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Analysis of Safety Performance of Indian Fertilizers Plants

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Abstract

FAI has been conducting safety survey of fertiliser plants for the past several years to assess the status of the safety performance of the industry as a whole and to help fertiliser plants improve their performance to establish a safe and healthy working environment. The present survey was carried out for 31 ammonia-urea and NP/NPK complex fertiliser plants for a period of five years for the years 2005-2010. The paper provides the results of analysis of accident data with respect to various safety parameters viz. incidence rate, severity rate and fatality rate. The analysis also identifies the causes of incidents and fatalities and plant areas prone to incidents so that plant management can address the issues to minimize the occurrence of incidents.

1. Introduction

India is the third largest producer of fertilizers in the world. There was a production of 38.5 million tonnes of various fertilizer products in the year 2010 – 11. It involved production of large quantities of intermediate chemicals like ammonia, sulphuric acid, phosphoric acid and nitric acid. These chemicals along with the wide range of finished products involve application of complex process technologies. There are extreme operating conditions in terms of temperature, pressure and hazardous chemical environment. The safety of personnel and plants remains a top priority for any plant management. Extreme care is taken in design, operation and maintenance of fertilizer plants. The safety performance of fertilizer industry in India has been quite satisfactory. A number of units have received international safety performance awards.

The Fertilizer Association of India (FAI) has always been active in promotion of the cause of safety in the industry. A systematic collection and analysis of safety related incidents was started in 1990s. FAI also instituted an award for Excellence in Safety in the year 2001. The present paper presents the analysis of data on reportable accidents during the five year period of 2005 – 10. The data concerns with the human injuries and loss of life in fertilizer industry. The data includes 15 integrated ammonia-urea plants, 7 ammonia urea plants integrated with NP/NPK fertilizer plants, and 9 NP/NPK complex fertilizer plants including five acid plants. These plants accounted for 97 per cent of total nitrogen and 88 per cent of total P_2O_5 during the period. The average regular and contractual manpower of about 52.4 thousand was employed by 31 fertilizer plants in almost equal share.

2. Safety Indices

An injury which requires minimum 24 hours absence from work is defined as a reportable accident. The data was analyzed w. r. t. frequency and severity of accidents and their causes. Various indices have been worked out to indicate the frequency of accidents and their impact on human life.

2.1. Incident Rate

Only the data for reportable accidents are included in the analysis including fatal accidents. An injury which required a minimum of 24 hrs of absence from work after an accident is defined as reportable accident.

The incidence rate i.e. the number of accidents per million man hours indicates a gradual decline during the survey period of (2005-2010). The lowest incidence rate of 0.47 was reported in 2009-10 and highest incidence of 0.75 was reported in 2005-06. The average of five year period was 0.59 as shown in **Table 1**

Table 1: Incidence Rate (based on million man hours worked)

Year	Million man hours worked	Total no. of reportable accidents	Incident Rate*
2005-06	114.44	86	0.75
2006-07	121.39	89	0.73
2007-08	126.16	66	0.52
2008-09	126.89	62	0.48
2009-10	125.4	59	0.47
Average			0.59

*Incidence Rate = $\frac{\text{No. of reportable accidents}}{\text{Million man hours worked}}$

Figure 1 depicts quartiles for incident rate for five year period for Indian fertilizer plants. It can be seen that the best 25% plants showed an average incident rate of 0.07 while the last 25% reported an average incident rate of 1.22. The fertilizer plants reported incident rate from 0.0 to 1.59.

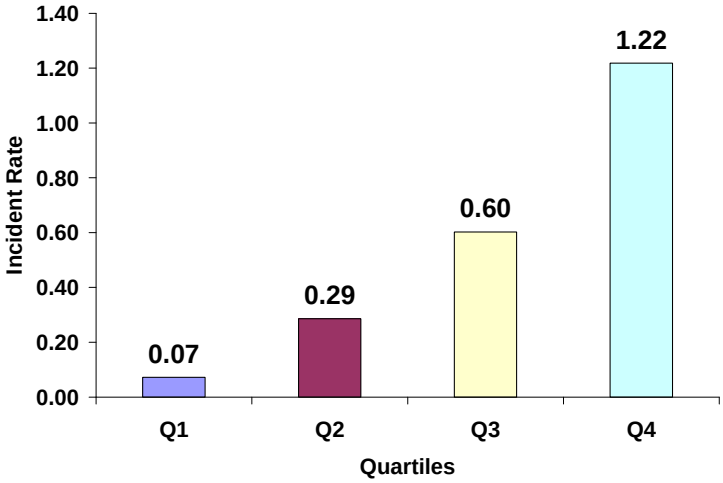

Figure 1: Quartiles of Incident Rate (2005-10)

2.2. Severity Rate:

The severity rate is calculated to examine the impact of accidents on human health. Severity rate is the lost time due to injury preventing an employee from working in his assigned work shift. Thus severity is calculated as million man hours lost due to accidents as a percentage of total direct man hours worked, as shown in **Table – 2**.

Table : 2 Severity Rate of Indian Fertiliser Plants

Year	Million- Man hours worked	Million-Man hours lost	Severity Rate@
2005-06	114.44	0.446	0.39
2006-07	121.39	0.546	0.45
2007-08	126.16	0.405	0.32
2008-09	126.89	0.499	0.39
2009-10	125.40	0.451	0.36
Average			0.38

$$@\text{Severity Rate} = \frac{\text{No. of man-hour lost due to reportable accidents} * 100}{\text{No. of man -hours worked}}$$

From Table 2 it can be observed that less than half a percent of time was lost due to injuries in accidents in plants. The severity of accidents increases due to fatal accidents.

2.3. Fatal Accident Frequency Rate (FAFR)

There was increase in number of fatalities from 38 in 2000-05 to 47 in 2005-10. The Fatal Accident Frequency Rate (FAFR), i.e. the number of deaths from industrial injury expected in a group of 1000 persons during their working life (1000x 40 years x 52 weeks x 48 hours) is equivalent to 99.840 million man-hours worked. FAFR for the period of 2005-10 (five years) has been worked out in **Table 3.**

Table-3 Fatal Accident Frequency Rate (FAFR)

Year	Fatal Accident Frequency Rate (FAFR)	No. of Casualties
2005-06	7.85	9
2006-07	9.05	11
2007-08	6.33	8
2008-09	7.87	10
2009-10	7.18	9
Average	7.65	

The FAFR was the highest in 2006-07. The average FAFR for the period of current survey is 7.65 which is much higher than that of 5.63 for the period 2000-05.

2.4. Accident Free Period:

It can be seen in **Table 4 that** accident free period is becoming longer from the past 15 years**.** This indicates that on an average, number of accidents is decreasing from each survey of 5 years consistently.

Table : 4 Comparison of Longest Accident free Period

	2005-10	2000-05	1995-00
Average of Accident free period (days)	929	657	459

3. Causes of Reportable Accidents:

Detailed analysis of major reportable accidents is tabulated in Table 5 which shows that maximum accidents have occurred due to Slip & fall (78) followed up by those due to Hot Condensate/Chemical burn (42). Fall from Height (27), falling objects (28) and entanglement with moving equipments like conveyors (31) also caused a significant number of accidents in plant. Accidents due to movements of vehicles (30) in the battery limit of the plant are noteworthy. Total number of reportable accidents in this period has reduced to 361 from 719 in 1995-2000 and 857 in 2000-05.

Table 5: Causes of Reportable Accidents

Sl. No	Causes	2005-06	2006-07	2007-08	2008-09	2009-10	2005-10
1	Slip and Fall	18	16	7	22	15	**78**
2	Hot Condensate / Steam / Chemical Burn / Hot water	8	16	7	6	5	**42**
3	Entanglement with Moving Equipment	9	8	5	5	4	**31**

4	Road/Rail/Moving Vehicle	6	11	11	0	2	**30**
5	Falling Objects	5	9	5	4	5	**28**
6	Fall from Height	7	3	7	5	5	**27**
7	Improper Tools, Tackles and Procedures	4	4	6	1	1	**16**
8	Ammonia Cold Burn /Inhalation	11	1	0	1	1	**14**
9	Electric Burn / electrocution	3	3	4	1	1	**12**
10	Explosion	0	7	0	0	5	**12**
11	Equipment/Vessel /Line Failure	1	3	4	1	3	**12**
12	Fire	2	0	0	5	2	**9**
13	Entanglement with Static Equipment	2	2	1	3	1	**9**
14	Asphyxia/Drawning	1	2	1	1	2	**7**
15	Construction	2	1	0	3	1	**7**
16	Collapse of Material/Goods	0	1	4	0	0	**5**
17	Miscellaneous	6	2	4	5	5	**22**
18	**Subtotal**	**85**	**89**	**66**	**63**	**58**	**361**

4. Accident analysis Area wise:

Accidents were classified according to location of the incidents occurred for identify areas which are more prone to accidents. Area wise accidents are given in Table -6.

Table 6: Area wise accidents analysis

Sl. NO.	Areas	2005-06	2006-07	2007-08	2008-09	2009-10	2005-10
1	NP/NPK complex	13	14	16	9	13	**65**
2	Ammonia	15	10	9	8	9	**51**
3	Material handling/Bagging	11	11	6	15	6	**49**
4	Utilities/offsites/ETP	12	5	13	6	7	**43**
5	Roads/rail track	3	9	10	2	6	**30**
6	Urea	12	8	1	4	2	**27**
7	Sulphuric acid	3	8	4	2	3	**20**
8	Workshop	2	8	0	0	1	**11**
9	Phosphoric acid	3	1	2	2	2	**10**
10	Stores/yard	2	2	1	4	1	**10**
11	Godown/warehouse/silo	1	3	2	0	3	**9**
12	Electrical area	0	3	1	4	0	**8**
13	Laboratory	1	2	0	0	0	**3**
14	Garage/locmotive shed	0	1	0	0	0	**1**

15	Nitric acid	0	0	0	1	0	**1**
16	Miscellaneous	7	4	1	6	5	**23**
	Subtotal	**85**	**89**	**66**	**63**	**58**	**361**

This analysis shows that maximum number of accidents have been reported from the plants that involve large manpower for process and material handling. NP/NPK Complex fertilizer plants accounted for maximum 65 accidents followed by Ammonia plant (51). Ammonia plants are highly automated and large number of accidents in ammonia plants need to be investigated further. Material handling and bagging areas accounted for large number (49) of accidents perhaps due to large number of persons employed in these operations. A significant part of employees in these areas are contract labours. Again a high number of accidents (30) are road and rail track bring out need for precautions during driving on road or shunting of rail wagons.

5. Fatal Accidents:

Causes of fatal accidents are listed in **Table 7**, it can be seen that most of the fatal accidents were due to slip and fall/fall from height and rail. Significant fatal accidents were due to road accidents and moving vehicles in the factory. There was a major accident due to process related explosion which caused collapse of prill tower which resulted in two workers death and injuring three workers. Another fire and explosion accident in CO shift converter resulted in 3 casualties. A total of 47 fatal accidents were reported from 31 fertiliser units.

Table 7 Cause of fatal Accidents

Sl. No.	Cause of fatal Accidents	No. of fatal Accidents
1	Slip and Fall / Fall from Height	14
2	Rail/Road Accident in Factory	10
3	Explosion	7
4	Fire	4
5	Electrocution	3
6	Entangle with rotating equipment	2
7	Equipment/vessel/line failure	1
8	Asphyxia/ Drowning	2
9	Collapse of Material / Goods	2
10	Miscellaneous	2
	Total	**47**

Brief description of some major accidents which caused fatalities:

(i) **Explosion in Nitro phosphate plant** :

An explosion occurred in nitro phosphate plant in 2006-07. Decomposition of ammonium nitrate took place due to high temperature in NP melt tank and its piping resulting in an explosion. Control Room underneath the tank and the surrounding structure on the top of prill tower collapsed and the victims got trapped/ buried under the debris resulting in the death of two workers and injuring three workers.

Causes: High temperature leading to decomposition of Ammonium Nitrate.

Remedial Action: Prilling technology was changed to granulation technology where temperature requirement is quite low.

(ii) Fall of scaffold from height:

This accident happened in urea plant during painting of internal shaft of urea prilling tower, julla fell down from height of about 30 feet due to shearing of pinion of electrical winch , in which 3 persons were badly injured and 2 fatalities was reported.

Causes: Shearing of pinion of electrical winch machine.
Remedial Action: Second holding of the julla to be made foolproof.

(iii) **Minor Flash Fire** :

This accident occurred inside DM plant, when repair job for application of FRP coating inside vessel was done. Minor flash fire took place resulting in 3 fatalities.

Causes: Sparking in the chemical used for FRP coating.

Remedial Action: Proper rescue equipments have been procured by the company for vessel entry and chemicals used for FRP coating were reviewed. Permit system was initiated before the start up of any process and it is made mandatory to conduct gas test in each shift by competent person of E & QC department.

6. Area of Concern:

Any of the accidents reported did not cause shut down of the plants. Majority of accidents were not due to process hazards. The detailed analysis of fatal accidents reveals that most of the accidents could have been avoided if proper procedures/techniques were followed with proper training to the labours especially contractual. A large number of accidents in fertiliser plant have occurred due to improper housekeeping, inadequate safety procedures, equipment inspection and lack of supervision. A Road accident within the battery limits is an example of completely avoidable incidents. Safety is the result of control of recognized hazards with a good policy, programme and proper organizational structure with clearly assigned responsibilities.

7. Hazard Evaluation:

The ability to ensure safety in a plant is influenced by many things, for example employing appropriate technology in design and construction, anticipating the effects of external circumstances, understanding and dealing with human behavior and having effective management systems. However all these efforts depend on a successful hazard evaluation programme, without these evaluations, the company will not know what layers of protection are needed. Every fertiliser plant carries out safety audit every year and recommendations from the auditors are to be implemented in the prescribed time frame. Numbers of plants carry hazard evaluation with assistance of experts especially for the accident prone areas of the plant. Many plants have taken safety initiatives like OHSAS 18001, PSMS and have earned prestigious safety awards. HAZOP studies are frequently done by the process experts for periodic hazards reviews of existing equipments or review of new equipment before its start-up. Proper training programmes and good housekeeping system should remain top priorities. Committee comprising of multidisciplinary team drawn from operation, maintenance, fire and safety should be entitled for surprise visits to any area of plant and hefty fines should be imposed for violation of any safety rules.

8. Conclusion:

The safety survey of five years for fertiliser industry shows that today the biggest challenge before any chemical industry is the safety of their plant personnel. It was observed that most of the accidents occurred during this survey period was due to human error, adopting unsafe working practices and lack of supervision. For adoption of safe work practices safety of chemical plants requires full commitment of management, interaction of plant personnel with various departments. Only two major accidents occurred due to process hazard leading to some fatalities. The analysis of data clearly brings out the need for focus on behavioral safety.

There should be frequent training sessions to sensitize the employees of hazards of each work process and task. Special attention need to be paid to use of personnel protective equipments, cleanliness of area, safe entry into vessels and avoid any shortcuts.

9. References:

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