrative framework

Morocco's mining sector is overseen by the MEM and its regional divisions. The MEM has three departments (Energy and Mines, Water and Environment) and is primarily responsible for the minerals industry as well as issuing exploration permits. The Moroccan Government owns all minerals (USGS 2017a). The exploration and promotion of mineral resources (with the exception of phosphates) lies in the hand of the National Office of Hydrocarbons and Mines (ONHYM) [USGS 2017c].

Given its crucial role in Morocco's mining sector, phosphates are not managed by the ONHYM but by the separately state-owned Office Chérifien des Phosphates (OCP also known as OCP Group since 1975) (Redstone Exploration Services 2017; OCP 2018a).[21] The OCP employs around 24,000 people (OCP 2018a) and is a major exporter of amongst others phosphate rock, acid and fertilizer (OCP 2018b). Besides the Bou Craa mine OCP holds several other mining sites and subsidiaries. Phosboucraa is one of OCP's biggest companies.

With regard to environmental aspects the main responsibility lies with the MEM's Department of Environment (DoE) which is tasked with the drafting of environmental laws and regulations, the coordination of national environmental activities, the implementation of environmental policies and EIAs. The DoE has a Directorate of Regulations and Control (DRC) and regional offices monitoring and supporting the implementation of environmental legislation. However, according to the budget from 2011 the DRC was underfinanced and had only limited personnel capacities designated to fulfilling its mandate (UNECE 2014).[22]

Legal and regulatory framework on mining

Morocco's mining sector is mainly regulated by the Mining Code from 1951[23] amended in 2015 (Law No. 33-13) (ONHYM 2018b). The amendment (implemented by a decree in 2016) applies to all mineral substances including phosphates and seeks to modernize the mining sector by: a) further promoting mining notably increasing investments, exploration permits and jobs in the mineral sector (OBG

[20] The consulted Frensh literature names the "plan d'abandon" while the Englisch literature mentions abandonment plans. It can be assumed that this is the equivalent of a mine closure plan. However, this could not be confirmed with certainty since no regulation on the plan d'abandon could be found.

[21] In 2008, the OCP was changed into a limited company (OCP S.A.) which is owned to approximately 95% by the government and 5% by Banque Centrale Populaire (BCP) (OCP website; OGB 2018a).

[22] Other enforcement authorities for environmental legislation are the Water Police as well as the paramilitary agents of the High Commission for Water, Forestry and Desertification Control mandated with the reporting of violations (UNECE 2014).

[23] The ONHYM (2018a) website states the old code was from 1954 but other sources mention 1951.

2018b), b) further regulating mining activities[24] and demanding transparency regarding mining operators' activities (Finan 2017), and c) promoting Morocco's labour and environmental laws as well as sustainable development (USGS 2017c; OGB 2018a; OBG 2018b). This implies conducting an EIA and the elaboration of an abandonment plan (de Richoufftz and Coune 2016; Major 2015). Regulations offering more details on these requirements are yet to be determined by specific regulations (Finan 2017; de Richoufftz and Coune 2016). The country has a National Mining Sector Development Strategy which, however, excludes phosphates. The strategy focuses on the modernization of mining regulations, the geological mapping and the restructuring of artisanal mining in the Tafilalet and Figuig region[25] (MEM 2018).

With regard to the fiscal framework the mining sector generally benefits from favourable tax conditions in form of reduced tax rates of 17.5% (compared to a 30% general income tax rate), 3% mining royalties and tax exemptions (OBG 2018b; Redstone Exploration Services, 2017). A former tax on phosphate extraction has been repealed (UNECE 2014).[26]

Even though Morocco has further worked on its legislation framework in the past years, it is still missing a sound governance system of its resources due to a fractured regulatory framework and a lack of transparency (GAN 2016).

Environmental legislation relevant to mining

Morocco has made progress on environmental policies and developed several relevant laws in recent years (UNECE 2014). The National Charter for Environment and Sustainable Development enacted by Framework Law 99-12 in 2014 sets a focus on climate change and in particular mitigation (Nachmany et al. 2014). The Framework Law prepares the ground for financial compensation in cases of environmental damages (LSE 2014).

In 2003 the country took crucial steps towards environmental protection notably with three laws: First on environmental protection and enhancement (Law No. 11-03), second on combatting air pollution (Law No. 13-03) and third on EIAs (Law No. 12-03) (UNECE 2014). The latter law and its respective application decrees[27] allot national and regional committees to assure the EIA implementation of the EIAs, public consultation (enquiry) and the presentation of the EIA to the public (WB 2015).[28] According to the law, the concerns and comments raised by the public within the public enquiries have to be considered in the EIAs (ONHYM 2018a). In line with Law No. 12-03 any drilling or mining operation requires conducting an EIA (ONHYM 2018b). In addition, the country has laws on water, waste and disposal and dangerous goods (including hazardous waste) (cf. GIZ 2014).

However, an environmental performance review by the UN from 2014 criticizes the lack of a conclusive legal framework for environmental protection, a corresponding national strategy as well as an

[24] It regulates amongst others by differentiating categories of mining licenses and their respective durations (authorisations for explorations, research permits and (operating) mining licenses) (Finan 2017; OGB 2018a; OBG 2018b; USGS 2017c)

[25] This region is intensively used by individually working small-scale miners. The National Mining Sector Development Strategy seeks to promote partnerships between the miners and corporate investors ("restructure") in order to increase the mining profits in the region (OBG 2018a).

[26] Various taxes and fees apply on a local, regional and national level. According to ONHYM the relevant documents are the General Tax Code, the annual budget Law and Law No. 47-06 on the taxation of local authorities (ONHYM 2018a).

[27] Decree No. 2-04-563 concerns the role and operations of the National Committee on Environmental Impact Assessments (CNEIE) and Decree No. 2-04-564 on the public inquiry procedures, both adopted in 2008 (cf. GIZ 2014).

[28] ONHYM has an environmental strategy, which primarily focuses on the implementation of EIAs (ONHYM 2018a). ONHYM, however, does not cover phosphates.

action plan including all relevant actors and authorities (UNECE 2014).[29] In 2014, Morocco developed a National Strategy for Sustainable Development (2015-2030) which however does not give details on phosphate production.[30] The same applies to the follow-up National Strategy for Sustainable Development 2030, which establishes goals for 2017-2030 (Royaume du Maroc 2017).

Implementation of environmental legislation

Although Morocco has introduced environmental reforms, set ambitious goals for its transformation towards renewable energy and green growth (WB 2013), the implementation of and compliance with the environmental legislation adopted in recent years remains unclear. The UN environmental performance review criticises the lack of monitoring and enforcement of the respective authorities (UNECE 2014). No specific information for the implementation of environmental requirements e.g. the implementation of an EIA at the Bou Craa site could be found. However, EIAs carried out for OCP's Safi and Jorf Lasfar generally state no to low environmental impacts according to international norms.[31] OCP also declares to have rehabilitation plans for all mining sites (OCP 2018c). Such a plan could not be found for the Bou Craa. Moreover, OCP's measures to reduce environmental impacts seem rather arbitrary or optional than focused on the implementation of specific environmental requirements.[32]

Furthermore, despite wide recognition of Morocco's recent commitment towards climate change and "green policies", the progress of implementation of environmental legislation relevant for the mining sector seems to be slowed down by a lack of commitment of the government. First of all, relevant legislation has not been fully concretised by means of application decrees or the determination of specific industrial thresholds e.g. on emissions. Secondly, the failures to comply with legislation are not penalised by the respective authorities and the responsible (UNECE 2014).

Illegal mining and corruption

According to various corruption indices, Morocco still shows regular cases of corruption (Transparency International 2017; GAN 2016). The government has launched a national 10 years anti-corruption strategy in 2016 (EGOV 2016). Yet, the creation of the National Anti-corruption Commission (NACC) tasked with the monitoring of the strategy's implementation has been deferred (Morocco World New 2017).

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[29] According to the review a National Environment Strategy from 1995 and a corresponding Action Plan have been suspended.

[30] Although the strategy names phosphate as a key element to the country's economy, it refers only to the National Mining Sector Development Strategy – excluding phosphates (see above) – and related identified measures to improve environmental aspects (Royaume du Maroc 2014).

[31] OCP provides information as regards its methods used for an EIA on its phosphate site at Safi where the company follows a three step procedure: an initial environmental diagnosis, an environmental audit, and a multi-criteria environmental assessment in which it determines – based on a rating system – the most significant environmental aspects. The EIA refers to several social as well as environmental standards such the Occupational Health and Safety Management System (OHSAS 18001) (Bouain et al. 2015). An EIA on the Safi site carried out in 2010 finds only low to negligible or medium negative impacts on the physical, biological and human environment (OCP 2011). A WikiLeaks document31 from 2005 also refers to EIAs for the Jorf Lasfar and Safi site with overall no environmental impacts according to international norms. The $S0_2$ (sulphur dioxide) emissions at Safi are however stated to be a "larger danger" according to the Safi general manager. To reduce the emissions, OCP planned to improve its smoke pipes (WikiLeaks 2005).

[32] In a presentation by OCP from 2005, the company confirms several environmental impacts related to phosphate extraction in Morocco e.g. dust from phosphate rock waste and indirectly the contamination of water which is however not referred to a specific mine site. As a response, OCP names several countermeasures such as the recycling of mine water as well as preventive measures e.g. reforestation projects and research on the environment and water by a specific OCP laboratory (Kabbabi et al. 2005). In 2014 the OCP Group created the Foundation Phosboucraâ (Fondation Phosboucraâ) in order to support "the corporate social responsibility of OCP Group" and its subsidiary Phosboucraa and local community development in the region. One of its five programmes focuses on a sustainable Saharan agriculture and environment preservation (Phosboucraa Foundation 2016).

Corruption and nepotism (Transparency International 2017; GNA 2016) also apply to the extraction of natural resources e.g. sand quarrying (GAN 2016). Centralism, a slow judicial system, an under-funded public sector and interdependences between politics and the private sector fuel corruption (Sabra 2018). Persons affiliated to the king and active in the mining business – including the phosphate industry – enjoy benefits such as receiving contracts and non-prosecution in cases of corruption (GAN 2016). In the past, the justice system has equally been influenced by the king, who amongst others appoints the judges (Maghraoui 2012). Based on WikiLeaks documents, the king and his family have been accused of bribery (Black 2010). While OCP holds the monopole on phosphate extraction, the royal family is reported to have a strong influence on the state-owned company (Paravicini 2018).

Given the contested legal status of the Western Saharan territory, opponents – above all the Sahrawi people and Frente Polisario – claim Morocco's mining activities in the region, their exportation and the distribution of profits illegal and have filed respective lawsuits (see chapter 5.2.).

5.2 Social context of mining and conflicts

The Western Sahara conflict has a complex history. The interests in the region are immense. Extremely rich in natural resources, while sparsely populated, Western Sahara has drawn the attention of many contenders including colonial powers such as Spain and France in the past. The territory has abundant phosphate and oil deposits, as well as vast fish stocks (WSRW 2015). Yet, conflicts around the environmental impacts of mining could not be found in Bou Craa. Possible explanations are the location of the mining site, a sparsely populated region, and the focus of tensions on the economic exploitation of the Moroccan annexed territory. The Sahrawi population in Western Sahara is estimated at approximately 600,000 of which the majority is located in the "Southern Provinces" administered by Morocco. According to UNHCR 90,000 Sahrawi live in refugee camps in Tindouf, Algeria (CIA 2017). The Sahrawi people criticise the exploitation of the natural resources of their territory by Morocco, lacking sharing of profit, and human rights abuses e.g. regarding their right to assemble and the freedom of expression (Amnesty International 2016; HRW 2008).

The Western Sahara Conflict

The development of Morocco and Western Sahara has been strongly influenced by its colonial history and natural resources.[33] In the aftermath of Morocco's decolonisation the political situation of the region and its native population has been subject to great conflict.

When Spain withdrew and left the control over Western Sahara to Morocco and Mauretania it did not follow through with the demand by the United Nations (UN) to organise an independence referendum allowing the Sahrawi people to determine their fate for themselves, as demanded by the UN (Bruneau and Rhode 2016). In response, the Popular Front for the Liberation of Saguia el Hamra and Rio de Oro (Frente Polisario)[34] was founded to fight for an independent Western Sahara of the Sahrawi people. The movement soon identified the importance of natural resources and started attacking mining and production infrastructures. By disturbing iron ore exports, Frente Polisario managed to weaken the state of Mauretania to the extent that it was driven off the territory by 1979. In its struggle against the Moroccan state, the independence fighters focused on attacking the phosphate production in Bou Craa and its related infrastructure, as well as international fishery boats off the coast. Following considerable losses in the wide territory, the Moroccan army withdrew to concentrate on the defence of the are-

[33] Interested in its riches, the European powers and the USA assured the Sultan of Morocco political sovereignty at the Madrid Conference in 1880, for as long as they could retain an open access to Morocco's resources. With the 1885 Congo Conference in Berlin, a power sharing agreement was struck among colonial powers, granting Northern Morocco and Western Sahara to Spain and the remaining parts to France (Sabra 2018).

[34] Frente Polisario now leads the government from exile for the Saharan Arab Democratic Republic (SADR).

as where the phosphate mines were located and which it holds since (BAMF 2014). In 1991, Frente Polisario and the Moroccan Government reached a ceasefire (MINURSO 2018).

Key issues of the lasting conflict are the exploitation of natural resources and the sharing of its benefits. As resource extraction is increasing, the Sahrawi's see the wealth, which they consider their own, dwindling. Moreover, they criticise not benefiting from the income and economic growth generated through mining activities as companies mainly employ Moroccan and French workers and profits are channelled to Morocco (BAMF 2014). In addition, there is no reliable data on the profits generated by phosphate exploitation in Bou Craa as a basis for calculating the percentage that should be shared with the Sahrawi population (Robert F. Kennedy Human Rights 2015). Sahrawi people therefore campaign and lobby internationally for a stop of the natural resources extraction in Western Sahara (WSRW 2017)[35] and file law suits in other countries against the exportation of the minerals, urging other states to seize exporting ships. This has led to partial success (Dudley 2017; Reuters 2017) and generated international attention.[36] In addition, the UN (2002) has also questioned the legality of extractive activities, stating in a legal opinion that exploration and exploitation of natural resources in Western Sahara need to be in the interest of the Sahrawi people.

The main strategy of the Moroccan government is thus to invest heavily into development projects in the territory and to reason that their revenues would be directly reinvested for the benefit of the local population (McTighe 2013). The claims for such investments and their extent in practice, however, are contested (WRSW 2015).[37]

Environmental conflicts

No accounts of conflicts around the environmental impacts of mining could be found in Western Sahara. The population seems to be unaware of the risks they are enduring (AMRPENWS 2016) with the exception of fishing as local fishermen often demonstrate or take direct action against the apparent overfishing off their shores (WSRW 2013). However, reports of conflicts over the environmental impacts of mining in Morocco exist, for example around the silver mine in Imider that is said to have drained local water resources (Bouhmouch and Bailey 2015).

Concerning environmental degradation, OCP has undertaken several environmental protection efforts at Moroccan sites (OCP 2016).[38] For the Saharan sites, only little information could be found. At Bou Craa, 95% of electricity is provided by a wind farm. Moreover, to diminish the use of freshwater, OCP has built a desalination plant for Phosboucraa[39] (OCP 2016), which will however require great amounts of energy.

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[35] Under pressure of the public denouncements, several international phosphate companies have already stopped using phosphate from this region (WSRW 2016; WSRW 2018).

[36] Furthermore, in December 2015, the General Court of the EU followed Frente Polisario's plea and declared an economic agreement with Morocco void as it would be detrimental to the population of Western Sahara and their basic rights. Consequently, exports from Western Sahara could not benefit from the trade agreement (Smyrek and Benyoucef 2016) and the German government declared that it could not financially support any commercial involvement in the territory of Western Sahara for as long as its international legal status is not settled (Machnig 2017).

[37] At the same time, Morocco encouraged relocations to Western Sahara by offering financial incentives to Moroccan settlers such as fuel subsidies and tax exemptions (U.S. Department of State 2016). As another strategy, in particular since Morocco's return to the African Union, Morocco has endeavoured to isolate the Frente Polisario internationally (Lamlili 2017).

[38] At Jorf Lasfar, for instance, sulfur dioxide emissions are being reduced. At Safi, according to OCP, environmental standards are increasingly deployed and the environmental impact diminished. Most salient however is the construction of the new Slurry Pipelines between Khouribga and Jorf Lasfar and between Gantour and Safi which -OCP states- decrease the use of water and the emissions of carbon dioxide significantly (OCP 2013a; OCP 2016).

[39] According to the website of Phosboucraa (2016d) the desalination plant has already been installed: "Phosboucraa has built its own seawater desalination plant for its industrial process and all excess water is redistributed to the Region". This could not conclusively be clarified.

The reason for the absence of environmentally-induced conflicts around Bou Craa is most probably the location of the mining site, a relatively sparsely populated region. Furthermore, the conflict mostly revolves around economic exploitation.

Social conflicts and human rights violations

Most reports on social conflicts and human right violations name the general conflict of the Sahrawi people struggling for their independence as the key reason. In 1991 the United Nations Mission for the Referendum in Western Sahara (MINURSO) was established in accordance with settlement proposals by Morocco and the Frente Polisario in order to hold a referendum (MINURSO 2018b). In addition, the peacekeeping mission's mandate includes the monitoring of the ceasefire between the two parties but lacks a human rights mandate (Amnesty International 2016). [40] Subsequently, international attention to the conflict has been low and reporting on ongoing human rights violations limited (Gopalan 2017).

There are claims by Sahrawi workers denouncing reduced work opportunities for them (WSRW 2015), poor working conditions, including little protection of their health (White 2015) and unequal treatment. Apparently, OCP excludes them from certain benefits it grants to its Moroccan (WSRW 2015) or Spanish staff (CSTS 2010). There are several reports of workers' demonstrations stopped by the police (Støttekomiteen for Vest-Sahara 2007), menaces and suppression of OCP against striking workers and unionists (Tawri 2013; Roudaby 2016) and general police violence and detentions of Sahrawi people and human rights activists involved in peaceful demonstrations e.g. in El Aaiun (HRW 2008). With respect to solving workers conflicts, no official strategy by OCP or Phosboucraa was found.

Demonstrations for Western Saharan independence are often put down violently and many Sahrawi activists are imprisoned in Moroccan prisons – in some cases because of participations in such demonstrations – and are frequently judged in military and not civilian trials (Meiborg 2016). The press is hindered in their reporting on Western Sahara and in accessing the territory (Hilary 2014; Hamouchene 2016; Meiborg 2016).

Demonstrations and unrest in Morocco (Sabra 2018) and in the territory of Western Sahara have been met with violence and prohibitions. The UN referendum process is stalled, and the violent conflict between both parties persists (Snorek 2016) and has recently reignited (Nichols 2018).

[40] Yet, the resolutions of April 2016 and April 2017 extending MINURSO (most recently until 30 April 2018), call for further human rights protection in Western Sahara as well as in for the Sahrawi people in the refugee camps in Algeria (UN 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 will be compared with the results of nine additional case studies that are conducted as part of this project as well as the case studies conducted in UmSoRess and OekoRess I. By comparing the findings of the case studies, a set of governance indicators will be identified that can be used to improve the assessment approach to analyse the environmental hazard potentials of the OekoRess I project.

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

Only limited sources and data were available regarding the environmental impacts of phosphate extraction and treatment at Bou Craa and El Aaiun. The assessment of both, environmental hazards and environmental impacts, was thus in parts based on literature on general environmental hazards and impacts of phosphate extraction. The main environmental impacts outlined in this study were the potential contamination of air, water and soil in the surrounding area by the release of dust, phosphate, fluorine, cadmium, uranium and phosphogypsum, all of which can cause health problems.

Overall, the assessment of the environmental hazard potentials adequately pointed to the identified environmental impacts. For example, the indicator "deposit size" reflects well the high use of land. The Bou Craa mine is one of the largest phosphate resources worldwide and an open pit mine, therefore affecting large areas of surface. The potential dust, erosion and sediments, which lead to a high environmental hazard potential, are indirectly included in the indicator on mining method. The indicator "Water Stress Index (WSI) and desert areas" showed a high environmental hazard potential and reflects well the severe water shortage in the arid region, shown by the high demand of freshwater for processing and the environmentally questionable production of freshwater by using desalination plants. The indicator for governance has a high environmental hazard potential. The governance analysis shows that – particularly when focusing on the environment – Morocco's legislation is "relatively good". However, there is a lack of implementation, corruption is common and non-compliance with legislation is hardly ever sanctioned. Thus, the governance indicator reflects the situation well.

The eutrophication process in the marine environment close to the processing plants in El Aaiun, which is potentially caused if waste water is discharged directly into the sea, is not reflected in any of the EHP indicators.

Main findings of the governance analysis

The governance analysis shows that Morocco has a broad range of legislations relevant to the mining sector in place. The recently amended mining code seeks, among other things, to further promote mining, to further regulate mining e.g. by transparency of mining activities, and to improve social and environmental aspects. However, in reality, transparency is still missing and the regulatory framework is incomplete. The major impediments are a weak commitment by the Moroccan government to implement the legislation and to punish cases of non-compliance and widespread corruption as well as nepotism. The royal family has strong influence on the state-owned company OCP that manages all of Morocco's phosphates including the Bou Craa mine. Affiliates of the king active in the phosphate industry enjoy advantages and non-prosecution in cases of corruption. Environmental legislation does not seem properly implemented e.g. EIAs – which are a requirement for mining sites and need to be made public – could not be found for Bou Craa.

Conflicts in the Western Sahara region are principally focussed on Morocco's presence in and economic exploitation of the territory, which opponents – above all the Sahrawi people and the Frente Polisario movement – claim to be illegal. As regards to the mining sector, the main reasons for conflict that could be identified are the economic exploitation by Morocco without sharing the profits with the Sahrawi people, human rights violations and the depletion of natural resources. The UN has questioned the legality of extractive activities by Morocco. The analysis shows furthermore that protests by workers and human rights activists have taken place against Morocco's mining activities and law suits have been filed. Protesters have been imprisoned and the press is hindered in their reporting on Western Sahara and accessing the territory.

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

The case of Morocco's phosphate extraction in Bou Craa is a special case because of the contested legal situation of Western Sahara and the fight of the Sahrawi people for their self-determination. Morocco's mining activities on the territory are highly contested. For the analysed indicators (WGI, EPI, CPI and Fraser Policy Perception Index), no individual rankings for Western Sahara exist, thus the indicators for Morocco were used. Against this background, the assessed governance indicators applied to Morocco do not necessarily reflect the situation in Western Sahara. The difference between the territories is striking, like a look at the Freedom House (2018) rating, which is available for both, shows: while Morocco is rated "partially free" with an aggregated score of 39 out of 100 (0 representing "least free" and 100 representing "most free"), Western Sahara is rated "not free" with an aggregated score of only 4 out of 100. With this in mind, the assessment of governance indicators applied to Morocco should be treated with caution.

Morocco's overall average sector governance is well reflected in the set of Worldwide Governance Indicators (WGI). However, the mining and environmental legislation, its implementation and the special situation of Western Sahara are not well reflected. Based on the governance and conflict analysis of Western Sahara – for which the WGI is not separately applied –one can expect even lower ranks than most WGI ranks for Morocco show.

Morocco has the lowest value (-0.65) for WGI Voice and Accountability in comparison to its other WGI values, with a percentile rank of only 29.06. This reflects the overall situation in Morocco well. The indicator captures the citizen's ability to participate in selecting the government, the freedom of expression and free media. Yet, voice and accountability in Western Sahara seem to be in an even weaker position. The governance analysis shows for example that human rights of the Sahrawi people have been violated and their freedom of assembly and of expression has been hindered by Moroccan authorities.

Morocco has its second lowest value for WGI Political Stability and Absence of Violence with a value of -0.29 and a percentile rank of 35.71. This reflects the situation in Morocco and in the Western Sahara well. Particularly Western Sahara's unresolved legal status and the stalled UN referendum process pose a threat to political stability. For all of the other WGI indicators Morocco receives a range in average percentiles between 45.19 and 52.88: With a value of -0.10 and percentile rank of 50.96, the WGI Government Effectiveness reflects only the governance performance in general, but does not reflect the relevant challenges in the mining sector. As regards the weak implementation and the government's low commitment in particular for environmental legislation, the rank would have to be even lower. The same applies to the WGI Regulatory Quality, with a value of -0.23, and a percentile rank of 45.19. The governance analysis indicates that the implementation of regulations is weak and the regulatory framework is still incomplete.

The WGI Rule of Law Morocco receives a value of -0.14 and a percentile rank of 49.04, making it an average result. The indicator represents the overall governance performance in Morocco. Yet, the rule of law, property rights and the confidence in police can be expected to be particularly low in Western Sahara where police violence against the Sahrawi people has been reported.

Lastly, Morocco's WGI Control of Corruption with a value of -0.15 and a percentile rank of 52.88 does not reflect the governance performance of the country: The governance analysis shows clearly that corruption and the dominant role of elites in the mining sector is high. On this basis, one would expect a much lower value for Control of Corruption.

An index that aims specifically at capturing Morocco's performance regarding the protection of human health and of ecosystems is the Environment Performance Index (EPI). Morocco ranks 54 out of 180, scoring 63.47 out of 100. Based on this case study and the available data, it is hard to assess if this indicator reflects the actual situation. This index reflects Morocco's overall average to strong performance as regards green energy developments. However, for the mining sector it seems to be too high e.g. with regard to health impacts and potential contamination of water linked to the mining site.

Morocco's sector governance and its associated problems are well reflected in the Fraser Policy Perception Index (Stedman and Green 2018) surveyed yearly by the Fraser Institute. Morocco ranks only 48th of 91 countries in the world in terms of attractiveness of its policy environments (65.88 /100 points). However, interestingly, Morocco's score fell by almost 20 points compared to previous years.[41] In 2015[42] Morocco had the 24th rank (Mining Review Africa 2016) meaning that it recently lost in policy perception (as well as in attractiveness for investors). One possible explanation could be a general increase in unrest in Morocco (Sakthivel 2017). Another reason could be that even two years after the new mining code was introduced the regulatory framework is still incomplete and thus might discourage investors. Furthermore, uncertainties concerning disputed land claims (included in the Fraser's index calculation) still exist, particularly for Western Sahara.

The Corruption Perception Index (CPI) rates countries on how corrupt their public sector is seen by experts. Morocco ranks 81 out of 180 countries assessed with a score of 40, which reflects the results of the governance analysis well. Even though Morocco has a strategy against corruption, the country still shows a high degree of corruption, which is particularly true for the extractives sector.

Conclusion

The existing indices and indicators show in some cases a good ability to also reflect the specific and nuanced governance challenges in the mining sector of Morocco. Morocco' overall average (with a tendency towards weak) sector governance is well reflected in key governance indices of the WGI. However, Western Sahara territory is only somehow represented for all the WGI as the sector governance and its impacts can be expected to be different and most probably – based on the governance analysis – worse.

The Fraser Policy Perception Index reflected the specific challenges of Morocco's sector governance best. However, none of the chosen governance indicators reflected the governance assessment from the analysis very well. The special and contested legal situation of the Western Sahara territory – location of the phosphate extraction – leads to some deviations between the indicator results and the find-

[41] 2015 and 2014.

[42] Morocco was not ranked in the 2016 report.

ings of the governance analysis. The application of the governance indicators is difficult for an annexed territory with a contested legal status and a governance situation differing from that of the country, which administers the territory.

Furthermore, the case study underlines, that even with legislations in place, a country can fail in effectively implementing its legislation. In Morocco, stronger political will to fight corruption and punishment of non-compliance are needed in order to improve mining governance and the implementation of its laws.

Table 6-1: Overview on the governance indicators

Indicator	India	Year	Indicator measures…	Applicability
Voice and Accountability (WGI)	-0.65 (estimate between -2.5 and 2.5) 29.06 (percentile rank terms from 0 to 100, with higher values corresponding to better outcomes)	2016	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 weak governance performance in this specific area in Morocco. The situation in Western Sahara however could be even worse. +
Political Stability and Absence of Violence (WGI)	-0.29 (estimate between -2.5 and 2.5) 35.71 (percentile rank terms from 0 to 100, with higher values corresponding to better outcomes)	2016	Political Stability and Absence of Violence/Terrorism measures perceptions of the likelihood of political instability and/or politically-motivated violence, including terrorism.	Reflects well the overall weak governance and Morocco's political stability. However, violence is a key issue for Western Sahara which is not completely reflected by the indicator. +
Government Effectiveness (WGI)	-0.10 (estimate between -2.5 and 2.5) 50.96 (percentile rank terms from 0 to 100, with higher values corresponding to better outcomes)	2016	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 overall average governance. However, as regards the weak implementation, the continuation of corruption in the mining sector and the government's low commitment in particular for environmental legislation, the rank would be expected to be even lower. -
Regulatory Quality (WGI)	-0.23 (estimate between -2.5 and 2.5) 45.19 (percentile rank terms from 0 to 100, with higher values corresponding to better outcomes)	2016	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 overall weak to average governance performance. Yet, as regards the weak implementation of regulations and an uncompleted regulatory framework the rank would be expected to be even lower. -

Rule of Law (WGI)	-0.14 (estimate between -2.5 and 2.5) 49.04 (percentile rank terms from 0 to 100, with higher values corresponding to better outcomes)	2016	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 average governance performance well. Yet, the rule of law, property rights and the confidence in police can be expected to be particularly low in Western Sahara where the resources are depleted and police violence against the Sahrawi people has been reported. -
Control of Corruption (WGI)	-0.15 (estimate between -2.5 and 2.5); 52.88 (percentile rank terms from 0 to 100, with higher values corresponding to better outcomes)	2016	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 the overall average governance in this area. In the case of mining, corruption and the dominant role of elites seems particularly high. -
Environmental Performance Index (EPI)	Rank 54 of 180, Score 63.47 (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. +
Fraser Policy Perception Index	Rank 48 of 91, Score 65.88 (out of 100)	2017	The index measures the overall policy attractiveness and the country’s government policy on attitudes towards exploration investment	Reflects well the average to strong governance in the mining sector as the government’s policy is to further promote mining activities and to increase investments.
	Rank 24 of 109, Score 84.27	2015		It shows a significant decrease from 2015 to 2017, two years after the mining code was amended, in policy perception possibly reflecting the lack a complete regulatory framework and ongoing uncertainties about disputed land claims in the case of Western

				Sahara. +
Corruption Perception Index (CPI)	40 (rank 81/180; scale 0 -100)	2017	Describes the perception of the corruption in the public sector by experts	Reflects well the overall weak governance in this area where corruption remains a key issue. +

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