A COMPARATIVE ASSESSMENT OF SAFETY CLIMATE AMONG PETROLEUM COMPANIES

By

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Abstract

Introduction: Occupational health and safety is an important component of national development. Occupational health and safety is relevant to all branches of industry, business and commerce including traditional industries, information technology companies. Safety climate can be regarded as the surface features or indicator of safety culture emerged from workforce's attitudes and perceptions. Organizational climate is conceived to be a critical determinant of individual behavior in organizations. **Aim of work:** The current study was designed to perform a multi-level comparative analysis on employee's perception for safety climate dimensions in petroleum and petrochemical of three industrial sectors; multinational, investment and public, in Egypt. **Materials and methods:** Data were collected utilizing a modified-NOSACQ-50 questionnaire for the seven safety domains including 66 questions, constructing safety climate dimensions which are; management commitment, safety training, workers' involvement, safety communication and feedback, safety rules and procedures, and safety promotion policies, as well as self-reported safety behavior of employees. The questionnaire was distributed to 6 petroleum companies (two companies of each sector) targeting all employees. **Results:** Analysis of data revealed significant differences in employee's perception on safety management practices among the three petroleum sectors especially in worker involvement domain and safety rules and procedures applied in those companies. **Conclusion:** Workers' involvement was the main extracted factor for proper safety climate establishment within an organization and should be taken into consideration for decision making in safety matters. The research provides useful information for project managers and safety practitioners who desire to improve safety performance within an organization.

Keywords: Safety climate, Occupational health and safety management, Safety culture and Safety performance.

Introduction

Occupational health and safety (OHS) is an important component of national development and is relevant to all branches of industry. Safety culture and climate are concepts that today attract much attention across a broad number of industries to promote and enhance safety performance (Clarke, 2000). Safety culture refers to a commitment to safety at all levels of an organization from frontline personnel to executive management. A subset of safety culture is safety climate and refers to the aggregated employee perception for workplace safety management implementation and its effectiveness (Flin et al., 2000 and Cooper and Phillips, 2004). Good safety culture and climate are the most important factors in achieving not only safe workplace but also meeting business goals (Bergh, 2011). Misnan et al. (2008) argued that a company's intangible safety culture may be more important than safety procedures or standards.

Safety climate can be regarded as the surface features or indicator of safety culture emerged from workforce's attitudes and perceptions (Cox and Flin, 1998). Safety climate is considered as an organization's temporal ‘‘state of safety'' at a discrete point in time. Bergh, 2011, concluded that the organizational culture is expressing itself through the organizational climate. It refers to workers' shared perception of their organization's policies, procedures, and practices as they relate to the value and importance of safety within the organization (Griffin & Neal, 2000). It is the measurable components of safety culture (Mearns et al., 1997). Safety outcomes are conceptualized as the consequences or effects of safety climate. Safety climate may be a more distal antecedent of accidents/injuries, having a direct effect on safety-related behaviors which in turn have a direct effect on accidents/injuries (Zohar, 2003). Historically, organizational climate is conceived to be a critical determinant of individual behavior in organizations (Payne et al., 2009).

Safety climate can be assessed by means of quantitative, psychometric questionnaire surveys, so called ‘safety climate scales', measuring the shared perceptions/opinions of a group of workers on certain safety related dimensions or factors. Examples are perceptions towards management, commitment to safety, leadership safety support, worker communication, participation and competence (including training aspects) with regard to safety, safety systems (policies, rules, reporting, preventive measures, etc.), risks, and work pressure (Zohar, 2003 and Seo et al., 2004,). The outcome of such safety climate scales are regarded by many researchers as a predictor or indicator of safety performance (Eeckelaert et al., 2011).

Aim of work

The objective of the underlying study was to perform a comparative and multifactorial analysis on employee's perception on safety climate dimensions among the three petroleum and petrochemical sectors working in Egypt; multinational, investment and public, in order to determine the constituents of safety climate that positively impact safety performance on the targeted sectors.

Materials and methods

- **Study design:** A cross sectional survey study was adopted in six petroleum companies working in Egypt representing three sectors (Multinational, investment and public) who accept to participate in the study.
- **Place and duration of study:** The study was conducted among workers of petroleum Companies at Alexandria city, Egypt from November, 2015 to July, 2016.
- **Study sample:** The study population constituted of two hundreds seventy seven workers (n=277) from the three studied different petroleum sectors, two companies of each sector. All of the six companies were selected to be certified and have an integrated management system (OHSAS 18001, ISO 14001 and ISO 9001). It comprised workers from all departments inside each company such as; maintenance, planning, Health, Safety and Environment (HSE), production, laboratories, utilities, information technology, IT, administration departments, and included all of staff categories (senior managers, junior managers, engineers, supervisors, technicians and technical helpers).

- **Study methods:** A questionnaire, NOSACQ-50 (Kines et al., 2011) was adapted and modified to include 66 items to assess seven dimensions in safety climate and suitable for oil and gas field. The seven dimensions measuring safety climate were: management commitment, worker involvement, safety communication and feedback, safety rules and procedures, safety promotion policies, self-reported safety behavior of employees, and safety training. The modified-NOSACQ-50 has proven reliable and valid for assessing safety climate. The questionnaire was designed to contain responses on positively and negatively (reversed) formulated items using a five-point Likert scale. The scale challenging respondents to take a stand as to what degree they agree with each item, and are scored as follows: Strongly disagree=1; Disagree=2; Moderate=3; Agree=4; Strongly agree=5.

The seven safety climate dimensions contain 66 items dealing with management commitment (10 items, of which 2 are negated or reversed), worker involvement (10 items, 3 negated), safety communication and feedback (9 items, 2 negated), safety rules and procedures (7 items), safety promotion policies (6 items), self-reported safety behavior of employees (15 items, of which 2 are negated), and safety training feedback (9 items, 1 negated).

Consent

Verbal consent from study subjects to participate in the study was obtained before the start of work with assurance of confidentiality and anonymity of the data.

Ethical approval

Approval of the administrative authority of each Company was obtained. Also, the study protocol was approved by Ethical Research Committee of Institute of Graduate Studies and Research, Alexandria University.

Data management

- **Data collection:** The questionnaire was distributed to the companies to get the feedback of perception from the employees from all categories to analyze the safety climate dimensions and the factors that are needed to build up and enhance safety performance at these companies.

- **Statistical analysis:** After data were collected, data were revised, coded and fed to statistical software IBM SPSS version 20. The given graphs were constructed using Microsoft excel software (version 2016). All statistical analysis was done using two tailed tests and alpha error of 0.05. P value less than or equal to 0.05 was considered to be statistically significant. Scoring for discrete statements was summed together to produce the scores for each dimension which in turn was summed together to produce the overall scores for each respondent. The internal consistency of each of the seven questionnaire dimensions was tested by calculating Cronbach's alpha coefficients (coefficients of reliability). ANOVA, Pearson's chi square test, Mont Carlo exact test and Fishers exact test, Factor Analysis, Multi Layer Perceptron (MLP) and Radial Basis Function (RBF) were utilized to assess and analyze the data.

- **Artificial Neural Network (ANN).** Neural networks are the preferred tool for many predictive data mining applications because of their power, flexibility, and ease of use. The term neural network applies to a loosely related family of models, characterized by a large parameter space and flexible structure, descending from studies of brain functioning. Neural networks used in predictive applications, such as the Multi Layer Perceptron (MLP) and Radial Basis Function (RBF) networks, are supervised in the sense that the model-predicted results can be compared against known values of the target variables. The model divided data into 2 sets, 73% for algorithm training to identify the best model parameters and 27% for testing identified parameters on observed data. The model was stable over iterations with minimal error of 0.9 and very good association between predicted and actual score (linear trend). The importance of each domain was identified by calculating relative importance score which transferred to normalized relative importance which range from 0% for unimportant domain to 100% for the most important one.

- **Radial Basis Function.** The RBF procedure fits a radial basis function neural network, which is a feed forward, supervised learning network with an input layer, a hidden layer called the radial basis function layer, and an output layer. The hidden layer transforms the input vectors into radial basis functions. Like the MLP procedure, the RBF procedure performs prediction and classification.
- **Multilayer Perceptron (MLP).** MLP is a procedure that produces a predictive model for one or more dependent variables based on values of predictor variables. MLP is a feed-forward, supervised learning network with up to two hidden layers. MLP neural network based approach for estimation of the constituent measurement of a safety climate dimensions that would enhance safety culture and positively impact safety performance in the three petroleum sectors.

Results

Table (1): Analysis of workers' perception for domains of safety climate in the three studied sectors.

Perception domain	Organization Type						F (p)
	Multinational		Investment		public sector		
	Mean	SD	Mean	SD	Mean	SD	
Management commitment	4.32	.42	3.96	.48	3.07[d]	.70	0.001*
Worker Involvement	3.98	.53	3.82	.57	2.82[d]	.67	0.001*
Safety communication and feedback	4.19	.48	3.96	.52	3.00[d]	.52	0.001*
Safety rules and procedures	4.21	.51	4.03	.57	2.99[d]	.57	0.001*
Safety promotion policies	3.87	.61	3.84	.72	2.69[d]	.74	0.001*
Self-reported safety behavior of employees	4.26	.42	4.19	.50	3.52[d]	.51	0.001*
Safety Training	4.29	.43	4.18	.50	3.53[d]	.43	0.001*
Overall	4.16	.40	4.00	.45	3.09[d]	.52	0.001*

F: One Way ANOVA d: Significantly different group * $p < 0.05$ (significant)

Table (1) shows a comparative analysis of employees' perception domains of three petroleum sectors for the seven studied domains of management and safety practices that were considered as domains of safety climate. Analysis revealed that the highest mean score values was for multinational petroleum sector compared to investment and public sectors (statistically significant differences at $p \leq 0.05$)

Table (2): Correlation matrix for safety climate domains among the three studied categories.

Correlation Matrix								
Domains		Management commitment	Worker Involvement	Safety communication and feedback	Safety rules and procedures	Safety promotion policies	Self-reported safety behavior of employees	Safety Training
Correlation	Management commitment	1.000	.832	.819	.792	.743	.749	.722
	Worker Involvement	.832	1.000	.836	.774	.752	.804	.771
	Safety communication and feedback	.819	.836	1.000	.837	.766	.802	.772
	Safety rules and procedures	.792	.774	.837	1.000	.809	.805	.809
	Safety promotion policies	.743	.752	.766	.809	1.000	.705	.739
	Self-reported safety behavior of employees	.749	.804	.802	.805	.705	1.000	.838
	Safety Training	.722	.771	.772	.809	.739	.838	1.000

Factor analysis was used to identify and group variables by their common dimensions.

Table (2) illustrates inter correlation values between different studied domains which showed strong correlation (above 0.7), indicating the cohesiveness of variables in the pre-designed questionnaires. Principal components analysis was used in conjunction with multiple correlation matrix in an attempt to reduce the number of predictor variables. KMO-value (Kaiser-Meyer-Olkin; measure of sampling adequacy) was 0.932, indicating that the data was appropriate for factor analysis. Barlett's test for sphericity was carried out (chi-square value = 2156.00) with the associated significance level being equal to 0.000, indicating that data produce an identity matrix. The overall Cronbach's Alpha value was 0.98, indicating good internal consistency and reliability between factors.

Table (3): Principal components analysis for domains of safety climate among the three studied categories.

Component Matrix (a)				
	Component	Initial Eigenvalues		
	1	Total	% of Variance	Cumulative %
Safety communication and feedback	.923	5.709	81.558	81.558
Safety rules and procedures	.922	.341	4.867	86.425
Worker Involvement	.913	.311	4.449	90.874
Self-reported safety behavior of employees	.903	.198	2.822	93.696
Management commitment	.895	.172	2.457	96.154
Safety Training	.894	.147	2.100	98.254
Safety promotion policies	.871	.122	1.746	100.000
Extraction Method: Principal Component Analysis.				
a; 1; components extracted				

Table (3) shows principal components analysis of variance in the employee's perception on safety climate dimensions among the multinational, investment and public studied companies. The 1st principal component (1st extracted factor), is the combination that accounts the largest amount of variance in the sample, was the domain of "Safety communication and feedback" (0.923). The 2nd principle component (2nd extracted factor), accounts for the next largest amount of variance and is uncorrelated with the first component, was the domain of "Safety rules and procedures" (0.922). Successive components that explain progressively smaller portions of the total sample variance, and all are uncorrelated with each other, were “Worker Involvement” (0.913); “Self-reported safety behavior of employees” (0.903); “Management commitment” (0.895); “Safety Training (0.894); and “Safety promotion policies”(0.871). As illustrated, the value of Eigen for verifying the factor analysis of principal components to decide on how many factors can affect and represent the data that is greater than 1, was attributed to “Safety communication and feedback” (5.709). Other domains showed values of variances less than 1 are no better than a single variable.

- **Radial Basis Function.** A RBF neural network based approach for estimation of the constituent measurement of safety climate dimensions that would enhance safety culture and positively impact safety performance in the three sectors petroleum companies (multinational, investment and public) working in Egypt. The case processing summary shows that 204 cases were assigned to the training sample, 73 to the testing sample. No cases were excluded from the analysis.

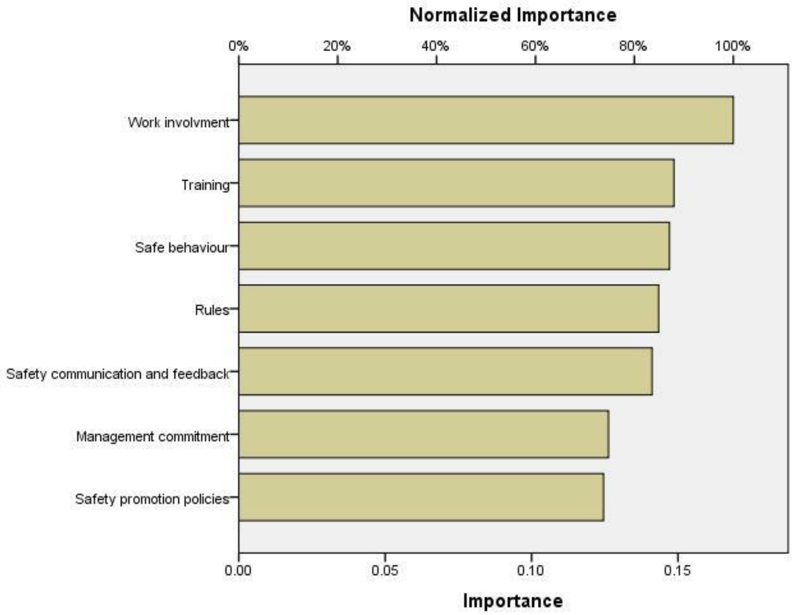

Figure (1): Radial-basis function network structure for the seven domains of safety climate.

Figure (1) illustrates the network information of RBF chart. Analysis illustrated the RBF independent variable importance. The number of units in the input layer is the number of covariates plus the total number of factor levels; a separate unit is created for each category of management commitment, worker involvement, safety communication and feedback, safety rules and procedures, safety promotion policies, self-reported safety behavior of employees, safety training and none of the categories are considered "redundant" units as it is typical in many modeling procedures.

Results revealed that "worker involvement" is most important safety climate domain with importance of 0.169 and normalized importance, NI, of 100%. The 2nd important safety climate domain accounts for "Safety Training" (0.149) with NI of 88.0%. The successive domains with regards to their importance were "Self-reported safety behavior of employees" (NI=87.1%), "Safety rules and procedures" (NI=84.9%), "Safety communication and feedback" (NI=83.6%), "Management commitment" (NI=74.8%) and "Safety promotion policies" (NI=73.7%).

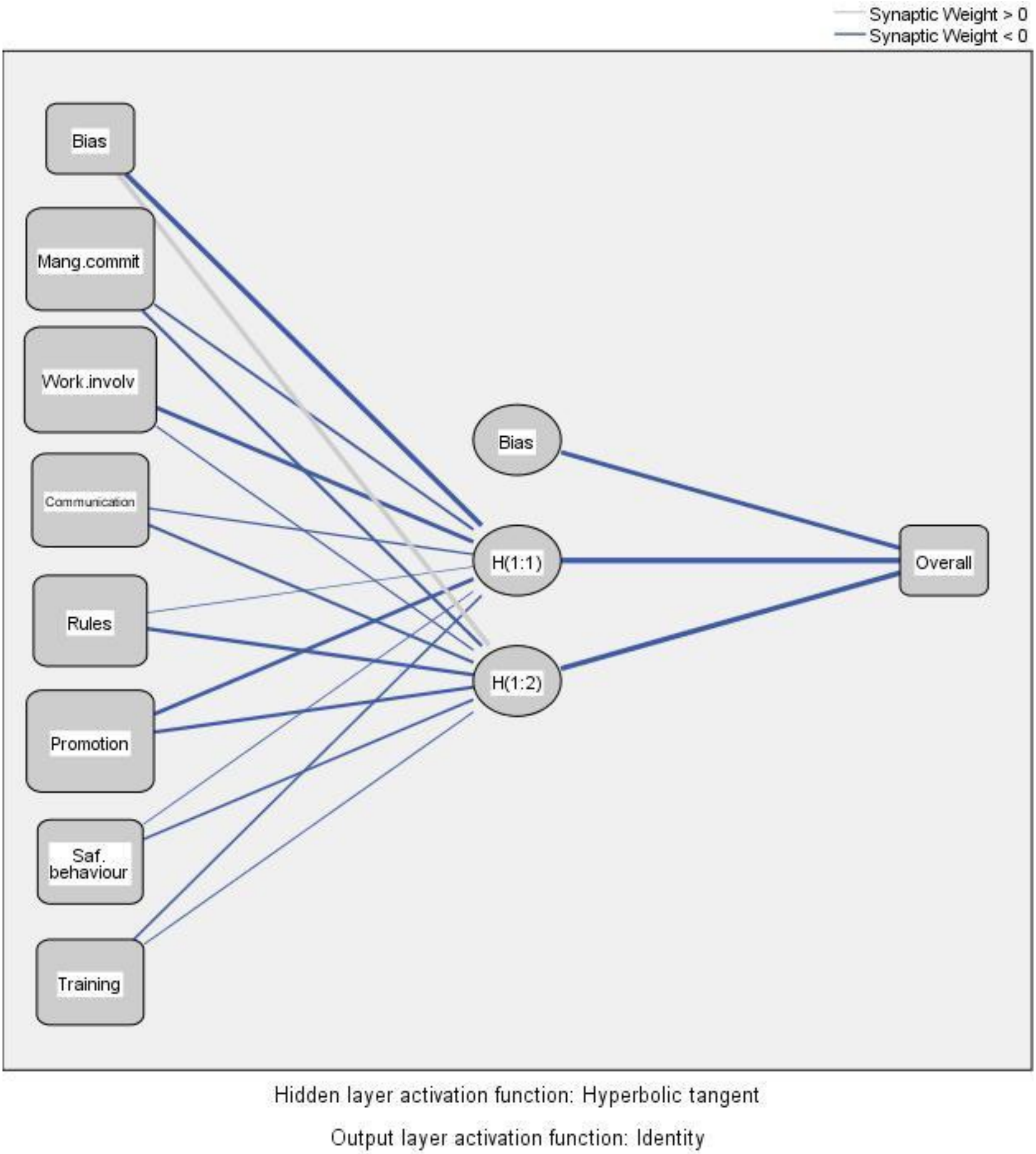

Figure (2): Multi-layer perception network structure for the seven domains of safety climate.

- **Multilayer Perceptron (MLP).** From the MLP analysis, 190 workers (68.6%) were assigned to the training sample, and other 87 (31.4%) to the testing sample. No cases were excluded from the analysis. The choice of the records was done in a random manner. The whole effort targeted in the development of an ANN that would have the ability to generalize as much as possible. Two units were chosen in the hidden layer. The number of units in the input layer is the number of covariates plus the total number of factor levels; a separate unit is created for each category of Management commitment, Worker Involvement, Safety communication and feedback, Safety rules and procedures, Safety promotion policies, Self-reported safety behavior of employees, Safety Training and none of the categories are considered "redundant" units as is typical in many modeling procedures.

As illustrated in Figure (2), the input layer contains the predictors. The hidden layer contains unobservable nodes, or units. The value of each hidden unit is some function of the predictors; the exact form of the function depends in part upon the network type and in part upon user-controllable specifications. The output layer contains the responses. Since the history of default is a categorical variable with two categories, it is recoded as two indicator variables. Each output unit is some function of the hidden units. Again, the exact form of the function depends in part on the network type and in part on user-controllable specifications.

Analysis illustrated that "worker involvement" is the most important safety climate domain with importance of 0.168 and NI of 100%. The 2nd important safety climate domain accounts for "Management commitment" (NI=95.6%). The successive domains with regards to their importance were "Safety promotion policies" (NI=95.0%), "Safety communication and feedback" (NI=82.7%), "Safety rules and procedures" (NI=79.2%), "Safety training" (NI=71.7%) and "Self-reported safety behavior of employees" (NI=69.8%). The MLP network shows that Worker involvement and

Management commitment are the most important predictors and Self-reported safety behavior is the least important predictor of an organization safety climate.

Discussion

Safety climate can be regarded as the surface features of the safety culture discerned from the workforce's attitudes and perceptions within a Safety Management System (SMS) at a given point of time (Flin et al., 2000). Analyzing safety climate can aid in identifying its dimensions, and propose the consequences of safety culture and employees' safety behavior and providing evidence on factors that should be encouraged to reduce risks and improve performance in these types of organizations. Waring, 1996, a key researcher in Occupational Health and Safety (OHS) area, described a SMS as a systematic framework so that policy, objectives, strategy, organizing, planning, resourcing, risk assessment, implementation, monitoring and measuring performance, auditing and review can be tackled coherently. The underlying results showed that the managers' commitment, training, communication, and employee involvement are the priority domains on which it is necessary to stress the effort of improvement, where they had all the descriptive average values lower than 3.0 at public sector (Table 1). A comparative study for safety culture assessment among two Algerian petrochemical plants was conducted by Boughaba, et al. (2014) to identify the factors that contribute to a safety culture, he concluded that workers' involvement and management commitment are the important factors for establishing proper safety culture. Results of worker involvement, safety rules and procedures, and safety promotion policies were not satisfied in public sector, mean scores were less than 3 (Table 1), so worker involvement in health and safety matters and participation in decisions making should be enhanced, as well as for application of safety procedures, rules and international standards. Applying incentives and punishments rules on the workers for using safety equipment's and applying safety rules and relate it to employee appraisal and promotion is vital in order to enhance safety culture and consequently safety climate in public sector companies (Bergh, 2011 and Hosny et al., 2014). The result of mean scores of the seven safety climate domains for multinational and investment sectors were satisfied (Table 1) and consistent with the result of Vinodkumar and Bhasi, (2011) who studied the impact of management system certification on safety management. They presented an empirical investigation on the influence of management system certification on the relationship between safety management and safety performance in major accidents in chemical industry. Their analysis revealed that the mean score of the seven safety climate dimensions for the certified organization was above 3 and employee's perception for safety climate dimensions in OHSAS 18001 organizations are significantly higher compared to other companies.

The underlying factor analyses showed inter item correlations with a sufficient sample size. Seven principal components were examined for measurement of safety climate that would positively impact safety performance on petroleum and petrochemical industrial sectors. The principal component analysis showed that "Safety communication and feedback", followed by "Safety rules and procedures ", "Worker Involvement", and "Management commitment" were the most significant factors (Table 3) for establishing positive safety climate on petroleum and petrochemical sectors. Similar results to the current study was obtained from the study of assessing safety climate in construction projects in Hong Kong conducted by Choudhry, et al. (2006) with objective to determine what constitutes measurement of safety climate that would enhance safety culture and positively impact safety performance on construction projects. The results indicated that management commitment and employee involvement made significant contributions to safety climate.

The artificial intelligence model was used to identify which domain recorded the best performance in identifying safety climate constructs. The model reveals that "Worker involvement" was the most important safety climate domain and the 2nd was "Safety training" (Figure 1 and 2). The successive domains with regards to their importance were "Self-reported safety behavior of employees", "Safety rules and procedures", "Safety communication and feedback", "Management commitment", and "Safety promotion policies".

The importance of Safety communication and feedback factor as a safety climate construct dimension was reported in many literatures such as; Embrey (1992) who argued that deficiencies in communication systems contribute directly to a series of error-inducing factors that contribute to disasters. Prussia et al., 2003, concluded that effective communication between employees and managers can facilitate forming a collective mind or set of perceptions, which further promotes safer behavior. Apart from safety communication between employees and managers, a high regard for the leader and the extent to which employees perceive their managers in coordinating safety jobs to be done, lead to employees' positive perceptions of safety and engagement in safety behavior. Cox and Cheyne (2000), Vredenburgh (2002), and Mearns et al. (2003) included Safety communication and feedback as a factor in their surveys using questionnaire among various category of workers and showed that Safety performance is influenced by the level of communication in an organization.

The importance of "Safety rule and procedure" factor as a safety climate construct dimension was reported by Glendon and Litherland (2001), who categorized it as a reliable factor utilizing factorial analysis of data collected from construction workers. Cox and Cheyne (2000), and Mearns et al. (2003), reported that safety rules and procedures have significant correlation with accident rates in their offshore safety studies.

Worker involvement is empowering for employees to be involved in their work processes and associated safety processes. Branham (2010) suggested that a workforce is engaged when individuals promote safe behaviors and actively reduce workplace hazards. Dollard & Bakker, 2010, stated that employee's engagement in safety can lead to positive organizational outcomes such as fewer work-related injuries if employees have adequate resources. Interestingly, overall safety culture is more correlated with worker engagement than worker compliance with rules and procedures. Vredenburgh (2002), included worker participation, safety training, hiring practices, reward systems, management commitment and communication and feedback as the safety management practices in the study of hospital environment. Worker involvement has been reported as a decisive factor in safety management by Cox and Cheyne (2000).

Conclusion and recommendations

The significant differences in safety climate dimensions among the three petroleum sectors working in Egypt (multinational, investment and public) were illustrated through a cross sectional survey aiming at determining the current level of safety climate and safety culture in some companies. Among the seven domains of safety climate including management commitment, worker involvement, safety communication and feedback, safety rules and procedures, safety promotion policies, self-reported safety behavior of employees, and safety training, workers' involvement domain was the most important factor that can enhance safety performance. Worker involvement in decision making for safety matters, applying international standards of safety procedures in addition to safety promotion policies in workplaces, are factors that should be enhanced to improve levels of employee's responsibilities and accountabilities toward their safety and consequently to proper safety climate within organizations.

Conflict of interest

None.

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