# 화학공정산업에서 안전문화 이행과 영향 변수

백 종 배
충주대학교 안전공학과
(2006. 7. 3. 접수 / 2006. 8. 14. 채택)

# Safety Climate Practice and its Affecting Variables in the Chemical Process Industry

**Jong-Bae Baek**
Department of Safety Engineering, Chungju National University
(Received July 3, 2006 / Accepted August 14, 2006)

**Abstract** : The major purpose of this paper to identify safety climate practices, and to find the affecting variables that influence to the difference in the level of safety climate between plants and employees. And this paper attempted to find the interventions for improving safety climate in the chemical plants. The questionnaires were developed from literature review, especially made by HSE(Health and Safety Executive) in the UK and distributed to managers and workers. The frequency analysis was applied for identifying the level of safety climate. The affecting variables(plant size, accident occurrence, accident experience, injury experience and severity, and length of employment) are tested through analysis of variance(ANOVA). The results of frequency analysis showed that both managers and workers recorded generally high level of safety climate, and the major underlying problems are inadequate H&S procedures/rules, pressure for production, and rule breaking. According to the outcomes of ANOVA, the variable 'length of employment' is the only variable which makes the level of safety climate different. From the survey of safety climate practice, this study finds the level of safety climate and three major underlying problems in safety climate factors of the responded plants, and presents two interventions for improving safety performance. Despite of these outcomes, the applied factors are remained questionable for reflecting as the best ones for identifying safety climate in the chemical industry. In addition, the bias caused by self-report exist in the reliability of the response, and the equivalent size of respondents.

**초 록** : 이 논문의 주요 목적은 안전 분위기를 확인하여 공장과 근로자의 안전문화 수준에 영향을 주는 변수들을 찾아내고 더 나아가 화학공장의 안전문화를 향상시킬 수 있는 영향요소를 찾는데 있다. 이 논문에 사용된 질문표는 영국의 HSE(Health and Safety Executive)의 질문표를 근간으로 문헌 조사를 통하여 경영자와 근로자로 분류하여 개발하였다.
안전문화 수준을 확인하기 위해 빈도수 분석을 하였으며 공장규모, 사고 발생, 사고 및 상해 경험과 심각성, 그리고 고용기간 등과 같은 영향변수들은 ANOVA(Analysis of Variance) 분석을 적용하여 테스트 하였다. 빈도수 분석의 결과 일반적으로 경영자와 근로자 모두가 안전문화의 수준이 높게 나타났으며 주된 문제점들로는 부적당한 안전보건 절차와 규칙, 생산에 대한 압력, 그리고 규칙위반으로 나타났다. 또한 ANOVA 분석결과에 의하면, '고용기간'은 다른 안전 문화의 수준을 만드는 유일한 변수인 것으로 나타났다. 그리고 안전문화의 조사로부터 공장들의 안전문화요소에 대한 주요 3가지 문제점과 안전문화수준을 발견하였으며 안전 이행 능력을 향상시킬 수 있는 2가지 영향요소를 제안하였다.
**Key Words** : safety culture, safety climate, PSM(Process Safety Management), risk assessment

## 1. Introduction

Safety culture/climate has been recently recognized as a fundamental and ultimate solution for improving workplace safety in various industries including chemical industries. Lord Cullen[1] said that, during the Piper Alpha inquiry, it is essential to create a corpo-

parkkd@pknu.ac.kr

rate atmosphere or culture in which safety is understood to be and is accepted as, the number one priority. Fennell[2] stated that, following the Kings Cross fire, a cultural change in management is required throughout the organization. Petersen[3] demonstrated that culture is to a large degree behind human-caused catastrophes. Zebroski[4] found eleven attributes which have had medium to large degrees of commonality in the basis for the TMI-2, Chernobyl, Challenger, and Bhopal events.

Although the study which was related to the safety culture and climate has not formally and actively been carried out in Korea, there have been some initial movements to improve safety culture/climate by not only industries' practitioners but also regulatory authorities. In light of these initiatives, this paper studied the practices of safety climate in the chemical industries by applying the HSE-suggested core items. In addition, this paper describes a series of studies that are focused on finding affecting variables which influence to difference of the plants' or workers' safety culture/climate. The result showed that the level of safety climate was recorded generally high(overall mean: 1.89) for managers and workers and the affecting variable that made the level of safety climate different among workers was 'length of employment'. But some of the affecting variables such as age, gender, work area, etc. which were used in previous researches were not applied in this study.

## 2. Literature Review

### 2.1. The concepts of safety climate

Glendon and Stanton suggested that climate is usually regarded as being more superficial than culture in that it involves the current position of a plant[5]. Guldenmund described that safety climate refers to the attitudes towards safety within an organization while safety culture concerns the underlying beliefs and convictions of those attitudes, in other words the prevailing values of the social group[6]. Mearns et al. suggested that the term safety climate is more appropriate for the questionnaire surveys because they provide a snapshot of the organization's state of safety discerned through the attitudes and perceptions of the workforce[7]. Cox and Flin[8] suggested that safety climate can be seen as the indicator of the organization's safety culture as perceived by employees at a point in time. Although the concepts of safety culture and safety climate have been a little different, these two terms have been used interchangeably[9]. HSE reviewed the literature on safety culture, focusing particularly on research carried out from 1998 onwards to review the main features of safety culture and safety climate and to explore the links between safety culture and safety performance[10]. The result of reviewing the concept of safety culture and safety climate which was one of the four findings in this study, was demonstrated as follows; Culture can be seen as a concept that describes the shared corporate values within as organization which influences the attitudes and behaviors of its members. Safety culture is a part of the overall culture of the organization and is seen as affecting the attitudes and beliefs of members in terms of health and safety performance. Safety climate is a distinct yet related concept which can be seen as the current surface features of safety culture which are discerned from the employees attitudes and perceptions[11].

### 2.2. Measurement of safety climate

According to the previous studies, there are at least two ways of treating safety culture, those are as something an organization is (the beliefs, attitudes, and values for safety) and has (the structure, practices, controls,

**Table 1.** Research purposes and related studies

| Research Purposes | Related Studies |
|---|---|
| Correlation between safety climate and safety performance, such as accidents or injuries | Mearns et al.(2003)<br>Glendon et al.(2001)<br>Neal et al.(2000)<br>Lee and Harrison(2000)<br>Cheyne et al.(1998)<br>Diaz and Cabrera(1997)<br>Hofmann and Stetzer(1996)<br>Niskanen(1994)<br>Tomas et al.(1992)<br>Dedobbeleer and Beland(1991)<br>Brown and Holmes(1986)<br>Zohar(1980) |
| Correlation between safety climate and organizational climate | J.B. Baek(2005)<br>DeJoy et al.(2004)<br>Neal et al.(2000) |
| To find the practices of safety climate | Correll et al.(2001) |

and policies for safety). So safety culture can be measured as some combination of both of these aspects[12]. Most of the researches have been conducted using questionnaires for measuring safety climate and a few were carried out by observational study[6,10,13]. These studies were conducted by having a couple of purposes, which were presented in Table 1 below.

## 3. Research Methods

### 3.1. Overview

The targeted plants were chosen with special consideration of suggestions of Health and Safety Commission(HSC) in the UK. HSC suggested that if safety climate measurement is carried out for maturing safety culture in the plants, it is important that the plants were constructed the basic technological safety systems such as facilities and processes which was precondition for developing safety culture. By this reason, HSC presented four pre-conditions below for measuring safety climate.

- an adequate safety management system
- technical failures are not causing the majority of accidents
- the plant is compliant with health and safety law
- safety is not driven by the avoidance of prosecution but by the desire to prevent accidents.

The selected 642 plants were located all over Korea and covered the petrochemical, chemical industries, which have had potential major accidents such as fire, explosion, and toxic release, have taken special inspection by government authorities, and have showed better health and safety management and performance than others. The data were collected through two routes, one was an on-line e-mail collection using SQL-Database Server and the other was an off-line direct posting for two months. Among 642 plants that are targeted for the questionnaire survey, the number of responded plants was 195 plants(30.4%), which the figure means the number of managers who are participate in the survey, and 184 workers.

Table 2. Questionnaire survey factors and number of Items

| Target | Factors | No. of Items |
|---|---|---|
| Managers | Management commitment to safety(M1) | 16 |
| | Merits of the H&S procedures, instructions, and rules(M2) | 8 |
| | Accidents & Near-misses(M3) | 10 |
| Workers | Training & Competence(W1) | 10 |
| | Job security and Satisfaction(W2) | 8 |
| | Pressure for production(W3) | 4 |
| | Communications(W4) | 12 |
| | Perceptions of personal involvement in H&S(W5) | 10 |
| | Perceptions of organizational & management to H&S(W6) | 8 |
| | Rule breaking(W7) | 8 |
| | Workforce view on state of safety & culture(W8) | 13 |

Table 3. The classification of the hypotheses

| Level | | Hypotheses |
|---|---|---|
| Plant | 1.1 | Safety climate of the plant level will be made different by Plant size(number of employees) |
| | 1.2 | Favorable safety climate at plant level will be associated with lower numbers of official accident reports |
| Individual (Worker) | 2.1 | Respondents providing favorable safety climate scores at the individual level will be less likely to have experienced an accident |
| | 2.2 | Respondents providing favorable safety climate scores at the individual level will be less likely to have experienced an injury |
| | 2.3 | Safety climate of the individual level will be made different by length of employment |

The questionnaires used in this survey, which were targeted to managers and workers, were developed mainly according to the HSE framework and the factors applied in questionnaire are shown in Table 2. The hypotheses were classified into two levels, plant and individual worker, as shown in table 3 below.

Hypothesis 1.1 and 1.2 may be tested using data aggregated to the plant level responded by managers, and Hypothesis 2.1, 2.2, and 2.3 to the individual level responded by workers. These hypotheses were tested by analysis of variance(ANOVA). These hypotheses have been tested in the previous researches as described below, and will be compared with the results of this study. This study resulted that a positive significant correlation was found between injury severity and the safety climate scores.

Table 4. Correlations among managers

| Factors | M1 | M2 | M3 | SC | Cronbach α |
|---|---|---|---|---|---|
| M 1 | - | | | 0.75 | .8778 |
| M 2 | 0.38 | - | | 0.84 | .6932 |
| M 3 | 0.62 | 0.59 | - | 0.88 | .7215 |

Table 5. Internal-scale reliability and correlations among workers

| Factors | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | SC | Cronbach α |
|---|---|---|---|---|---|---|---|---|---|---|
| W 1 | - | | | | | | | | 0.79 | .8558 |
| W 2 | 0.71 | - | | | | | | | 0.85 | .7007 |
| W 3 | 0.42 | 0.65 | - | | | | | | 0.79 | .6109 |
| W 4 | 0.73 | 0.71 | 0.48 | - | | | | | 0.82 | .9321 |
| W 5 | 0.63 | 0.59 | 0.34 | 0.70 | - | | | | 0.73 | .8327 |
| W 6 | 0.64 | 0.78 | 0.63 | 0.81 | 0.64 | - | | | 0.86 | .8723 |
| W 7 | 0.41 | 0.45 | 0.68 | 0.32 | 0.31 | 0.39 | - | | 0.70 | .9499 |
| W 8 | 0.63 | 0.60 | 0.41 | 0.69 | 0.64 | 0.68 | 0.29 | - | 0.73 | .6665 |

## 3.2. Reliability and Correlations

To identify consistency of the items in each factor, Internal-scale reliability was analyzed. Internal-scale reliability is applied to groups of items that are thought to measure different aspects of the same concept. It is important that a group of items should be clearly focused on that variable and the accepted level of the result(Cronbach a) is approximately 0.7. Measures of internal-scale reliability for each of the factors are presented in Table 4. It can be seen that all the alphas reported are in the range from 0.6109 to 0.9499. In the factor of 'Pressure for production', the initial a was equal to 0.5951, so one (A consistent message that production pressures must not compromise safety is communicated by management to the workforce) of four items was deleted and also this item was not applied in ANOVA. Cronbach alpha is based on every scale and generally satisfactory.

Correlations(Pearson's r) among managers and workers can be seen in Table 4 and Table 5 respectively, which are significant at the 0.01.

# 4. Results

## 4.1. Demographic and work-related data

Among the responded 195 plants, 'more than 1,000 employees' group was recorded the biggest response

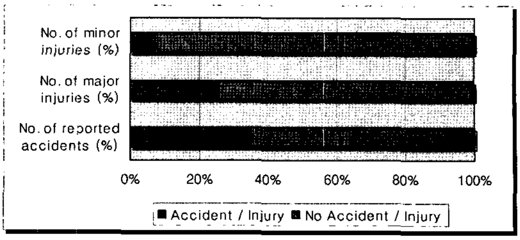


Fig. 1. Distribution of accidents and injuries occurred in recent 12 months.

rate(73 plants; 37.4%) in plant size, in contrast, 'between 100 and 499 employees' group was showed the least(7 plants; 3.6%). It can be noticed that, in the case of dividing into small/medium and large plants at 100 employees, large plants were 133 plants(68.2%), and small and medium sized plants were 47 plants (24.1%).

By number of accidents or injuries in recent 12 months, 'No Accident/Injury' group was much more responded than 'Accident/Injury' group by about 2, 3, and 13 times respectively, and the details were shown in Fig. 1.

## 4.2. Level of safety climate

Frequency analysis was conducted to identify the level of safety climate in plant level and individual level. Correll et al. measured safety culture to identify the underlying cultural issues, and to develop and conduct a survey of the occupational health and safety culture within Australian Meat industry. In this study, twelve item components were applied for scoring safety culture that each component with a minimum of 0 and maximum of 16. The results of scoring were that 'A strong focus on safety' component recorded the biggest score that mean value was approximately 11, and the least value was showed in 'Good organizational learning' component that around 6. Individual factors that comprise the safety climate score were summed in Table 6, and the items of one factor was composed of scoring a minimum 5 and a maximum 1. This is of concern, as it is a higher level of consistency across the industry that will result in overall improvement in safety climate and safety outcomes. As can be seen in the Table 6, there is a small variability on all factors across managers and

Table 6. The result of frequency analysis

| Target | Factors | Mean | Mode | SD | Variance |
|---|---|---|---|---|---|
| Managers | M1 | 1.41 | 1 | 0.68 | 0.49 |
| | M2 | 2.08 | 1 | 1.03 | 1.15 |
| | M3 | 1.70 | 1 | 0.90 | 0.88 |
| Workers | W1 | 1.82 | 1 | 0.95 | 0.94 |
| | W2 | 2.18 | 1 | 0.99 | 1.03 |
| | W3 | 2.28 | 1 | 1.19 | 1.45 |
| | W4 | 1.68 | 1 | 0.85 | 0.72 |
| | W5 | 1.83 | 1 | 1.06 | 1.15 |
| | W6 | 1.77 | 1 | 0.94 | 0.91 |
| | W7 | 2.25 | 1 | 1.33 | 1.76 |
| | W8 | 1.87 | 1 | 0.93 | 0.97 |

workers. In the survey to managers, the mean value recorded between 1.41 and 2.08, and showed generally high level of safety climate. Particularly, 'Management Commitment to Safety(M1)' is the most consistently well rated factor (as determined by the mean value). Workers' responses showed a little more negative and recorded that 'Communications(W4)' is the highest level of safety climate(mean value of 1.68) and 'Pressure for Production(W3)', 'Rule Breaking(W7)', and 'Job Security & Satisfaction(W2)' are relatively low rated factors.

## 4.3. Affecting variables

### 4.3.1. Hypothesis 1

To test the hypothesis, analysis of variance(ANOVA) was applied to sample groups. Hypothesis 1 asserts that safety climate of the plant level will be made different by plant size(number of employees). As can be seen in Table 10, excepting the missing value(15 plants), the hypothesis 1 was tested in the number of 180 plants which were divided into five groups by plant size. Firstly this study analyzed the difference in mean value between five groups. 'less than 30 employees' group recorded the biggest level(1.51) of safety climate, in contrast, 'between 100 and 499 employees' group showed the lowest(1.81). And then this study identified F-value which decide whether mean value was based on just numerical difference or on significant difference statistically. The F-value was 1.758 and significance of F-value was 0.14. This means that in the F-distribution which the degree of freedom was 4 and 175 respectively, the probability which show the value more than 1.758 was 0.14. So in the both significant level was 0.05 and 0.01, null hypothesis that the mean value in the level of safety climate was equal in all five groups was supported. In short, it was analyzed that there was not any difference in safety climate level by plant size. On the other hand, hypothesis 1.2 is that favorable safety climate at plant level will be associated with lower numbers of official accident reports. In analysis of difference of mean value in each group, accident-occurred plants (98 plants) showed 1.76 and non-accident plants(97 plants) recorded 1.70. So non-accident plants showed the higher level of safety climate than the other. The level of safety climate didn't showed any difference based on accident between two groups because F-value was 0.924 and significant value was 0.338.

### 4.3.2. Hypothesis 2

Hypothesis 2.1 is that respondents providing favorable safety climate scores at the individual level will be less likely to have experienced an accident. The number of accident-experienced workers was 10 and the other group was 166 excepting missing value(8 workers). The mean value in accident-experience group was showed 2.21 and standard deviation(SD) was 0.4543, but that in other group was recorded 1.94 and SD showed 0.5650. So the comparison with mean value in two groups demonstrated that non-accident-experience group recorded relatively higher level of safety climate than the other group. But as the F-value showed 2.251 and significance of F was 0.135, the difference in two groups didn't supported statistically. Hypothesis 2.2 asserts that respondents providing favorable safety climate scores at the individual level will be less likely to have experienced an injury. The number of workers who experienced severe injury was 10 workers and that of workers who experienced minor injury was 5 workers. The mean value in severe injury group was showed 2.05(SD was 0.5447) and that in minor injury group was recorded 2.09(SD was 0.3983). But because the F-value showed 0.019 and the significance was 0.894, the difference between two groups was not supported statistically. Hypothesis 2.3 is that safety climate of the individual level will be made different by length of employment. The length of employment was divided into four groups(less than 1 year, between 1 and 3 years, between 4 and 9 years, and more than 10 years) and the number of respondents in each group recorded 4, 27, 61, and 81 workers respectively including the missing value was 11. The mean value and standard deviation in each group was 1.52(SD: 0.3930), 2.15 (SD: 0.6840), 1.87(SD: 0.5637), and 1.98(SD: 0.5067). So the result of descriptive statistics showed that less than one year group had the highest level of safety climate, in contrast, between 1 and 3 years group recorded the lowest level. In this hypothesis, as the F-value was 2.684 and significance of F was 0.048, the difference between groups was supported statistically.

## 5. Discussion

The results of frequency analysis were shown that 'Management commitment to safety(M1)' was the highest among plant level factors and 'Merits of the H&S procedures, instructions, and rules(M2)' recorded the lowest. On the other hand, in individual level, 'Communications(W4)' showed the highest, which was followed by 'Perceptions of organizational and management to H&S(W6)', 'Training and Competence( W1 )', W5, W8, W2, W3, and 'Rule breaking(W7)' recorded the lowest level. These results are a little different to the results from Correll14 ). Both studies showed that workers were not satisfied with their jobs, and perceived positively on organizational and management commitment to safety. In contrast, workers perception on communication, and on safety education and training showed very differently. According to the outcomes from hypothetical test, plant size(hypothesis 1.1) had not any relationship to the level of safety climate, as the result of the previous study. But, in accident occurrence in plant level(hypothesis 1.2), accident experience in worker level(hypothesis 2.1), and injury experience/severity(hypothesis 2.2), the results of the tests were opposite to the prior researches.

The findings of this study should be viewed with consideration to the limitations. Firstly, the design of questionnaires did not sufficiently include the suggestions of some previous studies. Although selected factors and items in other study were applied to show the level of safety climate, these were remained questionable for reflecting as the best factors and items for identifying the level of safety climate in the chemical plants. In addition, all of our measures were self-reported, thus introducing the possibility of common method bias. Particularly, the number of responded samples was different in some items. For example, the number of response of five plant size groups was very different from 7 to 73, and this kind of difference was showed similarly in the response of injury/accident occurrence and length of employment. Secondly, too little affecting variables might be applied to this study. DeJoy et al. assessed the affecting variables(communication, organizational support, safety policy and programs) of safety climate using four control variables such as age, gender, tenure, and hours worked per work, but the result just indicated that the three affecting variables made significant contributions to safety climate, and these control variables would not affect to those affecting variables. On the other hand, Lee & Harrison identified that four variables(gender, age, shifts/days, and work area) were correlated with accident, but admitting these variables as affecting ones to safety climate could not possible. Even though this study found the affecting variable(length of employment) in individual worker level, too little affecting variables to differentiate the safety climate were applied to represent sufficient empirical data. Generally, the possibility of safety management improvement in any plant could be identified by measuring safety climate but it can be significant consideration, as argued by Grote, in inspecting by regulatory authorities and auditing from qualified organizations, that the respondents could write, talk, or behave more positively than normal conditions for measuring safety climate by using questionnaire, interview, or behavior observation methods respectively. Although the result of frequency analysis showed that all managers and workers have high level of safety climate, this bias might not be exempted to this kind of only research-purposed survey.

## 6. Conclusion

Most of all, relatively late-started effort for measuring and improving safety climate have been done in the chemical industry with the high risk, this study could be a little value as an initiative to do active elaboration on safety climate/culture. Despite those limitations above, this study revealed findings that have practical significant.

Firstly, according to the responses from managers, managements actively commit to safety and health of their employees and also well operated for investigating actions. But the H&S procedures, instruments, and rules did not reflect the current working practice and also a little complicated to understand and implement. The former two positive results could be caused from their fundamental hazardous business characteristics. But it can be possible to think from latter little positive result that these plants did a little effort to manage for continuous safety improvement from day-to-day practice.

Secondly, we could say from the results of responses from workers that pressure for production and rule breaking were more serious problems than other factors. These two worst problems are closely interrelated so that it is the most important actions to build a culture of not-accepting the violating behaviors of the regulatory laws and rules, and their health and safety procedures in any circumstance.

Lastly, as a result of the analysis of affecting variables to safety climate, the length of employment influence to the difference in the level of safety climate showing S-type distribution(High-Low repeatedly). So it could show the need to educate and train for safety and health by regularly and systematically. In conclusion, the best two interventions for chemical plants to improve their safety climate would be more management commitment to compliance safety and health rules and procedures, and better(regular and systematic) safety and health education and training.

## References

1) Cullen, W. D., The public inquiry into the Piper Alpha Disaster', Department of Energy: HMSO, 1990.
2) Fennell, D., Investigation into Kings Cross Underground Fire. Department of Transport, HMSO, 1988.
3) Petersen Dan, Human error reduction & safety management 3rd edition, International Thomson Publishing, 1996.
4) Zebroski, E., Lessons Learned from Man-made Catastrophes, in Risk Management, New York: Hemisphere Publishing, 1991.
5) Glendon, A. I., Stanton, N. A., Perspectives on safety culture, Safety Science, Vol. 34, pp. 193～214, 2000.
6) Michael O'Tool, The relationship between employees' reputations of safety and organizational culture, Journal of Safety Research, Vol. 33, pp. 231～243, 2002.
7) Mearns, K., Flin, R., Gordon, R., Fleming, M., Organizational and Human factors in offshore safety(OTH 97 543), London: HSE, 1997.
8) Cox, S., Flin, R., Safety culture: philosopher's stone or man of straw, Work and Stress, Vol. 3, No. 12, pp. 189～201, 1998.
9) Health and Safety Laboratory(HSL), Safety Culture: A review of the literature, HSL Human Factors Group, 2002.
10) Health and Safety Executive(HSE), Safety culture maturity model. HSE, HSE Books, 2000.
11) Flin, R., Mearns, K., O'Connor, P., Bryden, R., Measuring safety climate: identifying the common features, Safety Science, Vol. 34, pp. 177～193, 2000.
12) Reason, J., Achieving a safe culture: theory and practice, Work and Stress, Vol. 12, No. 3, pp. 293～306, 2000.
13) Jong-Bae Baek, A Measure for the Improvement Status of Process Safety Culture in the Chemical Process Industries, Journal of the Korean Institute of Gas, Vol. 10, No. 2, 2006.