Green mining techniques to curb environmental problems – A review

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Abstract: Many methods are used to extract the ores causing huge threat to environment. Mining practices lead to un sustainability and the problems created by it were not yet controlled. So adoption of Green mining technologies helps to attain sustainable development and control the problems to maximum extent. The main objective of green mining is to start mining process and end it to ensure that adopting green mining practices lead to sustainability. Green mining also reduces greenhouse gases prone to effect conserve minerals, using energy more efficiently etc. According to Mission 2016 plan many green mining techniques were adopted and increased focus on research and became more popular so every industry focusing on environmental friendly technologies. Some of the major mining nations like Canada, Australia, South Africa etc adopted sustainable development viewed on not only environment but also other dimensions like local stake holder engagement, socio economic development in mining project areas and transparency in communication with stake holders. Sustainable strategies of mining includes measurement, monitoring mainly to improve the performance of environment and ensure that the mining operations are perfect or not. This paper reviews impacts of mining in various countries and Green mining solutions adopted over the world. It also discussed about Green supply chain management and the barriers of it and given the suggestions to control these barriers.

Keywords: Environmental impacts of mining; Unsustainable Mining; Green Mining; Practices of Green mining; Green Supply Chain Management; Barriers in Green Supply Chain Management; Practices of green mining
1. Introduction

Mining is essential process it gives many benefits like employment, development at local national and international level. Mining industry is one of the largest money oriented industry in the world. Many impacts occur due to mining and the miners have to focus on various environmental issues to maintain financial status [1–3]. Impacts associated with mining like air, water, soil, noise pollution, loss of biodiversity, land degradation and desertification, depletion of natural resources, occupational health hazards, acid mine drainage, erosion, sink holes, issues of waste water disposal, depletion of ground water and lowering of water table, issues of rehabilitation and resettlement. Over exploitation of minerals causes pollution of surface and ground water and effects the sustainable development. Many harmful gases like Sulfur oxides, Nitrogen compounds and Hydrogen sulphide were added in the atmosphere pollutes it which leads to acid rain and prevents the growth of endangered flora and fauna. Approximately every year in India 400,000 tons of methane is releases effecting thousands of people with lung diseases. Present fossil fuel combustion play a vital role in the world. Rapid urbanization and industrialization over exploited the resources created huge impact on environment and made the situation worst in many countries. In Latin America Caribbean region explained that adoption of Green technology can make environment more sustainable it reduces carbon emissions and control adverse effects on environment, usage of renewable energies to power vehicles makes mining sector more sustainable. According to agenda 2030 many sustainable development goals were developed by United Nation (UN) to achieve sustainability and improve environmental performance in mining sectors 2015 still unsustainable mining practices are found causing threat to environment. So research was carried out in mining and adapted green mining technology for sustainable development and it is required for healthy environment. Main goal of green mining technology reduces the toxic emissions and improves the efficiency. Green mining gives assurance for the future generations that the mineral resources were not harmed and can with stand long time on earth [4,5].

2. Environmental impacts of mining

Mining releases large amount of waste like mine tailings, waste rocks, slag and in some cases both vegetation and over burden is also treated as mining waste [6,7]. Both large scale and small scale mining industries cause great destruction to environment. Some of the impacts associated with mining like depletion of biodiversity, soil erosion, Pollution, acid mine drainage, land subsidence etc. It causes serious hazard to human life and property due to the depression caused by sudden failure of earth. Many impacts were noticed at each stage of mining mentioned in Table-1 Mining industry effect aquatic organisms due to addition of high levels of toxic effluents in water. Diversity of plants decreases in mining areas compared to normal areas [8–10]. According to Joshua Kirkey communications adviser natural resources Canada said there were many problems faced by the industries even today by using technologies and unknown practices so in order to overcome these Green mining technology is essential. Mining and smelting industries produce large amounts of wastes and Rivers like Vistula and Odra are contaminated with chlorides and heavy metals. Extraction of minerals and production activities not only effects environment but also the inhabitants living there. For safe generations of the nature sustainable development is required. Water quality of pit lake is degraded due to acid mine drainage [11–13]. Minerals can be extracted in different ways and many of these activities were done in an unplanned manner and non eco friendly causing threat to environment so many reviews and publication brought to the notice of unsustainability. Many problems associated with mining and effects the elements of air water and land. Some metals in mining industries release toxic substances like cyanides and heavy metals lead to huge destruction to ecosystem and disrupts human health. At Witbank coal field in South Africa Pillar Robbing program was commenced and this resulted in subsidence, formation of cracks on the surface, deterioration of water quality resulted in depletion of biodiversity. There are 325 mining sites are located in Jhansi district of Uttar Pradesh causing deforestation, air, water and noise pollution and depletion of resources. According to Donoghue and Olney mining cause physical, chemical, biological and psychosocial hazards. Bauxite mining in Jamaica has removed 5,099 hectares of trees and 3,218
hectares of forest that lead to destruction of complete vegetation and top soil. In Chile the tailings dams are the common residue of mining caused serious threat to human beings and environment. Unsafe mining released excess amount of lead which killed 400 children in Zanfara, Nigeria. These problems were due to lack of eco friendly practices and even though the green mining or sustainable mining adopted they were not strictly implemented in many countries [14,15].

3. Unsustainable mining
Mining that creates havoc in the environment becomes unsustainable or if the mineral that is completed exhausted after extraction becomes unsustainable. So many countries developed sustainable mining technologies to protect environment. Improper and unplanned mining activities result in environmental destruction. Some of the unsustainable mining examples were described. Long back in South Africa many pumping systems were used to extract large amount of gold resulted in depletion of ground water table. Water quality disrupted with acid mine drainage and heavy metal contamination as ground water exposed to pyrite. Almost of all the mining activities are unsustainable due to over exploitation of non renewable resources and causes maximum destruction to nature and society that is irreversible. In Chile large amount of water is extracted in mining as there is water scarcity in that place which leads to un sustainability [16–18]. But however Neptuno energy efficient water saving pumps were used to rectify the problem. Unsustainable Bauxite mining in Kuantan, Pahang caused destruction to environment and damaged the health of individuals and if this continued it leads to irreversible changes to environment and seriously threatens the ecosystems. China and India are practicing unsustainable sand mining which effected the marine organisms, disrupts the water quality and cause repeated floods and drought but these countries are taking measures to reduce illegal and irresponsible sand mining. Excess sand mining in Kerala caused serious damage to rivers systems and deepened the river beds leads to un sustainability so uniform dredging helps to reduce the effect. It was noticed by Dr. P. K. Jenna 2017 that many illegal mining practices were carried out in places like Odisha, Jharkhand, Chhattisgarh and wasting low grade ores behind that should be stopped immediately and green mining should be adopted to reduce the wastage of low grade ores and destruction of land. Many unsustainable practices created lot of impacts to society and environment. Lack of proper rehabilitation and resettlement practices due to mining also becomes unsustainable as these issues were not solved yet [19,20].

4. Green mining
Mining creating a lot of problems both to society and environment all over the world. Improper activities of mining activities and lack of proper control can cause serious problems. Mining can remain sustainable only if it follows the principles of ecological sustainability, economic vitality and social equity at all stages of mining life cycle. In order to reduce all the impacts in Finland Green mining concept was adopted. Adopting Green mining reduced impacts of mining at all stages of operations. Giving proper training, application of green technologies, sound environmental management tools and formation of sustainable partnerships help the mines to improve the performance and attain sustainability. Thickened tailings, Dry stacking and Paste back fill are the new technologies and innovatives to dispose the waste produced during and attain. Cyanide released from the mining industries can be degraded using microorganisms and this technology is alternative to physical and chemical treatment processes and this process was first demonstrated in gold mining industry at USA. In order to curb the impacts of mining every mining should get environmental clearance from Indian government. Noise pollution produced by blasting can be controlled by following noise emission standards. Open Pit mining lakes causing threat to the environment can be controlled by transforming them in to fish farms that play a vital role in providing employment and food for the communities impacted by the mine closure. Ecological impact of mining activities can be reduced by using innovative like Carbon capture storage which catches the carbon dioxide released during mining and transport it to underground. Eco innovation help in preventing the mining waste for example byproducts produced after processing of the minerals in mining industries can be reused. Instead of sodium cyanide used in recovery of gold alternative called Ammoniacalthiosulfate is used that reduces toxicity. Implementation of eco efficiency strategies in Australian mining industries achieved significant environmental benefits. Usage of green mining vehicles help to control the foot
print on environment caused by acid related damage. Recently many of the mines developed and implemented green technology and new mines also began to adopt it and by 2030 the implemented methods like shutting of illegal mining completely, control of pollution and waste water and cleaning of shut down mines immediately can achieve sustainability. Almost all the countries are using green mining initiatives to reduce environmental impact and remove the sites after completion of mining. Companies get more profits and does not harm the environment by adopting Green Technology.

5. Green supply chain management

Increased production and consumption levels made supply chain activities to increase and this caused environmental degradation. So in order to curb problems many mining companies in India adopted new concept that is Green supply chain management. The scope of Green supply chain management includes general environmental management programmes and the implementation of proactive measures with reduce, recycle, reuse, reclaim, remanufacture and reverse logistics. Green supply chain management is applied in almost all the industries to attain sustainable development. It is an important tool to reduce ecological and environmental risks and also helps to achieve organizational profits. It can be defined as combination of Green procurement, Green manufacturing, Green distribution and reverse logistics. It is applied in all stages of product life cycle during extraction through design, Production and distribution phases, production use by the consumer and its disposal. Green supply chain is the process of applying ecological concept in to supply chain system to attain environmental sustainability and it also involves green practices like green manufacturing, green distribution and transportation by using bio fuels. Adoption of Green supply chain management helped many industries to save costs, reduce energy consumption and protect their supply chain from environmental degradation. It was confirmed that implementation of green supply chain management achieved the financial and environmental performance in the manufacturing sector.

6. Barriers in Green supply chain management

Many problems faced by the industries made them to adopt Green supply chain management. GSCM focus on the issues caused by supply chain and reduce it. American mining industries identified three barriersto clean production like technological constraints, legislative issues and economic limitations. Some of the barriers like lack of support from government, Lack of public participation, qualified staff in industries and planning management and implement green initiatives etc were identified by many researchers. Even though there are numerous benefits by adopting green supply chain management, different countries are unable to implement green supply chain management. Many of the government departments will not reveal the problems and this leads to lacking of information on environmental issues. Many barriers were discussed in many research papers and still more research and awareness is required to tackle the situations. If experts from the mining industries identify the potential barriers they can provide a skill full plan to minimize the impacts of those barriers and achieve sustainable development.

7. Practices of Green mining

There were many sustainable methods were developed to reduce the impacts of mining. For example, 3RS technique Reduce, Recycle and Reuse in Europe and Australia. Total mined waste can be reused without reprocessing that can save energy and water where as recycling helps to produce new product. According to Struthers toxic metals like Arsenic, Cadmium, Thorium can be extracted using continues stirred tank reactor.

Gangue back filling mining technology: One of the major environmental threat of mining is land subsidence and discharge of gangue. It is used in coal mining and helps to reduce the waste and controls the deformation of roofs. Mining under the roof can effect working force strongly so in order to control and to support the roof control the coal seam Gangue back filling mining technology is adopted. Application of back filling technology lead to many problems as it effects the mining face. There are various back filling technologies were developed but their implementation is not that much successful. At China in 2006 the university of mining and technology has undergone research and developed a new mechanization Gangue back filling system that improved the effect caused by
gangue filling in gob area. Some of the green mining practices adopted by the different countries mentioned in the Table-2.

Biosurfactants can be produced by bacteria like Bacillus subtilis to remove heavy metals from contamination by precipitation-dissolution, ion exchange, counter ion binding. Sophorolipids play a vital role in removing Iron, Arsenic and Copper from mine tailing.

Sonic drilling is an innovative in green mining utilizes the mechanical oscillation drills quickly than a conventional drilling. It mines diamonds, gold and lithium without using drilling fluids are used and it helps to reduce the environmental impact.

7.1 Hybrid diesel electric equipment on underground mining

It is used in underground mining helps to control pollution, green house gases, improves energy efficiency and leads to sustainable development. The survey revealed in Canada that 32% of green house gases emissions reduced by using Hybrid diesel electric equipment in underground mines.

7.2 Biomining

Addition of microorganisms removes the metal from rocks which is eco friendly technology. Copper can be extracted from rocks when bacteria is added to bioleaching ores placed in acid.

7.3 Liquid emulsion technology

Acid mine drainage is one of the major problem that shows more effect on environment and many methods were adopted (Biosorption, ion exchange solvent, chemical precipitation) to rectify the problems but there are many disadvantages in those methods. So Liquid emulsion technology used to remove copper from acid mine drainage in central part of Chile.

7.4 Dust Suppression technique

This method helps to remove the dust by pre-wetting the areas in mining areas. Spraying dust performance technique was improved by negative pressure secondary dust suppression technique was developed it effectively absorb the dust air flow and covers all the spaces between coal walls and hydraulic supports column, see Table 1 and 2.

### Table-1 Impacts at different stages of mining

| Stage  | Prospecting and Exploration | Results in clearance of vegetation |
|--------|-----------------------------|------------------------------------|
| Stage1 |                             |                                    |
| Stage2 | Development                 | Effects ecological sensitive areas, Huge over burden is formed, accumulation of toxic substances [Over view of mining and impacts Guide book] |
| Stage3 | Exploitation                | Effects ecological sensitive areas. Emission of dust, Release of toxic substances like Cadmium, Lead and Arsenic [Over view of mining and impacts Guide book] |
| Stage4 | Closure and Reclamation     | The impacts on environment may persist for a long time. Release of toxic substances from various mines such as open pits and mine tailings |


Mining becomes more friendly by the following measures like reducing the inputs and outputs, use sustainable equipment to reduce to reduce waste output, Use renewable energy resources that help to conserve energy and Shut down illegal mining.

Vadlamudi is located in Guntur district of Andhra Pradesh and it is the head quarters of Chebrolu mandal in Tenali region. It is covered with very good plantation in and around. But it was noticed there was a quarry near Vadlamudi which was ceased now. Large amount of sand and stones were extracted and the large pits were not closed remained in that place without any treatment. All the plantation was removed and only unwanted plants were seen in that area and the land became barren. The waste generated by quarrying remained there still now. That open place is now dumped with the surrounding waste and unhygienic conditions prevail. Some apartments, shops and institutions reside near this place. Places near Vadlamudi effected due to Quarrying were shown in the figures 1, 2, 3, 4, 5, 6, 7. There are many examples like this in most of the places and immediate actions should be taken.

These are some of the places in Vadlamudi quarry at Guntur district of Andhra Pradesh

![Figure-1 Vadlamudi quarry at Guntur district where large amount of stones and sand](image)

![Figure-2 Picture showing removal of sand](image)

![Figure-3](image) ![Figure-4](image)
Figure 3 and 4 Place where complete vegetation was removed

![Figure-3.png](image)

Figure-5 and Figure-6 Large amount of untreated waste dumped in this area became unhygienic

![Figure-5.png](image)

Figure-7 Water accumulated in the quarry

![Figure-7.png](image)

Table 2 Problems in different countries and Green mining practices to attain sustainability

| Name of the country             | Problem                                                                 | Methods adopted to control the problem                                                                 |
|---------------------------------|-------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|
| China                           | Environmental pollution caused by the open accumulation of gangue        | Gangue back filling mining technology help to control environmental pollution, controls the gangue accumulated on the land |
|                                 | Coal mining huge threat to environment ie disturbs ecosystem, disrupts water quality, land subsidence and aesthetic view is lost | Construction on Green industrial chains based on recycling economy                                     |
| New Zealand                     | Pollution                                                                | Municipal bio solid waste is used to replace old mining sites that causes effect. This green mining innovative increases the organic content of soil [https://www.mainlandmachinery.com/green-mining/] |
| Chilliwack in British Columbia Canada | Pollution and land degradation                                           | Sonic drills are used these move fastest, don’t use drilling fluids and reduce environmental impact [https://www.mainlandmachinery.com/green-mining/] |
| Country          | Region/Project                                                                 | Impacts/Issues                                                                 | Solutions/Technologies                                                                 |
|------------------|---------------------------------------------------------------------------------|--------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| Canada           | North west territories of Canada                                                | Using port land cement to prevent collapse in underground mining increases Carbon dioxide and created impact. Contamination of Great Slave lake with Arsenic due to discharge of waste from mine tailings. | Slag binder is environmental friendly binder used in mine shafts which is made up of slag ie waste rock from mining operations and calcium hydroxide[https://www.miningtechnology.com](https://www.miningtechnology.com) Bio surfactants which are nontoxic and biodegradable produced by bacteria, fungi or plants can be used during the process of soil washing to remove heavy metals. |
| India            |                                                                                | Generation of toxic waste and dust [https://www.insightssuccess.com](https://www.insightssuccess.com) | DST can be used to remove the dust by prewetting the areas and LEM used to remove the material from highly toxic acidic waste[https://www.insightssuccess.com](https://www.insightssuccess.com) |
| America          |                                                                                | Large amount of untreated wastes entered in the air, water soil and degrades its quality in many areas and only selected mines reduced pollution and many barriers prevent implementation of clean technologies and cleaner production practices. | Providing clean technologies and cleaner production practices for remaining mine |
| India and China  |                                                                                | Threat to fresh water and marine ecosystems, rise in flooding and depletion of ground water table due to extraction of sand. | Reduction of unwanted constructional activities, using green infrastructure and creating awareness |
| Netherlands/North Western Europe | Causing effect to environment during Pulling metals from mine waste waters | Recovery of metals from waste waters using biological capacities of microorganisms [https://horizon-magazine.eu](https://horizon-magazine.eu) | |
| Australia        |                                                                                | Generation of polluted stagnant water Carbon dioxide emissions | Polluted water can be removed by using hydrotalcite mineral that can remove the impurities from the mined waste water developed by Virtual Curtain [https://www.mining-technology.com](https://www.mining-technology.com) Planting of Mallee trees reduce Carbon dioxide emissions by capturing |
Usage of high emission fuels, Generation of large amount of waste and mine tailings\[http://web.mit.edu/12.000/www/m2016\99\]

Utilization of natural gas
Recycling of water
Removal and recycling of water from mine tailings to create paste and layered to reduce the problem

Coal mining leads to loss of forest cover and biodiversity, land degradation, Soil Erosion

Sustainable practices like revegetation /afforestation \[www.sciencedomain.org\100\]

Acid mine drainage and toxicity
Excess energy consumption and green house gases

Usage of Acidophillic bacteria that treats acid mine and kill the toxic nature
Adoption clean and energy efficient technology to reduce the impacts on environment

8. Conclusion

Even today mining is creating serious consequences all over the world. There are still some mines lacking quality standards and environmental rights that can be banned or use eco friendly technology for improvement. Creating awareness to the society about the importance of green and usage of environmental friendly commodities help to reduce green house effect and attain sustainability. Although Environmental Impact Assessment and Legislations were mandatory to curb the problems it is very important to practice sustainable mining to prevent health problems and also to protect environment. Spending more time in doing research and provide green mining technology help to solve the problem. Green mining make sure the industries to attain sustainability and turn the world in to a green friendly place. Green mining is sustainable and new technique and benefits the future generations. There were many research activities taking place to control the problems from mining activities that is not enough and implementation of green mining concept is required to support ecosystem and protect biodiversity on earth. Whenever technology develops there is a need to develop sustainable solutions in mining industries to rectify the problems created by it. Measures like improved environmental management programmes, enhanced community development and implementation of clean technology should be adopted and followed in all the mining industries. Green supply chain management is an innovative developed and adopted for sustainability. Green supply chain management can become successful due to the continues creation of many innovative like reduction of waste, reuse and recycling of minerals and efficient use of energy. Many of the barriers regarding its implementation were studied and reviewed by the researchers was not up to the mark. More research should be encouraged and implement Green supply chain management in all the places of mining projects.

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10. Conflicts of interest

Author declares no conflicts of interest
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