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The Effectiveness of Emergency Response Plan in Specialty Chemicals Company in Malaysia

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Data-based decision making, which is an essential element for continuous improvement, helps individuals and teams to assess the efficiency and effectiveness of on-going processes. This paper describes the emergency drill data-based approach in determining the effectiveness of Emergency Response Plan (ERP) in Specialty Chemicals Company in Malaysia. As most ERP are based on personnel response towards an emergency, the study also examines the human factors that contribute to the degree of effectiveness of an ERP. These include analysing each site's ERP communication, employees' understanding of ERP, employees' confidence in site safety, the involvement of employees in ERP related activities and employee readiness to attend emergencies. Specific improvement actions are then recommended based on the critical deficiencies identified, which include improvement of Emergency Response Team deployment to the scene, making muster and headcount mechanism more efficient and enhancing ERP communication to the employees on-site.

1. Background

Control of Industrial Major Accident Hazard (CIMAH) is a regulation under Malaysia's Occupational Safety and Health Act, which is similar to the UK's COMAH or under EU's Seveso III Directive 2012/18/EU. These regulations generally require demonstration of safe operations for high risk chemical plants, and this includes the need to have a working and effective Emergency Response Plan (ERP). Emergency Response Plan is a live document that needs to be tested, reviewed, updated and improved periodically. Every ERP is unique in such it will depend on the site's location, nature of process, hazards imposed, management system, number of employees available at a time of the emergency cases (Jeffereli et al., 2004).

With concern on the data confidentiality issue and its subsequent impact, the name of the company where the study was conducted will be kept anonymous, and will be referred to as "Specialty Chemicals Company". In this paper. The company belongs to the Specialty Chemicals Group, with more than 1900 employees, operating in 90 countries and 33 production units worldwide and it is one of the biggest specialty chemicals manufacturers in the world. Specialty Chemicals Asia, one of the Specialty Chemical's main divisions, consists of four production sites which are all located in Malaysia. Therefore in this paper, Specialty Chemicals Asia will be referred to as Specialty Chemicals Company in Malaysia. Also here, the four sites will be referred to as (Site A, Site B, Site C and Site D. Generic description of each of the production site and its CIMAH category is summarized in Table 1 below.

Since ERP is unique for each site and managed independently, the aim of this study is to analyse the effectiveness of the ERP in each site individually before the results are compared among the four sites, based on common performance criteria. A data-based conclusion can then be taken on deciding either a particular sites have an effective ERP or not. This is followed by a study on the human factors, which contributed significantly to the ERP effectiveness as ERP is basically human-response oriented. Correlation analysis is also included to investigate the relation between the human factors selected.

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Table 1: Four production sites of the Specialty Chemicals Company in Malaysia

Specialty Chemicals Company in Malaysia				
Site	Site A	Site B	Site C	Site D
Location	Kluang, Johor	Kluang, Johor	Pasir Gudang, Johor	Pasir Gudang, Johor
Site Area	0.72 km^2	0.28 km^2	0.26 km^2	0.15 km^2
No. of Production units	4	1	1	1
Production Capacity	100,000 wet tons	120,000 wet tons	160,000 wet tons	18,000 wet tons
No. of employee	200	90	80	30
Main Product	Natural rubber, Polymer dispersions, Alkyd resins and Polyester resins	Nitrile-butadiene rubber (NBR)	Nitrile-butadiene rubber (NBR)	Polymer dispersions
CIMAH Category	Major Hazard	Major Hazard	Major Hazard	Non-Major Hazard

2. Measurement of the Effectiveness of Emergency Response Plan in Specialty Chemicals Company

Comprehensive Emergency Response Plan is very important, both for legal compliance and for safe operations. ERP must not only beautifully written, but it has to be proven practical, reliable and able to be executed in any given time. An effective ERP must able to perform their duty accordingly and this requires continuous training and drills to be done. Drills and exercises are a good way to test out an ERP in which it could determine whether an organization functions as anticipated in an emergency event and if not, they would serve as a way to identify opportunities for improvement. Drills and exercises also provide an opportunity for staff to practice their skills and to identify future areas for training (Cope, 2003). A good drill performance will reflect if the employees, especially the Emergency Response Team (ERT) and those involved directly in ERP, could react effectively in an emergency.

The overall effectiveness of the ERP in all production sites of the Specialty Chemicals Company in Malaysia were measured based on the site's individual emergency drill performance. Two types of drill were used in the study; Fire Drill scenario with Level 2 Emergency (external assistance is required) and Loss of Containment (LoC) scenario with Level 1 Emergency (managed in-house). The actual response time were compared with the expected response time on the critical performance indicators, which were pre-determined based on the current setup and available resources on the sites (U.S. Fire Administration, 2006; Nicholas et al., 1995). The performance indicators (for Fire Drill - level 2) and Table 3 (For LoC – level 1) are shown in Table 2. The indicators used in the study are generic enough that it could be applied to all the four sites under study.

3. Human Factors in ERP Effectiveness

Basically, without access to an extended automated emergency mitigation system or prearranged specific procedures, ERP is actually depending heavily on the unique human abilities of intuitive and creative thinking and acting (Lackman et al., 2013). Since ERP is human oriented, this study also covers few human-related elements that influence the ERP effectiveness (Au, 2009). Among the factors investigated were ERP communication on site, employees' knowledge on ERP, employees' confidence in site safety, employees' readiness to attend emergencies and employees' involvement in ERP activities conducted in their plant. Since responses from employees are required, surveys were used to gather the required data. The survey covered all employees within the sites, which include personnel from multiple levels and departments.

Table 2: Performance indicator set for Fire Drill scenario with Level 2 Emergency (external assistance is required)

Indicator	Description	Target Completion Time
Alarm raised and first response	When the fire is notified by fire alarm or other means of communication. First response include activating the local sprinkler or crash shutdown	1 minute
Emergency attended by ERT	ERT are on the emergency scene and begin to setup and combat the fire	4 minutes
Headcount completed	Headcount completed for the muster	6 minutes
Fire Brigade arrived on-site	Fire Brigade are at the emergency scene and begin to setup and combat the fire	10 minutes
Total response time	Time taken from discovery until the area declared safe	21 minutes

Table 3: Performance indicator set for Loss of Containment (LoC) scenario with Level 1 Emergency (external assistance not required, emergency managed by in-house personnel)

Indicator	Description	Target Completion Time
Alarm raised and first response	When the LoC is notified by fire alarm or other means of communication. First response include stopping and containing the spill	1 minute
Emergency attended by ERT	ERT are on the emergency scene and begin to stop and containing the spill	4 minutes
Spill is contained and controlled	The spill is contained and the situation is under control	10 minutes
Total response time	Time taken from discovery until the area declared safe	11 minutes

3.1 Relationship between the Human Factors - Correlation Analysis

Pearson correlations were used to analyse the relationship between factors that are commonly assumed to affect the effectiveness of a site's ERP. The relationships studied are between the 1) site's ERP communication and employees' understanding of ERP, 2) employees' confidence in site safety and their readiness to attend emergencies and 3) lastly employees' involvement in ERP and their readiness to attend emergencies. Based on the results from the correlation study, the weaknesses of the sites' ERP could be identified and appropriate improvements can be recommended.

4. Results and Discussions

4.1 Overall ERP Effectiveness

Figure 1 below represents the drill performance for Fire Drill – Level 2 and Figure 2 represents the drill performance for LoC Drill – Level 1 for all four sites. The figures generally indicate the performance of each site to complete specific milestones (indicators) within a stipulated timeframe as indicated in the ERP. The horizontal dashed lines in the figures represent the benchmarks, which are the duration within which the sites are expected to achieve the milestone.

Three out of four sites (Site A, Site B and Site C) failed in terms of the time required for the ERT to attend the emergency in both Fire Drill - level 2 and LoC – level 1 drill scenarios. Meanwhile, Site A and Site B were identified to have prolonged time to complete the headcount. These results conclude that two out of four sites (Site A and Site B) have ineffective ERP. The results reflect directly to the size of the site, number of personnel on-site and how the ERP in these plants are devised. In general, smaller sites (with smaller area and lower number of personnel), would have better ERT response time.

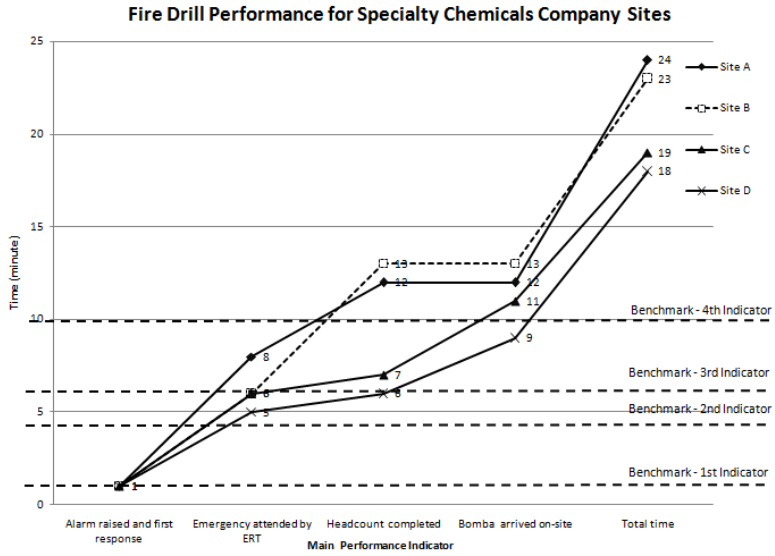

Figure 1: drill Performance for Fire Drill – Level 2 at Specialty Chemicals Company in Malaysia

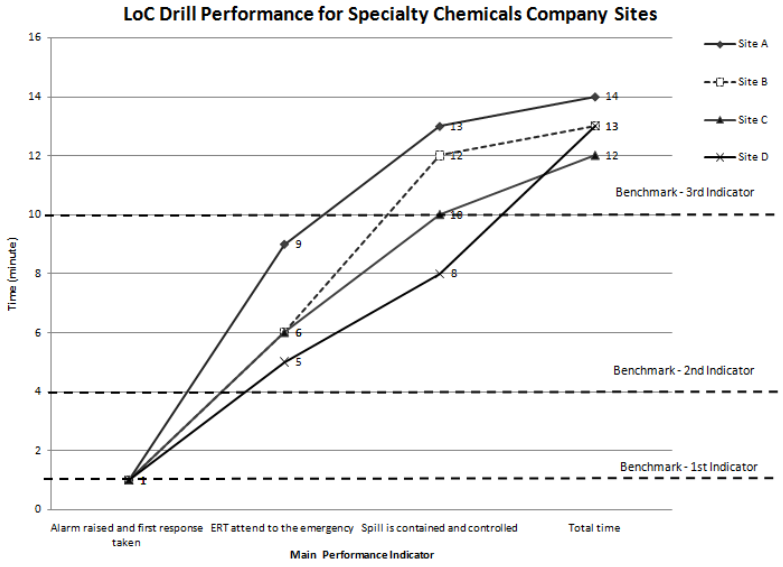

Figure 2: drill Performance for LoC Drill – Level 1 at Specialty Chemicals Company in Malaysia

4.2 Study on Human Factors

4.2.1 Survey Results

The results of the survey are summarized in Table 4, where μ is the mean value that dictates the answer of the question while σ is the standard deviation of the answer. Questions are both closed-end question - yes (1) and no (2), and forced-choice questions - with the rating from strongly disagree (1) , disagree (2) , neutral (3), agree (4), and strongly agree (5). A total of 267 responses (n) were recorded from the total of 400 questionnaire form distributed (response rate, R at 67 %). From the response, it was found that employees in Specialty Chemicals Company sites are communicated with ERP and they have adequate knowledge on the site's ERP. The employees are also confident that the sites they are working at are safe and the responses also showed that the employees perceive that they have adequate level of readiness to attend any emergency. However, only employees in Site C and Site D agree that they have been actively involved in ERP activities.

Table 4: Summary of the survey result analysis – by the research questions

Human Factor Studied	Specialty Chemicals Company Sites n = 267, R = 67 %			
	Site A n = 124 R = 62 %	Site B n = 62 R = 69 %	Site C n = 54 R = 68 %	Site D n = 27 R = 90%
Personnel working in the plant were being informed on the purpose and content of the site's ERP.	Yes μ = 1.133 σ = 0.244	Yes μ = 1.134 σ = 0.231	Yes μ = 1.111 σ = 0.221	Yes μ = 1.068 σ = 0.137
The employees have confidence on site safety.	Agree μ = 3.745 σ = 0.510	Agree μ = 3.762 σ = 0.498	Agree μ = 3.793 σ = 0.368	Agree μ = 3.909 σ = 0.482
The employees have adequate knowledge on the site's ERP.	Agree μ = 3.631 σ = 0.537	Agree μ = 3.633 σ = 0.551	Agree μ = 3.636 σ = 0.380	Agree μ = 3.750 σ = 0.498
The employee readiness to attend any emergencies is acceptable.	Agree μ = 3.518 σ = 0.513	Agree μ = 3.500 σ = 0.515	Neutral μ = 3.426 σ = 0.400	Neutral μ = 3.417 σ = 0.666
The employee involved actively in ERP activities.	No μ = 1.637 σ = 0.309	No μ = 1.605 σ = 0.343	Yes μ = 1.500 σ = 0.398	Yes μ = 1.454 σ = 0.375

4.2.2 Correlation between Human Factors

The Pearson Coefficient of determination (r) and the significance (2-tailed) – (p) acts as an indicator of the relationship between the factors compared. With a higher r value, combined with p value less than 0.05 ($p < .05$), it indicates that the two factors are in fact have significant relationship. The summary of Pearson Correlation analysis results, based on the relations between the human factors studied is as shown in Table 5.

Table 5: Pearson correlation analysis on relationship between the human factors

Relationship between human factors studied	Specialty Chemicals Company Sites			
	Site A	Site B	Site C	Site D
There is relationship between ERP communications and adequate employee knowledge on the site's ERP	Accepted r = .319 P = .000	Rejected r = .223 p = .106	Accepted r = .456 p = .001	Rejected r = .347 p = .113
There is relationship between employee readiness to attend any emergencies and employee's confidence on site safety.	Accepted r = .612 p = .000	Accepted r = .751 p = .000	Accepted r = .525 p = .000	Accepted r = .639 p = .001
There is relationship between employee involved in ERP activities and employee readiness to attend any emergencies.	Rejected r = .034 p = .710	Rejected r = .007 p = .958	Rejected r = .224 p = .104	Accepted r = .639 p = .001

4.2.2.1 Relationship between ERP communications and knowledge on the site's ERP

There are mixed result on the relationship between ERP communications and knowledge on the site's ERP. Site A and Site C show a mild relationship (with relatively low r value at r = .319 for Site A and r = .456 for Site C while Site B and Site D show no relationship at all (both with p value > .05). Possible cause for the absence and low relationship is due to ineffective ERP communication, which leads to poor employee knowledge on the site's ERP.

4.2.2.2 Relationship between employee readiness to attend any emergencies and employees' confidence in site safety

From the correlation analyses done, there is a strong relationship between employee readiness to attend any emergencies and employees' confidence on site safety across Specialty Chemicals Company sites. This was shown by a significant r values in all four sites, with r = .612 for Site A, r = .751 for Site B, r = .525 for Site C and r = .639 for Site D. The result implies that increasing employee readiness to attend any emergencies (by performing regular drills) will enhance employees' confidence in site safety.

4.2.2.3 Relationship between employees involved in ERP activities and employee readiness to attend any emergencies

There was no correlation between ERP activities and employee readiness to attend any emergencies across Specialty Chemicals Company sites. This was shown by a high p value ($p > .05$) and a significantly low r values in all four sites, with $r = .034$ & $p = .710$ for Site A, $r = .007$ & $p = .958$ for Site B, $r = .224$ & $p = .104$ for Site C and $r = .222$ & $p = .320$ for Site D. This is most probably due to the employees' perception that emergency drill activity will not reflect the employee readiness for Specialty Chemicals Asia sites and the fact that only a handful portion from the employee on a site is involved in ERP.

5. Recommendations for Improvements

Based on the results from the ERP effectiveness study, the management of the sites with ineffective ERP (Site A and Site B) should improve:

- The mechanism to communicate, assemble and deploy their ERT to attend emergencies as soon as possible so that to prevent the escalation of an emergency.
- The muster procedure and headcount methodology. This will require lots of coordination, exercises and drills, and may even involve reconfiguration of the site's emergency communication and equipment.

Meanwhile, based on the human factors studied, the following improvements are recommended:

- Communications on ERP need to be improved, and it should cover each employee on site. A simple ERP understanding assessment should be considered to ensure adequate awareness among all employees.
- ERP based drill need to be performed with greater frequency, and should involve all employees. This will not only increase employee readiness, but it will also enhance employees' confidence towards the site's safety.

6. Conclusions

By testing the Emergency Response Plan in their sites, Specialty Chemicals Company in Malaysia was able to measure the effectiveness of their ERP, in each individual site. From the study, it is found that Site C and Site D have an effective ERP while both sites in Kluang (Site A and Site B) have an ineffective ERP. This serves as an important input to the site's management to prioritize the company's resources to address the critical weaknesses identified. Follow up drill performance test should be done, to ensure that the corrective actions taken are effective. With proven and tested ERP, the stakeholders e.g. the management of Specialty Chemicals Company and its employees, can rest assured that the sites are ready to cope and react accordingly when real emergency do occur.

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