Green practices adopted by the mining supply chains in India: a case study

Kamalakanta Muduli*

Department of Mechanical Engineering,
CV Raman College of Engineering,
Bhubaneswar, India
Email: kamalakantam@gmail.com
*Corresponding author

Akhilesh Barve

School of Mechanical Sciences,
IIT Bhubaneswar,
Bhubaneswar, Odisha, 751013, India
Email: akhilesh@iitbbs.ac.in

Sushant Tripathy

School of Mechanical Engineering,
KIIT University,
Bhubaneswar, Odisha, 751024, India
Email: sushant.tripathy@gmail.com

Jitendra Narayana Biswal

Department of Mechanical Engineering,
CV Raman College of Engineering,
Bhubaneswar, India
Email: jitendra2000_biswal@yahoo.co.in

Abstract: Growing public awareness regarding mining environmental issues has put mining industries under a lot of pressure lately from everyone including government and their investors. In response to these pressures, mining industries worldwide have taken various green initiatives [for example, green supply chain management (GSCM)] to minimise their wastes and emissions and enhance performance and economic front. However, a large number of Indian mining industries are blamed for poor GSCM performance. The reason being unavailability of sector specific implementation guidelines or/and inadequate information regarding the factors that influence GSCM adoption. Hence, cases of three mining sectors and the green practices adopted by them are investigated in this research and it was found that apart from challenges suffered by small scale industries the green attempts made by large scale industries have been successful. Few policy suggestions recommended by the study helps validate the barriers of GSCM implementation and improve performance of mining industries particularly the smaller ones upon adoption.

Keywords: mining industries; green supply chain management; GSCM; case study; SWOT analysis; India.

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Biographical notes: Kamalakanta Muduli is presently working as an Assistant Professor in CV Raman College of Engineering, Bhubaneswar, India. He has obtained his PhD in the area of Green Supply Chain Management from School of Mechanical Sciences, IIT Bhubaneswar, Orissa, India. He has obtained his Master's in Industrial Engineering. He has over eight years of academic and research experience. He has published 11 papers in peer reviewed international journals and presented more than 12 papers in national and international conferences.

Akhilesh Barve is working as an Assistant Professor in School of Mechanical Sciences IIT Bhubaneswar, Orissa, India. He has ten years of academic and research experience. He obtained his Master's and Doctorate from Indian Institute of Technology Delhi, India. He has authored several research articles in number of international journals and presented papers in national and international conferences. He is a reviewer of some reputed international journals. His area of research includes agile and lean issues of supply chain, logistics, green supply chain management, quality control, etc.

Sushant Tripathy is currently working as a Professor and Head PhD and Post Doc programs at KIIT University, Bhubaneswar. He has more than 20 years of teaching and research experience. He has authored several research articles in number of international journals and presented papers in national and international conferences. He is a reviewer of some reputed international journals.

Jitendra Narayana Biswal is currently working as an Assistant Professor in Mechanical Engineering Department in CV Raman College of Engineering, Bhubaneswar. He is also pursuing his PhD in KIIT University. He has more than 12 years of teaching and research experience.

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1 Introduction

Rapid industrialisation that creates massive employment opportunity and stimulates economical development of any country requires intensive support from mineral extracting industries. The increasing importance of the sector is due to its ability to supply energy and raw materials to a wide range of companies. However, its activities are still generally considered as a threat to the natural environment and human health (Vintró et al., 2014). Mining supply chain is the talk of the day due to its negative impact on the environment, i.e., global warming, acid rain, ground level ozone, and water pollution due to the emission of harmful gases like CO_2, SO_2, NO_x and CH_4. These harmful gases are responsible for air pollution, poor vision, and reduction in crop production caused by unregulated mining activities.. Besides these, mining activities are also responsible for a number of health-related complexities such as silicosis, asbestosis, and lung cancer of the mines workers as well as nearby residents. With the growing awareness regarding the adverse impacts of mining industries, governments in several countries both industrialised and industrialising have revamped sector specific environmental regulations to promote environmental management tools in the mining industry (Nikolaou and Evangelinos, 2010). In response to the increasing environmental regulations, many mining companies worldwide have adopted green practices which have helped them in reducing the adverse impact of their supply chain activities on the environment (Suppen et al., 2006; Driussi and Jansz, 2006; Nikolaou and Evangelinos, 2010). However, many mining companies in India, particularly smaller units are standing on the crossroads of GSCM adoption. This is owing to inadequate information on sector specific GSCM initiatives and issues associated with their implementation. To address these issues, this work is conducted to explore current state of green practices in Indian mining supply chains. Three sectors, coal, iron ore and manganese ore, are chosen for study.

The idea behind choosing these sectors are that open cast mining is predominant over underground mining in these sectors which is regarded as highly polluting in comparison to the later one (Chikkatur et al., 2009). Further, both small-scale and large-scale industries operating in public as well as private sectors are engaged in the extraction of these minerals. Total number of industries operating in these three sector accounts for nearly 35% of total operating mines in India. SWOT analysis has been employed in this paper to examine the strengths, weakness, opportunities and threats for the select mining sectors in India in implementing GSCM strategies. This could be helpful for the companies in deciding their long range and short range strategies.

2 Literature review

Interest of the customers for better and cheaper products, quicker delivery, higher product variety and higher levels of service is growing day by day. In other words, to sustain in a competitive market, organisations have to focus on delivery of high quality product and after sales service at a lower cost (Genovese et al., 2013). While making attempts to fulfil customer requirements, organisations are experiencing that it is beneficial to work as an entity of a supply chain instead of working individually. In fact, it has been well recognised by the practitioners and the decision makers that the success of any organisation depends upon the capacity as well as the capability of its supply chain rather than that of the individual organisation (Chow et al., 2008). A supply chain can be thought of as a set of business entities that is directly involved in the upstream or downstream flows of products, services, and information from a source to a customer or vice versa (Hsu et al., 2013). The concept of supply chain management (SCM) was introduced in the early 1980s, and since then it has been used extensively to describe the planning and control of materials, information flows, and the logistics activities internally within a company and also externally between companies (Ahi and Searcy, 2013). Over the time, research on SCM explored that increased level of supply chain activities in the process of satisfying the ever growing need of the consumers has led to escalated deterioration of the environment including depletion of natural resources, energy crisis, climatic problems, waste generation, emission of harmful gases, scarcity of landfill areas and ecosystem disruption. As a consequence, the organisations started experiencing pressures from regulative bodies, environmental societies and general public to reduce their environmental impact. In response, industries have adopted a lot of environmental management programs. However, most of the traditional environmental management practices are found to be incapable of eliminating pollutants and merely transform them from one form to another, as a result organisation are often exposed to the negative spillover effects from the poor environmental performance of their supply chain partners (Hsu et al., 2013). In contrast to this, green supply chain management (GSCM) that focuses on reduction of sources of waste throughout the entire supply chain is gaining importance among the companies as a proactive environmental management strategy.

2.1 Green supply chain management

The voluntary pursuit of any activity that encompasses the concern for energy efficiency, the environment, water conservation, the use of recyclable products, and renewable energy is defined as 'green' (Mudgal et al., 2010; Muduli and Barve, 2013). In GSCM, the word 'green' is used in conjunction with SCM to portray its environmental friendliness image. GSCM has evolved as a proactive strategy with the objective of enabling organisations to comply with environmental regulations by improving their ecological efficiency. It can be defined as "the set of supply chain management policies held, actions taken and relationships formed in response to concerns related to the natural environment with regard to the design, acquisition, production, distribution, use, re-use and disposal of the firm's goods and services" (Zsidisin and Siferd, 2001; Diabat and Govindan, 2011). GSCM concepts enable managers to consider the potentially adverse impacts of the supply chain process on the environment at the source, ideally before any adverse impact occurs (Nikbakhsh, 2009). The scope of GSCM practices implementation ranges from green purchasing to integrated life cycle management supply chains flowing from supplier, through to manufacturer, customer, and closing the loop with reverse logistics (Zhu et al., 2007; Diabat et al., 2013). The major GSCM practices that have been adopted by various organisations from different industrial sectors are summarised in Table 1.

Table 1 GSCM practices

GSCM practices	*Description*	*Authors*
Environmental management	It refers to various initiatives taken by the organisations to control their internal process in order to either eliminate or reduce the production of emissions or wastes.	Zhu et al. (2007), Diabat et al. (2013)
Green purchasing	It address to the purchasing practices that emphasises on purchasing environmentally friendly products that meets environmental objectives such as reduction of sources of waste, substitution of materials, hazardous material minimisation, promotion of recycling, resource reduction, etc. set by the purchasing organisation.	Diabat et al. (2013), Zhu et al. (2007), Eltayeb et al. (2011), Lin (2013)
Supplier environmental collaboration	It addresses to various initiatives taken to enhance the environmental performance of the supplier. It includes supplier education, support to the supplier in terms of technical and financial assistance and working jointly with suppliers.	Diabat et al. (2013), Eltayeb et al. (2011), Lin (2013), Vachon and Klassen (2008)
Product recovery	This concept focuses on extracting materials from various used products and then utilising them in place of virgin materials in the supply chain to gain positive sustainable effect in terms of lower cost.	Diabat et al. (2013), Lin (2013), Chien and Shih (2007)
Customer environmental collaboration	Various activities performed by the organisations such as customer support and education with a view to help customers to improve their environmental performance are known as customer environmental collaboration. It also encourages customers to develop green products or processes.	Zhu et al. (2007), Eltayeb et al. (2011), Lin (2013), Vachon and Klassen (2008)
Reverse logistics	It refers to the activities involved in return of product from the consumption point to the forward supply chain for the purpose of remanufacture, recycle, reuse, repair or safe disposal of the material or the product.	Diabat et al. (2013), Eltayeb et al. (2011)
Design for the environment (eco-design)	It refers to various activities performed during product development to reduce the adverse impact of the product on environment throughout its life cycle. It focuses on incorporating environmental aspects into product design process.	Diabat et al. (2013), Zhu et al. (2007), Eltayeb et al. (2011), Lin (2013)
Waste management	Waste minimisation through segregation practices, pollution prevention, and safe disposal of waste or reuse of the waste of a process in some other activity is some of the waste management practices performed by the industries.	Vachon and Klassen (2008), Walker et al. (2008)
Green manufacturing	It refers to the incorporation of environmental aspects into manufacturing process reduce the negative environmental impact of the manufacturing process as well as the products produced by these processes. It mainly focuses on design and of adoption of low energy intensive and highly efficient production process.	Chien and Shih (2007), Walker et al. (2008)
Green packaging	It refers to environmentally responsible packaging practices that includes minimal use of packaging material, use of light weight, recyclable or biodegradable packaging material and avoidance of use of environmentally hazardous materials for packaging.	Shang et al. (2010), Kumar et al. (2013), Mitra and Dutta (2014)
Green distribution/ transportation	It refers to various practices that aims at reducing adverse environmental impact of transportation. These include choosing alternative mode of transportation such as railways or waterways which involve lesser emission in comparison to road or air transportation. It also emphasises on shipping full truck load rather than shipping less truckload in case of road transportation.	Kumar et al. (2013), Mitra and Dutta (2014)

Table 2 GSCM practices in mining industries

Green practices	*Description*	*References*
Fugitive dust control	Mining activities such as drilling, blasting, crushing, screaming and material handling operations produce dust. Fugitive dust control refers to various measures taken by the mining industries to keep the amount of suspended particulate matter (SPM) below 430 µg/cum and that of respiratory particulate matter (RPM) below 215 µg/cum in the ambient air. It consists of a series of dust preventive and suppressive measures along with dust extraction using sophisticated equipments.	Mohanty and Goyal (2012), Ghose (2007), Singh and Shukla (2008), Singh (2009)
Reduction of green house gas emission	Harmful gases like SO_2, NO_x, methane, CO_2 are generated and emitted to the atmosphere during mining activities. These gases are not only responsible for ‘global warming’ but also acid rain’ and ‘ground level ozone’. Hence mining industries are looking at developing and implementing technology which reduces generation of gaseous emissions and eliminates gaseous waste streams through recycling as per their reduction of green house gas emission activity. This also includes identification of all pollutants and selection of appropriate technologies to control them effectively. One of the most common method used is installation of self-sealing doors on the coke ovens to reduce gas emissions.	Tinney and Roe (2002), Driussi and Jansz (2006b), Singh and Shukla (2008), Singh (2009), Vintró et al. (2014)
Energy management	Mining industries are very much energy intensive, approximately 4% to 7% of the global energy consumption. With the growing issues of energy scarcity mining industries are focusing on reducing their energy consumption and optimal use of the available energy. Energy management strategies of mining industries also involve development of infrastructures for generation of energy from renewable sources. A number of advanced technologies have been emerged that could be expected to assist the programs of energy saving are use of high pressure grinding rolls and stirred mills for grinding, use of mobile crushing and conveying systems for open-pit mining and advancement in diesel engine technology for loading and hauling applications	Singh (2009), Newbold (2006), Norgate and Haque (2010), Vintró et al. (2014)
Noise control	A cumulative effect of all mining activities produces enormous noise and vibrations in the mining area. Noise and vibration are unavoidable in many types of mining and require particular management at projects close to communities, where they can give rise to concerns for public health, safety. Industries quantify the extent of noise, vibration during the environmental impact assessment stage and make predictions of the levels likely at potentially sensitive locations, such as the nearest dwellings, school or public place as per their noise control activities. Additional measures like monitoring of the noise level at regular intervals in the mining areas to ensure that it is below the permissible level, constructing earth mounds along or around high noise areas, routine maintenance of the machines and covering of the generators and compressors with acoustic material are also practiced by mining industries to control the noise.	Driussi and Jansz (2006a), CPCB (2007), Singh (2009), Tinney and Roe (2002)

Table 2 GSCM practices in mining industries (continued)

Green practices	*Description*	*References*
Water management	Water is integral to a number of mining activities including beneficiation, washing and cooling purposes in power generating units and typically the prime medium, besides air, that can carry pollutants into the wider environment. Consequently, the management of the release of water, and any dissolved colloidal or particulate matter within it, into the environment, is of chief concern in the mining industry. Maximum water recirculation through all circuits is the principal means for reducing water use within a mining system. Some of the other important measures of water management include reduction of water use, minimisation of fresh water usage through recycling of waste water after treating it in effluent treatment plants, zero discharge practices and retardation of the evaporation rate of water through the use of suitable chemicals. A mine's water management system (WMS) must account for site-specific physical, chemical and climatic characteristics as well as mine process factors. As water features in most operational aspects, total company commitment to integrated water management is critical.	Driussi and Jansz (2006a), Newbold (2006), Boyle et al. (2012)
Recycling and re-use practices	It refers to various recycling and reuse operations performed by the mining industries. In order to reduce the usage of virgin materials several industries are focusing on recycling and the mining industries are of no exception. Reuse and recycling options not only minimise fresh inputs but also waste outputs. Recycling options also involve less energy consumption in comparison to the virgin material. The common recycling practices adopted by mining industries are recycling of used batteries. They also make arrangements for recovery of floating oil and grease and sell it for recycling purposes. In addition to this recycling of water, reuse of the coal rejects for power generation purpose, reuse of mill scale and flue dust in sinter plants are some of the reverse logistics practices practiced in mining industries.	Norgate et al. (2007), Driussi and Jansz (2006b), Tinney and Roe (2002)
Hazardous waste management	Most mining and mineral processing facilities use and generate hazardous materials. Approaches to minimising risk from these substances include: identifying and properly preparing materials, and compiling inventories of all hazardous materials including waste products; characterising the potential environmental hazards associated with them; documenting methods for transport, storage, handling and use; identifying options for disposal and long term storage, preparing contingency plans and emergency response plans; and training of all managers, workers and contractors who deal with or handle hazardous substances. Proactive companies emphasise on waste minimisation as one of the significant strategies of waste management. Waste minimisation can be achieved through improved process design that minimises waste generation, waste collection, waste segregation, waste recycling and the neutralisation of pollutants into detoxified forms.	Driussi and Jansz (2006a), Botta et al. (2009), Franks et al. (2011)
Dump stabilisation	Waste rock and overburden are generally stored in the form of waste dumps in surrounding mining operations and their acid generating potential is continuously monitored. Stabilisation of these waste dumps is essential as runoff from these waste dumps carries fine sediments in suspension that pollute water bodies. The process of making the dumps inert so that the materials deposited in these dumps neither can be swept by air nor by the water is called dump stabilisation. Once the dumps acquire the designed height and slope they are covered with mixture of grass seeds, agricultural soil and manure.	Tinney and Roe (2002), Singh and Shukla (2008), Franks et al. (2011)

There exist many literatures describing about GSCM implementation pressures, drivers and barriers in the context of India and other countries (Xu et al., 2013; Mathiyazhagan et al., 2014; Govindan et al., 2014; Mohanty and Prakash, 2014; Nunes and Bennett, 2010; Shen et al., 2013; Bhattacharya et al., 2014; Shukla et al., 2009). But the context of Indian mining industry is still unaddressed. Environmental impact of any industry can be reduced by reducing the amount of environmental burden inherited by it from its downstream supply chain partner. Hence, success of greening efforts of manufacturing industries depends upon that of their suppliers which are none other than the mining industries in many cases. Therefore, the present research was pursued in the context of Indian mining industries.

2.2 GSCM practices in the context of mining industries

Various GSCM practices adopted by mining industries are presented in Table 2.

Available literature on green practices in mining supply chain highlights some of the common practices followed in mining industries. What is missing is a discussion on sector specific best practices. Further, studies that analyse the internal and external factors influencing GSCM implementation in different mining sectors is scarce. Hence, to bridge this gap this study is conducted using SWOT approach to identify the core competence of different mining sectors and diagnose their core problems during GSCM adoption.

3 Methodology

When the purpose is theory building, then case research relies on theoretical sampling and the case may be chosen to replicate previous cases or extend emerging theory, or they may be chosen to fill theoretical categories and provide examples of polar types (Faisal, 2006). Case studies allow direct observation of the field, which would be particularly suitable for approaching several stages of a supply chain (Seuring and Müller, 2008). These emphasise in-depth qualitative analysis and is particularly suitable for answering questions regarding 'what', 'why' and 'how' for the problem under consideration (Yin, 1989). The approach is suitable for the situation where existing knowledge is limited because it generates in-depth contextual information which may result in a superior level of understanding (Oke and Gopalakrishnan, 2009). Contrary to other research methods, which often aim at statistical correlations with lesser regard for the underlying explanations, case research is capable of discovering true causal relationships (Faisal, 2006). Besides these, case study approach has several other advantages. Some of the major advantages are as follows (Eisenhardt, 1989):

- It enables the researchers to develop grounded theories that are practical and relevant.
- Inferences on causal relationships can be made with more validity due to availability of long-term observations.
- It provides broad holistic pattern of phenomenon in real world settings.

Case studies have been developed in this research to understand the green issues in the case of Indian mining industries. Case studies were developed using the data collected both from the primary as well as the secondary sources. Information collected through the questionnaire survey and semi-structured interview is referred as primary data in this study. Secondary data refers to the information collected from the websites of the organisations and through the scanning of published materials such as business dailies, corporate magazines and news papers. To maintain the confidentiality of information, disclosed by these companies in their response to our questionnaire and interviews, the names of the companies are not revealed in this chapter. The discussed cases are:

1 coal sector
2 iron ore sector
3 manganese ore sector.

3.1 SWOT analysis

SWOT analysis is used in this study for critical examination of the three above mentioned cases. SWOT, the acronym standing for strengths, weaknesses, opportunities, and threats analysis, is a commonly used tool for analysing internal and external environments in order to attain a systematic approach and support for a decision situation (Kahraman et al., 2007). It can be used both as a decision support tool during the preliminary stages of decision-making and as a precursor to strategic management planning (Arslan and Er, 2008). It helps the managers and decision makers to focus on key issues by providing means to systematically analyse an organisation's internal and external environments (Tahernejad et al., 2012). The two main components of SWOT analysis are the indicators of the internal situation described by existing strengths and weaknesses and the indicators of the external environment described by existing opportunities and threats (Markovska et al., 2009). This analysis on one hand focuses on grouping the negative factors (weakness and threats) that enables the decision makers to explore development possibilities, while on the other hand groups the positive factors (strengths and opportunities) to identify the areas for further development (Lozano and Vallés, 2007). The main advantage of this tool is its simplicity and clarity (Nikolaou and Evangelinos, 2010).

SWOT methodology has been successfully employed in the areas of waste management and environmental management practices. Srivastava et al. (2005) investigated formulation of static action plans for management of solid waste of Lucknow municipality employing SWOT analysis. The study framed a set of concrete strategic action plans for both the Municipal Corporation and community to enhance effectiveness of management of solid waste in that region. Another study that analysed environmental activities of Greek mining industries employing SWOT analysis by Nikolaou and Evangelinos (2010) claimed that the results of the study could facilitate improved environmental performance. In a recent study, Yuan (2013) investigate the status of construction waste management using SWOT analysis in China. The author claimed that the results of the study could be useful in developing and promoting future construction waste management at the strategic level. These studies have demonstrated ability of SWOT approach as a superior tool for analysing problems from a strategic perspective. Hence, SWOT analysis has been adopted in the current research to analyse GSCM practices in Indian mining industries.

4 Case companies

In this research, case studies have been carried out to gain an insight of the various green initiatives adopted in three mining sectors operating in India. The selected mining sectors are coal, iron ore and manganese ore sector.

4.1 Coal mining industries

India has a coal deposit of 257.4 billion tonnes that accounts for 10% of worlds coal deposit (Singh, 2009). The country is ranked 3 amongst the coal producing nations in the world by contributing 8% to the global coal production from its 573 coal mines (MoM, 2010). Coal mining companies are almost exclusively government-owned with Singareni Collieries Company Limited (SCCL) and Coal India Limited (CIL) and its seven subsidiary companies undertaking coal mining in different regions of the country following the nationalisation of coal mines in the 1970s and accounts for 95% of national coal production (Mohanty and Goyal, 2010). Coal currently accounts for more than 50% of total primary commercial energy supply in the country and for about 70% of total electricity generation (Chikkatur et al., 2009). Besides the thermal power generating units, iron and steel industries, cement industries, fertilisers industries are the coal consuming industries. Both open cast and underground mining methods are followed for coal mining, however, the former contributes to around 84% of the total coal production in India.

Coal mines are not only responsible for air pollution due to dust emission to the atmosphere during crushing and transportation of ore but also for the release of several harmful gases like CO, CH_4, SO_2, NO_X. Carbon monoxide (CO) and methane (CH_4) cause green house effect, while sulphur dioxide (SO_2) and oxides of nitrogen (NO_X) are responsible for acid rain and ground level ozone respectively. Acid mine drainage that originates from weathering and leaching of sulphide minerals present in coal is a major issue in case of coal mines (Singh, 2009).

4.1.1 GSCM practices followed in the coal mining industries of India

The following are some of the GSCM practices adopted by Indian coal industries.

4.1.1.1 Fugitive dust control practices in coal industries

To avoid spillage of coal dust, overloading of trucks is not allowed. Further, coal is wetted and covered with tarpaulin after loading to the trucks. Sprinkling of water is done on haul roads by both fixed and mobile type sensor controlled sprinkles. Bigger units employ modern blast less technologies such as surface miner technology which reduces dust production. Some units also employ vacuum operated mechanical road sweeper to keep the haul roads dust free. Service roads are made black topped by many companies.

4.1.1.2 Reduction of greenhouse gas emission practices in coal industries

Routine maintenance of vehicles and heavy earth moving machineries are done to reduce emission. Continuous ambient air quality monitoring stations have been installed by most of the companies. In addition to that fire hydrant systems have been installed by a large number of companies at coal handling plants and coal dumps in order to prevent fire (Singh, 2009). Various attempts are also taken by the industries to improve combustion efficiency. Few companies have introduced the practices of dilution of the gaseous emission through wind sweeping and vertical mixing.

4.1.1.3 Energy management practices in coal industries

Periodical overhauling of engines and regular checking of filters hoses and tyre pressures are done to reduce fuel consumption. Self-starters are regularly checked and maintenance of batteries is done periodically. Extensive use of CFLs, electronic regulators and electronic chokes in tube lights have been adopted by a number of companies. Few companies even have employed automatic control switches for street lights in colonies, yard lights and quarry lighting systems.

4.1.1.4 Noise control practices in coal industries

Coal industries make provisions of impact rollers at transfer points to dampen noise. Almost all the companies conduct regular checking of noise level and routine maintenance of machines. Practices of covering generators and compressors with acoustic materials have been adopted by a number of companies. Blasting operations are carried out with proper hook-up and optimum explosive charge.

4.1.1.5 Water management practices in coal industries

Provision of garland drains around the quarry area and dumps that prevent erosion of topsoil and entry of water into mine in rainy season is observed as a common practice in this sector. Construction of check dams at the bottom of the dumps that reduce siltation with suspended solids is also practiced by the companies in the coal sector. Rain water harvesting measures have been adopted by a number of companies. Few companies have installed flow metres in all make-up water lines to monitor and control the amount water consumption. A number of companies also have installed effluent treatment plants (ETPs) and sewage treatment plants. The treated water is used to fulfil the water requirement of township instead of using ground water. Few companies also conduct ground water sampling.

4.1.1.6 Recycling and re-use practices in coal industries

Industries operating in this sector perform the practices like recycling of used batteries and recycling of waste water from every unit after treatment in ETPs. They also use old drill rods for fencing purpose. Coal rejects are used for power generation purpose. Drained lubricant oils are collected and reused for the purpose of lubrication of mine tub axles. Reuse of old conveyor belts as temporary ventilation stopping and wipers are widely practiced by the industries in this sector.

4.1.1.7 Waste management practices in coal industries

Waste segregation practices and filling of low lying areas with fly ash are the common waste management practices observed in coal mining industries. Some of the companies are now focusing on supplier environmental collaboration and use of advanced technologies for the purpose of waste reduction. Practices of use of overburden waste for backfilling have been adopted by several companies.

4.1.1.8 Dump stabilisation practices in coal industries

Dumps are planned in non-forest and non-agricultural lands. Dumping of top soil is done in heaps to retain water in intervening spaces between heaps. Appropriate height and slope of the dumps are maintained. Proper water channelling provisions are made. Geo-textiles are used for covering of the dump. Peripheral green belt development with local plant species has been adopted.

4.1.2 SWOT analysis for coal mining industry

Strengths, weakness, opportunities and threats related to coal mining industry with respect to GSCM implementation has been identified through the discussion with experts in the sector and is presented in Figure 1.

Figure 1 SWOT analysis of coal mining sector

Strengths	*Weakness*
• Most of the industries are public sector units. • Skilled human resources. • Dedicated environmental management department with modern equipments and trained manpower. • Availability of adequate fund for environmental expenditure. • Adequate infrastructure availability. • Coal transportation is dominated by railway.	• Open cast mining. • Bureaucratic requirements. • No clear-cut mining industry specific policies. • Lack of broad environmentally clientele. • Coal mining in India is associated with poor employee productivity. • High ash content of Indian coal.
Threats	*Opportunities*
• Existence of coal reserves below thick forest. • Depletion of superior grades of ore leaving behind inferior ore grades to be mined that involves higher emissions. • Frequently changing regulatory policies. • Severe future legal requirements (heavy penalty due to disclosure of any fault) • Emission of CH_4 trapped in coal mines.	• Availability of hydro transportation method. • Availability of training facilities. • Innovation of new technologies for production of clean coal. • Cost saving opportunities provided by reverse logistics practices. • Introduction of X-ray assisted dry coal sorting.

4.2 Iron ore mining industries

India was ranked in fourth position among the iron ore producing countries in the world in the year 2009 (MoM, 2010). The country has an iron ore reserve of 25.2 billion tons, which constitutes 3% of the world's resources (Singh, 2009). An open cast method is mostly followed for iron ore extraction in India. The contribution of public sector companies to Indian iron ore production is 28% from 33 operating mines while that from private sector mines is 72% from 283 operating mines (IBM, 2012b). Two types of iron ore hematite (high grade iron ore) and magnetite (low grade iron ore) are found in the country. In India only 40% to 45% of the overall iron ore production is consumed while the rest which are in the form of fines(size less than 10 mm) are exported as Indian industries lacks the technology to use them (IBM, 2011). Iron ore primarily finds its use for the production of pig iron, sponge iron and steel; In addition to this it is also used in cement, coal washeries, ferro-alloys, foundry, vanaspati and glass industries (IBM, 2012b).

Several environmental problems observed in iron ore mines and nearby areas. The dust produced during extraction, crushing and transportation is a major source of air pollution. Burning of coke releases CO and CO_2 to the atmosphere. Tailings from beneficiation plants contaminate the nearby streams and rivers. Silt carried as runoff from the waste dumps of the mines cause pollution and heavy siltation of agricultural lands, irrigation canals and rivers.

4.2.1 GSCM practices followed in iron ore mining industries in India

This section details about the greening efforts undertaken by the iron ore extractive industries in India.

4.2.1.1 Fugitive dust control in iron ore industries

The iron ore extractive companies also follow some of the practices similar to that of coal industries like restriction of overloading of trucks, covering the trucks during ore transportation, water sprinkling on haul roads and use of vacuum operated mechanical road sweeper. In addition to these they use settling chambers and electrostatic precipitators to separate dust electro-statically from flue gases. A number of industries carry out drilling and blasting operations in the afternoon session as the wind has normally less speed during this period. Wheel and road washing practices are also followed by a number of companies.

4.2.1.2 Reduction of greenhouse gas emission in iron ore industries

These companies also perform routine maintenance of vehicles and installation of ambient air quality monitoring stations. Few companies have also employed mobile air quality monitoring vans. Besides these, hot blast stoves are used to cut down coke use that will ultimately reduce GHG emission. Few companies focus on developing and adopting GHG policy for reduction of GHG emission and setting targets to minimise emissions. In order to reduce consumption of fossil fuels for energy production, some companies have started producing energy from non-conventional sources such biogas plant using cow dung and municipal waste.

4.2.1.3 Energy management in iron ore industries

These companies also perform periodical overhauling of machines and regular checking of tyre pressure, filters and hoses as done by coal industries. Few big companies have started locating facilities in proximity to sources of raw materials for reducing consumption of energy in transportation. Energy audits are also done periodically by a number of companies. Use of conveyors for ore transport is observed in place of dumper trucks in case of bigger units. In case of ore transport by dumpers, 40% of energy is consumed for payload transportation and 60% energy is consumed to move self-weight of dumpers where as in case of conveyors 80% of the energy is available for payload transport (CPCB, 2007).

4.2.1.4 Noise control in iron ore industries

In addition to the common noise control practices like covering of generators and compressors by acoustic covers, regular inspection of noise level and routine maintenance of machines, companies operating in this sector are now focusing on selection and use of low noise prone rotary equipment.

4.2.1.5 Water management in iron ore industries

The companies in this sector also employ some similar practices to coal industries like installation of ETPs, construction of garland drains, rain water harvesting and installation of flow metres. Most of the companies also employ unused mine pits for storing rainwater. The stored water is used for beneficiation and spraying purposes. Besides these practices, bigger mining houses employ air cooled condensers that saves 95% of water usage. Garland drains with sufficient number of settling pits have been constructed on the toe of all the overburden dumps to collect surface runoff (CPCB, 2007). Few big companies also have adopted the practice of reduction of rate of evaporation water at local reservoirs through the use of evaporation retarding chemicals.

4.2.1.6 Recycling and re-use practices in iron ore industries

The iron ore extracting companies perform some common recycling and reuse practices like recycling of batteries, recovery of floating oils from oil and grease traps and selling it for recycling purpose. In addition to that, few companies reuse the slag generated from blast furnace in cement manufacturing. Some companies are even reusing the iron ore recovered from tailings through the use of high gradient permanent magnetic separators. Bigger companies have setup waste heat recovery plants. These plants generate power using the waste heat from the coke oven plant and from the flue gases of the blast furnaces. Few companies also have been using tailor made sinter plants that can make use of 100% of the mill scale and flue dust generated in mills and blast furnace.

4.2.1.7 Waste management in iron ore industries

Common waste management practices such segregation of waste, use of fly ash for filling of low lying areas and use of overburden for filling voids of previous quarry are followed by most of the companies. Few companies have been adopted the practices of conversion of canteen waste into the vermin-compost and using it as manure is followed by few bigger companies. The tailings generated by iron ore industry is used as one of the raw materials for making ceramic floor and wall tiles (CPCB, 2007).

4.2.1.8 Dump stabilisation practices in iron ore industries

Dumps of appropriate height between 30–50 metres and with slopes less than 280 are maintained. Slope height depends upon availability of dumping space. Gabion walls made of GI wire net cages and stone boulders are constructed with proper water channelling arrangements at the toe of the dumps (CPCB, 2007). Besides, these covering of dumps with geo-textile mat and peripheral green belt development is also done.

4.2.2 SWOT analysis of iron ore industry

Discussion with experts from the iron ore mining sector led to identification of the strengths, weakness, opportunities and threats related to GSCM implementation in the sector has been explored and summarised in Figure 2.

Figure 2 SWOT analysis of iron ore mining sector

Strengths	*Weakness*
• Development of blast less technologies. • Support and initiatives from various government organisations. • Availability of common beneficiation facilities for small mining units. • Large-scale mining units have dedicated environmental management department with modern equipments and trained manpower. • Increased demand of iron ore even of inferior grade outside India.	• Open cast mining • Poor management support systems. • Lack of attention to safety and health standards. • Lack of broad environmentally clientele. • Waste produced is high due to non-availability of technologies for utilising inferior ore grades. • Ore transportation via roads involves higher emission. • Production beyond permissible specified limits.
Threats	*Opportunities*
• Frequently changing regulatory policies. • Severe future legal requirements (heavy penalty due to disclosure of any fault). • Depletion of superior grades of ore leaving behind inferior ore grades to be mined that involves higher emissions. • Lack of professional training facilities. • No clear-cut mining industry specific policies.	• Increased demand for green products from foreign customers. • Cost saving opportunities provided by reverse logistics practices. • Higher amount of FDI. • Development of technologies for mine waste utilisation in urban planning. • Support and encouragements from voluntary organisations like Federation of Indian Mineral Industries (FIMI) for sustainable development practices.

4.3 Manganese ore mining industries

India got fifth position amongst the manganese ore producing countries in the world in the year 2009 (IBM, 2011). Manganese ore reserves of the country are estimated to be as 430 million tonnes. There are 141 manganese ore mines in operating condition in India in which eight are underground sector mines and the rest are opencast (MoM, 2010). Manganese production from 20 public sector mines is nearly 45% of the total manganese production of the country while the rest are being produced by the private sector companies (IBM, 2012a). Country's domestic manganese ore demand during the year 2010 to 2011 was 3,478 thousand tonnes in contrast to its domestic production of 2,881 thousand tonnes (MoM, 2010). Hence, part of the domestic manganese requirement of the country is met from imports. The country primarily imports manganese ore with 46% Mn content while exports that with 30% to 35% Mn content. Manganese not only has good sulphur fixing and de-oxidising properties but also has good alloying characteristics, for which nearly 95% of the country's manganese consumption is shared by silico-manganese and ferro-alloys industries and the remaining is consumed by iron and steel, battery, chemical, glass and abrasive industries (IBM, 2012a).

Dust is a major problem found in the open cast manganese mines. Extraction of manganese ore produces on an average 51.51 tonnes of waste per tonne of the metal ore. Besides this substantial amount of sub-grade ore(less than 10% Mn content) is produced which is not saleable. These huge volumes of waste not only requires more dumping area but also act as sources of air pollution through dust production and water pollution through run offs.

4.3.1 GSCM practices followed by the manganese ore mining industries in India

4.3.1.1 Fugitive dust control in manganese ore mining industries

These companies also follow some of the dust control practices followed by iron ore and coal companies. In addition to that few companies restrict ore transport by trucks after sunset. Bigger units have made arrangements to enclose the material handling plants and conveyors. Smaller units generally do not have their own crushing plants. Wet drilling techniques are adopted by many companies where some prefer to carry out drilling and blasting operations only during monsoon. Few companies also have adopted delayed non-electronic blast initiation system (NONEL) blasting techniques to reduce vibration and minimise fly rocks. Rock breakers are also employed by few companies to reduce blasting.

4.3.1.2 Reduction of greenhouse gas emission in manganese ore mining industries

The practices followed by the companies are almost similar to that of iron ore companies. Few bigger companies are promoting the use of renewable sources of energy such as wind energy, to reduce use of fossil fuels.

4.3.1.3 Energy management in manganese ore mining industries

Programmable logic controller (PLC) driven compressors has been commissioned at few mines for energy saving. Employment of modern exploration techniques like geophysical exploration by gravity magnetic method has been observed in case of few mines. Apart from these practices, they follow few practices similar to that of iron ore industries.

4.3.1.4 Noise control practices in manganese ore mining industries

Noise control practices performed by manganese ore extracting industries are similar to that of iron ore industries.

4.3.1.5 Water management practices in manganese ore mining industries

Smaller mining units in this sector conduct dry crushing. As a result, no waste water is discharged from crushing plants. Larger units have commissioned ETPs for treatment of discharge from beneficiation plants and workshops. These units also have made provisions of settling tanks for underground discharge. Most of the bigger units have provided sedimentation basins for treatment of the surface runoff or driving to the tailings ponds. Besides these practices they also employ few practices similar to that of iron ore mining industries like commissioning of air cooled condensers, rain water harvesting, use of mine pits for water storage, minimisation of water consumption through recycling of treated waste water from every unit t, etc.

4.3.1.6 Recycling and reuse practices in manganese ore mining industries

Manganese ore extractive industries also perform few practices similar to that of iron ore extractive industries such as recovery and selling of floating oils, use of heat of waste gases in heat recovery boilers for power generation and recycling of batteries. Besides these practices, use of manganese oxide slag for the production of silico-manganese is also practiced by few big companies. These companies also use silico-manganese slag for construction of roads.

4.3.1.7 Waste management practices in manganese ore mining industries

Manganese ore extractive industries follow some of the common waste management practices like coal and iron ore industries. In addition to these, separate dumping of magniferous and non-magniferous waste is practiced by these industries. This will help them to utilise these lower grade ores upon availability of appropriate technology with lower cost. Few bigger industries have started avoiding unnecessary use of hazardous materials and adopted purchasing and using of environmentally responsible materials as a strategy to reduce waste generation.

4.3.1.8 Dump stabilisation practices in manganese ore mining industries

Dump heights are limited 30 metres so that space requirement will be lower. The matured dump soils are covered with shrubs, grass or, fast growing plants.

4.3.2 SWOT analysis of manganese ore mining industry

In a discussion with the experts of the manganese ore extraction companies strength, weakness, opportunities and threats related to the sector have been identified and represented in Figure 3.

Figure 3 SWOT analysis of manganese ore mining sector

Strengths	*Weakness*
• Availability of modern blast less technologies such delayed non-electronic blast initiation system (NONEL) blasting technique. • Many iron ore mining companies are involved in extraction of manganese as associated mineral. • In case of smaller mining units no waste water is generated during mining process; workshops were also absent within mining lease area. • Large-scale mining companies like MOIL has setup an integrated manganese ore beneficiation plant.	• Dominance of open cast mining over underground mining. • Absence of proper maintenance system for equipments and machineries. • Operating style of management in most cases is traditional instead of scientific. • Poor human resources due to poor working condition and low salary levels. • High volume of waste (51.51:1 waste to metal ratio) produced during extraction of manganese. • Ore transportation via roads involves higher emission.
Threats	*Opportunities*
• Frequently changing regulatory policies. • Severe future legal requirements (heavy penalty due to disclosure of any fault). • Depletion of superior grades of ore leaving behind inferior ore grades to be mined that involves higher emissions. • Necessity of additional funds. • Lesser number of R&D units in mining sector compared to developed countries.	• New markets, new consumer and competitive advantages. • Availability of technologies for use of mine waste for road construction. • Innovation and development of new technologies for utilisation of inferior ore grades. • Cost saving opportunities provided by reverse logistics practices. • Increased demand for green products from steel industries.

5 Discussions

The picture that emerges from the analysis of the situation of coal mining industries is that most of them are public sector units. Therefore, they are in relatively better position in arranging fund, attracting skilled human resources, developing necessary infrastructure. They possess a well developed dedicated environmental management department equipped with modern instruments. In addition to these, transportation of a major portion of coal through railways leads to lower CO_2 emission. Further, introduction of X-ray assisted dry coal sorting reduced the possibility of waste water generation. Similarly, development of hydro transportation method reduced the possibility of gaseous emission and dust production during transportation. Though coal mining industries have the above mentioned strengths, still they suffer from a lot of challenges like open cast mining method, lack of broad environmental clientele, poor employee productivity, lack of clear cut industry specific guidelines, existence of coal reserves below thick forest, depletion of superior ore grades leaving behind the inferior grade ores that involve higher amount of energy consumption and GHG emission, etc. with respect to GSCM adoption. Moreover, high ash content of Indian coal also offer resistance to its green practices as transportation of such high amounts of inert material over long distances increases emissions in transportation (Tinney and Roe, 2002).

In contrast to coal mining industries, a majority of the iron ore mining industries lies in private sector. Their environmental management programs are encouraged by support and various initiatives from governments like subsidies for purchase of equipments, development of common beneficiation facilities for smaller mining units and conduction of training programs are a few to name. Development of blast less technologies and availability of expert guidance add strength to their GSCM implementation programs. Further, there is an increased demand of inferior grade of iron ore outside India that helps in reduced amount of waste generation. It has been found that large-scale mining units have dedicated environmental management department with modern equipments and trained manpower. In addition to these few voluntary organisations like FIMI are working in India whose prime intention is to support and encourage sustainable development practices in metallic ore extracting mining industries. Hence, interested organisations can avail necessary guidance and expert advice from these organisations. In contrast to these favourable conditions their also exist several factors that inhibit GSCM adoption in iron ore industries. Use of open cast mining method is one such factor. Relatively large amount of over burden waste and dust is produced in comparison to underground methods. Similarly transportation of higher percentage of ore via roads is a factor responsible for higher amount of gaseous emission. In addition to these, depletion of superior ore grades, frequently changing regulatory policies are some of the major factors that offer resistance to GSCM practices in iron ore mining industries.

Study of manganese ore industries reveals the following interesting facts. Many iron ore mining industries extract manganese as associated mineral. Further, steel giants are focusing on production of greener products and process. Hence, manganese ore extraction units being a supplier of the steel industries can readily get cooperation from these industries for their environmental management programs. Large-scale mining companies like Manganese Ore India Limited (MOIL) has setup an integrated manganese ore beneficiation plants. In case of smaller mining units, workshops are found to be absent within mining lease area hence no waste water is generated during the mining process. However, high volume of waste (51.51:1 waste to mineral ratio) produced during manganese extraction is a major factor that offer challenge to GSCM practices in manganese ore mining industries.

6 Managerial implications

The following are some of the managerial implications of this study.

- The current research explores that 'fugitive dust control', 'reduction of green house gas emission', 'energy management', 'noise control', 'water management', 'recycling and re-use practices', 'hazardous waste management', 'dump stabilisation' are the green practices followed by mining industries. Additionally, the importance of these green practices in the context of mining industries has also been reported in this research. Knowledge regarding these practices and their advantages may encourage the mining industries to adopt such practices to reduce their environmental burden.

- Further, various initiatives taken by industries from different mining sectors under the category of each green practices have been reported in this paper. This will help the interested mining industries to learn and duplicate the best performing activities.
- Internal capabilities of the select Indian mining sector and the external environment with respect to GSCM implementation have been evaluated using SWOT analysis in this research. This could be used as a guide line to identify weaker areas and bring necessary improvements. For example, coal mining industries should try to reduce extraction by open cast methods which are considered to be a major weakness of the coal industries. Further, the Indian coal extractive industries should employ hydro transportation method which has proven its success in reducing emissions significantly. Similarly, iron ore and manganese ore extractive industries could reduce ore transportation via roads and choose rail transportation or hydro transportation as the former method involves higher amount of emission.

7 Conclusions

Poor environmental consequences of the mining companies not only lead to substantial liabilities for the public but also impose costs on the mining and mineral processing industries by eroding share value, increasing the risks of temporary or permanent shutdown, exposure to compensation, fines and litigation costs, lost future opportunities and increased remediation and monitoring, to name a few (Franks et al., 2011). Hence, efforts are being made at all levels including academic institutions, environmental protection agencies, governments and various organisations to develop feasible methodologies for effective implementation of green practices in Indian mining supply chains. In this regard, an understanding of the current state of green initiatives adopted by these industries is essential. In this research an attempt has been made to explore various green practices implemented by Indian mining industries in three different sectors which have not been addressed by earlier researches. Further, SWOT analysis has been employed to highlight the strengths and opportunities of each sector and identify the underperforming areas to fill the research gap on identification as well as analysis of sector specific environmental best practices in the context of Indian mining industries. The results of the study can act as a guide for the firms to enhance their environmental performance.

The study shows that significant green initiatives have been taken by large-scale mining units, while the small-scale mining industries have exhibited negligence towards greening activities. This can be due to the fact that Indian Government has largely ignored the industry from a policy-making standpoint and failed to provide the operators with the necessary guidance and support (Ghose, 2003). In addition to this, these industries suffer from shortage of fund and skilled human resources. Hence, Indian mining industries need to work with government and academic institutions to setup training and skill development facilities to meet their manpower requirements. Further, the government need to develop infrastructure for ore beneficiation and waste management that will be helpful particularly to the small-scale industries. Moreover, the governments, academic institutions and the mining industries have to work collaboratively to develop technologies for the use of low grade ores which in turn will reduce volume of waste generated.

8 Limitations and scope for future research

SWOT approach used here categorises the factors into strengths, weaknesses (internal) or opportunities, threats (external) as they relate to a decision, and enables the decision maker to make a comparison of opportunities and threats with strengths and weaknesses, respectively. However, the importance of each factor in decision-making cannot be measured quantitatively and assessment of the factor having the greatest impact on the strategic decision becomes difficult (Arslan and Er, 2008). Hence, use of SWOT in combination with an analytic hierarchy process (AHP) is suggested.

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