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Research

ASPECT IDENTIFICATION AND ENVIRONMENTAL RISK ASSESSMENT IN THE ELECTRICITY SECTOR: A CASE OF SWAZILAND ELECTRICITY COMPANY

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ABSTRACT

The electricity industry is central to the world's economy and for economic development, particularly for third world countries notwithstanding all known benefits there remains risks associated with electricity generation, transmission and usage. Therefore, the focus of this paper is to identify the aspects and risks associated with the various processes involved in each step and suggest all possible measures to control the identified risks.

A tool was explored and designed from clause 4.3.1 of ISO14001 Environmental Management System standard, for environmental risks assessment within Swaziland Electricity Company (SEC). The tool was used to identify, evaluate risks significance and propose mitigation measures and/controls. The sampled populations in this study were employees from the generation, transmission and distribution departments at SEC. The top five significant impacts identified in the study were: air and water pollution, natural resource degradation/depletion, loss of disturbance to flora and fauna, social impacts and visual impacts respectively**.** This study provides a baseline information and a simpler tool for environmental risk assessment in any sector. It will also improve environmental performance at SEC and ensure sustainability in the sector.

INTRODUCTION

Electricity and its infrastructure is lifeblood of society. The processes in its generation, distribution and transmission have caused various occupational health and safety risks to employees and the public as well as serious environmental degradation. (Darbra, *et al.,* 2008) states that over the years, there is a growing concern about the environment and the potential risks associated with many human activities and new technologies have created increasing interest in environmental risk assessment, a critical, essential tool in any decision making process in business. (Thornton, 2009), also notes that, failure to effectively incorporate and manage risks can more, often than not, lead to serious consequences to a business such as damaged reputation, loss of profits, disruption of productivity or at worst, business shutdown. Supporting the above statement, (Sand, *et al.,* 2007), further highlights the electricity industry involves many processes and operations which are associated with various risks. They document such risks as; economic, safety, environmental, quality of supply, reputational, vulnerability and regulatory risks. The issue of risk management is therefore, critical in the electricity sector in order to ensure improved efficiency and reduce environmental risks during service delivery. In particular hydro dams and transmission lines have significant effects on water and biodiversity. It is therefore, essential for the electricity sector to identify such environmental risks and evaluate them.

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A report by the Ministry of Energy and Parks, 2000, defines environmental risk assessment (ERA) as a process that evaluates risks to environment caused by human activities and natural disasters. ERA also assesses the appropriate level of precaution and interrelated risk management measures to reduce and mitigate aspects and their adverse impacts so as to achieve an acceptable risk level. It is an important component and useful technical method of environmental impact assessment (EIA). Thefore, this helps to evaluate, prevent and alleviate extremely adverse environmental impacts. In this way, it can provide scientific evidence for environmental decision-making, and therefore has been widely applied across the world over the past several decades. However, it has been observed that forecasts on risks on the environmental is often lacking hence it is necessary to undertake risk assessment to ensure sustainable development. In addition, Jorge also argues that while knowledge and research about environmental consequences of systems for power generation is abundant, data and available studies on environmental impacts for power transmission and distribution systems are somehow limited.

Nordgård states that there is an increased awareness to incorporate risk analyses into the (companies' decision making and such risks include economic, safety and environmental impacts. Additionally solutions must be sought for risks and that all risk aspects must be sufficiently taken care of. Therefore this motivates for the use of various risk assessment methods to ensure that all risks are identified and controlled to acceptable levels. Norgard, *et al.*, states that there are different risk consequences relevant to the electricity sector; amongst these are the environment risk which include, emissions from oil filled components, SF6 gas leakage, visual pollution from overhead lines. Therefore, the management of environmental risks is key, in the electricity sector. This paper therefore presents the risk assessment methodology used in the electricity sector in Swaziland. The basic step of the framework generally follows risk management principles based on Australia/New Zealand Standard (2004).

The study's main objective is to identify the aspect associated with each step involved in the generation, transmission and distribution of electricity at SEC and to generate controls to ensure that risks are eliminated or reduced to tolerable level. The aspect identification and risk assessment tool was developed from clause 4.3.1 of ISO14001 to improve safety at Swaziland Electricity Company. Brain storming sessions were used to gather the data.

Section 2 of the paper presents the definition of aspect identification and risk assessment with reference to some concepts from literature. The proposed simplified tool is then presented in section 3. Section 4 concludes with the findings of the study.

BACKGROUND

Aspect identification and risk assessment

An environmental aspect is defined by the international standard ISO14001:1996 as an element of an organization's activities, products or service that can interact with the environment.The environment is defined as surroundings in which an organization operates including air, water land, natural resources, flora, fauna, humans and their interrelation. The identification of environmental aspects often considers, e.g., emissions to air, releases to water and land, use of raw material, waste and natural resources and impacts on biodiversity. Zobel and Burman, state that, the identification and assessment of environmental aspects are key element to organizations implementing environmental management systems. It is very important in decision making to reduce the risk and possible environmental in organizations

The process of aspect identification is key in organizations as it helps to understand how the organization's activities, services and products affect the environment. Semi quantitative and quantitative methodologies can be used for aspect identification. ISO 14004 states: there is no single approach for identifying environmental aspects and environmental impacts and determining significance that will suit all organizations. The analysis used for identifying and assessing the environmental aspects includes brain storming, screening processes, inspections, analyzing process by process and environmental aspect grip (Stowe, 2001). For this paper brain storming has been used to identify environmental aspects related to SECs operation departments. The other methods were not chosen since they are more formal, laborious and sophisticated.

General framework of risk assessment

Risk assessment is a step-wise process consisting of interrelated but distinct phases. Thus the context must be established first before the aspect is identified. The same is true for estimation of the risk stage, in that it cannot start until finishing identification of the aspect stage. Five stages of risk assessment have been identified (Bowden, *et al.*, 2001), which are establishing the context, identifying the risk, estimating the risk, evaluating the risk and controlling/responding to the risk. This has

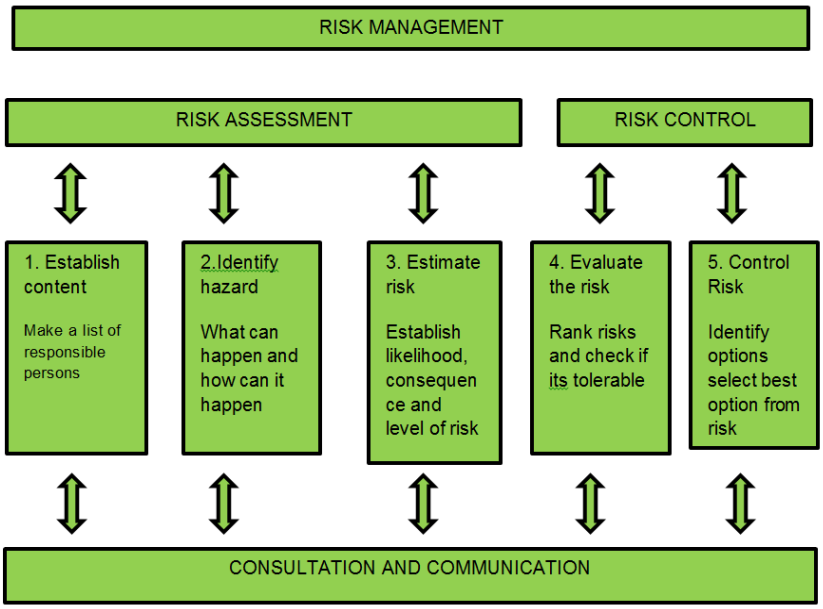

Fig. 1 Shows hazard identification adopted from Australia New Zealand risk standard (2004).

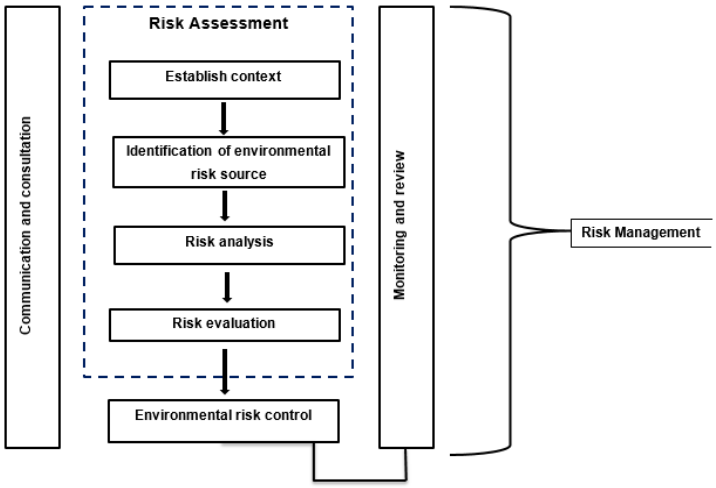

Fig. 2 Environmental risk assessment and management process which has been used in this study adopted from Australia New Zealand risk standard (2004).

been adopted from a framework by Australia New Zealand risk standard 2004 as shown in Fig. 1.

A simplified version has been developed from this framework for this study as shown in Fig. 2.

METHODOLOGY FOR ASPECT IDENTIFICATION AND RISK ASSESSMENT

The steps in the following sections highlight the tool that was used for aspect identification and risk assessment at Swaziland Electricity Company, the case for the study.

Planning

Sampling and data collection: In this research study, sampling involved the various business units of the electricity company; Operations, Customer Services, Finance, Support services and Corporate services. The sampled business units were generally those representing operations namely power generation, transmission, and distribution and the study explored the aspects associated these units. The study employed qualitative and quantitative research techniques to arrive at the purported objectives. The research used a field survey where questionnaires and interviews were used for data collection as well as brainstorming sessions with teams of experts from the various electricity operations. To obtain a better understanding of business unit's activities and their environmental risks, on-site observations were done and brain storming sessions were conducted by the researcher. The business unit teams consisted of experts for instance (electrical technician or engineer, mechanical engineer, equipment operators, the safety officer, station manager and the researcher).

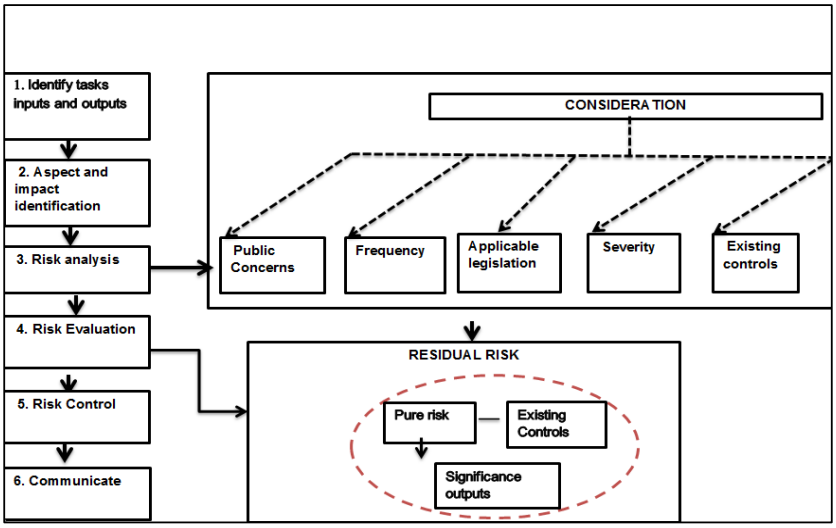

Fig. 3 Aspect identification and risk assessment process.

Aspect identification: Data collection was based on the following, experienced employees who were well versed of their daily activities and associated risks and control and a competent team to do the aspect identification. The business unit's teams from (generation, transmission and distribution) assembled and conducted the aspect identification and environmental risk assessment following the process using the chart in Fig. 3. A team of experts from the sampled business units engaged in a brainstorming session and identified the aspects. The business units listed all activities and processes in their departments, including those carried out in routine, emergency and non-routine basis. They identified all processes and related inputs and outputs and determined the associated aspects. They also had to identify legal requirements related to activities carried out and related controls. This stage was meant to determine potential risks associated with activities performed by personnel and their impacts on the environment.

Risk analysis/evaluation: The aspect identification stage was followed by risk analysis where the aspects and associated risks were evaluated. It determines the significance of risk and judges whether a risk is acceptable or not.

Aspect evaluation criteria for safety and significance determination: The purpose of the impact evaluation process was to identify and evaluate the significance of the identified environmental impacts associated with the particular activity. This was done according to the criteria given in the next section. Measures were identified that avoid or minimise adverse effects and enhance environmental benefits. The residual impacts are those impacts that remain even after mitigation. The impacts are described in terms of significance which is usually the function of the magnitude of the impact, or likelihood of impact to occur. The impact magnitude is sometimes referred to as severity (a function of extent, duration and intensity of the impact. This was done according to the criteria shown in the next section.

The risk evaluation process was carried out by a selected team of competent personnel depending on the issues being addressed. Each identified aspect was assigned a rating from 1-4 to indicate the relative importance of its related environmental impact using the criteria discussed below. The risk evaluation methodology was assessed using the scoring tables developed from a risk assessment process by Newbury, 2000 and is shown below:

Criterion 1=Legislation and/or other requirements

Is the identified aspect applicable to the country's environmental legislation and or other legal requirements the company subscribes to?

Criterion 2=Concerns of interested parties

Is the identified aspect a concern to the surrounding community, stakeholders etc.?

Criterion 3=Impact of aspect on the environment (severity)

What is the effect of the identified aspect/impact on the environment?

Criterion 4=Frequency

How often does the identified aspect occur?

Criterion 5=Controls

Are there any existing controls/mitigation measures?

(Operational controls, administration controls, engineering controls, permits etc.)

Significant risks: Significant aspects were determined as those with a priority score between 12 and 16. The following table was used as a guide to determine timeframes and appropriate action to be undertaken for the different priority environmental aspects and impacts identified. Actual timeframes were agreed upon with the different risk assessment teams (Tables 1-6).

Table 1. Criterion for Legislation and or other requirements

Score	Description	Definition
1	Insignificant	Applicable to neither
2	Minor	Could be (Lack of awareness)
3	Moderate	Applicable to either one
4	Major	Applicable to both legislation and other requirements

Table 2. Criterion for concerns of interested parties

Score	Description	Definition
1	Insignificant	Not a concern
2	Limited	Could become a concern
3	Moderate	Some interested parties may be concerned
4	Significant	Serious concern to interested parties including political or activities, intense negative media, public anger/lawsuits etc.

Table 3. Criterion for impact of aspect on the environment (severity)

Score	Description	Definition
1	Insignifi-cant/Negli-gible/Minor	Minor consequences/easily correctable
2	Moderate/ Marginal	Small potential impact but correctable
3	Serious	Likely to significantly damage the environment. Difficult, but possible to remediate
4	Critical/ Catastrophic	Wide spread damage to the environment and requiring great effort to remediate or correct

Table 4. Criterion for frequency

Score	Description	Definition
1	Unlikely/ Rare	Minor consequences/easily correctable
2	Possible/ Regular	Small potential impact but correctable
3	Likely Occasional	Likely to significantly damage the environment. Difficult but possible to remediate
4	Frequent	Wide spread damage to the environment and requiring great effort to remediate or correct

Table 5. Criterion for controls

Score	Description	Definition
1	None existent	No controls in place
2	Limited	Limited controls: e.g. Administrative controls only in place
3	Moderate	Moderate controls: e.g. Administrative and Operating controls in place
4	Full control	Full controls: e.g. Engineering controls, Administrative controls, Operating controls and or other controls in place

Table 6. Time frames for auctioning risks

Total score	Level of significance	Action	Time-frame
1 -5	Low	Short Term	Monitor
6-11	Medium	Medium Term	Within 6 months
12-16	High (Significant)	Manage	Within 3 months

The intention is to reduce impacts to "as low as reasonably practicable" (ALARP)

RESULTS AND DISCUSSION

The aspect identification and risk assessment was conducted for the operations department (generation, distribution and transmission) at Swaziland Electricity Company. The results for the generation's department are presented in the risk register below (Table 7):

Environmental aspects and impacts in the electricity sector

Many serious environmental risks are by products of electricity generation, transmission and distribution infrastructure and processes. Jorge states that electricity generation and transmission processes have a number of environmental impacts. Processes such as maintenance and installation of infrastructure in the transmission and generation systems result in spillages and leakages of mineral oil, zinc and SF6 that occur from the equipment throughout the lifetime. For substation equipment using SF6, the impacts due to gas leakages can be the main process for climate change scores. For the transmission line in a study conducted by Golder in 2012, on a transmission line in southwest Washington State, the identified impacts were environmental and social issues in nature. Such impacts included land use, cultural resources, aesthetics, public health and safety, sensitive plants and animals, soil erosion, wetlands, floodplains, fish, wildlife and water resources, and environmental justice issues (potential impact on low-income and minority populations). The operational aspects included the construction activities, right-of-way clearing, and impacts of construction and operation

Table 7. Aspect register for the distribution department

Distribution Department Register																				
No	**Work Activity**	**Inputs and Outputs**	**Aspect**		Condition	**Assessment**														
					Normal/Abnormal/ Emergency (N/A/E)	**Significance Evaluation**														
				Impacts		Legislation	Concerns	Environmental Impact	Frequency	**Pure Risk Level**	Existing control	(5) No need for controls	(4) Full controls in place	(3) Moderate controls	(2) Limited controls	(1) Nonexistent controls	Existing Controls/ Mitigation measures	**Residual Risk Level**	**Significance (Low/Medium/High)**	**Legislation**
	Planned and Reactive maintenance	Man Power, Erosion	Disposal of waste electrical components	Soil pollution	N	4	3	2	3	12	Waste Procedures in place and trainings on waste management done				**X**		2	**10**	**M**	Waste Regulation 2000
	-Excavation and trenching (digging)	Tillage																		
1	-Pole mounting	Repaired line																		
	-Bush clearing	Scrapped material and Contaminated Scrap	Disposal of creosote treated poles	Soil pollution	N	4	3	3	3	13	None					X	1	12	H	Waste Regulation 2000
	-Use of ladder and other tools/ equipment	Disturbed flora and fauna	Disposal of scrap transformers	Soil pollution	N	3	3	2	4	12	Waste Procedures in place and trainings on waste management done				X		2	10	M	Waste Regulation 2000
	-Replacement of faulty transformers	Accidental spills	Generation and disposal of used transformer oils	Soil Pollution	A	3	3	2	4	12	Waste Procedures in place and trainings on waste management done				X		2	10	M	Waste Regulation 2000
	-Use of lifting equipment (cranes) -Pole erection, climbing and stringing -Testing of live circuit	Electric and magnetic fields (EMF), PPE	Soil tillage	Surface-water Pollution	N	3	3	3	4	13	None						1	12	H	Environment management Act 2002

		Man power, route , Transport , Location	Bush clearing	Degradation/ Use of biological resources	N	4	4	3	2	13	Bush clearing Guidelines in place				X		2	9	M	Environment management Act 2002
2	Earthing	Electric and magnetic fields (EMF), Link sticks	Soil tillage	Surface-water Pollution	N	3	3	3	4	13	None						0	13	H	Environment management Act 2002
	-Digging of the ground during earthling	Disturbed flora and fauna																		
	New Projects Execution and Connection of New Customers (Services)	Protective clothing , Erosion, Man power, Route	Disposal of waste electrical components	Soil Pollution	N	3	3	2	4	12	Waste Procedures in place and trainings on waste management done				X		2	10	M	Waste Regulation 2000
	-Excavation and trenching (digging)	Tillage																		
	-Bush clearing	Repaired line																		
	-Use of ladder and other tools/ equipment	Scrapped material																		
	-Replacement of faulty transformers	Disturbed flora and fauna	Disposal of creosote treated poles	Soil Pollution	N	2	2	3	3	10	Waste Procedures in place and trainings on waste management done				X		2	8	M	Waste Regulation 2000
	-Use of lifting equipment (cranes)		Disposal of scrap transformers	Soil Pollution	N	3	3	2	4	12	Waste Procedures in place and trainings on waste management done				X		2	10	M	Waste Regulation 2000
	-Construction of a new line		Generation of used transformer oils	Soil Pollution	A	3	3	2	4	12	Waste Procedures in place and trainings on waste management done			X			3	9	M	Waste Regulation 2000
	-Surveying of a new line		Soil tillage	Soil degradation	N	3	3	3	4	13	None						1	12	H	Environment management Act 2002

Table 8. Summary of aspects in the operations department at Swaziland Electricity Company

Aspect	Location (s)	Potential Impact (s)	Action (Controls)
Water consumption/Improper water management (water leaks)	All divisions/sites (With the highest rank recorded within Distribution department activities and for "car-wash" related activities)	Natural resource degradation/depletion	Water use is monitored. Resource management awareness conducted companywide through platforms such as bulletins, environment talks etc.
Waste disposal (Improper waste management and unplanned disposals) Applies all (general/special/ hazardous) types of wastes	All divisions/sites (With the highest ranks recorded within Operations division)	Land degradation/ pollution (Contributing also to increased volumes to landfill sites)	General recyclable waste is collected in segregated waste bins and picked by awarded legally authorized waste management service providers. Special and hazardous waste is also stored in allocated bins and collected by selected legally authorized waste management service providers. Contractors required producing manifests from disposal or recycling facilities.
Green House Gas release due to vehicle use/aerosol containing products/SF6 gas leaks	All divisions/sites (SF6 gas found within Transmission Substations)	Air pollution/Ozone depletion	Vehicles are inspected daily and serviced accordingly to prevent damaged exhausts. Unleaded petrol is used for fueling vehicles. MSDS sheets for products available on sites and chemical inventory done Company investigating for a technology to replace SF6 gas in transformers
Bush or vegetation clearing/soil tillage or land preparation	Distribution, transmission	Loss of or disturbance to flora and fauna Land degradation/ pollution Social Impact	Environmental impact assessments are conducted for large scale project prior to implementation. Consent from land owner or community representative(s) is requested before works begin Bush/vegetation clearance guidelines and legislation of flora are adhered to.
Contaminant runoff (Due to spills from transformer oil, diesel, paraffin, chemicals, detergents, oil from equipment such as dredging vessels etc.)	Mainly applicable to the Operations division and Commercial Services department, however also recorded within other divisional activities such as cleaning and "car-wash" related)	Water pollution Land degradation/ pollution Social Impact	Bunding around substation and depot transformers is established. Oil separators have been designed for oil management Oil spill kits are available on site for immediate response to spills.
Energy/Electricity consumption *More than 50% of our electricity is imported from Eskom who generates it from coal (a non-renewable resource)	All divisions/sites	Natural resource degradation/depletion Air pollution/Ozone depletion	Electricity use is monitored. Resource management awareness conducted companywide through platforms such as bulletins, SHERQ talks etc. Energy saving light bulbs are encouraged for use.

Storage and use of hazardous/ harmful products such as creosote treated poles, diesel (in diesel tanks)	Distribution Department and transmission department	Land degradation/ pollution Water pollution	Bunding in floor of shed to contain diesel spill. A procedure On handling and managing creosote treated poles is available Creosote treated poles are stored in such a manner that there is no contact with ground i.e. on a sealed surface or on racks above ground

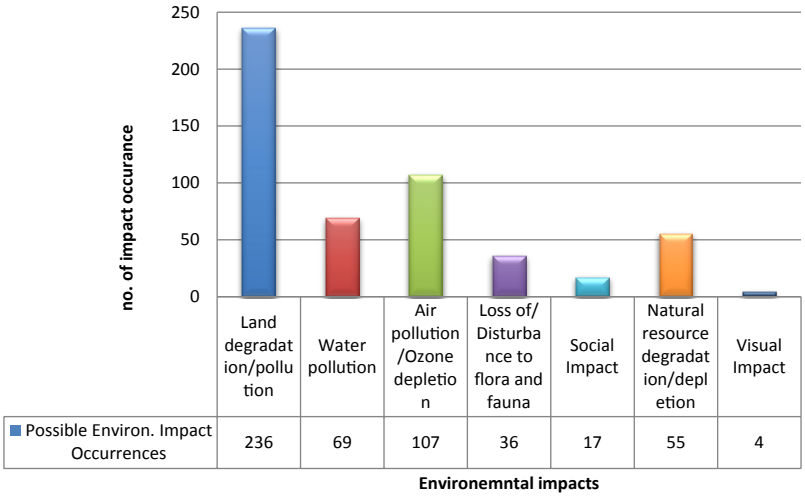

Fig. 4 Environmental impacts in the operations department**.**

Table 9. Environmental impact distribution in the operations division.

Department	Environmental Impacts					
	Water pollution	**Air pollution**	**Soil Pollution**	**Flora and fauna disturbance/loss**	**Soil erosion**	**Water and electricity resource use**
Generation	6	4	7	0	0	5
Transmission	3	2	12	3	1	0
Distribution	7	9	19	6	3	4

of towers, access roads, substations and related facilities.

The significant aspects identified in the operations department at SEC are presented in Table 8 and are in line with the above studies. These are generally water consumption, waste disposal, greenhouse gas release, bush or vegetation clearing, contaminated runoff, storage and use of hazardous/harmful and energy/electricity consumption (Fig. 4). The potential impacts and existing control measures were identified for each aspect. Additional control measures were also identified.

Table 9, below indicates that water and electricity resource utilization have a significant impact in the generation department. This can be attributed to the fact that electricity generation is mainly hydro-based hence after generation the water is recycled back into the river. It was also noted that impacts such as soil erosion and disturbance to flora and fauna are non-existent in the generation department. However, these results are challenged as there has been evidence of soil erosion where water from canals is discharged during maintenance of the generation infrastructure.

Soil pollution or degradation is caused mainly by poor waste disposal, petrochemical spillages and leakages as well as poor storage of materials and waste. It showed that 68% of the soil pollution is caused by poor waste disposal methods (Fig. 5).

CONCLUSION

The results elevate the need to identify the environmental risks and provide value to understanding the need for controlling and mitigating risks in the electricity industry. The simpler environmental risk assessment tool developed in this study provides opportunities to minimize and manage risks experienced by the operational division in the electricity sector. The developed tool has been tested and used by competent personnel within various departments in the electricity company. The

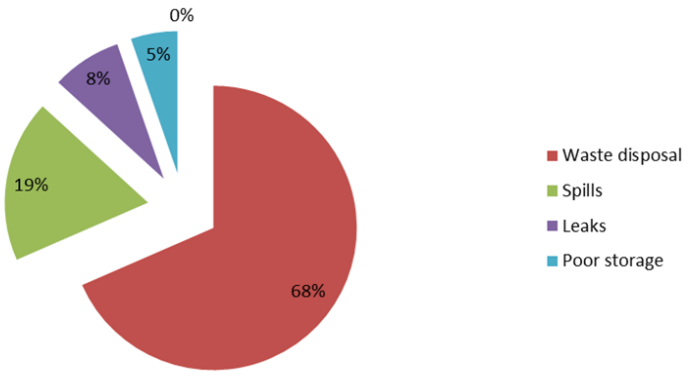

Fig. 5 Aspects and causes of soil pollution in the operations department.

teams attested that the tool was reliable and user friendly. The aspect of subjectivity was minimized by using consensus when undertaking risk analysis and estimation. Hence the developed tool can be used in any industry, provide an efficient and effective way of risk management.

This research has established a baseline for researchers who will be conducting studies on environmental risk assessment. This study will also help organizations and practitioners as they are trying to ensure continual improvement and meeting the requirements of King 11 act as well as other environmental legislations.

It is recommended that the tool could be used in other utilities and could also be tried out in other business sectors. The integration of other management system can be studied with a similar approach such as ISO 9001: 2015 Quality Management System and ISO 50001 for energy management.

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