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Original Article

An Investigation of Health and Safety Measures in a Hydroelectric Power Plant

Amevi Acakpovi [1,*], Lucky Dzamikumah [2]

[1] Electrical/Electronic Department, Accra Polytechnic, Accra, Ghana
[2] Open University of Malaysia/Accra Institute of Technology, Accra-North Accra, Accra, Ghana

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ABSTRACT

Background: Occupational risk management is known as a catalyst in generating superior returns for all stakeholders on a sustainable basis. A number of companies in Ghana implemented health and safety measures adopted from international companies to ensure the safety of their employees. However, there exist great threats to employees' safety in these companies. The purpose of this paper is to investigate the level of compliance of Occupational Health and Safety management systems and standards set by international and local legislation in power producing companies in Ghana.

Methods: The methodology is conducted by administering questionnaires and in-depth interviews as measuring instruments. A random sampling technique was applied to 60 respondents; only 50 respondents returned their responses. The questionnaire was developed from a literature review and contained questions and items relevant to the initial research problem. A factor analysis was also carried out to investigate the influence of some variables on safety in general.

Results: Results showed that the significant factors that influence the safety of employees at the hydroelectric power plant stations are: lack of training and supervision, non-observance of safe work procedures, lack of management commitment, and lack of periodical check on machine operations. The study pointed out the safety loopholes and therefore helped improve the health and safety measures of employees in the selected company by providing effective recommendations.

Conclusion: The implementation of the proposed recommendations in this paper, would lead to the prevention of work-related injuries and illnesses of employees as well as property damage and incidents in hydroelectric power plants. The recommendations may equally be considered as benchmark for the Safety and Health Management System with international standards.

1. Introduction

Health and safety at the workplace is paramount for the well-being of the workers and neglecting these can result in several unfortunate losses. Studies on occupational health and safety management have tended to cluster in certain areas during historical periods of time, focusing on policy and practice, individual characteristics and social relationships, events and incidents of injuries or accidents, management control, and industrial relations [1]. Early research by psychologists and sociologists examined individual dispositions and social causes utilizing disciplinary frameworks in developing concepts and theoretical insights into occupational health and safety [2]. These findings were further enhanced by the results of workplace surveys by industrial relations specialists that drew attention to the importance of legislation and innovative nonregulatory as well as regulatory strategies [3]. Since 1950, the International Labor Organization and the World Health Organization have shared a common definition of occupational health that was adopted in 1950 and later in 1995. The definition reads as follow:

> "Occupational health should aim at: the promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations; the prevention amongst workers of departments from health caused by their

* Corresponding author. P.O. Box: GP 561, Accra, Ghana.
E-mail address: acakpovia@gmail.com (A. Acakpovi).

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working conditions; the protection of workers in their employment from risks resulting from factors adverse to health; the placing and maintenance of the worker in an occupational environment adapted to his physiological and psychological capabilities; and, to summarize, the adaptation of work to man and of each man to his job."

Furthermore, it was argued that the subject of safety and health in the workplace covers a wide spectrum of issues. Among them are issues related to working with hazardous chemicals and minerals as identified by Hirtenlehner [4]: (1) exposure to contagious diseases and passive smoking [5]; (2) psychological safety such as stress, fears, and attitudes [6]; (3) psychosocial safety such as indifference, xenophobia, homophobia, and lesbophobia [7]; (4) criminal and sexual harassment in the workplace [8]; (5) working within harmful workplace emissions [9]; (6) manufactured and manufacturing of harmful substances and innovations [10]; (7) harmful infrastructural constructions such as unsafe stairways, unsafely built structures, and slippery floors [11]; and (8) terroristic intrusions and massacres in the workplace and safety precautions, safety communication measures, and personal protection equipment [12–14].

In recent times, occupational health and safety in power plants has seen a significant improvement due to increased oversight and government regulations in safety. In South Africa, an occupational Health and Safety Act Number 85 enacted in 1993, states that the general duties of employers to their employees is to make sure that they provide and maintain as far as reasonably practicable, a working environment that is safe and without risk to the health of any employee. This means making sure those workers and others are protected from anything that may cause harm, and effectively controlling any risk to injury or health that could arise in the workplace. Despite the safety act mentioned above, there are unfortunately, an estimated 2 million men and women who die every year according to the International Labor Organization and this is as a result of occupational accidents and work-related diseases. This can be attributed to the noncompliance of most power industries to the regulations.

In 2009, an accident occurred at Sayano-Shushenskaya near Sayanogorsh in Khakassia, Russia where the failure of a hydroelectric power station caused death to 75 people [15]. The accident was due to a violent breakdown of turbines. The turbine hall and engine room were flooded, the ceiling of the turbine hall collapsed, and nine out of 10 turbines were damaged or destroyed. The entire plant output, totaling 6,400 MW, and a significant portion of the supply to the local electric grid was lost, leading to widespread power failure in the local area, and forcing major users such as aluminum smelters to switch to diesel generators. The Sayano-Shushenskaya dam failure was not the only hydroelectric dam failure which has caused loss of life and major damage in the surrounding area. Accidents in this sector are rare but the consequences are usually very fatal. Planners need to take a lot of geological and environmental issues into account when building new hydroelectric plants.

In addition, the Taum Sauk Hydroelectric Power Station, Missouri, USA, also witnessed a failure resulting into five people being injured and permanent damage to the surrounding landscape followed by a period of no power generation that lasted about 5 years. The cause of this failure can be attributed to technical faults that were neglected or mismanaged. It was observed that the gauging system was faulty but the plant was still run. The incident led to the draining of over a billion gallons of water (4 million m^3) in less than 1 hour [16,17].

Moreover, in June 2013, the failure of the Dhauliganga hydroelectric station (280 MW) in India caused an unprecedented flood leading to the complete submergence of a power house [18]. Some more adverse effects were massive debris accumulation, electrical equipment replacement, and loss of total generation capacity for more than 6 months.

Furthermore, Hirtenlehner [4] has supported the fact that construction of large hydropower plants involves potentially high risks for the health and lives of persons as well as for the environment. Therefore a particularly high level of safety is required for such plants. Although most regulations in this sector are provided by international organizations such as International Organization for Standardization (ISO) in the form of standards, many companies and countries, including Ghana, failed to live up to the expectation of those standards. This explains the motivation to measure the level of noncompliance to regulations by power plants in Ghana. A reputed power plant in Ghana will be adopted for this study. The ISO and Occupational Safety and Health (OSH) standards will be adopted to conduct a Health and Safety Audit in the selected power plant of Ghana to ascertain or to determine whether activities and related results conform to planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve the organization's policy and objectives. The concern of this paper is on existing great threats to employees' safety increasing the risk of occupational accidents and employee's exposure to hazards regarding hydroelectric power plant station operation. Furthermore this will help to measure the level of compliance of the power plant company to ISO regulations. Finally, this paper will also help to improve health and safety measures of employees at the hydroelectric power plant. The rest of the paper is organized as follows: Section 2 presents the materials and method (a quantitative method with administered questionnaires is first developed followed by a factor analysis). Section 3 presents the discussion of the results and the conclusion.

2. Material and methods

According to Antonsen [19] in 2009, safety climates are assessed/measured by conducting questionnaire surveys among a group of workers in an organization. In such surveys, workers are asked to complete a specific, standardized questionnaire, i.e., giving their perception/opinion (or the perception that is shared among the coworkers) on certain safety related dimensions. The resulting data of the survey are processed and analyzed, providing a snapshot of the present safety climate in an organization. Furthermore, Bennet [20] in 2002 argues that workers, unlike tools or objects of production, are living human beings that need to be involved in the improvement of working conditions and should participate at all levels, including international levels, on issues that affect their livelihoods. Workers' perspectives need to be considered in devising and carrying out health and safety measures at the workplace.

In this regard, both qualitative and quantitative research approaches have been adopted in this paper. A random sampling technique was applied on a population of 60 workers. Fifty respondents were selected from the hydroelectric power plant. This included four managers, 14 supervisors, eight safety officers, and 24 technician engineers of the hydroelectric power plant in Ghana. Questionnaires made of close-ended questions were distributed to the following departments: the Project and System Monitoring Department and the Power Generating Station Department (the power house). SPSS version 14.0 (SPSS Inc., Chicago, Il, USA) was used to perform the analysis and Microsoft Excel 2010 (Microsoft Corporation) was used to generate the charts to explain the results. A factor analysis was also conducted on the collected data in order to determine the most influential factor and recommend means of curbing their impacts.

Table 1
Respondents view on the company's health and safety policy

S/N	Questions	D		SD		DK		A		SA		Total	
		Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
C1	OHS policy objective	4	8.0	0	0.0	0	0.0	16	32.0	30	60.0	50	100
C2	Relevant legal legislation awareness	5	10.0	0	0.0	3	6.0	19	38.0	23	46.0	50	100
C3	Current applicable OHS legislation	3	6.0	0	0.0	4	8.0	31	62.0	12	24.0	50	100
C4	Safety policy reviewed periodically to meet OSH standard	4	8.0	1	2.0	4	8.0	28	56.0	13	26.0	50	100
C5	Policy covers all employees, contractors, and subcontractors	3	6.0	1	2.0	1	2.0	18	36.0	27	54.0	50	100
C6	Cleaning of surfaces inside the power plant	3	6.0	0	0.0	1	2.0	21	42.0	25	50.0	50	100

Source: field work data, October 2014.
A, agree; DK, don't know; Freq., frequency; OSH, occupational safety and health; SA, strongly agree; SD, strongly disagree; S/N, serial number.

3. Results

3.1. Summary of sections investigated by the questionnaire

A summary of the different sections investigated by the questionnaire is provided below.

3.1.1. Section A: Safety and health organization

The reason for this section is to ascertain whether the company has safety departments, committees, and sectional safety committee.

3.1.2. Section B: Health and safety policy

The reason for this section is to determine whether the hydroelectric power plant station's safety management has Health and Safety Policies and whether these policies are implemented effectively as required by OSH standard. A 5-point weighted Likert scale (disagrees, strongly disagree, do not know, agree, and strongly agree) was used to rate the responses of the respondents as shown in Table 1.

3.1.3. Section C: Accident reporting, investigation, and analysis

This Section of the questionnaire captures data from the respondents concerning accident reporting, investigation, and analysis as required by the Occupational Health and Safety Authority. A yes or no scale (yes, do not know, and no) was used to rate the responses of the respondents in this Section.

3.1.4. Section D: Safety inspection

This Section of the questionnaire captures data from the respondents concerning safety inspection. A yes or no scale was used to rate the responses of the respondents.

3.1.5. Section E: Hazard identification and control

This section of the questionnaire solicits data on the company's hazard identification and control as required by Occupational Safety and Health Standard. This section of the questionnaire measures the company's commitment in identifying safety risks and putting safety procedures for task-based activities which have safety risks. A 5-point weighted Likert scale (disagrees, strongly disagree, do not know, agree, and strongly agree) was used to rate the responses of the respondents. Table 2 shows the detail of data collected.

3.1.6. Section F: Safety operations and procedures

Data were further gathered from the respondents concerning the company's safety operations and procedures. A 5-point weighted Likert scale (disagrees, strongly disagree, do not know, agree, and strongly agree) was used to rate the responses of the respondents in this Section.

3.1.7. Section G: Equipment safety

This section of the questionnaire gathered data on equipment safety at the power plant. A 5-point weighted Likert scale (disagrees, strongly disagree, do not know, agree, and strongly agree) was used to rate the responses of the respondents in this Section as shown in Table 3.

3.1.8. Section H: Personal safety and personal protective equipment

Section H of the questionnaire aims at capturing information on personal safety and protective equipment at the power plant. A 5-point weighted Likert scale (disagrees, strongly disagree, do not know, agree, and strongly agree) was used to rate the responses of the respondents in this Section. Table 4 shows the summary of data collected.

Table 2
Information on respondents view on Hazard identification and control

S/N	Questions	D		SD		DK		A		SA		Total	
		Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
J1	Hazards include fire, WMSDs, noise, etc.	5	10.0	1	2.0	2	4.0	25	50.0	17	34.0	50	100
J2	Is there alarm system in place?	1	2.0	1	2.0	0	0	15	30.0	33	66.0	50	100
J3	Company conducts HAZOP study internally	1	2.0	2	4.0	22	44.0	16	32.0	9	18.0	50	100
J4	Awareness of known hazards	0	0	0	0	6	12.0	19	38.0	25	50.0	50	100
J5	I have experienced work-related injury at work before	10	20.0	6	12.0	3	6.0	15	30.0	16	32.0	50	100
J6	Company's register of all hazardous chemicals	18	36.0	13	26.0	10	20.0	6	12.0	3	6.0	50	100
J7	Company does not perform risk assessment regularly	13	26.0	23	46.0	7	14.0	2	4.0	5	10.0	50	100
J8	Faulty electrical equipment is the cause of injuries	11	22.0	23	46.0	5	10.0	10	20.0	1	2.0	50	100

Source: field work data, October 2014.
A, agree; DK, don't know; Freq., frequency; HAZOP, hazard and operability study; SA, strongly agree; SD, strongly disagree; S/N, serial number; WMSD, work-related musculoskeletal disorders.

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Table 3
Equipment safety at the power plant

S/N	Questions	D		SD		DK		A		SA		Total	
		Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
N1	All moving machines are properly safeguarded	12	24.0	25	50.0	3	6.0	4	8.0	6	12.0	50	100
N2	All valves, switches, isolators are labeled for easy identification	0	0	3	6.0	3	6.0	24	48.0	20	40.0	50	100
N3	Machines are periodically checked, & maintained	0	0	2	4.0	1	2.0	21	42.0	26	52.0	50	100
N4	Checking of electrical earth pits for soil resistance	2	4.0	3	6.0	2	4.0	20	40.0	23	46.0	50	100
N5	All hand tools are defect free	7	14.0	1	2.0	11	22.0	22	44.0	9	18.0	50	100
N6	Lifting machines have manufacturer's certificate	2	4.0	1	2.0	2	4.0	28	56.0	17	34.0	50	100
N7	Approval from DOSH concerning machinery	1	2.0	1	2.0	4	8.0	22	44.0	22	44.0	50	100

Source: field work data, October 2014.
A, agree; DK, don't know; DOSH, Department of Safety and Health; Freq., frequency; SA, strongly agree; SD, strongly disagree; S/N, serial number.

3.1.9. Section J: Fire protection

This section of the questionnaire collects data from the respondents concerning fire protection issues at the hydroelectric power plant. A 5-point weighted Likert scale (disagrees, strongly disagree, do not know, agree, and strongly agree) was used to rate the responses of the respondents in this Section (Table 5).

In addition a factor analysis has been conducted and the outcomes are presented in the paragraph below.

3.2. Factor analysis

The overall data are summarized so that relationships and patterns can be easily interpreted and understood. At this stage, variables are grouped into a limited set of clusters based on shared variance in order to focus on some key factors rather than having to consider too many variables. There are two main factor analysis techniques: exploratory factor analysis and confirmatory factor analysis. Confirmatory factor analysis attempts to confirm hypotheses and uses of path analysis diagrams to represent variables and factors, whereas exploratory factor analysis tries to uncover complex patterns by exploring the dataset and testing predictions [21]. In this paper an exploratory factor analysis is conducted.

3.2.1. Descriptive statistics

The first output from the analysis is a table of descriptive statistics (Table 6) for all the variables under investigation. Typically, the mean, standard deviation, and number of respondents who participated in the survey are given. Looking at the mean, one can conclude that the checking of machines periodically is the most important variable. It has the highest mean of 4.4200.

3.2.2. Correlation matrix

A correlation matrix has been generated at this level. It simply consists of a rectangular array of numbers which gives the correlation coefficients between a single variable and every other variable in the investigation. The correlation coefficient between a variable and itself is always 1; hence, the principal diagonal of the correlation matrix contains 1s. The correlation coefficients above and below the principal diagonal are the same. The determinant of the correlation matrix is shown at the foot of Table 7.

3.2.3. Kaiser–Meyer–Olkin and Bartlett's test

These tests measure the strength of the relationship among variables. The Kaiser–Meyer–Olkin (KMO) measures the sampling adequacy, which should be greater than 0.5 for a satisfactory factor analysis to proceed. If any pair of variables has a value lesser than

Table 4
Personal safety and protective equipment

S/N	Questions	D		SD		DK		A		SA		Total	
		Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
O1	PPEs are made available to all employees	2	4.0	1	2.0	3	6.0	23	46.0	21	42.0	50	100
O2	PPEs conform to ISO/OSH Standard	1	2.0	1	2.0	0	0	23	46.0	25	50.0	50	100
O3	Working premises have adequate work space, ventilation, and lighting	10	20.0	3	6.0	3	6.0	20	40.0	14	28.0	50	100
O4	Workers are protected from falls more than 10 ft	2	4.0	2	4.0	4	8.0	24	48.0	18	36.0	50	100
O5	80 out of every 100 accidents are the fault of person involved in the incident	16	32.0	9	18.0	14	28.0	10	20.0	1	2.0	50	100
Which of the following PPEs do you have in your company?													
O6	Eye goggles	0	0	0	0	2	4.0	0	0	48	96.0	50	100
O7	Apron	1	2.0	0	0	3	6.0	0	0	46	92.0	50	100
O8	Safety boot	0	0	0	0	3	6.0	0	0	47	94.0	50	100
O9	Safety helmet	0	0	0	0	1	2.0	0	0	49	98.0	50	100
O10	Safety belts, life line, safety net	2	4.0	0	0	1	2.0	0	0	47	94.0	50	100
O11	Gloves (rubber, leather, PVC, electrical)	1	2.0	0	0	2	4.0	0	0	47	94.0	50	100
O12	Protective clothing like acid, alkali, and chemical handling suits	3	6.0	0	0	4	8.0	0	0	43	86.0	50	100
O13	Fire proximity suits	7	14.0	0	0	8	16.0	0	0	35	70.0	50	100
O14	Ear plugs and ear muffs	1	2.0	0	0	1	2.0	0	0	48	96.0	50	100
O15	Dust masks, gas masks, breathing apparatus	3	6.0	0	0	2	4.0	0	0	45	90.0	50	100

Source: field work data, October 2014.
A, agree; DK, don't know; Freq., frequency; ISO, International Organization for Standardization; OSH, occupational safety and health; PPE, *personal protective equipment*; PVC, polyvinyl chloride; SA, strongly agree; SD, strongly disagree; S/N, serial number.

Table 5
Respondents view on fire protection

S/N	Questions	D		SD		DK		A		SA		Total	
		Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
P1	Adequate fire hydrant network/hydrant monitors	1	2.0	1	2.0	0	0	26	52.0	22	48.0	50	100
P2	Fire extinguishers	1	2.0	1	2.0	0	0	18	36.0	30	60.0	50	100
P3	Approval of firefighting systems	2	4.0	1	2.0	0	0	19	38.0	28	56.0	50	100
P4	Sirens	7	14.0	2	4.0	1	2.0	20	40.0	20	40.0	50	100

Source: field work data, October 2014.
A, agree; DK, don't know; Freq., frequency; SA, strongly agree; SD, strongly disagree; S/N, serial number.

Table 6
Descriptive statistics

S/N	Factors	Mean	Standard deviation	No. of respondents
1	Work-related injury	3.4200	1.53981	50
2	Stairways and floors	4.2200	0.70826	50
3	Moving machines are safeguarded	2.3400	1.27151	50
4	Valve switches isolators are labeled	4.2200	0.81541	50
5	Machines are periodically checked	4.4200	0.73095	50
6	Workers are exposed to noise	4.2000	1.17803	50
7	Workers are protected from falls more than 10 ft by the use of safety belts	4.0800	0.98644	50
8	Safety belt, life line, safety net	1.1000	0.41650	50
9	Gloves (rubber, leather, PVC, electrical)	1.0800	0.34047	50
10	Protective clothing like acid, alkali, and chemical handling suits	1.2000	0.53452	50
11	Fire proximity suits	1.4400	0.73290	50
12	Ear plugs and ear muffs	1.0600	0.31364	50
13	Dust masks, gas masks, breathing apparatus	1.1600	0.50950	50
14	Confined spaces are properly ventilated	3.8400	1.01740	50
15	Lockout and lock tag circuit breakers are provided in confined spaces	3.7600	1.36367	50

Source: field work data, October 2014.
PVC, polyvinyl chloride.

the threshold of 0.5, the variable should be dropped out from the analysis. Also, the off-diagonal elements should all be very small (close to zero) in a good model. Looking at Table 8, the KMO measure is 0.564.

Bartlett's test is another indication of the strength of the relationship among variables. This test considers a null hypothesis that the correlation matrix is an identity matrix. An identity matrix is a matrix in which all of the diagonal elements are 1 and all off-diagonal elements are 0. The objective is to reject this null hypothesis. From the same table, it can be observed that the Bartlett's test of sphericity is significant; that is, its associated probability is less than 0.05. In fact, it is actually 0.000, i.e., the significance level is small enough to reject the null hypothesis. This means that the correlation matrix is not an identity matrix. Table 8 illustrates the results obtained for both the KMO and Bartlett's tests.

Table 7
Correlation matrix

S/N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	0.0071	0.1341	−0.091	−0.0148	0.2002	0.420	−0.035	−0.260	−0.228	−0.1670	−0.1802	−0.191	−0.0995	0.243
2	0.007	1	−0.266	0.162	0.449	0.289	0.383	0.062	0.01	−0.28	0.046	−0.061	−0.326	0.106	0.352
3	0.134	−0.266	1	0.163	0.151	−0.223	−0.103	−0.143	−0.064	−0.064	−0.208	−0.052	0.072	0.153	0.072
4	−0.091	0.162	0.163	1	0.698	0.059	0.105	0.054	−0.065	−0.056	0.108	−0.053	−0.037	0.092	−0.208
5	−0.015	0.449	0.151	0.698	1	0.114	0.32	−0.007	−0.056	−0.219	0.029	−0.112	−0.184	0.092	0.062
6	0.2	0.289	−0.223	0.059	0.114	1	0.285	−0.083	−0.092	−0.097	−0.009	−0.088	0.014	−0.126	−0.008
7	0.421	0.383	−0.103	0.105	0.32	0.285	1	−0.119	−0.141	−0.108	0.007	−0.148	−0.148	−0.109	0.379
8	−0.035	0.062	−0.143	0.054	−0.007	−0.083	−0.119	1	0.662	0.367	0.455	0.734	0.404	0.039	−0.029
9	−0.26	0.01	−0.064	−0.065	−0.056	−0.092	−0.141	0.662	1	0.471	0.429	0.91	0.513	0.097	−0.046
10	−0.228	−0.28	0.048	−0.056	−0.219	−0.097	−0.108	0.367	0.471	1	0.552	0.536	0.629	0.023	−0.325
11	−0.167	0.046	−0.208	0.108	0.029	−0.009	0.007	0.455	0.429	0.552	1	0.327	0.518	−0.068	−0.137
12	−0.18	−0.061	−0.052	−0.053	−0.112	−0.088	−0.148	0.734	0.91	0.536	0.327	1	0.577	0.031	−0.061
13	−0.191	−0.326	0.072	−0.037	−0.184	0.014	−0.148	0.404	0.513	0.629	0.518	0.577	1	−0.225	−0.12
14	−0.1	0.106	0.153	0.092	0.092	−0.126	−0.109	0.039	0.097	0.023	−0.068	0.031	−0.225	1	0.089
15	0.243	0.352	0.072	−0.208	0.062	−0.008	0.379	−0.029	−0.046	−0.325	−0.137	−0.061	−0.12	0.089	1

Source: field work data, October 2014.
Determinant = 0.000.
S/N, serial number.

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Table 8
KMO and Bartlett's Test

Parameters	Values
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.564
Bartlett's Test of Sphericity, Approximate Chi-Square	345.713
df	105
Significance	0.000

Source: Field work data, October 2014.

3.2.4. Communalities

Communalities analysis, displayed in Table 9, shows how much of the variance in the variables has been accounted for by the extracted factors. For instance, over 85.8% of the variance in the checking of machines periodically is accounted for, ear plugs and ear muffs 84.6%, valve switches isolators are labeled 84.3%, rubber, leather, polyvinyl chloride (PVC), and electrical gloves 83.6%, while 81.5 % of the variance in "moving machines are safeguarded" is also accounted for.

3.2.5. Total variance explained

Table 10 shows all the factors extractable from the analysis along with their eigenvalues, the percent of variance attributable to each factor, and the cumulative variance of all the factors. Notice that the first factor accounts for 26.560% of the variance, the second 15.079%, and the third 11.644%. All the remaining factors are not significant.

3.2.6. Scree plot

The scree plot is a graph of the eigenvalues against all the factors. The graph is useful for determining how many factors to retain. The point of interest is where the curve starts to flatten. According to Fig. 1, it can be seen that the curve begins to flatten between Factors 3 and 4. Note also that Factor 4 has an eigenvalue of less than 1, so only three factors have been retained.

3.2.7. Component (factor) matrix

Table 11 shows the loadings of the 15 variables on the five factors extracted. The higher the absolute value of the loading, the more the factor contributes to the variable. The gap on the table represent loadings that are less than 0.5—this makes reading the table easier. All loadings less than 0.5 have been suppressed.

3.2.8. Rotated component matrix

The idea of rotation is to reduce the number of factors on which the variables under investigation have high loadings. Rotation does

Table 9
Communalities

S/N	Factors	Initials	Extraction
1	Work-related injury	1.000	0.662
2	Stairways and floors	1.000	0.789
3	Moving machines are safeguarded	1.000	0.815
4	Valve switches isolators are labeled	1.000	0.843
5	Machines are periodically checked	1.000	0.858
6	Workers are exposed to noise	1.000	0.482
7	Workers are protected from falls more than 10 ft by the use of safety belts	1.000	0.703
8	Safety belt, life line, safety net	1.000	0.679
9	Gloves (rubber, leather, PVC, electrical)	1.000	0.836
10	Protective clothing like acid, alkali, and chemical handling suits	1.000	0.664
11	Fire proximity suits	1.000	0.575
12	Ear plugs and ear muffs	1.000	0.846
13	Dust masks, gas masks, breathing apparatus	1.000	0.752
14	Confined spaces are properly ventilated	1.000	0.522
15	Lockout and lock tag circuit breakers are provided in confined spaces	1.000	0.699

Source: field work data, October 2014.
PVC, polyvinyl chloride; S/N, serial number.

Table 10
Total variance explained

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	3.984	26.560	26.560	3.984	26.560	26.560	3.717	24.777	24.777
2	2.262	15.079	41.639	2.262	15.079	41.639	2.000	13.336	38.113
3	1.747	11.644	53.283	1.747	11.644	53.283	1.928	12.850	50.963
4	1.431	9.541	62.824	1.431	9.541	62.824	1.624	10.826	61.789
5	1.301	9.541	71.500	1.301	8.676	71.500	1.457	9.711	71.500
6	0.842	5.615	77.115	–	–	–	–	–	–
7	0.829	5.526	82.641	–	–	–	–	–	–
8	0.729	4.862	87.503	–	–	–	–	–	–
9	0.528	3.518	91.021	–	–	–	–	–	–
10	0.408	2.720	93.741	–	–	–	–	–	–
11	0.281	1.873	95.614	–	–	–	–	–	–
12	0.224	1.490	97.104	–	–	–	–	–	–
13	0.207	1.377	98.481	–	–	–	–	–	–
14	0.185	1.231	99.712	–	–	–	–	–	–
15	0.043	.288	100.000	–	–	–	–	–	–

Source: field work data, October 2014.

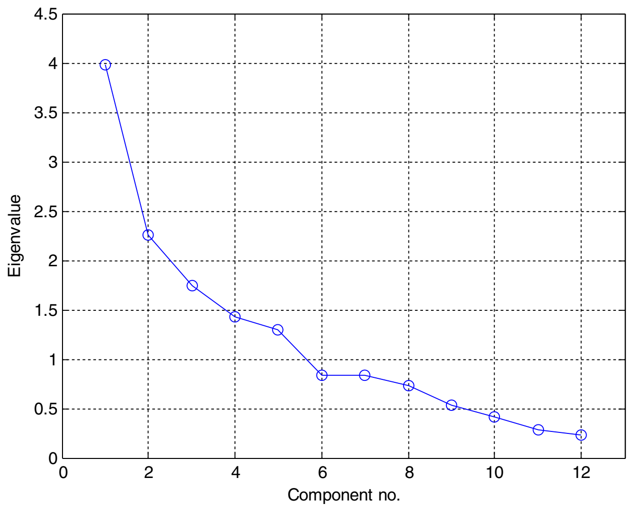

Fig. 1. Scree plot. Source: field work data, October 2014.

not actually change anything but makes the interpretation of the results easier. Table 12 shows the results obtained from thee rotated component matrix.

4. Discussion

This study sought to assess the health and safety measures of power plants. A case study has been conducted in a hydroelectric power plant in Ghana using questionnaires and in-depth interviews. The first stage of this analysis will consider the level of compliance of the company to OSH and ISO standards, followed by a discussion on the factor analysis.

4.1. Level of compliance of the hydroelectric power plant to OSH standards

It appears from the results obtained that the company complies with few health and safety regulations stipulated by the Occupational Health and Safety Act 85 which was amended to Act 181 in 1993. The main goal of the Occupational Safety and Health Act 181 is:

> "to provide for the health and safety of persons at work and for the health and safety of persons in connection with the use of plant and machinery; the protection of persons other than persons at work against hazards to health and safety arising out of or in connection with the activities of persons at work; to establish an advisory council for occupational health and safety; and to provide for matters connected therewith."

Act 85, later amended to 181, with the objectives stipulated above, have been used in this study for comparison for the fact that it is an international standard that mainly deals with hazards related to machinery and equipment operating at the workplace which happen to be the case in hydroelectric power plants. Even though the Act is enacted in South Africa, it is suitable and highly applicable to evaluate health and safety hazards in a hydropower plant. Moreover, Ghana does not have a specific Act that deals with safety and health in power plants.

Moreover, the European Union directives on safety and health at work do not establish any strict regulatory framework on OSH management. It is up to the employers to decide on how to organize their business.

The results also revealed that, even though the hydroelectric power plant is committed to health and safety excellence, it is yet to realize its full potential with regard to current applicable Occupational Health and Safety Legislation that are available on risk and safety standards such as: the OHSAS 18001:2007 (Occupational Health and Safety Management) specifies the requirement for a work health and safety management system. By implementing this system, the hydroelectric power plant can show more improvements in its performance, by means of effective control of occupational accidents and disease risks.

4.2. Level of compliance of the hydroelectric power plant to ISO standards

The level of compliance of the hydroelectric power plant to ISO as revealed by the results presented above indicates that the hydroelectric power plant is implementing most of the ISO certifications. The power plant is committed to operating its power

Table 11
Component (factor) matrix

S/N	Factors	Component				
		1	2	3	4	5
1	Ear plugs and ear muffs	0.847	–	–	–	–
2	Gloves (rubber, leather, PVC, electrical)	0.822	–	–	–	–
3	Dust masks, gas masks, breathing apparatus	0.770	–	–	–	–
4	Protective clothing like acid, alkali, and chemical handling suits	0.769	–	–	–	–
5	Safety belt, life line, safety net	0.706	–	–	–	–
6	Fire proximity suits	0.623	–	–	–	–
7	Stairways and floors	–	0.742	–	–	–
8	Machines are periodically checked	–	0.694	0.539	–	–
9	Workers are protected from falls more than 10 ft by the use of safety belts	–	0.584	–	–	–
10	Valve switches isolators are labeled	–	0.487	0.718	–	–
11	Confined spaces are properly ventilated	–	–	–	0.592	–
12	Lockout and lock tag circuit breakers are provided in confined spaces	–	–	−0.423	0.569	–
13	Workers are exposed to noise	–	–	–	−0.455	–
14	Moving machines are safeguarded	–	–	0.430	–	0.686
15	Work-related injury	–	–	−0.429	–	0.577

Source: field work data, October 2014.
PVC, polyvinyl chloride; S/N, serial number.

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Table 12
Rotated component matrixes

S/N	Factors	Component				
		1	2	3	4	5
1	Ear plugs and ear muffs	0.898	–	–	–	–
2	Gloves (rubber, leather, PVC, electrical)	0.877	–	–	–	–
3	Safety belt, life line, safety net	0.799	–	–	–	–
4	Dust masks, gas masks, breathing apparatus	0.734	–	–	–	–
5	Protective clothing like acid, alkali, and chemical handling suits	0.695	–	–	–	–
6	Fire proximity suits	0.655	–	–	–	–
7	Valve switches isolators are labeled	–	0.902	–	–	–
8	Machines are periodically checked	–	0.901	–	–	–
9	Lockout and lock tag circuit breakers are provided in confined spaces	–	–	0.749	–	–
10	Work-related injury	–	–	0.715	–	–
11	Workers are protected from falls more than 10 ft by the use of safety belts	–	–	0.707	–	–
12	Moving machines are safeguarded	–	–	–	−0.821	–
13	Stairways and floors	–	–	–	0.701	–
14	Confined spaces are properly ventilated	–	–	–	–	0.709
15	Workers are exposed to noise	–	–	–	–	−0.503

Extraction method: principal component analysis.
Source: field work data, October 2014.
PVC, polyvinyl chloride; S/N, serial number.

plants in a manner that ensures the suitable performance in the business of energy generation. The company is ISO 9001:2000 certified and has other ISO certifications. They have highly trained and qualified employees for quality assurance, and each operation undergoes strict inspection guidelines. They are committed to adhering to quality standards which are also aligned with certifications.

However, from the observation and in-depth discussion it can be argued that, managers and supervisors are central to the success of behavior-based safety and they are required to display more transformational leadership skills such as coaching, mentoring, engaging, and facilitating their teams. Therefore managers and supervisors need to be enabled by supplying them with tools and skills to manage all deviations proactively since they have a general duty to ensure, as far as reasonably practicable, the health, safety, and welfare at work of all their employees.

4.3. *Factor analysis (KMO and Bartlett's test sphericity)*

From the factor analysis conducted, 15 variables were identified to further investigate the health and safety measures at the hydropower plant. The patterns of intercorrelation has clearly shown from the correlation matrix that:

- Variables 1, 2, 4, 5, and 14 are highly correlated with each other, but fairly uncorrelated with other variables (see Table 7); and
- Variables 3, 6, 7, 9, 10, 11, 12, 13, and 15 are highly correlated with each other, but not with the rest of the variables and only variable 8 alone does not correlate with any other variables (see Table 7).

It is therefore derived that the highly correlated variables have bigger or positive influences on health and safety at the hydroelectric power plant station. However, management needs to take into account serious health and safety measures to avert any future accident from occurring. These factors are recalled here as follow:

- work-related injury;
- stairways and floors;
- valve switches isolators are labeled;
- machines are periodically checked; and
- confined spaces are properly ventilated.

Referring to Table 12, it can be observed that ear plugs and ear Muffs, gloves (rubber, leather, PVC, electrical), safety belt life line safety nets, dust masks, gas masks, breathing apparatus, protective clothing like acid, alkali, and chemical handling suits, and fire proximity suits are substantially loaded on Factor (Component) 1. Valve switch isolators are labeled and machines are periodically checked are substantially loaded on Factor (Component) 2. Lockout and lock tag circuit breakers are provided in confined spaces and "work-related injury" and "workers are protected from falls more than 10 feet by the use of safety belts" are substantially loaded on Factor (Component) 3. "Moving machines are safeguarded" and "stairways and floors" are also substantially loaded on Factor (Component) 4. "Confined spaces are properly ventilated" and "workers are exposed to noise" are substantially loaded on Factor (Component) 5. These factors can be used as variables for further analysis. For instance, in Table 9, over 85.8% of the variance in the checking of machines periodically is accounted for, ear plug and ear muffs 84.6%, valve switches isolators are labeled 84.3%, gloves (rubber, leather, PVC, electrical) 83.6 %, while 81.5 % of the variance in moving machines are safeguarded is also accounted for.

In summary, the study assessed the health and safety measures of power plants and conducted a case study of one major hydroelectric power plant in Ghana. The results of the study indicate that training and supervision, safe work procedures, management commitment, and behavioral safety are significant predictors of the impact of safety on employee behavior at hydroelectric power plant stations. Looking at the factor analysis developed in the paper, one can conclude that the checking of machines periodically is the most important variable. It has the highest mean of 4.42. However, it has been observed during the study that adequate protection has been taken all over the plant to prevent accidents. If the specifications in the OSH and ISO standards are strictly followed, plant operation is expected to be accident free for many years. Great emphasis should be given by management for awareness of safety of employees and the plant as well. Safety education, training and supervision system, management commitment, safety of confined space entering, fire protection, use of personal protective equipment, and other safety equipment are found to be necessary and fortunately well embraced. It is, however, imperative that the organization proactively develops strategies to improve and sustain the level of perceived difficulty that is brought by the implementation of Occupational Health and Safety Laws.

Conflicts of interest

All authors have no conflicts of interest to declare.

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