ENVIRONMENTAL DATA BENCHMARKING REPORTING STRUCTURE FOR THE SOUTH AFRICAN GOLD MINING INDUSTRY

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ABSTRACT

In recent years legislative and economic pressure have placed pressure on the gold mining industry to be proactive in sustainable development. Companies should therefore not only report but manage their environmental impact.

Most mining companies have implemented an environmental data management system which collects the data for reporting. However, companies lack the reporting structure to identify environmental optimisation opportunities. This paper develops a simplified environmental report structure that can be used by top management for effective environmental management.

The methodology focuses on identifying environmental standard requirements followed by benchmarking each business unit in terms of best practices and previous performance. Each business unit will then be visually displayed against set benchmarking targets to identify underperformance. The main goal is to structure the knowledge obtain from the operations information in a manner to drive optimisation opportunity identification.

The methodology was implemented on a large gold mining company. Underperforming business units were identified. Further investigation identified electricity and water use saving opportunities at one of these operations.

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1. INTRODUCTION

The South African mining industry faces many challenges due to the impact that mines pose on the livelihood of local communities and the environment [1]. In 1998 the CEO’s of the largest mining companies came together at the World Forum in Davos to address the sustainable issues facing the mining industry. They decided to launch the Global Mining Initiative (GMI). The main role of the initiative was to define sustainable development and ensure long-term sustainability goals for the industry [2]. The GMI approached the World Business Council for Sustainable Development (WBCSD) to assist in the development of the definition [2].

They in turn asked the International Institute for Environment and Development (IIED) to assist in a global research effort [2]. A report was issued in 2002 named “Breaking New Ground” which defined sustainable development as follows [3]:

“One of the greatest challenges facing the world today is integrating economic activity with environmental integrity, social concerns, and effective governance systems. The goal of that integration can be seen as ‘sustainable development’. In the context of the minerals sector, the goal should be to maximize the contribution to the wellbeing of the current generation in a way that ensures an equitable distribution of its costs and benefits, without reducing the potential for future generations to meet their own needs. The approach taken to achieve this has to be both comprehensive including the whole minerals chain and forward-looking, setting out long-term as well as short-term objectives.” [3]

Since then the mining industry has come a long way in improving their sustainability [4]. Most mining companies have adopted a form of sustainability reporting. This reporting is based on numerous standards like the Global Reporting Initiative (GRI) standards and the ISO 14001:2015 standard. However, in 2018 M Tost et. al. [4] did a comprehensive literature review to evaluate how the mining industry has considered its environmental sustainability approach. They concluded that at this stage the mining industry is not setting on the wrong sustainability path. However, they are at risk of falling behind other industries leaders on natural capital considerations as well as societal expectations on climate change [4].

Additionally, to ensure effective environmental governance systems in South Africa numerous legislation were promulgated. This, however resulted in the mining industries focusing more on compliance, instead of focusing on optimisation opportunities identification.

The ISO 14031:2013 standard states guidelines for companies to evaluate their environmental performance. An environmental performance evaluation (EPE) is a useful tool to identify key environmental performance indicators (EPIs). EPIs are used to measure, evaluate and communicate a company’s environmental performance. The guidelines are based on the Plan-Do-Check-Act (PDCA) cycle. Figure 1 shows the ISO 14031:2013 guidelines in the context of this cycle. [5]

![ISO 14031:2013 PDCA Cycle for EPEs](adapted from [5])
The first step in the cycle, planning, involves selecting the EPIs that will form part of an organisation’s EPE. The EPIs are a manner of converting quantitative and qualitative data into an understandable format. This format conveys the success management efforts have in influencing the company’s environmental impact. The EPIs selected can be from existing indicators or new indicators. [5]

The do element specifies the direct actions that should be followed to complete an EPE. These actions are highlighted in the grey in Figure 1. This process generates three key elements namely data, information and results. This is the first three elements of the Data, Information, Knowledge and Wisdom (DIKW) hierarchy. This hierarchy is an integral part of information sciences and each element can be defined as follows [6], [7]:

- **Data:** A measurement of an observation
- **Information:** Processing data in the correct context to assist in answering interrogative questions like who, what and where.
- **Knowledge:** Is knowing how to create a conceptual framework of multiple sources of information to give instruction. Knowledge is understanding the patterns within information.
- **Wisdom:** Gives knowledge a frame of reference through a set of principles. It is the inherent framework of knowing good from bad.

The check and act action are important for continual improvement of the EPIs performance. The check action will include internal and external reporting whereas the act action focuses on a periodically review of the EPE system for improvement identification. [5]. Figure 2 integrates the ISO 14031:2013 PDCA cycle into the concept of the DIKW hierarchy.

As is seen from the Figure 2, executive/senior management will specify the EPIs that need to be used for an organisation’s EPE. These EPIs will be communicated to each operation. From here operations management and staff will collect the data and generate information. All the information from the different operations is then converted into a report by executive/senior management.

This report will be communicated to the board by executive/senior management in the form of a meeting. The knowledge obtained by the report will be discussed in this meeting. However, if the report already presented knowledge in a manner to assist the board with increased wisdom the likelihood of operational improvement is higher.

This paper will develop a reporting structure/layout that can be used to identify EPIs which are underperforming on facility level. The main goal is to structure the knowledge obtain from the operations information in a manner to drive EPI opportunity identification.
2. SUSTAINABLE REPORTING IN THE MINING INDUSTRY

2.1 Introduction

To develop a report structure for board level reporting which will drive improved EPI performance. It is important to understand which EPIs currently form part of the industry reporting chain and the data management principles pertaining to these EPIs. Furthermore, to improve the effectiveness of the report structure, methodologies which can drive EPI improvement should be investigated. These three key aspects will be discussed further in the proceeding sections.

2.2 Environmental Performance Indicators (EPIs)

Certain operational performance indicators (OPIs) directly relate to the impact that a company has on the environment. These OPIs are also known as EPIs. A company’s OPIs can be determined by listing the organisation’s inputs against its operational processes and relevant outputs. Figure 3 shows a general overview of a typical organisation’s OPIs. In a EPE a company needs to select their EPIs from these OPIs. [5]

![Figure 3: ISO 14031:2013 general overview of operations OPIs in terms of the environment (adapted from [5])](image)

Based on their annual integrated report, the top 5 biggest JSE listed gold mining companies in South Africa structure their EPE and equivalent EPIs against the Global Reporting Initiative (GRI) Standards. These standards are a set of modular, interrelated standards that outline global best practice in terms of sustainability reporting. They guide companies on which data and information is important to collect and report for each EPI. The 300 set of standards are relating to environmental and climate change reporting. Table 1 define the EPIs that need to be monitored by an organisation. [8]

<table>
<thead>
<tr>
<th>Table 1: GRI 300 set of standards [8]</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRI 300</td>
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<tr>
<td>GRI 301: Materials 2016</td>
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<tr>
<td>GRI 302: Energy 2016</td>
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<td>GRI 303: Water 2016</td>
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<tr>
<td>GRI 304: Biodiversity 2016</td>
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<tr>
<td>GRI 305: Emissions 2016</td>
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<td>GRI 306: Effluents and waste 2016</td>
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<tr>
<td>GRI 307: Environmental Compliance 2016</td>
</tr>
<tr>
<td>GRI 308: Supplier Environmental Assessment 2016</td>
</tr>
</tbody>
</table>

As can be seen from both the ISO 14031:2013 standard and the GRI set of standards Materials, Energy, Water, Emissions and Effluent/Waste are important indicators for the evaluation of a company’s environmental performance.

South Africa is a water scarce country. Gold mines do not consume large amounts of water compared with other industries like agriculture, but the mining industry has a significant impact on water quality [9]. Water is a crucial part of society and is closely monitored by government [10]. Water withdrawal and discharge therefore has a legislative risk [10].

Additionally, mines operational costs are increasing due to energy prices and the possibility of the taxation of greenhouse gasses emissions due to the consumption of energy [11][12]. Opportunities identification in energy and water is therefore crucial.

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2.3 Environmental data management systems

The quote by Lord Kelvin “to measure is to know” accentuates the importance of data. However, if you have large amounts of data (big data) that is either inaccurate, transferred incorrectly or contains unauthorised alterations. The knowledge obtained from this data becomes useless. Therefore, effective data management should be included in an EPE.

Data management consists of multiple fields of study. Focus should be placed on data quality and integrity for reporting purposes. Data quality is the evaluation of ensuring that the data is “fit for use” and accurate [13]. Data integrity on the other hand is the prevention of the unauthorised alterations of data [14]. Figure 4 shows the data collection for reporting process in a typical mine.

Data collection for reporting process in a typical mine

![Data collection diagram](image)

Figure 4: Environmental data collection for reporting in a gold mine

A mine’s data generation, collection, processing and reporting is handled by numerous personnel as is illustrated by Figure 4. This results that data management is not so effectively implemented. Dr M van Heerden [15] identified this problem in gold mines. She developed a web-based environmental data centralisation and management system. This system was implemented on a gold mine. The average error percentage for this mine’s reporting chain went from 20% to 4%.

2.4 Sustainable improvement through benchmarking and reporting

The evaluation of a mining operation’s current performance against an operational target or reference performance is known as benchmarking [16], [17]. Benchmarking can be used to identify the misuse of resources [18]. An intensity analysis is a method that is used to benchmark operations [11], [18]. This methodology consists of dividing an EPI usage with its operational driver which can be tonnes of product or services rendered.

The Mining Association of Canada in cooperation with other parties issued a series of publication relating to the benchmarking of energy consumption for the international mining industry. The methodology included a breakdown of the production flow into key operating sections like exploration, mining, crushing, processing and refining. An intensity analysis of the cost of the energy consumed against multiple product related drivers was done. The energy cost intensity of each operation is then compared to identify underperforming facilities. [11] [12]

Dr L.F van der Zee [11] expanded on this research by noting that this simple comparison can give a false representation that a high production mine is energy efficient. He therefore defined additional variables that need to be considered in terms of benchmarking mines with each other. These included mine operation size, mine profit contribution, mining technology and mining depth.

The study developed a table where each mine’s defined variables are compared to each other. Mines with the same parameters are grouped together for comparison. Dr C. Cilliers [18] however found that the only important variables to benchmark deep-level gold mines electricity intensity is the mining depth and tonnes rock mined. Each electricity intensity system will have an additional variable like ambient air condition and the hydrogeology of the mining area.

Dr J.I.G. Bredenkamp [21] argued that it is not always the operation with the highest electricity intensity that will result in the highest potential for cost savings. The thesis methodology simply multiplied each mine’s operations electricity consumption with a percentage of theoretical improvement. The operation with the highest theoretical improvement value should be investigated first for improvement projects. Dr L.F van der Zee,
Dr C Cilliers and Dr J.I.G Bredenkamp studies specifically focused only on benchmarking South African deep-level mines electricity usage.

In 2016 the South African Department of Water and Sanitation published a report that defines national benchmarking targets for the gold mining industry’s water intensity. The definition for consumptive specific water use in this report is like the GRI Standards. Water intensity for this indicator was benchmarked against total gold-rich rock (also known as ore) mined. This amount excludes the total waste rock mined. The average South African gold mine’s water intensity is $2.02 \text{ m}^3/\text{t}$. [22]

A combination of all these methodologies and targets will be used to define the benchmarking parameters within the reporting structure.

3. ENVIRONMENTAL REPORTING STRUCTURE

3.1 Introduction

To drive EPI improvement through reporting, the report structure should display knowledge in a manner that will stimulate increased wisdom. This will assist to ensure the correct decisions for improvement are made. Figure 5 illustrates the PDCA cycle displayed in Figure 1 in a new context of effective data management and improved report structure.

As can be seen in Figure 5, the top management report is an integral part of the reporting chain. Board level reporting should be simplified and not overly complex. The top management report structure should only indicate facility level performance. As discussed in section 2.4, to drive sustainability improvement through benchmarking, the report therefore will have the following key analysis namely operations classification, intensity analysis/benchmarking and theoretical improvement opportunity identification. Each of these sections will be discussed in more detail below.

3.2 Operational classification

To benchmark the mining facilities against each other to identify underperformance. Facilities with similar characteristic should be compared. Multiple OPIs can be used for a benchmarking comparison [11]. However, for this analysis the following three will be used.

3.2.1 Mining method

The Mining Association of Canada publications separated all the benchmarking methodologies into the different mining methods [20]. A breakdown was then done in terms of production flow. This same principle will be used for the report framework as the deep-level mines will be separated form open-pit mines. The gold processing facilities will also be separate from the mining operations.
3.2.2 Mining depth
As indicated by Dr C Cilliers [18] a mine’s depth can have a significant influence on the electricity intensity of deep-level mines and will therefore be used as part of the classification.

3.2.3 Volume of material
The volume of material generated or used will help to accurately classify the type of operation. In terms of mining this variable is important because older mine’s production will be lower than newer mines due to depleted resources. Gold processing plants will process two types of materials namely tonnes ore treated or old waste material each of these materials also have a significant impact on the processing intensity of the operations.

3.3 Intensity analysis and benchmarking
Benchmarking is defined in section 2.3 as comparing the current operational performance with previous performance or against a set target. The intensity analysis will display the previous financial year intensity against current performance. This will immediately show if a mine is improving or declining in performance. If there are similar operations in the company, as identified by the classification, the mines current performance can also be compared. Finally, if there is a company, national or international benchmarking target for a EPI this will be displayed on the analysis for improved decision-making.

3.4 Theoretical improvement
After an overview of the current operations have been given. A table or graph should be added to guide top management to allocated resources to the mine with the most theoretical level of improvement. This will be done by multiplying the EPI consumption with a company’s optimisation target.

4. APPLICATION OF STRUCTURE FOR A GOLD MINING COMPANY

4.1 Introduction
The purpose environmental report structure was based on Dr M van Heerden’s implemented web-based data management system. For the reasons mentioned in section 2.1 continual optimisation is crucial in EPIs water and energy. The top management report for this company is developed on a quarterly basis. The company consist of 11 mining operations, two independent gold processing plants and one retreatment facility. The mining company in same cases will define a mine with both its shafts and gold plant as can be seen in Table 2.

This is due to the limitation the company has with data collection and metering on systems level. The main problem is that when the operational inputs, energy and water, arrive at the operations it is difficult to allocate the consumption to the processing facility or the mining operations. The mine classification technique, intensity/benchmarking analysis and operational improvement is shown in the proceeding sections.

4.2 Operational classification
The mining operations were classified against the amount of rock that they mine and the mining depth. The gold plants were classified by the type and amount of product they treat. The product that a gold plant can treat is either ore milled (also known as tonnes treated) or old process waste, also known as tailings, that still have traces of gold. Table 2 outline the gold mining company’s classification. Due to the sensitivity of the processed volumes data. This variable will be classified as the following: small 0 - 700 000, medium 700 000 - 1 000 000, large 1 000 000 - 1 300 000 and mega > 1 300 000.

<table>
<thead>
<tr>
<th>Company operations</th>
<th>Mining method</th>
<th>Mining depth</th>
<th>Previous FY volumes</th>
<th>Product variable</th>
<th>Classification group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine 1</td>
<td>Deep-level shafts</td>
<td>3,388</td>
<td>Medium</td>
<td>Rock mined</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Gold plant</td>
<td>N/A</td>
<td>Medium</td>
<td>Rock mined</td>
<td></td>
</tr>
<tr>
<td>Mine 2</td>
<td>Deep-level shafts</td>
<td>1,978</td>
<td>Medium</td>
<td>Rock mined</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>Gold plant</td>
<td>N/A</td>
<td>Large</td>
<td>Rock mined</td>
<td></td>
</tr>
<tr>
<td>Mine 3</td>
<td>Deep-level shafts</td>
<td>1,452</td>
<td>Small</td>
<td>Rock mined</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>Gold plant</td>
<td>N/A</td>
<td>Small</td>
<td>Rock mined</td>
<td></td>
</tr>
</tbody>
</table>
4.3 Intensity analysis and theoretical improvement

The Department of Water and Sanitation report [22] and the mining company use the tonnes of ore treated/ore milled for calculations and reporting. This means that this product’s information is available for each operation. The intensity analysis was therefore done against this product. The total energy consumed by the mining company’s operations consists of electricity, diesel, petrol, polyfuel diesel and explosives. All these energy types were converted into the same energy unit namely gigajoules (GJ). The total water withdrawn only consists of two variables namely potable water and non-potable water. These inputs are both measured in kilolitres/cubic meters (m³). Figure 6 illustrates the OPIs against the mining operations processes.

Figure 6: Breakdown of energy and water consumption sources in mining company

The key observation of the intensity analysis is summarised in Table 3.

Table 3: Key observations made from intensity analysis

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Key observations</th>
</tr>
</thead>
</table>
| Figure 7 and 8 | • Open pit mines are less energy intensive  
| | • Only mine 2 and mine 10 operates below the group average energy intensity |
All the mines, except mine 11 had an increase in energy intensity in the first quarter of 2018
Retreatment of tailings is less energy intensive than ore milled
It can be observed that the intensity for all the operations are irregular and does not show consistency or a consistent decline. This is an indication that not effective management is implemented.

<table>
<thead>
<tr>
<th>Figure 10 and 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine 2 water intensity significant decrease due to the installation of a water treatment plant</td>
</tr>
<tr>
<td>Mine 1, 6 and 7 operates higher than the national benchmark</td>
</tr>
<tr>
<td>Mine 7 is 2 times more inefficient than its closest competitor.</td>
</tr>
<tr>
<td>It can be observed that the intensity for all the operations are irregular and does not show consistency or a consistent decline. This is an indication that not effective management is implemented.</td>
</tr>
</tbody>
</table>

The company defined a 5% improvement for the company operations in terms of water and energy consumption. Figure 9 and Figure 12 illustrate the theoretical improvement that each of the operations can achieve if their consumption is multiplied by the 5% reduction target. As is seen in these figures Mine 1 has the highest potential for improvement for both water and energy consumption. Mine 1 should therefore be firstly investigated for improvement opportunities.
Figure 7: Energy intensity analysis of mining company
Figure 8: Energy intensity analysis of mining company continue

Figure 9: Theoretical potential for energy improvement
Figure 10: Water intensity analysis of mining company
VALIDATION AND OPPORTUNITIES IDENTIFIED

The key requirement of the report structure is to assist in identifying underperforming facilities and improve EPI improvement at these facilities. The report structure identified that Mine 1 is both inefficient and has the highest level of theoretical improvement for energy. For water, Mine 1 is under the top three worst performers and second with theoretical improvement. The mining company is investigating available opportunities in the company. Table 4 outline the key opportunities that have been identified in Mine 1. In some cases, these projects have been already implemented.

Figure 11: Water intensity analysis of mining company continue

Figure 12: Theoretical potential for water improvement

5. VALIDATION AND OPPORTUNITIES IDENTIFIED
Table 4: Mine 1 key improvement opportunities identified

<table>
<thead>
<tr>
<th>Environmental Indicator</th>
<th>Opportunities Identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>The evaporator pump at the fridge plant that supplies cold air to underground staff is not dynamically controlled resulting in overcooling.</td>
</tr>
<tr>
<td>Electricity</td>
<td>Compressed air is wasted through the underground refuge chambers.</td>
</tr>
<tr>
<td>Electricity</td>
<td>The installation of a larger bypass control value for each production level compressed air supply. Reduce compressed air wastage.</td>
</tr>
<tr>
<td>Water</td>
<td>22 Cooling cars at the working stations were removed without compromising ventilation requirements. A 50 l/s reduction in services water consumption was achieved.</td>
</tr>
<tr>
<td>Water</td>
<td>Leak repairs in the water network were identified.</td>
</tr>
</tbody>
</table>

The total impact the mine has made to date in the electricity cost avoidance at Mine 1 is over R 33 million. A quarterly energy intensity reduction due to these saving can be seen in Figure 7. Further investigation into the water network was initiated by the mining company due to the identification of Mine 1’s underperformance. The water network audits identified that the mine’s single men’s hostels were consuming above average amount of potable water. Figure 13 illustrates the comparison of Mine 1’s consumption with a similar hostel in the mining group.

The occupancy of Mine 6 hostels is 1400 people whereas Mine 1 hostels only occupies 1104 people. This illustrates that there is large potential for water reduction savings at the Mine 1. Current investigations are underway to reduce consumption. The report structure methodology is therefore validated and can be used to identify underperforming facilities and EPI improvement can be achieved at these facilities.

6. CONCLUSION

The gold mining industries placed more focus on compliance, instead of focusing on optimisation opportunities identification. The ISO 14031:2013 standard can be used to evaluate a company’s environmental performance. An EPE is a useful tool to identify key environmental performance indicators (EPIs).

Gold mines should first prioritise the improvement of energy and water consumption due to the operational costs and legislative risks. A web-based database should be used to centralise all the environmental data and increase the data confidence in terms of quality and integrity. An intensity analysis can be used to identify underperforming facilities. The mines with the same characteristics can also be compared to identify underperformance in terms of benchmarking.

The PDCA cycle of the ISO 14031:2013 was applied to the gold mining industry’s reporting chain. It was found that the top management report is a key aspect of the reporting chain. This report can assist to stimulate...
improvement of EPIs water and energy consumption. The report should be presented in a manner that will assist top management in improved decision-making.

The methodology was applied to a gold mining company. It was found one of the mines, namely mine 1, was significant underperforming when compared with a similar mining operation and group level intensities. The cost avoidance in terms of electricity consumption is over R33 million to-date.

REFERENCES
