Hindawi Publishing Corporation
Journal of Waste Management
Volume 2013, Article ID 935843, 6 pages
http://dx.doi.org/10.1155/2013/935843

Research Article

Impact of ISO 14001 Environmental Management System on Key Environmental Performance Indicators of Selected Gold Mining Companies in Ghana

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Received 18 August 2013; Accepted 7 October 2013

Academic Editor: Chihpin Huang

The impact of ISO 14001 Environmental Management System (EMS) on waste management, noise level, air quality, energy consumption, and number of reported environmental incidents as key environmental performance indicators was assessed. The assessment was based on annual and monthly environmental data and report from the selected gold mining companies (Gold Field Ghana Limited (GFGL) and AngloGold Ashanti (AGA)) before and after the implementation of the management system. Interviews with environmental managers and staff as well as field observations were also conducted. The results show that the implementation of ISO 14001 EMS by the two gold mining companies led to significant environmental improvements, particularly in waste management, reported environmental incidents, and energy consumption. Segregation of waste was adopted in both companies to ensure appropriate disposal mechanisms to mitigate pollution. Energy consumption significantly decreased in AGA following certification because of the energy conservation policy adopted by the company. In addition, the implementation of the standard brought significant increase in the total number of reported environmental incidents due to the incident reporting protocol inherent in the environmental management system. In all, it was clear that the management system is related to the environmental objectives and targets of the individual organisations and commitment towards fulfilment of the set objectives.

1. Introduction

The environmental impacts of the gold mining industry have elicited growing national and global concerns. Similarly, catastrophic environmental accidents have raised worries regarding the industry's impact on the environment and generated a global interest in preventing pollution. These conditions and accidents have, among other things, motivated and accelerated the use of EMS in order to prevent pollution [1].

EMS is one of the most important tools available for the purpose of making organizations more environmentally proactive and efficient and aims to encourage an organisation to control its environmental impacts and reduce such impacts continuously [2, 3]. Through the establishment of an EMS, the company can demonstrate to clients and the public that they take environmental impacts seriously. In addition, an efficient EMS can also improve a company's operation and bring economic benefits. The companies set objectives and targets for managing their environmental issues. They monitor, measure, and evaluate their progress in environmental performance both in areas that are regulated and areas that are not (e.g., demand-side issues such as water or electricity use) [3, 4].

ISO 14001 is the internationally accepted environmental management standard that certifies that an organization is committed to reducing the environmental impact of its products and operations and is constantly monitoring and seeking to identify ways of reducing that impact further [4, 5]. It prescribes controls for those activities that have an effect on the environment. These include the use of natural resources, handling and treatment of waste, and energy consumption [4].

(a) (b)

Figure 1: Contaminated and uncontaminated waste bins for waste segregation (a) and waste oil (b) container after ISO 14001 Certification.

Despite the fact that ISO 14001 is so widely used worldwide by companies that claim to be environmentally responsible for its benefits in operational, attitudinal, and managerial improvements in environmental issues, there is also a lot of critical literature that shows that the standard is not effective in terms of environmental performance improvements. Sceptics argue that companies get registered for the standard only because it provides a business advantage in terms of "improved corporate image" or for being seen as "responsible citizens" [6, 7]. The objective of the study was therefore to assess the impact of ISO 14001 EMS on waste management, air quality, noise level, energy consumption, and number of reported environmental incidents as key environmental performance indicators of two major certified gold mining companies in Ghana.

2. Methodology

The research used multiple approaches and techniques to collect the data that is relevant for achieving the research objectives. These included desk study, field observations, and interaction with environmental managers and workers of the selected gold mining companies (Gold Field Ghana Limited (GFGL) and AngloGold Ashanti (AGA))—both in Ghana. Analysis and review of past EPA monthly and annual environmental reports (AER) of the companies were carried out to extract annual environmental data and, also, study the history of environmental management within the companies.

2.1. Waste Management Practices. Field visits and investigations were done in the various workshops, processing plants, laboratories, offices, and waste dump sites to assess waste management practices. Interaction with management and staff as well as review of AER was done to determine waste disposal and management practices prior to certification and after certification to the standard.

2.2. Air Quality. Fugitive dust emissions into ambient air were taken for fine particulate matter (PM10) analysis to quantify nonrespirable dust levels. It was used to determine the extent of airborne emissions around operations area and these emissions were monitored using deposition gauges and high volume PM10 monitors.

2.3. Noise Level. Noise monitoring was completed in accordance with regulatory requirements to determine the impact of mining operations on surrounding communities before and after certification. This was carried out at the selected compliance points which are within or close to communities that are likely to be affected with noise from the mining operations.

2.4. Energy Consumption Calculation. The energy consumed per company was calculated according to the following:

$$\text{Energy Consumption per ounce of Gold} = \frac{\text{Total Energy Consumed per Annum (Terajoules)}}{\text{Total Ounces of Gold Produced per Annum (Oz)}}. \quad (1)$$

3. Results and Discussion

3.1. ISO 14001 Impact on Waste Management Practices in Both GFGL and AGA. Waste management in both companies has been enhanced after implementation of the standard based on recommendations of external auditors and requirement of the standard.

An analysis in [1, 7, 8] suggests that ISO 14001-certified facilities have better environmental performance—they reduced their pollution emissions faster compared to nonparticipants. Based on the field investigations and review of annual reports, it was perceived that waste collection and disposal practices have evidently undergone significant improvement.

Figures 1 and 2 show the waste segregation practices adopted by both companies in the management of waste.

Figure 2: Waste bins for segregating waste.

In GFGL, waste is separated into contaminated and uncontaminated waste. Oil/water separators are provided at every engineering workshop to treat mixtures of waste oil and water before discharge. In AGA, waste is segregated into paper, glass, plastic, and metals after which the appropriate waste disposal method is adopted.

Implementing EMS has also improved the treatment/detoxification of effluent reducing the pollutant load in waste waters to appreciable and acceptable EPA discharge guideline.

Solid waste is segregated into contaminated, uncontaminated, and hydrocarbon waste at GFGL. Uncontaminated wastes include any domestic waste that has not come into contact with hydrocarbon or chemicals used on the mine site. Contaminated wastes include wastes that have been in contact with oil, fuel, grease, solvents (hydrocarbon), or chemicals. Waste containers for contaminated and uncontaminated waste on site are labelled with red and green triangular stickers, respectively, for easy identification and segregation (Figure 1(a)). The GFGL improved its waste segregation program in 2008 to ensure that all waste oil, lubricants, and solvents (Figure 1(b)) were collected and handled by approved and accredited vendors. Domestic refuse and other uncontaminated refuse from workshops are disposed of at a landfill site within the mine (Figure 2). Burning of waste materials is strictly prohibited due to its contribution towards atmospheric pollution and global warming and can only be undertaken with the approval of the environmental manager. The certification also influenced the siting of a landfill which is well away from any surface water body, appreciably above the ground water level and remote from settlements and, also, within clay lateritic materials with low permeability to prevent seepage of leachate into groundwater. AGA rather disposes their segregated solid waste at the municipal landfill site.

The attitude of workers in both companies toward waste management has become more positive because of environmental training that has increased environmental awareness and responsiveness. The resultant effect of these waste management practices is prevention of pollution especially to surface and ground water and prevention of the spread of diseases from unhygienic conditions to both man and wildlife.

Table 1: Ambient air quality (PM10).

Year	Mean ($\mu g/m^3$)	Maximum ($\mu g/m^3$)	Minimum ($\mu g/m^3$)	EPA guideline value ($\mu g/m^3$)
2003	53.94	109.92	18.69	70
2004	54.36	158.8	4	70
2005	71.98	202.3	18.3	70
2006	79	133	25	70
2007	78.6	138.6	22.7	70
2008	37.13	109.91	1.33	70
2009	44.33	68	20	70

3.2. Impact on Ambient Air Quality from 2003 to 2009. Table 1 shows the time variation in ambient air quality from 2003 to 2009 at GFGL.

The minimum and maximum ambient air quality levels were recorded in 2008 and 2005 and were 1.33 and 202.3 $\mu g/m^3$, respectively (Table 1).

The mean annual emission values show no significant improvement in the air quality after certification but rather a progressive increase from the year of certification till it exceeded the EPA guideline value in 2005, 2006, and 2007.

The major potential source of increased airborne emissions could be ascribed to excessive dust from vehicles on haulage and light vehicle roads or prolonged and intensive dry season.

Occasional peak values higher than the EPA TWA standard (70 $\mu g/m^3$) recorded were usually in the harmattan seasons between December and March which often cause a general seasonal increase in airborne dust. The exceedances are therefore consistent with the seasonal trend during the onset of the dry season [9]. It is worth noting that air quality in communities closest to the mines is rather much better than some remote/control communities like Tarkwa township.

The improvement in ambient air quality through certification is a result of strict adherence to the ISO 14001 EMS requirement which saw the implementation of dust suppression mechanisms which mainly included watering roads with water bowsers and use of water sprinklers for the reduction of dust generated from crushing unit. Schedule maintenance of vehicles was also done after the certification to further help reduce SOx and NOx emissions.

3.3. Ambient Noise Level. Noise monitoring measurement programs were carried out to assess nuisance impacts on surrounding communities. The minimum and maximum noise levels were recorded in 2008 and 2005 and were 32 and 72.9 dB, respectively (Table 2). The mean noise level rose from 48.76 dB in 2003 to a peak of 62.66 dB in 2005 and later reduced to 49.17 dB in 2009.

Trends within the dataset clearly show that noise levels have perennially been below EPA guideline value for areas with some commercial or light industry. The observation made in the reduction in noise levels could be attributed to certification in 2004. Through certification and the provision made in the EMS on noise reduction, the company planted several trees around the mine to serve as a buffer and it

Table 2: Ambient noise levels from 2003 to 2009 at GFGL.

Year	Mean (dB)	Maximum (dB)	Minimum (dB)	EPA guideline value (dB)
2003	48.76	59.1	44.6	65
2004	51.32	55.82	45.36	65
2005	62.66	72.9	56.2	65
2006	54.75	58.8	51.9	65
2007	38.9	45.5	32.2	65
2008	33.04	34.7	32	65
2009	49.17	60	35	65

Table 3: Annual energy consumption per ounce of gold at GFGL.

Year	Total energy consumption (TJ)	Ounces of gold produced (Oz)	Energy consumption (GJ/Oz)
2004	1,460.98	553,175	2.6411
2005	1,887.04	724,971	2.6029
2006	2,252.68	720,866	3.1250
2007	2,522.32	657,064	3.8388
2008	3,104.89	629,308	4.9338
2009	3,260.68	664,514.51	4.9069

Table 4: Energy consumption trend for AGA from 2006–2009.

Year	Total energy consumption (TJ)	Ounces of gold produced (Oz)	Energy consumption (GJ/Oz)
2006	1,892	387,000	4.89
2007	2,411	360,000	6.70
2008	2,017	357,000	5.65
2009	1,620	381,000	4.25

worked well to reduce noise level as evident in the measured parameter. Residents in communities close to the mine also confirmed the reduction in noise level in the mine. In addition, schedule maintenance of vehicles and equipment put them in good operating condition—no squeaking parts, no rattling parts, and so forth which contributed significantly in the reduction of noise levels in the mine. The company also ensured that the right equipment was used for specific tasks since inappropriate equipment may generate more noise and will usually generate noise for a longer time.

3.4. Energy Consumption in GFGL from 2004 to 2009. Table 3 presents the energy consumption pattern for GFGL from 2004 to 2009. Energy consumption per ounce of gold per annum increased rather progressively from 2.6411 to 4.9069 GJ/Oz from 2004 to 2009 (Table 3).

Table 4 depicts the energy consumption trend in AGA. Energy consumption increased from 4.89 GJ/Oz in 2006 to a peak of 6.70 GJ/Oz in 2007 and decreased progressively between 2007 and 2009 by 36.6%. Information on energy is available from 2006 to 2009.

Energy consumed in GFGL includes both electricity and fuel (diesel, petrol, and LPG) consumption. Mean annual energy consumption per ounce of gold increased over the years from 2005 after a slight decrease in 2004. Electricity consumption makes up 25% on average of the energy used per annum. There is little impact on the air environment from hydroelectric energy consumption by comparison with energy generated using fuels [10]. Though there is seemly no direct effects on the environment from hydroelectric power consumption, more environmental resources would be sacrificed to meet the growing demand of energy hence its impact on the environment. Combustion of fuels inherently generates by-products many of which are considered to be air pollutants (gases). Particulate matter is also generated during the combustion of diesel and petroleum. For every quantity of energy consumed, there is an equivalent amount of GHG emission. Therefore, with the increasing amount of energy consumption per ounce of gold, there is a corresponding increase in greenhouse gas emissions from GFGL.

Energy expended is high because much energy is used in the transportation of ore from mining pits to the processing plants and also in the transportation of people to and from the site daily. The increase in energy consumed also reflects the declining grade of ore processed over the years. This implies greater quantities of low-grade ore would have to be processed to produce the same ounces of gold from smaller quantities of high-grade ore. This could also be due to decrease in efficiency of the processing plant with time. The introduction of the ball mill in addition to the semiautogenous mill (SAG) at the CIL plant could also be a source of the increased energy consumption. Interestingly, energy is a scarce resource and can limit current and new project development. In Ghana, for example, energy-supply issues have had a negative impact on many industrial operations. The role of energy consumption and greenhouse gas emissions (GHG) provides further impetus for reduction.

Mining activities in AGA use significant amounts of energy, for transporting employees, equipment, ore, and waste; for ventilation and refrigeration in underground mines; for power drilling and other equipment; for running metallurgical plants and administration offices; and for domestic uses in onsite accommodation facilities. The annual energy consumption data trend shows a significant and progressive decrease in energy consumption after certification in 2007. However, in 2008, the overall energy usage decreased owing to the more stable VRA power supply which negated the need to run on-site diesel power generators [11]. The subsequent decrease in 2009 has been largely due to improved grade control which led to an increase in head grade to 5.85 g/t from 5.65 g/t. This was complemented by better recoveries resulting from the turnaround initiatives implemented in the plant [12]. Generally, the decrease in energy consumption could also be ascribed to the conscientious advocation for wise use of energy both on the plant and in on-site accommodation facilities and offices. Activities such as replacing all electrical bulbs and other electronic gadgets with energy saving ones were undertaken to ensure compliance with the ISO 14001 EMS requirement.

Table 5: Total number of reported environmental incidents at GFGL.

Year	Number of environmental incidents
2003	2
2004	38
2005	45
2006	49
2007	53
2008	52
2009	56

Table 6: Number of reported environmental incidents at AGA.

Year	Total number of environmental incidents
2006	10
2007	8
2008	16
2009	17

4. Impact on Environmental Incidents

The overall aim of the standard is to support environmental protection and the prevention of pollution by reducing the environmental impact of its operations and constantly monitoring and seeking to identify ways of reducing that impact further. Hence, it is expected that environmental incidents should reduce with the implementation of the standard [13].

The total number of environmental incidents per annum increased significantly a year after certification and continued to increase steadily in the subsequent years till 2009 which recorded the highest environmental incidents of 56 (Table 5). This phenomenon could be attributed to GFGL's reporting protocol adopted after the implementation of the standard that enables the company to identify and manage the risks and impacts of environmental incidents, as well as their associated costs.

The requirements to review procedures after occurrence of an emergency situation coupled with the training of workers to document and report all environmental incidents as a measure to avoid the recurrence of similar incidents contributed to the exponential increase in reported environmental incidents. This observation is corroborated by [14]. Hitherto the certification and training of workers on environmental issues, workers treated environmental incidents as trivial and did not see the need to report such incidents for appropriate measures hence the very little number of reported incidents prior to the certification.

More to the point is the fact that many expansion projects commenced just around the same time at which the standard was implemented. This increased the number of environmentally intimate activities and human population (mostly contractors) on site. Spillages of hydrocarbon and other chemicals, which comprised approximately 65% of all incidents reported, reflect the large increase in heavy machinery (generally contractor owned) on the site during the construction stage of major earthworks projects.

Environmental incidents in AGA per annum, as compared to GFGL, have not reduced contrary to what we expect from the implementation of ISO 14001 (Table 6). An analysis of the annual corporate reports shows that most incidents fall into three categories: unpermitted gas emissions, unauthorised solution overflows or discharges, and pipeline failures. These incidents occur primarily at the metallurgical operations. Paradoxically, the increase in the number of incidents reported over time is partly a function of more comprehensive reporting brought about by the implementation of the EMS. This has raised general environmental awareness and instilled a more knowledgeable and conscientious approach to incident reporting. This observation agrees with the work of [15]. Should a major environmental incident occur anywhere on the mine, a report is supposed to be made within 24 hours to the corporate office hence the increase.

5. Conclusion

The main conclusion of this work, which is in agreement with earlier published results, is that the establishment of international standards for EMS has led, during the relatively short time since their implementation, to important environmental improvements of the two mining companies. The strongest environmental effects can be found in fields where environmental improvements and cost savings go hand in hand, that is, waste management and increased number of reported environmental incidents.

It has been found that the most important indirect environmental contribution of EMS is that it raises the awareness of environmental issues [15].

Implementation of ISO 14001 leads to increase in the number of reported environmental incidents because the system encourages environmental incident reporting mechanisms. This on the long term would help the organization to have better control of their environmental footprints by developing mechanisms that help mitigate environmental impacts and the recurrence of such incidents.

The environmental performance improvements are enhanced only to the degree/extent that the system is implemented, alongside the objectives/targets and management commitment [5]. This is supported by the fact that while AGA has significantly reduced their energy consumption, the case of GFGL is contrary because of the energy conservation mechanisms adopted by the former. However, energy consumption could be dependent on the unique operation processes of each organization though they belong to the same industry.

The fact that the system requires the involvement and commitment of just about everyone at an operational level certainly helps to improve the level of environmental awareness within the company—which is the very first step towards enhancing environmental performance.

ISO 14001 certification/implementation is certainly proved to be an important driver for the enhancement of environmental performance [1, 7, 8].

Acknowledgments

The authors would like to acknowledge the management and staff of the environmental departments of the two companies—Goldfields Ghana Limited, Tarkwa Mine, and AngloGold Ashanti, Obuasi Mine—which allowed them to carry out this all-important study within their concession. The authors are indeed deeply indebted to them especially Michael Ampem-Sackey and Peter Owusu Yeboah (Environmental Superintendent and Manager of the two companies, resp.) for giving them access to their environmental data and laboratory facilities and for essential guidance they provided during the study.

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