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Safety Assessment of Fertilizer Plants in India

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Abstract

FAI has been carrying out the safety assessment of fertilizer plants periodically. The present study covered safety performance of fertilizer plants during the period 2015-2020. The fertilizer plants include ammonia, urea, acid and complex fertilizer plants. Safety data was analyzed with respect to causes and locations. Safety indices like loss time injury rate, severity rate and fatal accident frequency rate have been calculated. Results have been compared with the results of previous periods. It was found that the both loss time injury rate (LTIR) and severity rate declined compared to previous survey periods. The period for accident free operation was also increased from average of 847 days in 2010-2015 to 1150 days in 2015-2020. The paper highlights the causes and work areas prone to injuries. Some observations and learnings are also presented in brief.

Key Words: Safety, loss time injury rate, severity rate, fatal accident frequency rate, near miss, ammonia, urea, complex, acid, fertilizer plants.

1. Introduction

Fertilizer plants deploy a large manpower in manufacturing and material handling facilities. The safety of human capital is important in view of operations of plants at high temperature, high pressure, handling and storage of corrosive and hazardous chemicals and large volume of products. FAI has been carrying out the analysis of safety performance of fertilizer plants since 1990 when first report (Nand & Jain 1991) was published. Since then safety survey was conducted every five years, last report being published in 2016 (Goswami et al, 2016). The present analysis is for the period April 2015 to March 2020. The study included 44 fertilizer plants at 33 locations comprising of ammonia, urea, acid and complex fertilizer plants. These plants accounted for 98.9 per cent of urea production and 86.0 per cent of complex fertilizer production during the five-year period. The safety performance has been evaluated using indicators such as loss time injury rate (incidence rate) and severity rate. Analyses of all accidents for their causes and location have been carried out. These have been compared with the studies of past periods. Near miss incidents are also an indicator of safety management in the plant. This have been included in the survey for assessing the risks that may lead to accidents.

2. Sample characteristics

Fertilizer plants comprised of ammonia, urea, sulphuric acid, phosphoric acid and complex NP/NPK plants. There were 29 integrated ammonia and urea plants at 18 sites. Three plants having integrated ammonia-urea plants with complex fertilizer plants. There were 2 sites having ammonia-urea plants, complex and acid plants. There are 4 locations with only complex fertilizer plants and 6 sites having complex fertilizers and acid plants. These plants employed an average manpower of 55722 employees which included both regular and contract employees. The average man-hour worked including regular and contract employees for the period 2015-2020 was 139.4 million man hours per annum. This is lower than average of 151.2 million man-hours for the previous period. The lower man-hours for 2015-2020 period was due to lower man-hours contribution from contract manpower. During previous period, a number of plants carried out revamps mainly for implementing energy saving schemes and feedstock change from fuel oil to natural gas. Hence, employed a large number of contractual manpower.

3 Safety Indices

Number of injuries due to an incident are reported for an absence of work for 24 hours. The index for injury rate is calculated as number of reportable injuries per million man hours worked. This is referred as loss time injury rate (LTIR) or incidence rate and average values are given for each year of the period in **Table 1.** The average incidence rate

Table 1. Incidence Rate for 2015 to 2020

Year	Million man hours worked	Total no. of reportable injuries	Incidence rate
2015-16	140.35	46	0.33
2016-17	141.80	24	0.17
2017-18	135.02	31	0.23
2018-19	138.76	22	0.16
2019-20	141.14	31	0.22
Average	**139.42**	**31**	**0.22**

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Table 2. Year wise severity rate

Year	Million man hours worked	Man hours lost	Severity rate
2015-16	140.35	203680	0.15
2016-17	141.80	100984	0.07
2017-18	135.02	102552	0.08
2018-19	138.76	8072	0.01
2019-20	141.14	293251	0.21
Average	**139.42**	**141707.8**	**0.10**

$$\text{Severity rate} = \frac{\text{No. of man-hours lost due to reportable accidents}}{\text{No. of man -hours worked}} \times 100$$

Table 3. Fatal accident frequency rate

Year	Fatal accident frequency rate (FAFR)	No. of casualties	Million man hours worked
2015-16	2.85	4	140.4
2016-17	1.41	2	141.8
2017-18	1.48	2	135.0
2018-19	0.00	0	138.8
2019-20	4.24	6	141.1
Average	**2.00**	**2.8**	**139.4**

for the 2015-2020 period was 0.22 which is lower than previous period of 0.36. The total number of injuries over five-year period including fatal injuries were lower at 154 compared to previous survey period which recorded 275 injuries.

The severity rate is defined as the number of man hours lost as a percent of man-hours worked. The average severity rate during 2015-2020 period dipped to 0.10 from 0.19 from previous period (**Table 2**). This is due to reduction in fatal accidents from 29 in previous survey to 14 in the present survey period. Fatal accidents contributed about 94% to the total man hours lost. The maximum casualties of 6 happened during 2019-20 while 2018-19 was without any fatal accident.

Fatal accident frequency rate calculated as an indicator of probability of occurrence of a fatality in a group of 1000 persons during their working life. This has been reduced to 2.00 in this survey from 3.76 in the last survey (**Table 3**).

4. Longest Accident free period

During the current survey period, the number of reportable injuries including fatal ones have reduced significantly. Out of 33 locations there were 11 locations where no reportable incidents were reported during the current five-year period. The average accident free days increased from 847 days in 2010-2015 to 1150 days in 2015-2020 period. **Figure 1** shows the increase in average accident free days in the last five survey period.

There were 16 locations (22 plants) which operated for more than 3.0 years without any reportable injury of which there were 9 locations (13 plants) where no injury reported during the survey period.

5. Analysis of Injuries

The causes of injuries and areas where it happened have been analyzed. The fatal accidents are also covered.

5.1 Causes of injuries

Table 4 presents the cause-wise injuries for the five-year period. Coming into contact with hot water/ hot condensate /steam and chemical burn were the major causes of injuries. This is followed by slip & fall and fall from height. Improper use of tools & tackles and wrong procedures and

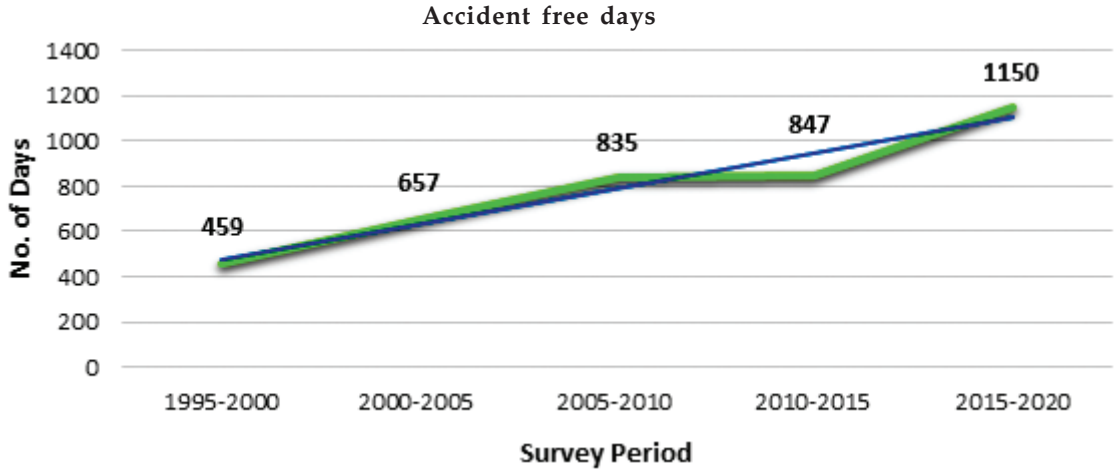

Figure 1. Average accident free days

Table 4. Cause-wise details of reportable injuries

S. No	Causes	2015-16	2016-17	2017-18	2018-19	2019-20	2015-20
1	Hot Condensate / Steam / Chemical Burn / Hot water	14	3	10	3	3	33
2	Slip and Fall	7	5	3	2	3	20
3	Falling Objects	6	1	2	1	4	14
4	Fall from Height	6	2	3	0	3	14
5	Improper Tools, Tackles and Procedures	4	3	1	4	2	14
6	Entanglement with Moving Equip.	1	0	4	4	4	13
7	Ammonia Cold Burn /Inhalation	0	1	3	1	6	11
8	Entanglement with Static Equip.	0	2	2	3	0	7
9	Road/Rail/Moving Vehicle	1	1	1	0	2	5
10	Explosion	4	0	0	0	0	4
11	Asphyxia/Drowning/ Other gases inhalation	1	2	1	0	0	4
12	Electric Burn / Electrocution	0	0	1	1	1	3
13	Equipment/Vessel /Line Failure	0	0	1	0	1	2
14	Fire	0	1	1	0	0	2
15	Construction	0	0	0	0	0	0
16	Collapse of Material/Goods	0	0	0	0	0	0
17	Miscellaneous	3	1	0	1	3	8
	Total	**47**	**22**	**33**	**20**	**32**	**154**

entanglement with moving equipment also contributed to significant number of injuries. Falling objects resulted in 14 injuries. Ammonia inhalation and cold burn accounted for 11 injuries. Four injuries were reported due to explosion. Almost 38% of the incidents occurred due to mechanical work or maintenance jobs. Management should review the procedures periodically and workers should be aware of hazards involved in the job. Use of appropriate PPE kits needs to be followed compulsorily.

Most of the incidents resulted in single human injury. But there were a few incidents that resulted in multiple injuries. A chemical container exploded during unloading which resulted in injuries to 3 workers including one fatality. Another explosion took place while cutting empty barrel lid by gas cutting. The drum got exploded due to flammable mixture formation inside the barrel and the lid got lifted up and hit the person's hand causing multiple cut injuries. In one of the incidents, the suction and discharged isolation valve of urea melt pump was dismantled for maintenance. Suddenly, hot water along with urea polymer slurry gushed out from the 6" open pipe of the suction strainer. Four persons working on the platform got burn injuries. In another incident, seven persons were affected due to inhalation of ammonia due to leakage of control valve line from ammonia storage tank. Such incidents emphasized need for respiratory protection in areas likely to have toxic gas/chemical exposure.

Construction activity at one site resulted in injuries to 3 persons. While concreting work was underway, suddenly the structure collapsed and persons fell from height of about 9 meters. Three persons got burn injuries while opening flange joint bolts for replacement of the leaking gasket of non-return valve flange on boiler feed water line. Suddenly, hot water splashed from the flange after some time. Probable cause of splash was improper drain line which may have resulted in accumulation of water inside the pipe and flashed into hot water/vapour while creating a gap between flange and NRV. A similar incident happened in another plant when work on a flange joint of sulphuric acid line was completed. Suddenly, there was a splash of sulphuric acid from the open flange joint resulting in acid burn injury to 3 persons working at the site. The post incident analysis recommendation included use of full PPE kit during the job, purging with adequate inert gas, ensuring gradient to remove pocket hold up and LEL test to be done periodically during the job.

An incident leading to injury to 2 persons happened when carbon dioxide compressor tripped. The carbon dioxide started venting from control valve to silencer. At the time 2 persons closing HPSH battery limit inlet valve, both got exposed to carbon dioxide from silencer due to carbon dioxide settling down near bottom control valve area. Post-accident analysis recommended installation of steam sparger arrangement at the silencer to dilute carbon dioxide. Compressor floor roof is to be totally covered with galvanized sheet and use of airline mask to perform such type of job.

5.2 Location of injures

The area wise analysis of the data (**Table 5**) showed that the majority of injuries took place in offsites and utilities area. There were 28 injuries in ammonia-urea plants accounting for 18% injuries while acid plants contributed 17.5% of the total injuries. Phosphoric acid and sulphuric acid plants reported 25 injuries while

Table 5. Area wise analysis of reportable injuries

S. No.	Areas	2015-16	2016-17	2017-18	2018-19	2019-20	2015-20
1	Utilities/Offsites/ETP	4	4	5	0	11	**24**
2	Phosphoric Acid	3	0	5	5	4	**17**
3	NP/NPK Complex	6	3	4	3	1	**17**
4	Material Handling/Bagging	4	0	3	4	5	**16**
5	Urea	6	5	1	2	1	**15**
6	Ammonia	6	1	2	1	3	**13**
7	Workshop	4	2	4	2	0	**12**
8	Roads/Rail Track	4	2	1	1	2	**10**
9	Sulphuric Acid	2	0	4	0	2	**8**
10	Godown/Warehouse/Silo	2	2	1	0	0	**5**
11	Stores/Yard	3	0	0	0	0	**3**
12	Electrical Area	0	0	2	0	1	**3**
13	Nitric Acid	1	1	0	0	0	**2**
14	Lab	0	0	0	0	1	**1**
15	Garage/Locmotive Shed	0	0	0	0	0	**0**
16	Miscellaneous	2	2	1	2	1	**8**
	Total	**47**	**22**	**33**	**20**	**32**	**154**

2 injuries were reported in nitric acid plant. Material handling and bagging plants accounted for 16 number of injuries. Workshop area reported 12 injuries. Ten injuries were reported due to road/rail accidents and five accidents also happened in godown/silo.

5.3 Fatal accidents

A few accidents also resulted in casualties. The causes of fatal accidents are given in **Table 6**. There has been reduction in fatal accidents from 29 in previous survey to 14 in the present survey period. The fatal accidents were reported by 7 plants out of 44 plants in the survey. Fall from height caused 3 fatalities and Rail/Road/Moving Vehicles caused 2 fatalities. Slip and fall, explosion, electrocution, entanglement with moving equipment, equipment failure, and asphyxia each caused one fatal accident.

6. Near Miss Incidents

Analysis of near miss accidents provides a leading indicator for improving the safety in an organization. The analysis of near miss provides an insight to the action or condition that may have potential to cause an injury. There were 40027 near miss incidents reported for the entire 2015-2020 period. **Figure 2** shows the reasons contributing to near miss accidents. Unsafe conditions accounted for 77.3% of near miss incidents. About 17.8 % near miss incidents were due to unsafe act. Near miss incidents due to unsafe use of equipment and unsafe equipment were only 1.1 and 0.75% respectively. The near miss analysis can be correlated with the causes of accidents during the period. Most of the accidents were caused due to hot condensate /steam/chemical burn, slip & fall and injuries due to falling objects, entanglement with the moving objects. This points towards unsafe conditions in the plants which needs attention of plant management. Unsafe act may have resulted in accidents like entanglement with moving or static equipment, improper use of tools, tackles and procedures, explosion during handling equipment/ material and also rail/road accidents.

IFA Safety Handbook, 4th Edition (2021) highlighted that for every reportable injury there are 10 minor injuries and 600 near misses. The near miss analysis therefore should be given due emphasis. During the survey period, 154 reportable injures indicates nearly 260 near misses per reportable injury. Categorization of reportable injuries for the period 2015-2020 similar to near miss classification showed that for every unsafe act there were 113 and for unsafe conditions there were 407 near misses. The unsafe act accounted for about 41% and unsafe conditions accounted for almost 50% of the reportable injuries. The fertilizer plants have introduced an online near miss reporting

Table 6. Cause wise Fatal Accidents

S.No.	Areas	2015-16	2016-17	2017-18	2018-19	2019-20	2015-20
1	Fall From Height	1	0	1	0	1	3
2	Road/Rail/Moving Vehicle	1	0	0	0	1	2
3	Slip And Fall	1	0	0	0	0	1
4	Electric Burn / Electrocution	0	0	0	0	1	1
5	Explosion	1	0	0	0	0	1
6	Entanglement With Moving Equip	0	0	0	0	1	1
7	Equipment/Vessel /Line Failure	0	0	0	0	1	1
8	Asphyxia/Drowning/Other gas inhalation	0	0	1	0	0	1
9	Miscellaneous	0	2	0	0	1	3
	Total	**4**	**2**	**2**	**0**	**6**	**14**

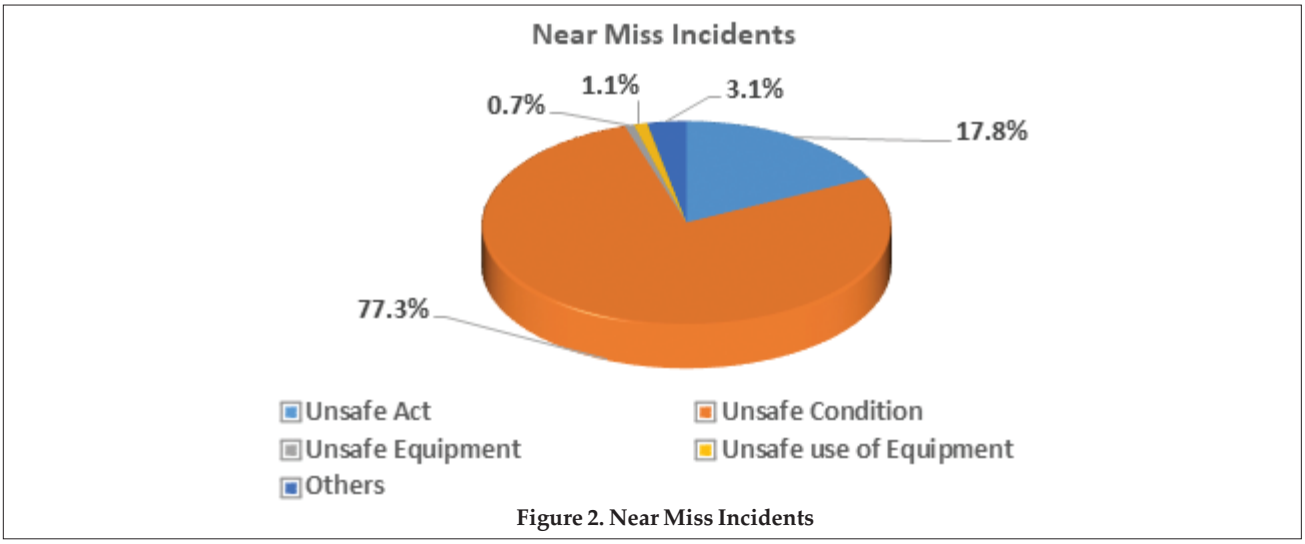

Figure 2. Near Miss Incidents

system. The near miss reporting by employees and workers are encouraged by way of incentive or cash. Digital technology driven intervention like CCTV's and face recognition technology may be adopted for recording near misses. Timely action by the plant management to address the unsafe conditions would minimize risks.

7. Key Observations and Learnings

The causes of incidents and injuries showed that most of the incidents were avoidable. Previous survey reports (Goswami et al. 2016, Goswami & Pooja, 2011 and Nand & Sood, 2001) extensively covered the recommendations for avoiding such incidents. Unsafe acts can be avoided by changing at-risk behavior through attentiveness, following standard operating procedures, use of PPE kits, etc. Procedure to identify unsafe conditions need to be strengthened. For example, working platform can be modified as per the job requirement with provision of hand rails. There should be dedicated location for chemical storage and Material Safety Data Sheets (MSDS) for each chemical to be maintained. Maintenance related activities to be carried out with utmost care.

Work safety permit system to be followed for carrying out any job of mechanical or electrical nature. Communication between operation and maintenance department must be maintained pre and post work to avoid any mistake that may lead to accident. Testing of tools to be made part of practice before maintenance work. Mesh Guard should be provided on all rotating equipment to avoid entanglement with them. Good housekeeping can also help in avoiding incidents such as slip and fall. Near miss incidents provides information on potential unsafe acts and conditions. Prompt follow up action should be taken, following near miss incidents. Regular training on safety aspects to be made a part of the organization's culture. There were average 3133 man-hours per million-man hours worked training provided during the survey period. More emphasis to be laid on the behavior based safety during training.

Conclusion

There has been 44% reduction in number of injuries from 275 in 2010-2015 to 154 in 2015-2020 period. A reduction was also seen in the fatal accidents. The reasons for injuries were due to both unsafe act and unsafe conditions. The average incidence rate has reduced from 0.36 in 2010-2015 to 0.22 during 2015-2020 period. The average severity rate for the same period was reduced from 0.19 to 0.10. The longest accident free period also improved from average of 847 days to 1150 days i.e. more than 3 years without reportable injuries. About 77% of near miss incidents were due to unsafe conditions during the period. The improvement in overall safety of the industry should not be a reason to be complacent and plant management should aim for zero incidents.

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