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RESEARCH ARTICLE

Mining and the sustainable development goals: Prioritizing SDG targets for proper environmental governance

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Abstract Inability to ensure sustainable mining practice has brought the awareness that mining enterprises must be more pragmatic on achieving the sustainable development goals (SDGs) in their operations. This research propose a new approach to select and prioritize relevant targets to the industry, which will allow companies, communities, and public authorities to establish a proper framework for environmental governance. The methodology includes appraisal of questionnaires, prioritization of targets following a thorough screening and quantitative assessment, and a bipartite network analysis approach. The results indicate that 55 out of the 169 targets were considered relevant for oil sands mining. The targets in SDGs 1, 12, and 16 were identified as having high or very high priority. There was high correlation between proposed conditions and targets based on the bipartite analysis, which signifies that the people's opinion has relevance in the priority ratings. To achieve SDGs, the implication of mining activities on the environment must be addressed. It was concluded that targets with high relevance in the three phases of mining should be given high consideration when establishing governance principles. Furthermore, engagement of relevant stakeholders that will be impacted directly or indirectly by mining operations is critical in the pursuit of achieving SDGs.

Keywords Mining · Oil sands · Sustainable development goals (SDGs) · Targets

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INTRODUCTION

Following the failure to fully achieve the millennium development goals (MDGs) by some African countries, including Nigeria, efforts are therefore being made to achieve sustainable development goals (SDGs) targets in the areas of mining, conservation, sustainable development, and tourism governance (AfDB et al. 2015; Siakwah et al. 2019). It was stated in the 2030 Agenda for SDGs that socio-economic development is dependent on the sustainable management of natural resources and the environment. The mining sector is therefore critical in achieving these goals and targets, with the need for the implementation of proper environmental governance framework. Government at all levels must therefore be committed to the enforcement of environmental laws that will ensure that the mining companies works toward the endorsed achievement of SDGs (Monteiro et al. 2019).

The SDGs were adopted in 2015 as a major part of the 2030 Agenda for sustainable development (SD) and was endorsed by 193 member states of the United Nations (UN) General Assembly (Assembly 2015; Biermann et al. 2017). The SDGs are a set of 17 goals, 169 targets, and 230 indicators for addressing SD challenges by 2030 with the aim of ending poverty, safeguarding the planet and ensuring peace and wealth among people (Annan-Diab and Molinari 2017). These SDGs include new agendas and were built and broadened upon the successes made under the MDGs set in 2000 (Assembly 2015; Annan-Diab and Molinari 2017; Biermann et al. 2017; Wood et al. 2018). With the advent of SDGs in 2015, there has been increasing interest in linking SDGs with the mining industry and its practices (Omotehinse and De Tomi 2019a). Mesquita et al. 2017 concluded that the SDGs would serve as a framework to offer clearer and common target that can be

achieved by any mining enterprise across the globe. SDGs alone do not integrate the three bottom lines (TBL) dimensions, which is a framework that incorporates the performance of social, environmental, and economic concerns (Slaper and Hall 2011), but some of the targets do. This was possible because the aim of the targets were on the interdependencies between issues and were managed in an integrated way. Experiences from MDGs showed that targets that can be quantified could have more significance than goals (Griggs et al. 2014).

As a guide for the mining sector, The Atlas (Sonesson et al. 2016), which recommends some strategies on SD for mining enterprises, was published (UNDP 2016). To maximize the contributions of this publication to the SDGs attainment, Yakovleva et al. (2017) suggested that an approach that is region specific to SDGs would allow mining companies to put their SD strategies together according to the local need, the regional economic, and social challenges. The SDGs address problems of which many are caused by mining activities, therefore the mining sector is positioned to make an outstanding impact in the achievement of these goals (Yakovleva et al. 2017; Fraser 2019). Researches that will show how organizations can support these targets within the context of their commercial priorities and activities are therefore needed (Sullivan et al. 2018). Despite the fact that these goals are universal, it is the responsibility of each country to select its targets and determine its priorities in terms of the pace of transformation (Allen et al. 2016, 2019). As so, there will be many challenges in choosing realistic targets by the government and setting out appropriate and cost-effective approach toward achieving the targets (Allen et al. 2016).

In recent times, there are growing use of bipartite network analysis by researcher in identifying key structure of data set. Bipartite network can be defined as a data structure showing the relationship and/or interactions between two types of entities (Gao et al. 2018). This is mostly used in applications such as questionnaires, search engines, and Online Social Rating Networks (OSRN) (Gao et al. 2018; Banerjee et al. 2017). This is to deduce the relationships between nodes of the same type (Pavlopoulos et al. 2018). To analyze bipartite networks, an approach termed projection is used. The bipartite networks analysis can be used in determining priorities and interactions of SDGs. Jaramillo et al. (2019) used bipartite network to analyze the priorities and interactions of SDGs with focus on wetlands and the study showed that the targets 6.3, 12.2, and 2.4 were ranked as priorities to achieve SD from a wetland perspective. Wood et al. (2018) in their research titled distilling the role of ecosystem services in the SDGs used a bipartite network analysis to plot the 178 ecosystem services–targets interactions and found targets under SDG 1, 2, 6, and 15 to be the most frequently evaluated and distinct targets. Corel et al. (2018) also used bipartite network to analyze gene sharing in the microbial world and the analysis showed a vertical and horizontal view of the gene flow.

Bipartite networks shows the potential for cooperation and actual connections (Hennemann and Liefner 2008) and it is commonly analyzed by projecting it into two unipartite networks (one for the top nodes and one for the bottom nodes) (Latapy et al. 2008). The unique characteristic of it is that there are no edges between nodes of the same set, but only between the different sets (Hennemann and Liefner 2008).

Our study focuses on a specific oil sands region in Nigeria. Mining data are not readily available online for Nigeria, because there are no standard mines available and minerals are mostly mined either illegally or using artisanal mining methods. Yakovleva et al. (2017) gave an analysis of mineral extraction and production in sub-Saharan Africa by local and foreign companies using small-, medium-, and large-scale operations, but there were no data for Nigeria on the total number of mines, the minimum, and maximum lifetime of a mine in the country.

Mining is the industrial extraction and processing of minerals. The activities involve five stages, which are prospecting, exploration, mine development, exploitation, and mine closure (Newman et al. 2010) which have various impacts on the environment. In this research, the prospecting, exploration, and development, which are the initial stages of a mining enterprise, are referred to as the *pre-mining phase* (Omotehinse and Tomi 2019b); the exploitation stage is referred to as the *mining phase*, while the mine closure is referred to as the *post-mining phase*.

The degrees of effects of mineral development depends on the stage and scale of activities attained. While only minor impacts occur during prospecting and exploration stage, more intense effects occur from the mine development stage (Unesco-Mab 1995). The mining phase can cause higher impacts than those mentioned in the pre-mining phase. The environmental effects include destruction of vegetative cover, major land-form changes, slope failures, acid mine drainage, pollution from heavy metals, and tailing ponds. The social effects include relocation, violence, human trafficking, and prostitution (Pring et al. 1999).

Oil sands are unconventional sources of petroleum that occur naturally, and they consist of a mixture of clay, sand, water, and bitumen (Tenenbaum 2009; Poveda and Lipsett 2011, 2013). Oil sands can also be called tar sands (Brandt 2011) or bituminous sands (Masliyah et al. 2004). The extraction of bitumen from the oil sands can be through the surface mining method or in situ production method (Jordaan et al. 2009; Poveda and Lipsett 2013). The estimate of oil sands deposits in Nigeria are between 32 and 47 billion barrels in place and can be found in Ondo, Ogun, Lagos, and Edo States (Ako et al. 1983; Enu 1985) and they remain unexploited. The development of the oil sand

resource has potential for environmental degradation, pollution, and problems, which is an integral part of environmental governance. The role of environmental governance is of high importance for the achievement of SDGs as the concept place emphasis on an all-round system of management (Falebita and Koul 2015).

In this research, we thereby propose an extensive analysis of the targets for the different mining phases to identify the ones that are more specific to each phase. All the 17 SDGs and their targets will be considered and our focus will be on the ones that are more relevant to the environmental sustainability category across the different phases. The motivation behind this study is to create a future whereby prospective bitumen mining companies can have a well-packaged environmental governance framework to follow, which will meet the stakeholders expectations in a balanced way.

Thus, the aim of this research is to propose a new approach to select and prioritize relevant targets to a specific industry (oils sands) which will allow companies, communities, public authorities, and other stakeholders involved in oil sands mining to establish a proper environmental governance for new mining enterprises.

The research questions are as follows:

(1) What are the specific SDG targets that are relevant to oil sands mining and how can they be prioritized across the three different mining phases?
(2) What is the correlation between the proposed conditions and specific targets?

MATERIALS AND METHODS

The linkage between SDGs and mining is a challenge for the mining enterprise to go beyond its conventional scope of activities (Yakovleva et al. 2017). However, for SDGs to be achieved, strategies based on science and community participation throughout the life of a mining process should be adopted (Wood et al. 2018). People and organizations therefore need to participate in making decisions that involve mining projects and be knowledgeable about the possible effects of the sector's activities (Yakovleva et al. 2017).

In order to develop a methodology that identifies the linkages between SDGs and the mining enterprises, a study was carried out in some oil sands communities in Ondo state, Nigeria. The proposed methodology started with qualitative research and questionnaires (Mack et al. 2005). This was aimed at understanding the effects of oil sands mining on the communities and the results generated were used for data analysis (Bricki and Green 2007). The data collected was analyzed using a bipartite network analysis as described below.

Data collection

The methodology for data collection for the fieldwork carried out in this region has been described in a recent publication (Omotehinse et al. 2019). The region, which is Ondo state, is an agrarian state where majority of the population engaged in agriculture. The settlement pattern is about 40% urban, 55% rural, and 5% riverine and about 38% of the rural area falls within the mining-licensed areas. The oil sands deposits cut across six local government areas, which are Odigbo, Ode-Irele, Idanre, Okitipupa, Ese-Odo, and Ilaje. The Odigbo local government is the study area in this study, which has a land area of 1818 km^2 and a population of 230,351 persons (Omotehinse 2020).

The data collection include interviews and administration of questionnaire with 14 questions to the members of Mulekangbo, Ilubirin, and Mile 2 communities in the study area. The leaders of the communities mentioned above were visited to discuss the aim of this research. The questionnaires were distributed to the selected interviewees and the questions presented during the interviews are shown in Supplementary Information S1. Interviewees were selected according to their availability and on a random basis. The sequence of interviews followed a sequence of visit to different households; however, only one representative per household were interviewed. The focus group of the interview was people involved in productive activities, but other actors such as students and community leaders were also interviewed (Table 1). In addition, in some occasions, interviews were selected through snowball sampling (Bernard 2006; Smith 2019).

As described in Omotehinse et al. (2019), there were 100 interviewees, 40 from Mulekangbo, 30 from Ilubirin, and 30 from Mile 2 community. The population in the communities are less than 350 people and most of the households have been interviewed, and the number of interviewees can be considered as representative sample.

The sample sites were selected because some exploration activities had been carried out in the area (Adegoke et al. 1980) and some oil sands outcrops of the geological formation were found within the axis, which will be highly relevant for new mining enterprise as they will prioritize near known outcrops, and this was emphasized by current exploration campaigns for oil sands.

Data analysis

Prioritization of targets

A screening exercise to identify the set of targets that are important for oil sands mining activities was carried out. All the 17 SDGs were required for this research and the relevant targets out of the 169 targets were chosen. Based

Table 1 Demographic profile of respondents

Questions and categories	Mulekangbo (N = 40)	Ilubirin (N = 30)	Mile 2 (N = 30)
Sex			
Male	21	23	21
Female	19	7	9
Age			
18–25	0	0	4
26–30	2	8	2
30–40	12	8	10
40 above	26	14	14
Educational status			
Primary	28	24	25
Secondary	7	4	4
Grade 2	3	2	0
No formal education	2	0	1
Occupation			
Farming/fishing	40	24	26
Students	0	0	2
Others	0	6	2

on recent regional assessments and reports by authors such as International Council on Mining and Metals (ICMM 2010, 2012), The Atlas (Sonesson et al. 2016), and Mining, Minerals and Sustainable Development Project (Mining 2002) and in terms of importance to mining activities, stakeholders priorities, an initial list of 169 targets (Table 2) was screened. Fifty-five (55) identified targets were prioritized in the three phases of mining according to their relevance in each phase. A quantitative baseline assessment is done based on the importance of each target to different phases of mining and the priority rate (PR) and category are gotten based on Eq. 1. The targets were scored and weighed across the three phases of mining and priority targets were identified.

The prioritization carried out in this research was aimed at evaluating the importance of each target to the 3 mining phases. The PR was done by considering each relevant target across the three phases of mining and was rated or scored according to its importance in each of the phase. Targets with PR of five was considered as "very high" priority and 1 "very low" priority. The net sum for each target in a goal shows an overall assessment of their net influence in the goal.

The priority rating for each goal (PR) for the 3 phases of mining is calculated using the formula:

$$\mathrm{PR} = \left(\left(\sum \text{targets scores}\right) \Big/ (\text{Number of targets} * 15)\right) * 5, \quad (1)$$

where 15 is the maximum score for the 3 phase (maximum of 5 score for each phase).

The screening process reduced the list of targets from 169 to a minimum number used as the basis for subsequent analytical steps in this research.

Network analysis of interlinkages between targets and "proposed conditions"

The proposed conditions were generated during various visits to the communities. It was divided into two: the likely impacts of oil sands mining and some suitable solutions, which were the first set. The second set are services that the mining companies can render to the communities and these were named "proposed conditions." The proposed conditions were generated based on various researches, available literatures, adequate knowledge on impacts of mining activities (Mining 2002; McWhinney 2014), and the basic amenities that were lacking in the communities. The possible effects of oil sands mining activities on the communities were discussed with participants during the interview, the questionnaire was presented to them, and the proposed conditions were the responses to the questions that were asked.

The interlinkages of each SDG target and the proposed conditions were identified and developed based on these three criteria: 1. level of relevancy; 2. relationship; and 3. interconnection. A bipartite network analysis was applied to evaluate the linkages between the targets and the opinion of the people.

RESULTS

Targets priority ratings for phases of mining

Using the screening results by the authors and reports, such as International Council on Mining and Metals (ICMM 2010, 2012), The Atlas (Sonesson et al. 2016) and Mining, Minerals and Sustainable Development Project (Mining 2002), the 55 identified targets were prioritized in the three phases of mining according to their relevance in each phase. Table 3 presents the lists of relevant targets for oil sands mining, which are the targets used for the subsequent analysis in this research (Supplementary Information S2: Definitions of SDG targets).

The 17 SDGs, the relevant targets, and their priority ratings across the three mining phases are shown in Table 4.

The 17 SDGs, the relevant targets, and their priority ratings across the three mining phases are shown in Table 4. The 55 identified targets were prioritized in the

Table 2 The 17 sustainable development goals (SDGs) and the 169 targets (UNDP 2016)

SDGs	Titles	Targets
1	No Poverty	1.1; 1.3; 1.4; 1.5; 1.a; 1.b
2	Zero Hunger	2.1; 2.2; 2.3; 2.4; 2.5; 2.a; 2.b; 2.c
3	Good Health and Well-being	3.1; 3.2; 3.3; 3.4; 3.5; 3.6; 3.7; 3.8; 3.9; 3.a; 3.b; 3.c; 3.d
4	Quality Education	4.1; 4.2; 4.3; 4.4; 4.5; 4.6; 4.7; 4.a; 4.b; 4.c
5	Gender Equality	5.1; 5.2; 5.3; 5.4; 5.5; 5.6; 5.a; 5.b; 5.c
6	Clean Water and Sanitation	6.1; 6.2; 6.3; 6.4; 6.5; 6.6; 6.a; 6.b
7	Affordable and Clean Energy	7.1;7.2; 7.3; 7.a; 7.b
8	Decent Work and Economic Growth	8.1; 8.2; 8.3; 8.4; 8.5; 8.6; 8.7; 8.8; 8.9; 8.10; 8.a; 8.b
9	Industry, Innovation, and Infrastructure	9.1; 9.2; 9.3; 9.4; 9.5; 9.a; 9.b; 9.c
10	Reduced Inequalities	10.1; 10.2; 10.3; 10.4; 10.5; 10.6; 10.7; 10.a; 10.b; 10.c
11	Sustainable Cities and Communities	11.1; 11.2; 11.3; 11.4; 11.5; 11.6; 11.7; 11.a; 11.b; 11.c
12	Responsible Consumption and Production	12.1; 12.2; 12.3; 12.4; 12.5; 12.6; 12.7; 12.8; 12.a; 12.b; 12.c
13	Climate Action	13.1; 13.2; 13.3; 13.a; 13.b
14	Life Below Water	14.1; 14.2; 14.3; 14.4; 14.5; 14.6; 14.7; 14.a; 14.b; 14.c
15	Life on Land	15.1; 15.2; 15.3; 15.4; 15.5; 15.6; 15.7; 15.8; 15.9; 15.a; 15.b; 15.c
16	Peace, Justice, and Strong Institutions	16.1; 16.2; 16.3; 16.4; 16.5; 16.6; 16.7; 16.8; 16.9; 16.10; 16.a; 16.b
17	Partnerships for the Goals	17.1; 17.2; 17.3;17.4; 17.5; 17.6; 17.7; 17.8; 17.9; 17.10; 17.11; 17.12; 17.13; 17.14; 17.15; 17.16; 17.17; 17.18; 17.19

three phases of mining according to their relevance in each phase.

The priority rate has been calculated according to Eq. 1. The processes of calculations in Table 4 use the following steps as explained, using Targets in SDG 6 as example.

Considering targets 6.1; 6.3; 6.4; 6.5; 6.6; and 6.b, while some were prioritized as very high, some were prioritized as high and some of moderate priority in the three phases of mining. Target 6.1 was prioritized as very high in all the three phases of mining because most mining communities are located in rural areas with little or no safe drinking water. Therefore, a mining company can make provision for safe drinking water to a community as part of its corporate social responsibility thereby achieving this target. Target 6.3 has zero priority at the pre-mining phase because at this phase, there is little use of hazardous chemical and there is less water pollution and drilling mud that is used during exploration activities can cause contamination but it can easily be controlled (Ashton et al. 2001). However, it is rated 5 both during the mining and post-mining phases because in these phases, there are different types of pollution from waste water, tailing ponds, chemicals, and heavy metals which affect water quality (Masliyah et al. 2004; Gosselin et al. 2010), therefore, it should be considered as very important.

Target 6.4 was prioritized as zero at the pre-mining phase because mine prospecting and exploration require little water usage; however, it was prioritized as 5 and 4 at both the mining and the post-mining phase, respectively. This target was highly prioritized at these phases because oil sands processing requires a large volume of water, and mining companies must be able to recycle the water from tailing ponds in order to reduce the amount of fresh water intake thereby ensuring water-use efficiency (Masliyah et al. 2004; Gosselin et al. 2010). Target 6.5 was prioritized as 3 at pre-mining phase, 4 at the mining phase, and 3 at the post-mining phase. It was prioritized as high at the mining phase because at this phase, water resource is usually affected by most mining operations (Ashton et al. 2001); hence, the prioritization of this target at this phase will ensure efficient management of water resources within the mine site. Target 6.6 was prioritized as zero at both the pre-mining and mining phases and rated five in the post-mining phase, because water ecosystem is usually affected during the mining phase; hence, after mine closure, it is the responsibility of a mining enterprise to protect and restore the water ecosystem (Gosselin et al. 2010). Target 6.b prioritized as 3 in both the pre-mining and mining phases and rated 5 in the post-mining phase. It was prioritized as very high at the post-mining phase, because at this phase, the community can work with the mining company to ensure the improvement of the contaminated water that is stored on site. In general, the priority of a target therefore has major influence on the prioritization of its goal.

Analysis of linkages between proposed conditions, SDGs, and their targets

The responses from the questionnaire, which are the proposed conditions as shown in Table 5, were analyzed to

Table 3 The 17 sustainable development goals (SDGs) and the relevant targets for oil sands mining

SDG	Titles	55 Relevant targets
1	No Poverty	1.1; 1.3; 1.4; 1.5
2	Zero Hunger	2.3; 2.4; 2.5; 2.a
3	Good Health and Well-being	3.8; 3.9; 3.d
4	Quality Education	4.1; 4.4
5	Gender Equality	5.a
6	Clean Water and Sanitation	6.1; 6.3; 6.4; 6.5; 6.6; 6.b
7	Affordable and Clean Energy	7.1
8	Decent Work and Economic Growth	8.3; 8.4; 8.6; 8.8
9	Industry, Innovation, and Infrastructure	9.1
10	Reduced Inequalities	10.3
11	Sustainable Cities and Communities	11.1; 11.4
12	Responsible Consumption and Production	12.2; 12.4; 12.5; 12.6; 12.8
13	Climate Action	13.1; 13.2; 13.3
14	Life Below Water	14.1; 14.2; 14.3; 14.c
15	Life on Land	15.1; 15.b; 15.2; 15.3; 15.5
16	Peace, Justice, and Strong Institutions	16.1; 16.5; 16.6; 16.7; 16.10
17	Partnerships for the Goals	17.7; 17.15; 17.16; 17.17

determine the perception of the community on mining activities and ways it could affect their lives. Table 5 shows the responses of the three communities on their basic needs from the mining company and their expectations from mining operations.

An approach involving the interlinkage of the prioritized targets with the proposed conditions (in Table 5) is adopted as shown in Fig. 1, which was analyzed to see the targets that are of utmost important. A mapping of the proposed conditions was done against the 17 SDGs and the 55 relevant targets. For example, targets 1.1, 1.5, and 8.3 were considered most relevant to this proposed condition, which is "job creation," and the other targets were considered and linked to their relevant proposed conditions.

Figure 1 shows that the proposed condition "restoration of degraded and polluted areas" and "Safe operations" have the highest number of related targets, and they both have 13 related targets. Targets related to achieving "restoration of degraded and polluted areas" are targets 2.3; 2.4; 2.5; 6.6; 8.4; 12.4; 14.2; 14.3; 15.1; 15.2; 15.3; 15.5; and 15.b. Targets related to achieving "Safe operations" are targets 3.9; 6.3; 6.4; 6.5; 8.8; 12.2; 12.4; 12.5; 13.1; 14.1; 14.2; 14.3; and 14.c. The related goals for these targets are SDGs 2, 6, 8, 12, 13, 14, and 15.

The proposed condition with the next highest number of related targets, which is 10 is "transparency in operations." The related target include target 3.d; 6.5; 6.b; 12.2; 12.6; 12.8; 13.1; 14.1; 16.6; and 16.10. The related goals for these targets are SDGs 3, 6, 12, 13, 14, and 16. This signifies that the mining enterprise should place more relevance on these proposed conditions in order to achieve these targets, thereby achieving the goals. At the bottom of the list are community participation in decision-making, provision of health care, and protection of cultural heritage, and they have just one related target each.

A mining enterprise, community, and environmental governing body can achieve these targets if there are appropriate planning and implementation of environmental laws. "Restoration of degraded and polluted areas" as a proposed condition can be accomplished by abiding and following the rules of ecosystem management, environmental management, and increase agricultural productivity. "Safe operations" can be achieved through waste management, management of natural resources, and the inclusion of secure and safe working operations. "Transparency in operations" can be achieved if the mining company can educate the communities and stakeholders about the impacts (positive and negative) of mining operations.

DISCUSSION

Key findings on prioritization of targets among mining phases

There is no direct relationship between the number of relevant targets in a goal and its prioritization. The priority of a target may vary when it is being considered for the 3 different mining phases. Achieving a target in a goal is indirectly achieving the goal to an extent. A target may have a very high priority in the pre-mining phase and will have a low priority in the post-mining phase; however, this does not refute the fact that the relevant targets can serve as a guide toward achieving the related goals.

Prioritized targets under SDG 16, 12, and 1 were of very high and high priorities, each perceived to have high impacts and peculiarities in the three phases of mining. Interestingly, Allen et al. (2019) used a multi-criteria analysis to prioritize SDG targets and based on their results, targets under SDG 16, 12, and 1 were among the highest scoring target. The top four prioritized targets in this research cover governance issues, which include reduction in corruption and bribery, accountability and transparency of institutions, access to information, and protection of fundamental rights. The targets were deemed very important at all the three phases of mining. This is because the community expects the mining enterprise to maintain peace and justice through responsible production and consumption of the natural resource thereby ensuring

Table 4 Priority rating of targets across the 3 mining phases using Eq. 1

SDGs	Target	Pre-mining					Mining					Post-Mining					Number of Targets	Priority Rate (PR)	Priority Category
		5	4	3	2	1	5	4	3	2	1	5	4	3	2	1			
SDGs	Target	Pre-mining					Mining					Post-Mining					Number	Priority Rate (PR)	Priority Category
SDG1 No Poverty	1.1	5							3							1	4	3.67	High
	1.3	5						4						3					
	1.4	5										5							
	1.5			3			5					5							
SDG2 Zero Hunger	2.3											5					4	1.33	Very low
	2.4											5							
	2.5													3					
	2.a													3					
SDG3 Good Health & Well-being	3.8	5							3								3	3.22	Moderate
	3.9						5						4						
	3.d		4					4					4						
SDG4 Quality Education	4.1		4														2	2.33	Low
	4.4	5					5												
SDG5 Gender Equity	5.a			3									4				1	2.33	Low
SDG6 Clean Water & Sanitation	6.1	5					5					5					6	3.33	Moderate
	6.3						5					5							
	6.4						5						4						
	6.5			3				4						3					
	6.6											5							
	6.b			3					3			5							
SDG7 Affordable & Clean Energy	7.1			3				4							2		1	3.0	Moderate
SDG8 Decent work & Economic Growth	8.3	5						4							2		4	2.83	Moderate
	8.4											5							
	8.6		4				5								2				
	8.8					1	5									1			
SDG9 Industry, Innovation & Infrastructure	9.1		4					4									1	2.67	Moderate
SDG10 Reduced Inequality	10.3			3					3								1	2.0	Low
SDG11 Sustainable Cities & Communities	11.1	5															2	1.5	Low
	11.4												4						
SDG12 Responsible Production & Consumption	12.2	5					5					5					5	4.0	High
	12.4						5					5							
	12.5			3			5							3					
	12.6	5					5					5							
	12.8		4					4								1			
SDG13 Climate Action	13.1					1			3				4				3	2.67	Moderate
	13.2					1				2			4						
	13.3		4							2				3					
SDG14 Life Below Water	14.1						5					5					4	3.33	Moderate
	14.2						5					5							
	14.3						5					5							
	14.c						5					5							
SDG15 Life on Land	15.1											5					5	2.53	Moderate
	15.b	5										5							
	15.2											5							
SDGs	Target	Pre-mining					Mining					Post-Mining					Number	Priority Rate (PR)	Priority Category
	15.3											5							
	15.5	5							3			5							
SDG16 Peace, Justice & Strong Institutions	16.1	5					5										5	4.67	Very high
	16.5	5					5					5							
	16.6	5					5					5							
	16.7	5					5					5							
	16.10	5					5					5							
SDG17 Partnership for the Goal	17.7							4								1	4	3.0	Moderate
	17.15	5					5					5							
	17.16			3					3							1			
	17.17			3					3					3					
		PRIORITY ≈5 = Very High; ≈4= High; ≈3 = Moderate; ≈2 = Low; ≈1 = Very Low															55		

Table 5 Result summary of the interviews carried out in the oil sands communities of Ondo State

Name of community and number of people interviewed	Mulekangbo (40)	Ilubirin (30)	Mile 2 (30)
Occupation	Farming/fishing (40) Students (0)	Farming/fishing (24) Students (0)	Farming/fishing (26) Students (2)
	Others (0)	Others (6)	Others (2)
What would you like the company to do for you? (Proposed Conditions)			
Infrastructure	Yes (40)	Yes (30)	Yes (30)
	No (0)	No (0)	No (0)
	Neutral (0)	Neutral (0)	Neutral (0)
Housing	Yes (35)	Yes (27)	Yes (29)
	No (5)	No (3)	No (1)
	Neutral (0)	Neutral (0)	Neutral (0)
Jobs	Yes (30)	Yes (30)	Yes (30)
	No (8)	No (0)	No (0)
	Neutral (2)	Neutral (0)	Neutral (0)
Health care services	Yes (36)	Yes (30)	Yes (30)
	No (2)	No (0)	No (0)
	Neutral (2)	Neutral (0)	Neutral (0)
Water facilities	Yes (34)	Yes (30)	Yes (30)
	No (0)	No (0)	No (0)
	Neutral (6)	Neutral (0)	Neutral (0)
Schools and vocational canters	Yes (32)	Yes (30)	Yes (30)
	No (0)	No (0)	No (0)
	Neutral (8)	Neutral (0)	Neutral (0)
Decisions about impacts of mining activities on the communities (Proposed Conditions)			
Ensure safe operations	Yes (40)	Yes (30)	Yes (30)
	No (0)	No (0)	No (0)
	Neutral (0)	Neutral (0)	Neutral (0)
Compensation on farmlands	Yes (40)	Yes (30)	Yes (30)
	No (0)	No (0)	No (0)
	Neutral (0)	Neutral (0)	Neutral (0)
Restoration of degraded and polluted areas	Yes (40)	Yes (30)	Yes (30)
	No (0)	No (0)	No (0)
	Neutral (0)	Neutral (0)	Neutral (0)
Community representation in decision-making process	Yes (34)	Yes (24)	Yes (22)
	No (6)	No (5)	No (6)
	Neutral (0)	Neutral (1)	Neutral (2)
Transparency of operations	Yes (40)	Yes (30)	Yes (30)
	No (0)	No (0)	No (0)
	Neutral (0)	Neutral (0)	Neutral (0)
Pre-mining activities would affect your source of livelihood. On what terms would accept to give this up?	Compensation (39)	Compensation (30)	Compensation (28)
	Freewill (1)	Freewill (0)	Freewill (2)
	Neutral (0)	Neutral (0)	Neutral (0)
Because your community sits on the resource there might be a relocation. On what terms would you accept to relocate?	Provision of housing (40)	Provision of housing (26)	Provision of housing (27)
	Not leaving (0)	Not leaving (4)	Not leaving (3)
	Neutral (0)	Neutral (0)	Neutral (0)
Pre-mining operation might affect your source of water, what would you like the company to do?	Boreholes (32)	Boreholes (21)	Boreholes (4)
	Compensation (8)	Compensation (9)	Compensation (25)
	Neutral (0)	Neutral (0)	Neutral (1)

there are economic progress and reduced poverty among the people, which is important for achieving multiple SDG targets.

Conversely, SDG 2 prioritized as "very low," SDG 11 and SDG 10 prioritized, as "low" are the least prioritized among the goals. This is because targets 2.3; 2.4; 2.5; 2.a; 10.3; 11.1; and 11.4 were only relevant at one phase of the mining operations and not throughout the 3 mining phases. Targets 10.3 that was relevant for the pre-mining phase and mining phase was of moderate relevancy at these phases thereby affecting the prioritization of the goal.

The three phases of mining are interlinked, for example, the mining phase may have to go ahead on its operation because the result from the pre-mining phase shows that the minerals are economically viable to mine, resulting to various social and environmental impacts on the communities (Pimentel et al. 2016). The results show that there is need for environmental and ecosystem management (Targets 6.6, 13.1; 14.2, 14.3, 15.1, 15.2, 15.3, 15.5, and 15.b) after mineral exploitation. This is crucial for the promotion and implementation of sustainable management of all ecosystems and reduction in the adverse impacts of mining activities on the community. Environmental management (Targets 8.4 and 12.4) is a crucial aspect of the life cycle of a mine to ensure sustainable exploitation of resources in order to reduce the amount of pollutants released into the air, water, and soil while achieving economic growth (Alekseenko et al. 2017). Increase agricultural productivity (Targets 2.3, 2.4., and 2.5) should be the focus during the mine restoration in ensuring that indigenous people implement agricultural practices that help increase yield through managed and diversified seed and plant bank which can in turn help to maintain the ecosystems (Sheoran et al. 2010; Alekseenko et al. 2017).

During mining, relocating the community to a new area is done to maintain peace and compensations are given for farmland destructions, which brings justice to affected members (Apeakoran 2014). In ensuring safe operations, mining enterprise should focus on waste management (Targets 6.3, 12.4, and 12.5) to reduce the amount of waste generated. Management of natural resources (Targets 6.4, 6.5, 12.2, 14.1, 14.2, 14.3, and 14.c) is equally important for the reduction in the number of people suffering from water scarcity, reduction in marine pollution from land-based activities, and enhancing conservation of natural resources. In addition, secure and safe working operations should be practiced (Targets 3.9 and 8.8) to reduce the number of illnesses and deaths.

The opinion-based conditions indicate that "community participation in decision-making" and "protection of cultural heritage" have the lowest numbers of linked targets and goals for the proposed conditions. This can be interpreted to mean that although ensuring the participation and representation of the community at all stages of mining is a crucial factor in decision-making, transparency of all operations would already serve to meet this need hence, its limited linkages with goals and target. Furthermore, conservation of natural and cultural heritage may also be deemphasized because of the inevitable destruction of the environment to allow for mining operations in the community.

Proposed conditions, SDGs, and their targets

Figure 1 provides a picture of the interlinkages; it shows the 14 proposed conditions and the number of targets to which they are linked. It also provides a perspective by showing the strengths of the links among the targets and the proposed conditions goals. The thicker the nodes on a proposed condition, the more targets are linking the two goals. The proposed conditions, SDGs, and their targets can be seen as a network, in which links among goals exist through targets. In this analysis, the proposed conditions were represented by nodes and SDG targets by arrow heads, both with different colors. The line color shows the SDG targets to which the proposed condition is related. The size of the node is proportional to the number of proposed condition–targets connections. Using network analysis techniques, it was shown that these targets are not equally connected to the proposed conditions as some were strongly connected through multiple proposed conditions, while other were weakly connected.

Furthermore, these proposed conditions are particularly relevant for a smooth mining operating within a country because it addresses challenges presented by mining impacts. For example, the proposed condition "reduced violence, corruption, and bribery" can be achieved if peace and justice are strongly maintained within the mining communities, which is the focus of targets in SDG 16. Corruption and bribery often lead to community–company conflict (Omotehinse and De Tomi 2020). Mining companies can contribute to these targets by reducing illegal financial flows through transparency of operations (Njie 2015) and ensure they support peaceful communities by reducing company–community conflict. The proposed conditions "job creation" and "establishment of schools and vocational centers" go hand in hand, which can help in achieving targets 4.1 and 4.4. This can partially be achieved during the pre-mining phase because the mine is not fully in operation; however, it can majorly be achieved during the mining phase when the mine is fully in operation. Investment in technical, vocational and educational training programs can be done to help the local communities (Sonesson et al. 2016). The less educated can be employed as skilled workers in the local community. Jobless youths can cause unnecessary protests and violence

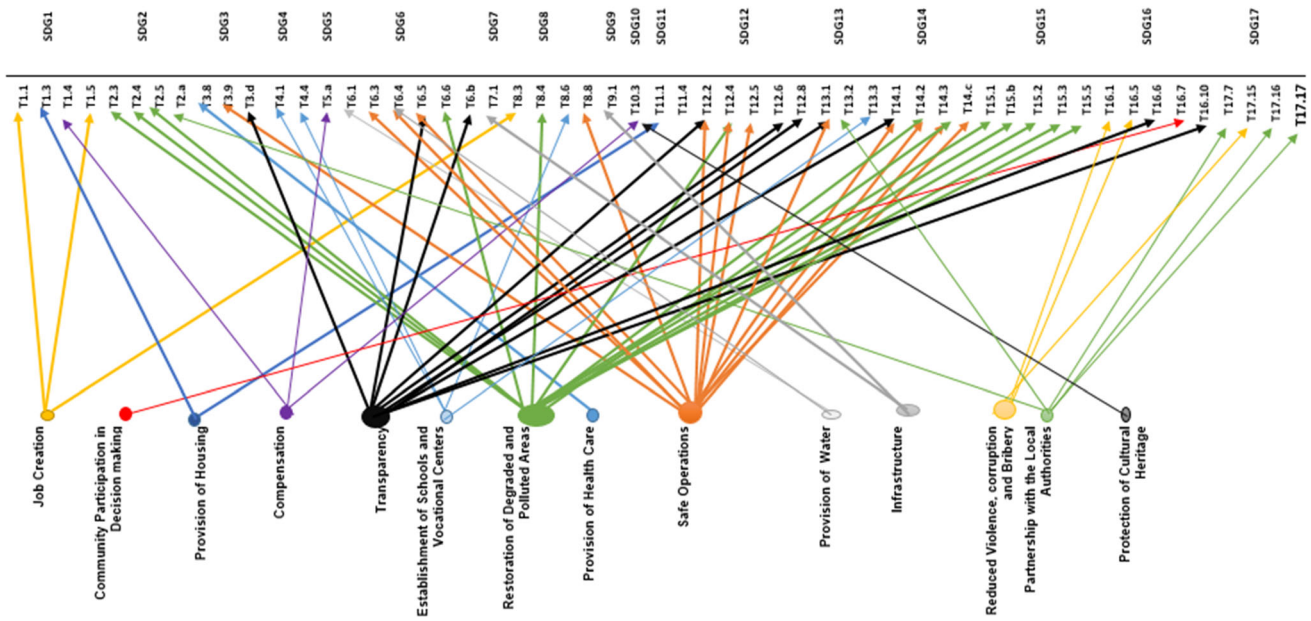

Fig. 1 Linkage between proposed conditions, SDGs, and their targets

in the mine environment, for example, a mining company employing other workers without considering the local communities could cause protests and violence.

The mining companies can work together with the government to achieve the proposed condition "health services" by building hospitals with proper health care facilities to areas that lack them which can help in achieving target 3.8. Health risk is usually associated with the mining phase, because mining activities may result in health risk like cardiovascular and respiratory diseases and tuberculosis due to silica dust exposure. The proposed condition "compensation" is important during the pre-mining phase where there will be deforestation; this could lead to loss of job. Compensating the farmers helps in achieving targets 1.1, 1.3, and 1.5. The proposed condition "provision of water," "basic infrastructure," and "provision for housing facilities" in case of relocation are seen as part of the company's corporate social responsibilities and this will bring some development to the community and thereby achieving the targets.

CONCLUSION

Recent literature shows that the implementation of the SDGs within the mining industry is still a challenging topic and this has led to researchers taking an analytical approach toward the adaptation of the SDGs in their different applications. Hence, the identification of the linkages between the SDGs, the associated targets, and the mineral industry sectors is a crucial task to be undertaken prior to any SDG implementation strategy. This research has focused on the SDG linkages in oil sands mining sector and the findings have identified that 55 out of the 169 SDG targets are relevant for this sector. The relationship between the number of relevant targets in a goal and its prioritization depends on the interpretation of each SDG target context.

Improving on screening results by the authors and reports, such as International Council on Mining and Metals (ICMM 2010, 2012), The Atlas (Sonesson et al. 2016) and Mining, Minerals and Sustainable Development Project (Mining 2002), the 55 identified targets were prioritized in the three phases of mining according to their relevance in each phase. The priority rating (PR) of the targets under each phase of mining was assessed according to the influence on the goal in the three phases of mining. For the oil sands case, SDGs 1, 12, and 16 were found to have high or very high PR because of the relevancy of their targets throughout the three phases of mining. On the other hand, SDGs 3, 6, 7, 8, 9, 13, 14, 15, and 17 had moderate PR because the targets under them were relevant in only two phases of mining or had moderate ratings throughout the three phases of mining. Finally, SDGs 2, 4, 5, 10, and 11 had low or very low PR because the targets under them were only relevant in one or two phases of mining or they have low or moderate relevance in two or three phases of mining according to the appraisal of the proposed conditions for oil sands mining. The results indicate that targets with high relevance in the 3 phases of mining should be given high consideration when establishing the governance

principles among companies, communities, and stakeholders.

In addition, the high correlation between the proposed conditions and targets based on the bipartite analysis proposed in this research proves that the people's opinion has significant relevance in the PR. More so, in the specific case of the oil sands deposits in Ondo state, Nigeria, mining will be welcomed in the communities if the mining companies will accept that mining operations will be carried out safely and the impacted areas will be restored properly. Engaging relevant stakeholders and prioritizing their opinion in policy planning can also significantly contribute to the achievement of SDGs and targets in this communities. Hence, future mining operation will have a robust environmental governance framework to follow, which will meet the stakeholders expectations in a balanced fashion.

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Declarations

Conflict of interest The authors hereby declare that there are no conflicts of interest during the research carried out and during the submission of this manuscript.

Ethical approval All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional of the First Author[2] and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the Ethics Committee of the University[2] of the First Author (Date 4th January 2016 / No 3.5.2 and 3.5.4).

Informed consent We hereby confirm that the informed consent was obtained from all participants and/or their legal guardians.

REFERENCES

Adegoke, O.S., B.D. Ako, and E.I. Enu. 1980. Geotechnical investigations of the Ondo State bituminous sands. *Report of Geological Consultancy Unit, Geology Department, Obafemi Awolowo University, Ile Ife, Nigeria* 257: 27–36.

African Development Bank (AfDB), Organisation for Economic Co-operation and Development (OECD), & United Nations Development Programme (UNDP). 2015. Regional Development and Spatial Inclusion.

Ako, B.D., A.O. Alabi, O.S. Adegoke, and E.I. Enu. 1983. Application of resistivity sounding in the exploration for Nigerian tarsand. *Energy Exploration & Exploitation* 2: 155–164.

Alekseenko, V.A., M.A. Pashkevich, and A.V. Alekseenko. 2017. Metallisation and environmental management of mining site soils. *Journal of Geochemical Exploration* 174: 121–127.

Allen, C., G. Metternicht, and T. Wiedmann. 2016. National pathways to the Sustainable Development Goals (SDGs): A comparative review of scenario modelling tools. *Environmental Science & Policy* 66: 199–207.

Allen, C., G. Metternicht, and T. Wiedmann. 2019. Prioritising SDG targets: Assessing baselines, gaps and interlinkages. *Sustainability Science* 14: 421–438.

Annan-Diab, F., and C. Molinari. 2017. Interdisciplinarity: Practical approach to advancing education for sustainability and for the Sustainable Development Goals. *The International Journal of Management Education* 15: 73–83.

Apeakoran, E.N. 2014. Relocation of Wassa West communities by large scale gold mining ventures and its socio-economic implications. *Apeakoran Ephraim Nana* (Doctoral dissertation, University of Ghana).

Assembly, U.G. 2015. *Transforming our world: The 2030 agenda for sustainable development*, 1. New York: United Nations.

Ashton, P.J., D. Love, H. Mahachi, and P.H. Dirks. 2001. An overview of the impact of mining and mineral processing operations on water resources and water quality in the Zambezi, Limpopo, and Oilfants Catchments in South Africa." Contract Report to Mining, Minerals, and Sustainable Development Project/Southern Africa. Pretoria, South Africa, and Harare, Zimbabwe: CSIR-Environmentek and University of Zimbabwe, Geology Department.

Banerjee, S., M. Jenamani, and D.K. Pratihar. 2017. Properties of a projected network of a bipartite network. In *Communication and Signal Processing (ICCSP), 2017 International Conference on* (pp. 0143–0147). IEEE.

Bernard, H. 2006. *Research methods in anthropology: Qualitative and quantitative approaches*. Oxford: Altamira.

Biermann, F., N. Kanie, and R.E. Kim. 2017. Global governance by goal-setting: The novel approach of the UN Sustainable Development Goals. *Current Opinion in Environmental Sustainability* 26: 26–31.

Brandt, A.R. 2011. *Upstream greenhouse gas (GHG) emissions from Canadian oil sands as a feedstock for European refineries*, vol. 18. Stanford: Department of Energy Resources Engineering, Stanford University.

Bricki, N., and J. Green. 2007. A guide to using qualitative research methodology.

Corel, E., R. Méheust, A.K. Watson, J.O. McInerney, P. Lopez, and E. Bapteste. 2018. Bipartite network analysis of gene sharings in the microbial world. *Molecular Biology and Evolution* 35: 899–913.

Enu, E.I. 1985. Textural characteristics of the Nigerian tar sands. *Sedimentary Geology* 44: 65–81.

Falebita, O.A., and S. Koul. 2015. Sustainable development of oil sands and host communities: preliminary system dynamics assessment.

Fraser, J. 2019. Creating shared value as a business strategy for mining to advance the United Nations Sustainable Development Goals. *The Extractive Industries and Society*.

Gao, M., L. Chen, X. He, and A. Zhou. 2018. Bine: Bipartite network embedding. In: *The 41st International ACM SIGIR Conference on Research & Development in Information Retrieval* (pp. 715–724). ACM.

Gosselin, P., S.E. Hrudey, M.A. Naeth, A. Plourde, R. Therrien, G. Van Der Kraak, and Z. Xu. 2010. *Environmental and health*

impacts of Canada's oil sands industry, 438. Ottawa: Royal Society of Canada.
Griggs, D., M. Stafford Smith, J. Rockström, M.C. Öhman, O. Gaffney, G. Glaser, K. Norichika, N. Ian, S. Will, and P. Shyamsundar. 2014. An integrated framework for sustainable development goals. *Ecology and Society*. https://doi.org/10.5751/ES-07082-190449.
Hennemann, S., and I. Liefner. 2008. Proposing bipartite network analysis for the evaluation of regional innovation systems-/-regions, actors, and content. In *International Conference on Innovation and Management ICIM* (Vol. 10).
International Council on Mining and Metals (ICMM). 2010. *Good Practice Guide: Indigenous Peoples and Mining*. London: International Council on Mining and Metals.
International Council on Mining and Metals (ICMM). 2012. *In brief: Mining's contribution to sustainable development—An overview*. London: International Council on Mining and Metals.
Jaramillo, F., A. Desormeaux, J. Hedlund, J.W. Jawitz, N. Clerici, L. Piemontese, and I. Åhlén. 2019. Priorities and interactions of sustainable development goals (SDGs) with focus on wetlands. *Water* 11: 619.
Jordaan, S.M., D.W. Keith, and B. Stelfox. 2009. Quantifying land use of oil sands production: A life cycle perspective. *Environmental Research Letters* 4: 024004.
Latapy, M., C. Magnien, and N. Del Veccio. 2008. Basic notions for the analysis of large affiliation networks/bipartite graphs. *Social Networks* 30: 31–49.
Mack, N., C. Woodsong, K.M. MacQueen, G. Guest, and E. Namey. 2005. Qualitative research methods: a data collectors field guide.
Masliyah, J., Z.J. Zhou, Z. Xu, J. Czarnecki, and H. Hamza. 2004. Understanding water-based bitumen extraction from Athabasca oil sands. *The Canadian Journal of Chemical Engineering* 82: 628–654.
McWhinney, R. 2014. Oil sands environmental impacts - Canadian Energy Research Institute. https://www.ceri.ca/assets/files/Study_143_Full_Report.pdf.
Mesquita, R.F., A. Xavier, B. Klein, and F.R.N. Matos. 2017. Mining and the sustainable development goals: A systematic literature review. *Geo-Resources Environment and Engineering (GREE)* 2: 29–34.
Mining & Sustainable Development Project. 2002. *Breaking new ground: Mining, minerals, and sustainable development: the report of the MMSD project*. London: Routledge.
Monteiro, N.B.R., E.A. da Silva, and J.M.M. Neto. 2019. Sustainable development goals in mining. *Journal of Cleaner Production* 228: 509–520.
Newman, A.M., E. Rubio, R. Caro, A. Weintraub, and K. Eurek. 2010. A review of operations research in mine planning. *Interfaces* 40: 222–245.
Njie, M. 2015. Illicit financial flows and the extractive sector in Africa. Graduate School of Public and International Affairs University of Ottawa
Omotehinse, A.O. 2020. Proactive management of the economic and environmental impacts of a proposed oil sands mine in Nigeria from the pre-mining phase (Doctoral dissertation, Universidade de São Paulo).
Omotehinse, A., and G. De Tomi. 2019a. Impact of mining activities on the achievement of sustainable development goals. In *9TH International Conference on Sustainable Development in the Minerals Industry (SDIMI 2019a),* pp. 58–60.
Omotehinse, A., and G. De Tomi. 2019b. A social license to operate: Pre-mining effects and activities perspective. *REM-International Engineering Journal* 72: 523–527.
Omotehinse, A.O., and G. De Tomi. 2020. Managing the challenges of obtaining a social license to operate in the pre-mining phase: A focus on the oil sands communities in Ondo State, Nigeria. *World Development Perspectives* 18: 100200.
Omotehinse, A.O., G. De Tomi, and Y. Baninla. 2019. Proactive management of ecosystem services in oil sands pre-mining phase. *Natural Resources Research* 208: 1–17.
Pavlopoulos, G.A., P.I. Kontou, A. Pavlopoulou, C. Bouyioukos, E. Markou, and P.G. Bagos. 2018. Bipartite graphs in systems biology and medicine: a survey of methods and applications. *GigaScience* 7: giy04.
Pimentel, B.S., E.S. Gonzalez, and G.N.O. Barbosa. 2016. Decision-support models for sustainable mining networks: Fundamentals and challenges. *Journal of Cleaner Production* 112: 2145–2157.
Poveda, C.A., and M.G. Lipsett. 2011. A rating system for sustainability of industrial projects with application in oil sands and heavy oil projects*:* Origins and fundamentals. *Journal of Sustainable Development* 4: 59.
Poveda, C.A., and M.G. Lipsett. 2013. Using sustainable development indicators (SDIs) for sustainability assessment of surface mining operations in the oil sands projects: Applicability, usefulness and cost. *WIT Transactions on Ecology and the Environment* 176: 55.
Pring, G., J. Otto, and K. Naito. 1999. Trends in international environmental law affecting the minerals industry. *Journal of Energy & Natural Resources Law* 17: 39–55.
Sheoran, V., A.S. Sheoran, and P. Poonia. 2010. Soil reclamation of abandoned mine land by revegetation: A review. *International Journal of Soil, Sediment and Water* 3: 13.
Siakwah, P., R. Musavengane, and L. Leonard. 2019. Tourism governance and attainment of the sustainable development goals in Africa. *Tourism Planning & Development* 18: 1–29.
Slaper, T.F., and T.J. Hall. 2011. The triple bottom line: What is it and how does it work. *Indiana Business Review* 86: 4–8.
Smith, N.M. 2019. "Our gold is dirty, but we want to improve": Challenges to addressing mercury use in artisanal and small-scale gold mining in Peru. *Journal of Cleaner Production* 222: 646–654.
Sonesson, C., G. Davidson, and L. Sachs. 2016. *Mapping mining to the sustainable development goals: An Atlas*. Geneva: World Economic Forum.
Sullivan, K., S. Thomas, and M. Rosano. 2018. Using industrial ecology and strategic management concepts to pursue the Sustainable Development Goals. *Journal of Cleaner Production* 174: 237–246.
Tenenbaum, D.J. 2009. Oil sands development: A health risk worth taking? *Environmental Health Perspectives* 117: A150–A156.
UNDP U. 2016. *Support to the implementation of the 2030 agenda for sustainable development*. Geneva: United Nations Development Programme.
UNESCO MAB. 1995. UNESCO MAB Regional Training Workshop, Akure, Nigeria, 23–26 July. pp. 314–323.
Wood, S.L.R., S.K. Jones, J.A. Johnson, K.A. Brauman, R. Chaplin-kramer, A. Fremier, M. Mulligan, and F.A. Declerck. 2018. Distilling the role of ecosystem services in the Sustainable Development Goals. *Ecosystem Services* 29: 70–82.
Yakovleva, N., J. Kotilainen, and M. Toivakka. 2017. Reflections on the opportunities for mining companies to contribute to the United Nations Sustainable Development Goals in sub-Saharan Africa. *Extractive Industries and Society* 4: 426–433. https://doi.org/10.1016/j.exis.2017.06.010.

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