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Evaluation of Safety Culture in Institutional Chemical Analytical Laboratories in Oghara and Warri, Delta State, Nigeria

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Abstract

This study was aimed at evaluating safety culture in 20 chemical analytical laboratories in Oghara and Warri, Delta state. This was achieved through a determination of the safety performance between tertiary education chemical laboratories and industrial laboratories, private and government-owned laboratories, and technical and non-technical labs. The method employed in carrying out this study was the use of a 5-point Likert scale questionnaire and a standard checklist. Comparison done between private and government-owned laboratories using t-test showed that safety culture of private-owned laboratories, irrespective of whether industrial or tertiary education, were more significant ($P < 0.05$) than that of government-owned laboratories. Analysis of t-test for the survey indicated no significant difference between tertiary education and industrial laboratories ($P > 0.05$), with a mean value of 3.69798 for tertiary education laboratories and 3.62842 for industrial laboratories. Analysis of t-test also indicated $P < 0.05$ for technical ($M = 75.00$) and non-technical ($M = 56.11$) tertiary education laboratories. However, further t-test analysis indicated that there is a significant difference between safety performance in tertiary education laboratories and industrial laboratories ($P < 0.05$). The conclusion is that tertiary education chemical analytical laboratories have a high level of safety culture with an overall mean of 67.90 than industrial chemical analytical laboratories with an overall mean of 54.50. It is recommended that laboratories should establish an internal review process of incidents and corrective actions with the departmental safety committee and provide periodic safety seminars on lessons learned from incidents. A strong and effective safety management system should also be implemented in all analytical laboratories.

Keywords

Safety, Culture, Industry, Institution, Safety

1. Introduction

According to the International Nuclear Safety Group (INSAG4); "Safety culture is that assembly of characteristics and attitudes in organizations and individuals, which establishes as an overriding priority". This definition highlights both structural and attitudinal Safety Culture [1] [2] [3] [4]. According to the Occupational Safety and Health Administration (OSHA, 2015) [5] in strong safety culture, "Everyone feels responsible for safety and pursues it on a daily basis, employees go beyond the "call of duty" to identify unsafe conditions and behaviors, and intervene to correct them".

With the promulgation of the Occupational Safety and Health Administration (OSHA) laboratory standard (29 CFR 1910.1450), a Culture of Safety consciousness, accountability, organization, and education has developed in industrial, governmental, and academic laboratories. Safety and training programs have been implemented to monitor the handling of chemicals from ordering to disposal and to train laboratory personnel in safe practices [5] [6].

Safety culture is a critical dimension in safety, ensuring success or causing failure in organizations and numerous studies in recent years have identified it as major issue requiring regulatory interventions [6]-[11].

Laboratories are associated with a variety of possible hazards which could lead to risk of fire or some chemical substances can be carcinogenic, toxins, irritants, corrosives, sensitizers, as well as agents that act on the blood system or damage the lungs, skin, eyes, or mucous membranes, mutagens, embryotoxic. It is important to keep in mind that chemicals can exhibit more than one hazard or combinations of several hazards because several factors can influence how a chemical will behave [12].

Biological hazard refers to biological substances that pose a threat to the health of living organisms, primarily that of humans. Infectious biological hazards like viruses, bacteria, fungi or parasites or their products can cause human diseases when they are inhaled, ingested, contact skin or eye [13]. Ergonomic hazards from Laboratory activities like pipetting of fluid, prolonged standing and bending, poor workspace and positions pose risk of injury to the musculoskeletal system [14] [15].

Physical agents such as needles, knives, broken bottles can lead to hazard of pricks and cut; electrical equipment and improper wiring can lead to electrocution; wet, uneven or damaged floors surfaces, trailing cables can cause hazards of slips and trips; noise and vibration produced from equipment such as centrifuges and stirrers can cause hearing loss and stress, entanglement of clothes, hair or fingers in rotating equipment such as centrifuges and mixers can cause bodily injury [16].

Psychosocial hazards are stress, the threat of danger, discrimination, constant low-level noise, violence, or bullying in the workplace environment. This can involve how workers interact with other workers and/or emotional responses workers have that negatively impact a worker's productivity or effectiveness [16].

Hazards are an intrinsic property of a substance or condition and cannot truly be removed, however, it is good to identify them so that appropriate controls can be implemented and the associated risk from the hazard can be reduced or mitigated. The active involvement of senior management in the health and safety system is very important and to identify the general attributes of strong or good safety culture [17] [18].

Therefore, management leadership is a key factor to high level of safety performance. A laboratory with high level of management commitment will likely have very low lost-time injury and vice versa [19]. It is important to conduct thorough hazard and risk analysis before beginning an experiment protocol or manufacturing processes [20] [21]. Positive safety culture would lead to Lower Absenteeism, Lower Wage Bills, Reduced Repairs and Re-Working, Happier Workforce, Lower Staff Turnover, Reduced Risk of Fines, Reduced Insurance Claims, Reduced Insurance, Improved Productivity, Quality and Profitability and more Satisfied Clients and Stakeholders [22].

This research work is to evaluate the level of safety performance and improved the level of safety consciousness in twenty (20) analytical laboratories in Oghara and Warri, Delta State, Nigeria. This is to enhance productivity, quality and profitability, reduce repairs, reworking and insurance claim, thereby providing a safe working environment (for workers and researchers) resulting in low accident/incident occurrence and improving job motivation as well as job satisfaction.

2. Materials and Methods

2.1. Sample Size and Population Size

A total number of twenty (20) analytical laboratories (ten industrial and ten tertiary educations) were carefully identified and selected for this research work. The population size of 200 members of staff and/or students were selected randomly for this study for the administration and completion of the safety culture questionnaires. Questionnaires were administered to ten (10) respondents at each of the twenty (20) sampling locations of the industrial and academic laboratories.

The method adopted for carrying out this work was the use of questionnaires and checklist. The questionnaire consists of close-ended questions which was self-administered and distributed to ten (10) employees in each laboratory.

The checklist contained seventy-seven (77) questions which were used to check the organizations performance to safety culture through inspections, and interview methods.

2.2. Safety Culture in Analytical Laboratories Questionnaire

The questionnaire consists of thirty-five (35) modified close-ended Likert Scale questions adapted from OSHA, New South Wales Government Questionnaire and Safety Climate Assessment Questionnaire [23] [24] [25]. Section A of the questionnaire covered the demographic information, while section B focuses on specific area of general safety culture in the laboratory which includes hygiene factors, training and competence, safety reporting and investigation, work duties/pressure, management commitment, safety communication, and emergency preparedness and response.

2.3. Safety Culture in Analytical Laboratories Checklist

The Checklist for safety culture in analytical laboratories contains seventy-seven (77) modified questions which were carefully answered by inspecting the laboratories and interviewing personnel where necessary. The checklist was adopted from the European Agency for Safety at work [26]. The 77 questions are distributed through 9 parts of the checklist. These 9 parts represent the core elements of safety culture as documented in OSHA standards. The parts include; General laboratory safety, information for workers, chemical safety, biological safety, hygiene, emergency procedure, personal protective equipment, hazardous waste handling, and housekeeping.

2.4. Method of Data Analysis

The data collected from the checklist and survey was compiled and assigned codes. Descriptive statistics were used to analyze the data using Microsoft Excel 2019. Further statistical analysis used includes t-test and one-way analysis of variance (One-Way ANOVA) in order to arrive at reasonable and reliable conclusions.

3. Results and Discussion

Table 1 represents the percentage scores obtained for the various variables used to assess the average safety performances of the 10 selected tertiary education chemical laboratories. The criteria variables used are; general laboratory, information for workers, chemical safety, biological safety, hygiene, emergency procedure, personal protective equipment, hazardous waste management, and housekeeping. The result shows that the emergency procedure and biological safety hazards scored far below averaged in Lab 1 with 26% and 27% respectively. Similarly, personal protective equipment in addition to poor emergency arrangement had the lowest scores in Lab 2 with 33% and 34% respectively. However, housekeeping had the highest score of 96% in Lab 6 followed by 95% in housekeeping and general Laboratory safety in Lab 7 and Lab 6 respectively.

Table 2 and **Figure 1** present the average satisfactory and unsatisfactory level of safety performance of the 10 tertiary laboratories studied. The result of the average safety performance showed poor performances in the first laboratory (Lab 1) and Second Laboratory (Lab 2) with satisfactory scores of 46% and 48% respectively. The tenth (Lab 10) and eighth (Lab 8) Laboratories performed excellently well with the highest level of satisfactory performance scores of 82% and 81% respectively. Generally the Laboratories 3 to 10 performed very well

Table 1. Percentage level of safety performance for tertiary education laboratories.

Safety Variables	Lab 1	Lab 2	Lab 3	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10
General Laboratory Safety	50	51	80	78	89	95	88	84	82	87
Information for Workers	57	54	78	70	80	86	86	82	82	82
Chemical Safety	51	53	77	69	84	84	82	78	79	78
Biological Safety	27	67	70	66	40	49	68	77	84	77
Hygiene	53	53	77	74	73	82	77	85	78	87
Emergency Procedure	26	34	71	68	76	74	78	79	74	79
Personal Protective Equipment	44	33	74	65	51	68	69	86	78	86
Hazardous Waste	48	40	68	62	64	73	59	84	83	86
Housekeeping	60	44	76	80	92	96	95	78	80	78

Table 2. Average safety performance for tertiary education laboratories.

Level of Safety Performance	Tertiary Education Laboratories									
	Lab 1	Lab 2	Lab 3	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10
Satisfactory	46	48	75	70	72	79	78	81	80	82
Unsatisfactory	54	52	25	30	28	21	22	19	20	18

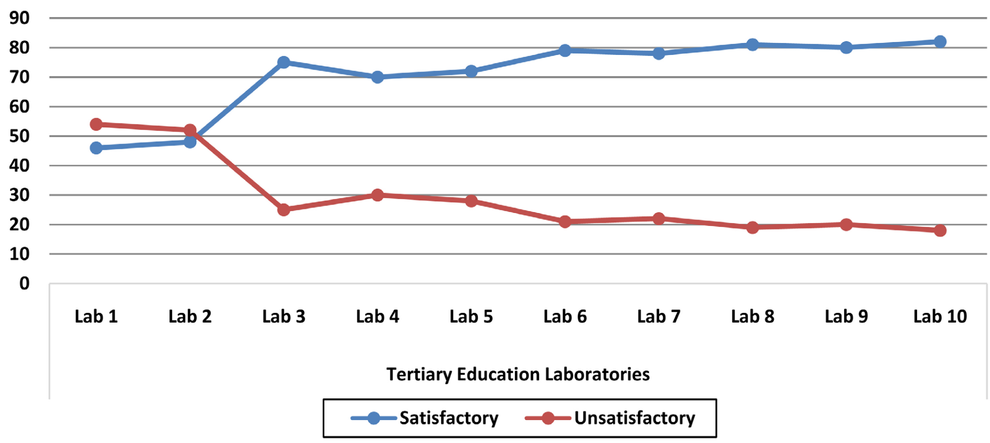

Figure 1. Level of safety culture in tertiary education laboratories.

with satisfactory performance scores far above average (50%) as shown in Table 2 and Figure 1.

The result of the Analysis of Variance (ANOVA) for Academic Laboratories showed that the value of the degree of freedom calculated (F_{cal}) is greater than $F_{critical}$ (15.873 > 1.999) and P-value is less than 0.05 ($P < 0.05$). This shows that there is significant difference in safety performance of the 10 tertiary education laboratories. This confirms to the low average scores of 46% and 48% in Lab 1 and Lab 2 respectively, against the high values in other laboratories especially Lab 10 and Lab 8.

Therefore, a further analysis may be necessary, by sectioning the tertiary education laboratories into government owned tertiary education laboratories and private owned tertiary education laboratories in order to ascertain a reasonable conclusion.

3.1. Determination of Safety Performance in Industrial Laboratories

Table 3 represents the percentage level of safety performance for the variables used to determine the average safety performances of the ten (10) Industrial chemical laboratories. The same variables were used as in the tertiary Laboratories as shown below. The result of the safety performance study in Industrial Laboratory showed that there were problem with inadequate worker information, especially in Lab 6 and Lab 5 with the lowest percentages of 34 and 37 respectively. Another potential area of concern as identified in study is the emergency procedure preparedness, especially for Lab 5 and Lab 7 both with score of 39%. High positive culture performances were observed in housekeeping (92% in Lab 9 & 10) and general safety of the Laboratory (91% in Lab 9) as shown in Table 3.

Table 4 and Figure 2 show the average satisfactory and unsatisfactory level of safety performance of the 10 industrial laboratories experimented. The result from the table shows that four laboratories (Lab 3, 7, 4 & 5) had satisfactory performance level below average (50%) with scores of 41%, 42%, 46% and 49% respectively. The highest score of 75% goes to Lab 9 whose safety performance is high and the industrial Laboratories.

Based on the analysis of variance (ANOVA) result obtained, the value of Freedom Ratio calculated (F_{cal}) is greater than $F_{critical}$ (13.1511 > 1.991) and P-value is less than 0.05 ($P < 0.05$). Therefore there is a significant difference in safety performance of the 10 industrial laboratories selected for this study. This is in line with wide ranges of average (41% to 75%) seen in Table 4. Therefore, a

Table 3. Percentage level of safety performance for industrial laboratories.

Safety Variables	Lab 1	Lab 2	Lab 3	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10
General Laboratory Safety	66	54	46	52	50	48	51	65	91	83
Information for Workers	57	50	49	43	37	34	48	56	60	54
Chemical Safety	71	46	46	58	48	48	37	64	80	64
Biological Safety	40	46	47	47	35	34	39	57	80	80
Hygiene	71	49	54	48	42	42	50	57	51	47
Emergency Procedure	60	46	50	56	39	39	39	54	89	84
Personal Protective Equipment	58	49	55	88	47	47	47	59	51	73
Hazardous Waste	40	47	46	42	41	43	49	53	84	84
Housekeeping	60	55	49	54	39	37	51	52	92	92

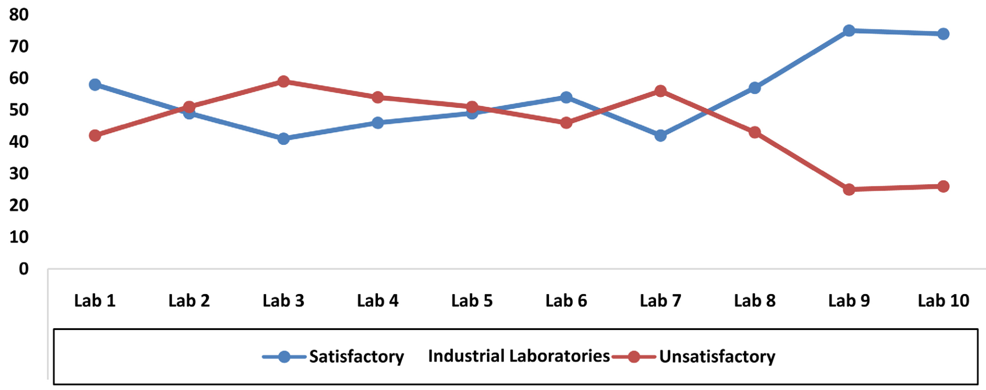

Figure 2. Level of safety culture in industrial chemical analytical laboratories.

Table 4. Average safety performance for industrial laboratories.

Level of Safety Performance	Industrial Laboratories									
	Lab 1	Lab 2	Lab 3	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10
Satisfactory	58	49	41	46	49	54	42	57	75	74
Unsatisfactory	42	51	59	54	51	46	56	43	25	26

further analysis may be necessary, by sectioning the industrial laboratories into government-owned industrial laboratories and private-owned industrial laboratories in order to ascertain a reasonable conclusion.

3.2. Comparison between Industrial and Tertiary Education Laboratories

The t-test analysis was used to ascertain the significant difference in the level of safety performance between tertiary education and industrial laboratories, at 5% level of significance. The evidence from the student t-test result indicated that there is significant difference between safety performance of academic laboratories and industrial laboratories, since the value of P ($T \leq t$) two-tail is less than 0.05 value of P, ($P < 0.05$). This means that there is significant difference between the two groups of laboratories. However, the difference in the mean performance can aid a justified conclusion, as the result of the tertiary laboratories has an average of 67.9%, while 54.5% was obtained for industrial laboratories. This result contrary to what was obtained in previous research done by [20] Imke *et al.*, (2016). They showed that commitment to health and safety programs was high in company laboratories. They observed that industrial laboratories recognize both their moral responsibility and their own self-interest in developing the best possible safety programs, extending them not just to employees but also to contractors. They also observed that industrial laboratory environment provides strong corporate structure and discipline for maintaining a well-organized safety program where safety culture is thoroughly understood, respected, and enforced from the highest level of management down (**Figure 3**).

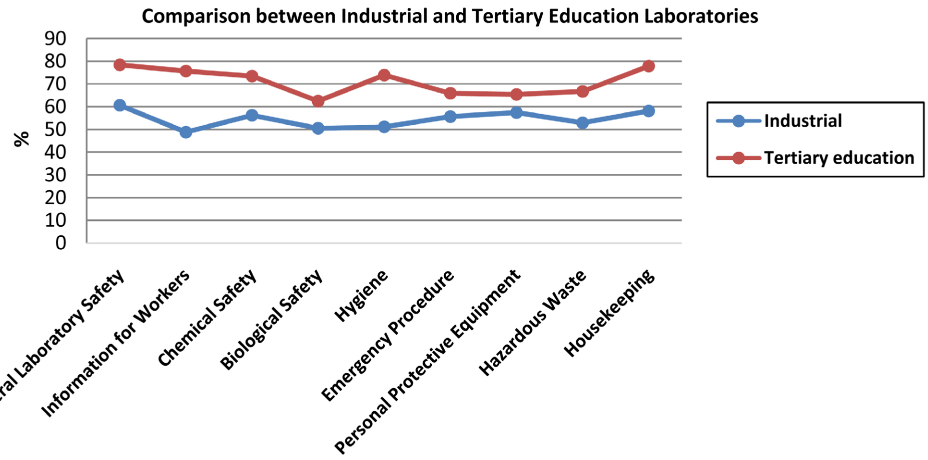

Figure 3. Percentage level of safety culture in industrial and tertiary education laboratories.

Another researcher [3] Guldenmund (2010) also suggested that industrial laboratory workers readily accept training as a benefit to their safety, or they are more compliant with safety regulations regardless of its perceived usefulness in improving safety.

3.3. Demographic Information of Respondents

The Demographic Information of Respondents as presented in **Table 5** shows 42% are males and 58% are females, consisting of 35% workers and about 65% of students/Interns. About 77% of the respondents have spent 1 - 5 years in the laboratory, 13% have spent 6 - 10 years and only 10% have spent between 11 - 15 years. 10% of the respondents were below 20 years old, 54% between 21 - 30 years of age; 19% between 31 - 40 years, 15% between 41 - 50; and only 6% between 51 - 60 years old.

From the information in **Table 6**, 45% of males and 55% of females, this is made up of 42% workers and about 58% of interns. About 71.5% of the respondents have spent 1 - 5 years in the laboratory, 16.5% have spent 6 - 10 years, 7% between 11 - 15 years, 2.5% between 16 20 years, and 2.5% have spent more than 20 years in the laboratory. 13% of the respondents were below 20 years old, 48% between 21 - 30 years of age; 21% between 31 - 40 years, 14% between 41 - 50; and only 4.5% between 51 - 60 years old.

3.4. Workers and Students' Perception in Tertiary Education Laboratories

Descriptive statistics were used to measure the variables of safety culture that is perceived to be the most important among employees in the laboratories. Workers and students' opinion on safety culture were measured by seven variables (hygiene factors, training and competence, safety reporting and investigation, work duties/pressure, management commitment, safety communication, and emergency preparedness and response) which was computed to obtain the average opinion for each of the tertiary education laboratories. From the result

Table 5. Percentage demographic distribution of respondents in tertiary education laboratories.

Gender		Category of Respondents		Length of Service (In Years)		Age Group (In Years)	
Male	42	Worker	35	1 - 5	77	<20	10
Female	58	Student/Intern	65	6 - 10	13	21 - 30	54
				11 - 15	10	31 - 40	19
						41 - 50	15
						51 - 60	6

Table 6. Percentage distribution of respondents in industrial laboratories.

Gender		Category of Respondents		Length of Service (In Years)		Age Group (In Years)	
Male	45	Worker	42	1 - 5	71.5	<20	13
Female	55	Intern	58	6 - 10	16.5	21 - 30	48
				11 - 15	7	31 - 40	21
				16 - 20	2.5	41 - 50	14
				>20	2.5	51 - 60	4.5

obtained, Lab 10 and Lab 4 were perceived high with mean of 4.334 and standard deviation of 0.8390, and 4.0086 with standard deviation of 0.8024. While Lab 1 was perceived as slightly low with mean score of 3.0857 and standard deviation of 0.8904. As indicated by the survey results, the mean of workers and students' perception on safety culture in the 10 tertiary education laboratories were between the ranges of 3.0857 to 4.3343, thus indicating a slight mixture of "Strongly Disagree/Disagree" to "Strongly Agree/Agree".

3.5. Workers and Students' Perception in Industrial Laboratories

Descriptive statistics were also used to measure the variables of safety culture that is perceived to be the most important among workers in the 10 industrial laboratories. Workers and students' opinion on safety culture were measured by seven variables, which was computed to obtain the average opinion for each of the industrial laboratory. From the result obtained, Lab 7 was perceived slightly high with mean of 3.7686 and standard deviation of 0.7800. While Lab 10 was perceived as slightly low with mean score of 3.5357 and standard deviation of 0.6393. As indicated by the survey results, the mean of workers and students' perception on safety culture in the 10 industrial laboratories were between the ranges of 3.5357 to 3.7686, thus indicating a higher mixture of "Strongly Disagree/Disagree" to "Strongly Agree/Agree" than the tertiary education laboratories.

3.6. Comparison between Tertiary Education and Industrial Laboratories

The t-test Analysis for Comparing Respondent's Perception was used to ascertain the significant difference in the opinion of the workers and students between tertiary education and industrial laboratories, at 5% level of significance. Evidence from the test result indicated that there is no significant difference between safety performance of tertiary education laboratories and industrial laboratories, since the value of P ($T \le t$) two-tail is greater than 0.05 value of P ($P > 0.05$). Hence, null hypothesis was accepted and the alternate rejected. The conclusion is that there is no significant difference in respondents' perception on safety culture between the two groups of laboratories. Although, the mean value of the academic ($M = 3.69798$) respondents exceeds that of the industrial respondents ($M = 3.62842$) slightly. However, the result of our observation demonstrated that the value of the mean is not enough to conclude that tertiary education laboratories are better than industrial laboratories. This is conformity with research done by [27], they observed that laboratory safety perceptions were similar between respondents from tertiary education and industrial laboratories and 90% of respondents or more agreed that their laboratory was a safe place to work. Furthermore, the majority of the respondents stated that safety in their laboratory took precedence over all other laboratory priorities.

4. Conclusion

Institutionalizing positive safety culture in any organisation is a major contributing factor for overall safety performance. The results from the assessment methods (questionnaire and checklist) used in this study showed that management commitment in form of supervision was high in tertiary education laboratories. It was also observed that experiment manuals, waste management, personal protective equipment, and housekeeping are of more priorities in academic laboratories than in industrial laboratories. Statistical test results discovered that the level of safety culture was significantly different among the tertiary education analytical laboratories as well as the industrial analytical laboratories. Finally, it is concluded that safety culture is more significant in tertiary education chemical laboratories than industrial laboratories.

5. Recommendations

1) Laboratory personnel should exercise a duty of care by working in a safe and efficient manner, having regard to their personal safety and the safety of other workers as well as the public.

2) The lines of authorities in any analytical Laboratory should demonstrate commitment to safety according to clause 5 of ISO45001[28] by establishing laboratory health and safety Management system, safety policy and objectives as well as institute evaluation and monitoring processes to ensure that they are met.

3) There should be periodic conduct of safety audit to assess the effectiveness

of the health and safety management system and other measures.

4) Hazards identification, classification and analysis procedures should be established and implemented in all new laboratory work, especially laboratory research.

5) Adopt a personal credo: the "Safety Ethic"—value safety, work safely, prevent at-risk behavior, promote safety, and accept responsibility for safety.

6) Establish and maintain an Incident Reporting System, an Incident Investigation System, and an Incident Database that should include not only employees but also students.

7) Safety supervisors should be competent and adequately empowered to be able to access and share legislation, codes and standards, plan and implement safety requirements, monitor and report safety performance or non-compliance.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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