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Adaptive governance of resources and environment in mining areas: a review

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Abstract: Mining is an important activity, while the supply of minerals and energy is essential to the development of global society. However, the cumulative impacts associated with it are paid a great concern by the public. Further, the industry must measure and assess its performance and respond to sustainability challenges, while other mining stakeholders such as local communities, international organizations and other non-governmental actors play an increasingly important role in sustainable mining development. In a large quantity review of literatures on mining governance, the paper finds that almost all the papers aim at achieving a sustainable performance in mining areas to realize sustainable development. For this reason, the paper illustrates the cumulative impacts and the sustainable development in mining areas. The paper concludes that the sustainable development framework, corporate social responsibility, social license to operate and hybridized governance are major approaches to address sustainability issues. Finally, this paper argues that China has to do more efforts associated with sustainable mining operation, too.
Keywords: Mining areas; Cumulative impacts; Sustainable development, Corporate social responsibility; Social license to operate; Hybridized governance.

INTRODUCTION

The extractive industries have been increasing with the increasing of global demand for minerals in recent decades [1,2], it is difficult for developing even desterilized countries to forego the opportunity that develop mining and associated with infrastructure [3]. Each country has both large-scale and small-scale mining (ASM) sector [4], and every country has experienced serious pollution, conflicts and public health incidents along with extraction [5]. Almost, inevitably, the extractive industry leads to cumulative impacts including various economic, environmental and social issues. However, there is positive correlation between them as well as negative impacts [6-8]. Due to the cumulative impacts, mining industries receive high levels of public concern [9,10].

Mining industries receive remarkable global attention owing to their environmental and social responsibilities; they must follow a sustainable practice to achieve a balance of mining activities [10]. In the mining industry, the sustainable development lies on making progress in economic development (to ensure the future development and long-term livelihood of the communities), environmental protection (minimizes environmental impact and rehabilitates land to allow successive use) and social unite (maintain the dialogue of stakeholder and transparency of operation) [10-12]. Thus, a sustainable performance in mining context requires a commitment maintain environmental and socioeconomic improvement from mineral exploration, operation and procession to closure [13,14].

To relieve the dream of sustainable development facing the global minerals sector, differing approaches vary with interests and values have been proposed. The sustainable development framework; corporate social responsibility (CSR), social license to operate (SLO) and hybrid governance are major approaches to address the sustainability challenge. The major value of the sustainable development frameworks is that they adopt a simple and understandable way to communicate data and help the users find the interconnections between variables; provide some commonality when adapted to particular contexts [15]. The external and internal pressure including reducing risks and enhancing reputation are the reasons to corporate social responsibility (CSR) [2], at the same time, CSR is seen as a more positive view of mining companies and their role in regional development [16]. The perfect implementation of CSR contributes to sustainable development, and this is why sustainability and CSR receive increasingly high concerns. Local communities around the world have emerged as important governance actors. The embrace of SLO, communities can get more involvement in decision making and a greater share of benefits, simultaneously, companies can reduce risk and avoid community conflict, it refers

to a community's views of the acceptability of a company and its local operations [17, 18]. Hybrid governance is a kind of governance that integrates governments, corporations, community .est. multiple actors to address the complexity sustainability problems.

At last, this paper concludes with discuss and analysis and argues that there needs more efforts associated with mining sustainable operation, especially the technical approaches and methods.

CUMULATIVE IMPACTS IN MINING AREAS

Large amounts of different ways about cumulative impacts have been conceptualized by experts and scholars [19]. It has been argued that probably the most common concept of cumulative impacts is that they arise from multiple projects and actors, but such a definition is fail to offer a model that is useful for measure, we can base on the actor, the action, the impact, or the receiving entity definite cumulative impacts [20]. The oft-cited earlier literature is offered by Franks etal., ''cumulative impacts are the successive, incremental and combined impacts of one, or more, activities on society, the economy and the environment''[21]. Thought this definition is deceptively simple, including key characteristics of cumulative impacts, whether positive or negative due to the process of aggregating effects of multiple activities and projects, and the impacts can accrue across time and space, interact in synergistic ways [22]. In the resource-rich areas, the acceleration in minerals production and the over-lapping developments including agricultural, housing, infrastructure, and tourism is increasing the size of social and environmental issues, surely, resource development have resulted in significant positive impacts (particularly in economic level) [9,23].

Mining is an important activity and minerals are essential to everyday life, they are the vital raw materials in almost all the industries, like drugs and electronics. Actually, all high-tech and medical progress today are dependent on mining activities. However, in the process of exploration, extraction and processing of minerals are combined with various economic, environmental and social problems [6,7]. The growth of the mining clearly has a positive impacts on employment and wealth creation, there are also negative impacts associated with it, These issues are classified and summarized in Table 1 [6,8,24]. Clearly, the economical impacts are positive, the environmental impacts are negative, social impacts are farraginous.

In the global economy, the mining and minerals sector offer approximate 30 million jobs in large-scale mining as well as 13 million in small-scale mining, produce over 80 mineral commodities [25]. If adding the dependants, it is likely that 250–300 million people rely on mining. As an industry, it contribute about 5 billion Euro to the Europe's GDP [26]. The World Bank advocates that mining development creates employment and downstream industries, increases family income and reduces poverty in developing countries [27]. In 2011, India's mineral production is US$41790 million, accounts for 2.5% of national GDP, one branch of the government estimates the mineral production could add 6 to7% to the GDP and13 to15 million people will be directly or indirectly employed in the mining sector by 2025 [24,28]. In fact, the public sector income generated by mining royalties and other types of taxes [29], this is one of the economic effects due to mining activity.

The economic effects of mining occur from national, regional to local levels, but the environment and society issues mainly appear at the local level. If the problems like waste piles, dust and noise not properly handled, may break the surrounding ecosystems and social structures [30,31]. Depletion of non-renewable resources, discharges of liquid effluents, large amounts of solid waste and air pollution are the most significant issues for the mining industry [25]. In addition, extraction activities have impact on biodiversity, some types of minerals are related to acid drainage problem. Furthermore, some contain cyanides and heavy metals can pose serious human health and ecological damage [6]. Mining activities also pose above-average threats for health and safety of employees and citizens due to and toxic substances [25]. In Xuzhou mining area, long-term coal mining activity has destroyed the regional ecological environment, normal agricultural production is stopped because of the seriously damage of the land and soil, water system and atmosphere(massive dust and noxious gas) have been polluted to different degrees, Infrastructure including highways, power supply and communication have been destroyed [32]. In the eastern plains of China, there are large overlapped areas of cropland and coal resources. Inevitably, coal mining has significantly damage on a large number of cultivated lands, mainly due to the farmland suffering subsidence and the heavy metal pollution of soil [33]. In Australia, mining activity heighten the conflict with local infrastructure, housing and service provision over land use and resource allocation [34]. On the west coast of southern Africa, the Namib has unique local biodiversity and dramatic scenery, but large exploration and mining developments currently destruct the habitats and ecological processes, may cause the loss of biological diversity and environmental degradation [35]. Indian extractive industries are blamed for their serious environmental impacts, large volumes of mine

waste (during 2005–06, 1,841 million tons) was one of the major issues [36]. Furthermore, the magnitude of this issue will increase in coming years due to production increases and ore grades decline, ore grade decline means higher energy consumption, lower mine productivity and more green house gas emission [24,37,38].

In early literature, it is usually stated ‘‘Resource Curse’’, the resource-rich countries develop more slowly resource-poor countries, on the contrary, resulting in corruption, poverty, low education level and living standards, political instability [39-41]. Recently, there has been the view that the mineral resource should, can contribute to development of country and reduce poverty [42]. If managed properly, the extractive industries can provide sufficient financial nourishment, thus improve the environment and improve the living standards [7].

Table 1. Economical, environmental and social impacts in mining area

	Positive impacts	**Negative impacts**
Economic impacts	Contribution to GDP and wealth creation	
	Reduction of costs	
	Increased sales and profits	
	Investments (capital, employees, communities, pollution prevention and mine closure)	
	Shareholder value	
	Distribution of revenues and wealth	
	Value added	
Social impacts	Creation of employment	Child labor and de-emphasison education
	Improvement Employee education and skills	Increased rates of infectious disease, violence and crime
	Improvement of local infrastructure	Bribery and corruption
	Heightened awareness of the importance of safety among the population	Exposure of miners to occupational hazards, including death
	Encouragement of the entrepreneurial spirit	Human rights and business ethics
	Equal opportunities and non-discrimination	Heavy vehicular traffic causing traffic jams and accidents
		Inability to invest mining earnings to benefit the community
		Forced relocation of communities
		Displacement and loss of land
		Degradation of social customs
		Destruction of traditional forms of livelihoods
Environmental impacts		Ground instability and landslides
		Water, air, noise and soil pollution now and in the future
		Biodiversity loss
		Sedimentation of rivers and flooding in nearby villages
		Energy/resource use and availability
		Water use, effluents and leachates (including acid mine drainage)
		Land use, management and rehabilitation
		Under ground mine fires
		Product toxicity
		Water scarcity
		Global warming and other environmental impacts

SUSTAINABLE DEVELOPMENT IN MINING AREAS AND ADAPTIVE GOVERNANCE

Sustainable development in mining areas

The term 'sustainable development' was first defined by the Commission's report Our Common Future as "development that meets the basic needs of the present without compromising the ability of future generations to meet their own needs" [43]. This definition arose out of consensus that we need an integrated method to solve the cumulative impacts, and a new, less harmful long-term strategy to develop global economy [44], this definition also marked a notable difference from the previous prejudice that economic growth and ecological values were incompatible [45]. It is probably in the early 1990s, the words 'sustainable development' used in the mining industry. It argued that sustainable mineral exploration, technological innovation, environmental restoration is important for mining [46], sustainable mining could exist if we have the ability to find new sources, available substitutes or recycle [47]. Generally, sustainable development is the combination of promoted socioeconomic growth, and improved pollution prevention and environmental protection [7], or described the complex objective of environmental quality, economic development, and social justice [48]. Thus, a sustainable performance in mining areas is one that integrates environmental, social, and economic considerations from exploration, extraction, procession until post-mine closure [13], later add the governance to economic growth, social concerns, environmental pressures, make up the four spheres of sustainable development [49]. In summary, more literatures concern about the sustainable development in the mining context, a time series analysis of the Scopus data from 1987 to July 2014 showed that the papers on topics including "mining and mineral" and "sustainable development" is increasing [50]. Almost all the literatures aimed at solving the cumulative impacts and realizing each dimension's sustainable development.

The true sustainable mining operations have the characteristics that the mine is economical; community support and engagement; high standards of safety; focus on mining the resource efficiently; high environmental standards. Mine managers can focus on the five aspects: safety, environment, economy, efficiency and the community, and establish a sustainable mining operation [51]. Different approaches are proposed to address the sustainability issues facing the global mining industry. These changes in individual, societal expectations and interests make the questions regarding mining, minerals and sustainability to become highly complicated and contested [52].

Sustainable development framework in the mining industry

The literature on sustainability appeared since 1987 and kept increasing, major methods can be applied in the mining industries [51]. The mainly and globally accepted sustainable development frameworks cover Global Compact; management systems ISO standards and AA1000; reporting such as Global Reporting Initiative (GRI) and Integrated Reporting; ICMM principles; and a specific context Enduring Value. However, the broad, underlying principles of these frameworks are failed to offer specific guidance to mining industry, a more comprehensive framework including consideration of surrounding stakeholders is needed [50,51]. Furthermore, ICMM principles for sustainable development are exclusively on the mining industry.

The global mining industry's negative impacts are stimulating the emergence of anti-mining campaigns [53], since the 1990s, the global mining industry began to debate on its role in the sustainable development [54], partly in response to criticism and sustainability challenges, a number of major mining companies along with mining and commodity associations established a high level group known as the Global Mining Initiative(GMI) in 1998 [55], aimed at creating an industry association that could focus on sustainable development of mining industry and analyze the key issues facing to industries independently [56]. One of the main achievements of the GMI was the formation of the International Council on Mining and Metals (ICMM) during October, 2001 [53]. The ICMM is a global industry organization that represents the attitude of the world's largest mining companies in sustainability-related problems, with the aim of identifying the main challenges and possible strategies relating to mining and sustainability. It comprises 22 of the world's largest mining companies, as well as 34 national, regional and commodity associations [57]. The Mining, Minerals and Sustainable Development (MMSD) project was released in 2002 [54], which is a part of the GMI, is just one of the instances of a synergistic action for promoting the corporate sustainability [6,58]. At the same time, ICMM SD framework was released and Global Reporting Initiative (GRI) links were established, the minerals industry and the Sustainable development timeline from1990s to 2006 was identified with a figure [54]. The Sustainable Development Framework is one of the ICMM relevant programs; the core of the framework is a request to use the Global Reporting Initiative (GRI) framework, Driven by ICMM and a global trend, more mining and minerals company publish GRI-based sustainability reports [53].

It argued that the so-called "Seven Questions" framework from MMSD project is a good example that reflects nature [51], it includes engagement; people; environment, economy; traditional and non-market activities; Institutional arrangements and governance seven components, each one pose a question assessing the net contribution to sustainability [59].

Recently, the 10 principles of the ICMM are reflective [51], they are according to the issues identified in the MMSD project and were leading international standards, including the Global Compact, the GRI .etc. [60]. Other main elements of the sustainable development framework include a public reporting initiative, an independent verification system and good practice mining information share [54].

In addition, some scholars and specialists are exploring the sustainable development framework in the mining industry activities. Base on the findings of MMSD, compatible with the general indicators proposed by the GRI, Adisa Azapagic (2004) establishing a framework for sustainability indicators was used to assess and improve the mining performance [6]. Through the overview of the industry and the analyze the relevant stakeholder, the framework covers economic, environmental, social and integrated indicators, specifically suitable for large-scale metallic, construction, industrial minerals and coal mining areas. Cooper and Giurco (2011) described The Mineral Resources Landscape framework as a new conceptualization of minerals sustainability [61]. The Mineral Resources Landscape contains four themes, namely resources; technology for extraction and processing; use-level of service and value; rates of production and consumption; it connects social, ecological, technological, economic and governance domains, covers local, national and global three levels. By mapping issues and stakeholders across the landscape, the gap between externalized impacts and the potential leverage could be addressed. The Mineral Resources Landscape works as a practical tool. For a mining company, the framework can be used visualize the results of annual sustainability reports and guide discussions regarding new technologies. For citizens, the landscape can assist in approaching social license to operate. Regarding governments, it could be used to structure minerals policy [61,62].

Vikki Uhlmann (2014) based on the coal seam gas extraction in Australia, through the review a range of projects indicator sets in order to extracting lessons and developing appropriate and reliable indicators that adapt to the local context[22]. It suggested that the five capitals framework: financial capital, natural capital, manufactured capital, human skills and social capital; offers a useful and common used structure. Furthermore, community involvement is regarded as a necessary element to develop the indicators. Although, there are no indicator sets backed by rigorous data analysis, convincingly theory, and accepted universally, they can provide the basis for decisions on actions and limits [63]. Furthermore, mining companies are increasingly adopting the green supply chain management (GSCM) to improve their ecological performance [24].

Finally, though the indicators may not guide specific action items to allocate the responsibilities of individual or group, they used to characterize and measure ambiguous, and ill-defined situations and to summarize large quantities of data that from diverse sources into sententious, synthesized and meaningful information. At the same, they serve as the beginning of a conversation and collaboration about what to do, to guide governance policy and planning, to provide a basis monitoring and assess achievement like sustainability, and to serve the purposes of different stakeholders such as administrator, company and affected communities [22,64-66].

Corporate social responsibility in mining industry

Due to the social and environmental contributions and consequences of mining industry, sustainability and corporate social responsibility (CSR) receive increasingly high concerns [56], the exhaustion of mineral resources is a main concerned problem when discussing sustainable development [11]. CSR first appeared in variety of forums in the 1960s to combat industrial environmental impacts and balance the rights and interests between corporate and general public [67], it is applied in business field to respond to social and environmental responsibilities, and became more aggressive from 1990 onwards [68]. CSR concern with a wider benefits of corporate contributions to economic and human development [16], contains stakeholder, social, economic, voluntariness and environmental five dimensions [69], and in some research is equivalent to corporate citizenship [67].

It argues that the literatures on corporate social responsibility contain three source stems and lead to different types of CSR practices [70,71], The first source stems from governments' specifical and formal requirements, in this case, CSR is regarded as a coercive practice[72]. The second source stems from non-government and CSR initiatives, through negotiate CSR frameworks and invite companies to follow them [73]. The third source stems from companies themselves, companies according to their own interests decide and apply best practices [72,74]. Furthermore, there are lots of approaches about the factors that force implementation of CSR activities; Kannan (2014)summarizes many researchers' onpoints about

the drivers of CSR, such as value driven approach, performance driven approach and stakeholder driven approach [10,75]; internal drivers, competitive drivers, external drivers, regulatory drivers [76]. In summary, the government, customer reputation, brand recognition, community relations, risk management, long term success, legal sanctions, cost reduction, corporate identity, as well as the external and internal pressure are the reasons for CSR [77-84].

Why are the CSR important for mining industries? It is summarized as follows: Public opinion about mining is poor due to its environmental and social performance; Pressure groups at local and international levels challenge its legitimacy; Challenge to maintain 'a license to operate' [56,85]. In recent decades, the high demand of sustainable practices in mining sectors resulted in many companies implementing corporate social responsibility [86], CSR as one of sustainable practices, increases sales revenue and capital share, improves customers' views on a company, and becomes core competitiveness in modern businesses [87]. At the same time, mining industries have been criticized for failed to implementing CSR strategies [10]. In general, mining firms implement CSR strategies such as company performance reporting and program to strengthen their relationship with local communities and increase employee well-being; furthermore, the CSR strategies through investments in schooling and common infrastructure to increase the well-being of local people [30], in the 21st century, governments increasingly rely on enterprise voluntary initiatives i.e. corporate social responsibility [88].

In summary, a significant body of literature was compiled is related to Corporate Social Responsibility, and suggest that the industries should increase their chances to practice the value-added CSR in industrial environments [50]. In addition, in social, environmental and economic aspects, the SLO is seen as a part of CSR, achieve and maintain the trust on company's performance, and approve the local stakeholders [89].

Social license to operate in mining area

In the mining sector, local communities have emerged as particularly important governance actors. Communities around the world have increasingly come to require more involvement in decision making, a greater share of benefits from local mining projects, and demand the mining area conduct safely and responsibly, There is now need for mineral to gain 'social license to operate'(SLO) [17].

In the limited literature a number of studies identify that the SLO is applicable to a mining context. Nelsen and Scoble (2006) identify success factors for earning a social license used in mining industry, These includes positive corporate reputation; the understanding of local culture and history; education about the project; open communication among all stakeholders; and adaptive situational analysis [90]. On the other hand, Thomson and Boutilier (2011) identify legitimacy, credibility, and trust three normative components of the SLO; withdrawal, acceptance, approval, identification with the project psychologically four levels of social license; and note that companies must learn how to participate in the community partnership that earn a SLO [91].

The mining area also needs 'social license to operate', if the community is not engage and support a mining operation, the confrontation may be occur [45]. The mine through the way of development of socially useful infrastructure and institutions, put a share of the social capital wealth back into the community [92]. Enlightened mining companies undertake preferentially employing local people, training and providing skills etc. various initiatives to maintain their social licence [45]. Through the embracing of SLO, economic feasibility, profit ability can be ensured, potentially costly conflict and business risk can be avoided. Simultaneously, impact assessments and public participation make mining company gain its social license to operate [93]. Jason Prno (2013) analyzed four kinds of international mining operations and provide valuable insights associated with the establishment of a SLO in the mining industry. There are five lessons for earning a SLO emerged from this analysis: (1) context of local is key; (2) SLO is built on relationships of trustworthy, respectful, transparency and open; (3) sustainability is a dominant concern for communities; (4) local benefits provision (allow communities to share in the benefits of development) and public participation play a crucial role; and (5) adaptability is needed to confront complexity associated with establishing and maintaining a SLO [17].

It is clear the SLO can be conceptualized as both a goal and rules that must be followed. For mining companies, it can reduce risks and avoids community conflict. For local communities, the granting of a SLO often means they have been involved in the process of making decisions and have received sufficient benefit from the project [18]. Global mining companies need to secure a social license to operate, are increasingly prioritizing the alignment of their interests with the values of society (especially the local communities in which they operate) [94]. However, some companies engage in irresponsible behavior like corruption may call into question the legitimacy of a SLO [18].

Hybridized governance and adaptive governance in mining area

Due to the complexity of the sustainability problems, hybridized governance arrangements and collaborative governance have been common recognition [95]. The term 'governance' has been used in many different ways, it is defined as the set of processes by which decisions (formal and informal) are made, governance theory is concerned with the changing roles and strategies. There is widespread acceptance that governing mechanisms no longer rest on the authority of the state alone rather a range of actors are involved [96-99]. Generally speaking, there are three single modes of governance [21,23], the state (governments) governance is traditionally enforced through compliance with regulation (include global, national, state and local levels), Environmental assessment (EA) is considered as pretty good in Canada [18]; Market-oriented (corporations) governance largely relies on price mechanisms to drive behavior, in the mining sector, this mode of governance is often associated with forms of corporate self-regulation like CSR [100]; Civil society (community organizations) governance is principally comprised of non-profit organizations [101], have gained increasing prominence in resource and environmental decision making [102]. Whereby the traditional roles of governing have been shifted, these shifts have taken place both in vertical (move up to transnational levels and down to local communities) and horizontal (moved from government actors towards non-government actors) visions [103], and then blur the boundaries between the public, private and voluntary sectors [104], a more complex set of governance arrangements including multiple levels of authorities, communities, non-profit organizations, private citizens, and corporate actors replace the traditional system [105].

Hybrid governance models have emerged in recent decades, largely out of recognition that no one mode of governance to manage can manage the problems of sustainability on its own [23,18,106], these encompass co-management, private–social, and public–private arrangements [18]. Collaborative governance is also one of such hybrid model, that merge multiple stakeholders with public institutions to engage in consensus-based decision-making [107]. Collaborative governance has potential to deliver more effective and sustainable solutions [23] and provides valuable opportunities to address the complexity, uncertainty, interdependency, and knowledge gaps problems [108,109]. However, to realize the promise of collaboration needs strong leadership and high level managerial skills to determine common goals, allocate responsibilities, share resources and coordinate stakeholder participation [110], furthermore, collaborative governance take longer, involve risk and require high levels of trust [111].

Adaptive governance integrates principles from adaptive management with empirical and experimental, recognizes that the complexity and uncertainty in natural resource policy need to negotiate trade-offs between multiple, diffuse and changing interests [112]. Adaptive governance integrates formal scientific and local knowledge and explores approaches in which government and communities arrangements complement each other to improve natural resource management [113].

DISCUSSION AND CONCLUSIONS

It has been widespreadly accepted that mining is an important and essential activity, meanwhile, the cumulative impacts especially the negative environmental and social impacts associated with it receive high levels of public concern, the realization of the sustainable development in mining area is the global public dream, a sustainable performance from mineral exploration, through operation and procession, to closure in mining context seemed very urgent.

The complexity of the sustainability problems make only hybridized governance arrangements effective in managing it, multiple actors integrates governments, corporations, community .etc. complement each other become an undoable choice, among them, the corporation is the core of governance. Mining is the source of negative impacts like pollution and destroy .etc., minerals sector must undertake their environmental and social responsibilities and achieve a balance on mining activities. The raise of sustainable development framework owing to the global mining industry, partly in response to anti-mining campaigns and sustainability challenges, they began to undertake its role in the sustainable development [53,54]. The framework and indicators serve as the beginning of a conversation and collaboration about what to do, guide governance, policy and planning, provide a basis monitoring and assess achievement like sustainability [64,65]. On one hand, corporate social responsibility (CSR) come from the external and internal pressure, on the other hand it is corporate's strategies under market mechanisms, at the same time, CSR is seen as a more positive view of mining companies. Anyway, the perfect implementation of CSR contributes to sustainable development. As to social license to operate (SLO), in another word, is the values of the society, especially the local communities in which they operate. To earn a social license, reduces risk and avoids community conflict, the corporate must have a positive reputation, transparency and open communication .etc. The embrace of SLO, communities can get more rights to speak and a greater share of benefits, it is a mode of civil society governance. All these approaches link with, complement and promote each other, aimed to realize the sustainable development in mining area.

As we all know, each country has both large-scale, corporate extractive sector and artisanal and small-scale mining (ASM) sector [4], ASM-low-tech, labor intensive mineral processing and excavation activity—is particularly prevalent in developing countries like Ghana, Liberia, etc. sub-Saharan Africa [114], often takes place in high-value resources such as gold and diamonds, without the proper legal authorization [115]. The negative impacts of ASM are relatively more serious, unfortunately, the framework above may be more suitable for large-scale mining [6], CSR in developing country is in a preliminary stage [10]. Therefore, more techniques and methods that suitable for artisanal and small-scale mining should be research and develop.

In addition, The specific technological approach should be explored, there are technical difficulties in tailings and waste disposal, and lack of knowledge about the carrying capacity in the selected site over time [8].The open cut mine sites threat the health of waterway, caused poor water taste and impacts on stock watering [23]. Through the ecological restoration including fish spawning grounds and development of wetlands, the open pit operations of Highland Valley Copper (HVC) Mine get notable rehabilitation [116]. The panicled golden rain tree and the common elaeocarpus tree in abandoned mining areas can remove heavy metals and improve scenery, Phytoremediation can be used as a sustainable technology [117]. Furthermore, Restoration and Monitoring Unit (NERMU) actively develops links with universities and other research institutions in Namibia and abroad, To achieve Namib's biodiversity through Ecological restoration [35].

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