Assessment of The Safety Climate of a Chemical Plant Using Spearman's Correlation Analysis

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ABSTRACT

The study aims to assess the state of safety in a chemical plant by using safety climate survey. A conceptual framework of safety climate questionnaire is developed and validated by a panel of experts. The survey has been conducted with 130 participants and Spearman's rank correlation analysis is used to interpret the results. The hypothesis testing demonstrates that the correlation coefficient is statistically significant at p level of 0.01. The correlation factor for the resin plant, laboratories and administration functions is found above the acceptable level as set by the organisation. However, the same has not been met for maintenance, stores and coatings plant. Several recommendations were made to change the safety climate of these later functions to improve further continually.

Key terms used:

Safety climate, Safety Performance, Chemical Plant, Questionnaire, Spearman's rank correlation analysis

1.INTRODUCTION

According to DGFASLI, in 2018 more than 400 accidents and around 450+ fatalities occurred in various factories situated in different states of India. In the state of Karnataka alone, 43 accidents and 55 fatalities occurred (DGFASLI, 2018). Heinrich stated that unsafe act and unsafe conditions account for around 88% of workplace accidents (Heinrich, 1931). Later researchers suggested that management failure has a share in contributing to workplace accidents (Weaver, 1971). The unsafe acts are driven by factors like worker attitude, behaviour and beliefs. Often, safety climate and safety culture are the terminologies used to understand the consciousness of workers towards safety matters. It also helps the organisation to understand what workers feel about the safety policies, procedures and practices (Mearns, et al., 2003) (Guldenmund, 2000) (Cox & Flin, 1998).

Over the years many researchers have given their definitions of safety climate for interpretations. According to Zohar (1980) safety climate is the shared perception about work environment prevailing at the workplace. According to Brown (1986) it is a set of perceptions or

beliefs of a person or group about a specific entity. However, Cooper (1994) holds the view that the safety climate reflects a collective point of view which employees hold regarding prevailing safety conditions at the workplace. Coyle (1995)'s opinion reveals that it is an objective measurement of attitude and views towards occupational health and safety issues. Williamson (1997) postulates that it is actually a concept where the behaviours and actions of the employees expose the mirror image of the completeness and honesty of the organization in terms of its holistic approach to safety management. Studies demonstrated that just the development and implementation of a safety management system is insufficient to enhance safety performance (Ghahramani & Salminen, 2019). It is the human factor on which the successful implementation of safety management system relies (Kim, et al., 2019). Recent studies have also marked the significance of the safety climate studies in attaining safety related outcomes (Newaz, et al., 2018) (Alruqi, et al., 2018). The safety priority or safety climate as comprehended by workers is a vital factor-the degree of comprehension may lead to the absence or recurrence of personal injuries, fire, explosions, chemical releases (Zohar, 2011) etc in the factory premises.

The concept of safety culture has largely evolved since the OECD Nuclear Agency (1987) (Agency, 1987) found that poor safety culture was the prime reason which led to the Chernobyl disaster at the plant (Pidgeon & O'Leary, 2000). When compared to safety culture, safety climate is more inclined towards workers' psychology, values and attitudes that they have with respect to safety in the organisation (do Nascimento, et al., 2017). Therefore, the assessment of safety climate in manufacturing industry becomes vital in understanding the values and beliefs of its employees. The vitality of safety climate in reducing workplace injuries has been widely acknowledged in research but the potential interaction is hardly implemented at industry level (Kim, et al., 2019). Recently, researchers have identified an optimistic relationship between safety climate and safety performance, where inversely proportional relationship was found between positive assessment of safety climate and injury rates (Chen, Jin, & Soboyejo, 2013) (Goldenhar, Williams, & Swanson, 2003) (Lingard, Tracy, & Blismas, 2011) (McCabe, Alderman, Chen, Hyatt, & Shahi, 2016) (Panuwatwanich, Al-Haadir, & Stewart, 2016)

The present study assesses the safety climate of a chemical plant by survey using a conceptually developed questionnaire for the site. The plant is a manufacturing unit of The Sherwin-Williams Company in Bangalore, Karnataka. The study was conducted at the organisation as a part of its behavioural based safety program which aims at evolving safe behaviour among its employees. One to one interviews were conducted with workers as well as the leaders. The total no. of participants in the survey was 130 which included 105 males and 25 females.

2.METHODOLOGY

2.1 CONSTRUCT OF SAFETY CLIMATE ASSESSMENT QUESTIONNAIRE

There are multiple dimensions of safety climate which serves as a platform for safety related actions at a workplace. For understanding the multi-dimensionality of safety climate, literature review was conducted. The review comprised of 2 phases; in the first phase a thorough study of organisation's past experiences related to safety issues and concerns was carried out. Trend analysis of past 10 years data of organisation's incident investigations, behavioural observations and risk assessments was initiated to understand the risks involved in a chemical industry. The questionnaire had an emphasis on the cultural background of employees because of two reasons. First, because of the severity of hazards they are exposed to and secondly, there were more head counts at the manufacturing department. The dimensions that were found most suitable for the organisation were: leadership & commitment, distractions, work motivation, incident reporting, safety programs and worker participation.

In the second phase, extraction of most cited articles from Scopus database was carried out. The articles selected were those whose title or keywords or abstract contained words like "safety climate", "safety culture or "safety performance". The articles searched were research publications from 1980 to 2012. The write-ups which didn't have any questionnaire were rejected.15 articles were thus identified as relevant (Mearns, et al., 2003) (Morrow, et al., 2010) (Jjiang, et al., 2010) (Cooper & Phillips, 2004) (Cox & Cheyne, 2000) (Dodek, et al., 2012) (Fogarty & Shaw, 2010) (Gershon, et al., 2000) (Griffin & Neal, 2000) (Raftopoulos, et al., 2011) (Williamson, et al., 1997) (Sexton, et al., 2006) (Zohar D., 1980) (Vinodkumar & Bhasi, 2010) (Varonen & Mattila, 2000). It was observed that the questionnaire had a dominant (more than 80%) articulated research elements, pertinent to this exercise.

2.2 SURVEY QUESTIONNAIRE VALIDATION

The questionnaire was then sent to the panel of experts in the organisation for review and validation. The panel of experts reviewed the questionnaire on the basis of their past experiences, site conditions, types of operations and employees working at different levels. The suggested changes were then incorporated into the questionnaire and the latter were referred to all the departments. The finalised questionnaire comprised of five dimensions and 18 questions.

2.3 SURVEY IMPLEMENTATION

2.3.1 GROUPING THE RESPONDENTS.

In the organisation, the employees were divided as leaders and workers. It was evident that employees working at different places in the organisation face different nature and magnitude of hazards; hence the workforce of the company was categorized as manufacturing and non-manufacturing. Furthermore, categorisation boiled down to coatings plant, resin plant, stores and maintenance in the manufacturing sector. In the non-production category, the departments were identified as lab and administrative staff (HR, Sales, Supply Chain, Operations, EHS, etc). The employees of the departments were segregated into leaders and workers. Incidentally the leaders are those employees who are working in the supervisory capacity while the workers are those who are working under supervision.

2.3.2 RECORDING THE RESPONSES

One to one interviews were conducted with the respondents and their responses were taken in a hard copy i.e. questionnaire sheet. In order to capture the response of the participants a Likert 5-scale response was used in which the respondents can rate their responses from “strongly agree=5”, “agree=4”, “neutral=3”, “disagree=2” and “strongly disagree=1”.

2.3.3 STATISTICAL TOOLS.

The statistical tool selected for drawing interpretations from the obtained data is Spearman’s rank correlation analysis. The reason for utilizing Spearman’s test was due to the fact that, the data were widely skewed and did not show a normal distribution curve, the small size of the sample (Nolan & Heinzen, 2011) being the spoiler. Another reason was that the scatter plots of the mean responses were non-linear. Hence it was considered that data should be reported as ranks and then only correlation has to be established. The scale data were converted to ordinal data by arranging them in ascending order. They were then ranked and co-related. The calculations for correlation were performed using CORREL function in Microsoft Excel 2010 version. The values obtained from the correlation coefficient can vary from +1 to -1. A positive correlation coefficient depicts that the increase in one variable will cause increase in the other whereas a negative correlation is indicative of increment in one variable when other variable

experiences decrement. A zero correlation coefficient depicts that no correlation can be established between the two variables.

2.3.4 RECOMMENDATION AND BRIEFING.

Based on the results, recommendations were forwarded to the management. The acceptable criterion of the correlation coefficient was a value equal to or more than 0.75. The recommendations were given for all the departments in which the obtained correlation coefficient was less than the acceptable limit.

3.RESULTS AND DISCUSSIONS

3.1 SURVEY PARTICIPANTS

The demographic details of the employees participated are tabulated in table 2. The total numbers of participants of the survey were 130. The total number of leaders and workers in the organisation were 37 & 93 respectively. Most of the leaders had more than 15 years of experience while that of the workers was less than 5 years.

No. of employees participated		
Items	Leaders	Workers
Resin Plant	5	22
Coatings Plant	4	14
Stores	2	14
Administration	20	17
Lab	4	17
Years of Experience		
>15 years	15	8
10-15 years	10	20
5-10 years	5	25
<5 years	7	44
Gender		
Males	Females	
105	25	

Table 1 Characteristics of the participants of safety climate survey

3.2 INPUT FOR PERFORMING SPEARMAN'S CORRELATION TEST

The mean of the responses given by the leaders and workers of at the organisational and departmental level were taken as input for performing the test. At the organisational level, the responses of 37 leaders and 93 workers were averaged for each of the 18 questions answered and ranked to establish the correlation. A similar approach was utilised for comprehending the correlation between the leaders and workers at departmental level. This approach was adopted because the prime motive behind the study was to understand that to what extent the view of workers and leaders regarding the safety climate are similar at the organisational and the departmental level.

3.3 STATISTICAL SIGNIFICANCE OF SPEARMAN'S CORRELATION TEST

Hypothesis testing was carried out to determine whether the correlations are statistically significant and different from a null correlation. For this purpose, 10 participants were selected at random (both from leaders and workers) so that external validity will not be limited (Nolan & Heinzen, 2011). The mean of the responses of 10 leaders and 10 workers were computed against 18 questions of the survey. The sample size (N) of the survey was taken as 18 as 18 questions were asked in survey. Researchers have reported statistical tables which pinpoints the specific values of coefficients which must be obtained against degree of freedom (Weber & Lamb, 1970). To ascertain that a correlation is significant, the value of correlation coefficient (r_s) obtained from the hypothesis test having sample size 18 must be equal to or greater than the critical value (Taylor, 1990). For the present study the degree of freedom (df_r) was calculated as:

$$df_r = N - 2, \text{ (Nolan \& Heinzen, 2011)}$$

$$df_r = N - 2 = 18 - 2 = 16,$$

Thus from the Spearman's correlation coefficient(r_s) table (Nolan & Heinzen, 2011), the critical value of coefficient against a degree of freedom of 16 at p= 0.01 is 0.582. The hypotheses which were tested are:

Ho: There is no correlation between the response of leaders and workers ($r_s = 0$)
H1: There is a correlation between the responses of leaders and workers ($r_s \neq 0$)

The mean of the responses of leaders and workers and their respective rankings are displayed in table 3. The correlation was calculated using CORREL which came out to be 0.79. Thus $r_s \neq 0$ and is more than the critical value of 0.582. Hence, the correlation can be stated as statistically significant and null hypothesis can be rejected.

#Q	Leader's mean response	Workers' mean response	Leader's Ranks	Worker's Ranks
1	4.7	4.8	1	1
2	4	4.2	6	3
3	4.6	3.8	2	7
4	4.4	4.2	4	3
5	1.9	2.5	16.5	13
6	1	2	18	15
7	2.7	3.4	9.5	9
8	1.9	3.1	16.5	10
9	2.2	3	14.5	11
10	2.4	2.7	12.5	12
11	2.2	1.9	14.5	16.5
12	2.7	2.4	9.5	14
13	2.4	1.9	12.5	16.5
14	2.5	1.5	11	18
15	4	4.1	6	5
16	3.6	3.7	8	8
17	4	3.9	6	6
18	4.5	4.2	3	3

Table 2 Mean responses of Leaders and Workers and respective rankings

3.4 CORRELATION ANALYSIS

The correlation coefficients determined for the overall organization and for individual departments are tabulated in Table 4.

	Correlation Coefficient
Overall	0.75
Resin Plant	0.85
Coatings Plant	0.68
Stores	0.68
Maintenance	0.22
Administrative	0.89
Lab	0.78

Table 3 Summary of obtained Pearson Correlation coefficients

Spearman's correlation coefficient for the overall organisation was determined at 0.75. It can be said from this correlation coefficient that there is a moderate cohesion between the responses of the leaders and that of the workers in the organisation. It indirectly signifies that the perception of safety climate between the leaders and workers is similar in nature. However, drawing a conclusion about the safety climate of the organisation from the overall correlation coefficient is a macroscopic point of view and would not therefore help the organization to comprehend the actual conditions which prevail at the shop floor.

The correlation coefficients for resin plant and administration were estimated as 0.85 and 0.89 respectively. In both the functions, leaders and workers have similar perceptions towards workplace safety. While analysing the data for resin plant, it is observed that the number of permanent workers is much more here as compared to the coatings plant. Even the tenure of the temporary workers working at the resin plant has been extended for a few years. It implies that the relationship between the temporary workers and the permanent workers in this case has received a shot in arm.

The correlation coefficient of 0.78 for lab may be credited to the fact that the workers working in the lab are educated enough to understand and follow the policies and procedures instructed to them. Due to their education it is easy for the leaders to mould their attitude by changing their behaviour towards workplace safety.

The correlation for Administration can be attributed to the fact that the agency staffs are serving in the organisation from a very long period of time and are well known to the leaders and safety climate prevailing in the organisation. Here the workers are involving in low risk activities viz. gardening, cleaning, housekeeping and security whereas the leaders are engaged in mostly desk work which involves finance, accounting and other office operations. Therefore, this is not comparable with manufacturing.

The safety climate survey, conducted in the coatings plant, has achieved a correlation coefficient of 0.68. The possible causes of obtaining such a correlation can be ascribed to the fact that a majority of the workers in the PCB plant are on contractual role (agency staff) while many of them are working for about two years. The understanding of the safety climate of the organisation hasn't yet been absorbed by them. It was observed during one-to-one interview that most of them didn't know certain basic terms in safety like safety hazards and behavioural observations, near miss etc. And because of their short tenure in the plant, they are unable to develop a strong relationship with their leaders to a point that they can convey their concerns to them freely. Another reason could be their past experience with other industries where the priority on safety might not the same as this organisation. These factors have led to a correlation coefficient value which is 20% less than that of the resin plant.

The survey conducted in the Stores yielded a correlation coefficient of 0.68. The possible reasons of obtaining such a correlation are similar to that of coatings plant. The survey conducted in the Maintenance department yielded a correlation coefficient of 0.20. As the sampling size of the survey for the Maintenance department doesn't qualify for a comprehensive statistical analysis, the interpretations would be quite speculative. However, interviewing with the workers at the Maintenance department reveals few concerns on their understanding on safety climate of the organization. Their priority is to attend the breakdown and handover the equipment to the production at the earliest and to do so they commit safety violations and by-pass some established processes and/ or procedures. They have experienced that safety is important to the leaders but when it comes for implementation of safety while working, the core maintenance activities get more value.

The key issues identified were communication without proper feedback mechanism, inadequacy of on-the-job training; priority of performance over safety, not-so-good credibility of leaders, supervisory and dependent stage of safety conditions, poor acceptance of continuous learning and repetitive violations. Specific recommendations were given to the various functions to eliminate or at least minimize these issues and to move towards positive safety culture. Following recommendations but not limited to these only were recorded to improve

the workplace environment vis-à-vis positive safety culture with proactive employee engagement:

1. Implement project on improving the ventilation system in the facility to minimize chemical exposure.
2. Educate the workmen regarding injury prevention emphasising on ergonomics.
3. The leaders are expected to receive feedback from the employees, review them and validate the feasible one to develop a two-way communication.
4. A dedicated module should be prepared for giving on-the-job training to the workmen addressing the high-risk activities. It is further suggested that an adequate mentoring program should be in place where a group of workers should be assigned to supervisors and line manager who would observe, monitor and review the performance of workers towards proactive safety climate.
5. Provide controls in place such as CCTV to monitor any violations done by the workmen.

3.1 CONCLUSION

Many researches in the past have identified various dimensions of safety climate questionnaires. Claims have been made to debate on single set of dimensions on questionnaires that could be used to assess the safety climate of all the organisations. The dimensions of a safety climate survey are very much industry specific and must be customized as per the type of industries including the cultural background of the employees, the management framework of the organization, safety regulations, site conditions, hazardous materials handled, technology used, location of factory and many more. These limitations have been governed the framework developed for this chemical industry in Bangalore. The dimensions specific to this factory were: leadership & commitment, distractions, work motivation, incident reporting, safety programs & worker participation.

There must be a clear decision of prioritizing safety when a choice between safety and performance arises. However, bringing change in the mind-set of employees is a herculean task and cannot be done quickly. The mind-set has to break all the resistances of beliefs and attitudes towards safety. It is a challenging task to make an employee practice safety at workplace, who is not prioritising safety in his daily life. However, the results seem to be encouraging for the laboratory, the resin plant and the administration and they are expected to sustain the safe practices. For the organisation to season holistically as a safe workplace, the other departments like the maintenance, the coatings plant and the stores are advised to adopt the

recommendations. The second survey should be conducted, once the recommendations are implemented and effectiveness verified and sustained, to check the improvement in the safety climate of the plant although most of these future results are speculative.

3.6 AUTHOR'S NOTE

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Appendix-A

Leadership & Commitment		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	Do you believe your leaders are committed to Safety					
2	Safety rules and requirements are followed by all team members					
3	Safety is always first when I conflict with plant operations or sales					
4	Are leaders listening to concerns and providing effective solutions					
Any distractions						
5	I have many pending jobs to complete					
6	I have personal issues that distract me from concentrating on my work					
7	Plant/ Business is not running well. I need to spend extra time to improve the situation.					
8	Work for improvement programs, sub-committee and other activities can't be planned effectively.					
Work Motivation						
9	I need a break as I have been working for long hours recently.					
10	There are too many things to follow up tomorrow, and it is affecting my regular job.					

Incident Reporting						
11	I see many at-risk behaviours and unsafe conditions.					
12	Contract workers are not following Safety procedures and practices					
13	Near-miss reporting, Safety walk and BBS observations are not properly followed.					
14	Not all incidents are reported, and root causes effectively rectified.					
Safety Programs and Worker Participation						
15	Safety programs are effective and relevant and are communicated properly to everyone.					
16	Safety training and committee meetings are adequate and I look forward to attending them.					
17	Suggestions are taken and followed up promptly					
18	Employee involvement is encouraged and accomplishments are celebrated/ rewarded					

Table 4 Finalized questionnaire for assessing safety climate (after validation)

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