

## ACCIDENT ANALYSIS IN FIREWORKS INDUSTRIES FOR THE PAST DECADE IN SIVAKASI

**N.RAJATHILAGAM\***

**N.RAJATHILAGAM \*\***

**A.AZHAGURAJAN\*\*\***

### **ABSTRACT:**

Fireworks industries are mostly prone to fire and explosion. The hazardous natures of chemicals are being used to produce the scintillating effects during the lighting of the fireworks crackers. The aim of this study was to evaluate the causes for fire & explosions in fireworks factories. Two hundred and sixteen fatal and sixty three are severely injured from 1994 to 2008. Data on age, sex, and incidence by month, causes of explosions were recorded. The majority of the fatal were male, with a mean age of 36.7 years. The result of the analysis shows that most accidents were caused by too much gunpowder put in at one time and accidents resulting from carelessness while making fireworks. Unsafe acts and unsafe conditions are the main reasons for these accidents. In this paper, the causes of accidents and prevention measures are also discussed.

**Key words :**Accident analysis, firework, Sivakasi.

\* Assistant Professor, S.F.R. College for Women, Sivakasi.

\*\* Principal, VHNSN College, Virudhunagar.

\*\*\* Assistant Professor, MepcoSchlenk Engineering College, Sivakasi.

## 1. INTRODUCTION:

Sivakasi town is in Virudhunagar District of Tamilnadu, India is known for its fire crackers and has attained importance for the same nationally and internationally. Virudhunagar District is famous for its match industries, fireworks and printing industries. And it is known throughout the world for fireworks production. About 90% of India's fireworks is produced here. During summer, the climate of is Virudhunagar District very hot and dry, which is suitable for manufacture of Crackers and Fire work, Match industries. There are nearly 700 fireworks factories giving direct employment to about 70,000 workers and about 1 lakh indirect such as paper tube making, wire cutting, box making in the country side.

Fireworks are the device that uses explosive, flammable material to create spectacular displays of light, noise and smoke. As in any manufacturing industry, Fireworks units also have accidents taking place in the worksite. To reduce the risk of accidents, safety norms are to be maintained strictly in the manufacturing areas.<sup>1-2</sup> Fireworks industry is now governing by Inspectorate of Factories and Explosive Act. Since fireworks are situated at village areas, most of the workers are illiterate; they are not having awareness on handling explosives and flammable materials. All the works are done manually. So, potential of accidents is very high.

The different chemicals using are Sulfur, Aluminium powder of different grades, Barium Nitrate, Pottassium Nitrate, Sodium Nitrate, Strontium nitrate, Dextrin, Charcoal, Aluminium chips, Iron chips, PVC powder, Magnesium powder & Boric acid. All of these chemicals are hazardous in nature because of their flammability and hence leads to fire & explosion.

The various process involved in the fireworks manufacturing are sparkles section, Colour pellets, fancy fireworks, filling, fuse cutting, fuse fixing, mixing, packing, sand preparation, sparklers section and weighing of chemicals.<sup>3-4</sup>

Analysis of accidents in the history is helps to reduce in the near future. So, the author has identified the nature of explosion hazards by conducting questionnaire survey in fireworks industries.

Sekar et al, conducted the survey in 77 authorized industries and 16 unauthorized firework industrial areas, which aimed at studying the status of working environment, type of construction and other social factors of firework industries. The survey concludes with the

recommendation for the construction of an explosion resistant industrial estate for the firework industries with necessary infrastructure facilities for the rehabilitation of unauthorized industries, considering the explosion hazards and the Socio-economic and environmental factors.<sup>5</sup> In another report published by the State Administration of Work Safety subordinated by State Council, China, the occurrence of accidents can be associated with risk factors from multiple perspectives such as workers, occupational environment, social environment, natural environment, regulations, and injury objects. They concluded that strength of supervision and adjustment of public health policy are needed in China to decrease the occurrence rate of fatal accidents.<sup>6</sup> Elisabetta Renni et al, had conducted the analysis of lightning-triggered accident case histories and extract information on types of vulnerable equipment, failure dynamics and damage states, as well as on the final consequences of the event. They conducted a quantitative approach for assessing lightning risk at industrial facilities.<sup>7</sup> Valerio Cozzani et al, had analysed the past accidents related to flood events and they collected data on final scenarios highlighted the presence of specific events, as those due to substances reacting with water. The results obtained were used to generate substance-specific event trees for the quantitative assessment of the consequences of accidents triggered by floods.<sup>8</sup> Xu-Lin Chen et al, analysed three hundred and fifty-one patients having burns caused by gunpowder explosions in a fireworks factory were admitted to center from 1 January 1987 to 31 December 1999 and the clinical notes of 339 patients. Data on age, sex, size, depth and sites of burn, incidence by month, inhalation injury, associated injuries, number of operations, length of hospital stay, morbidity, mortality, and causes of explosions were recorded.<sup>9</sup> Carolet al studied the severity of Industrial accidents with hazardous substances by historical analysis. In the study, the authors taken the variables like the levels of risk in industrial facilities where hazardous substances are used, the severity of the accidents. This study revealed that accidents in developed countries are less severe than those that occur in other geographical areas. Also, it establishes the influence on the severity (number of fatalities) of this kind of incident of certain factors: the type of incident and the type and amount of substance involved.<sup>10</sup> Ester Galli, studied the accidents occurring in a petrochemical plant located in South Eastern Brazil. It was based on comprehensive interviews with engineers and workers concerning major accidents. Information collected during the interviews highlighted the contrasts in how management and workers interpret industrial accidents.<sup>11</sup> Zoe Nivolianitou et al, created the European major accident reporting system (MARS) within the framework of

European Union (EU) directive 82/501, the so-called “SEVESO” directive in order to register all the major industrial accidents notified to the European Union authorities from the member states.<sup>12</sup> Byung Yong Jeong, investigated the characteristics and causes of accidents in the manufacturing industry of Korea. The national statistics of industrial accidents in the years 1991–1994 were extracted from the annual publications of the Ministry of Labor. These data were analyzed in terms of size of company, age of injured person, work experience, injury severity, accident type, injury type, injured part of body, and agency of accident.<sup>13</sup> Andris Freivalds, et al had considered the cyclical nature of accident and injury data and with the use of time-series analysis for modeling.<sup>14</sup> Palle Haastrup et al had analysed the accidents to explore systematic ways to address the problem of how many accidents involving hazardous materials actually occurred in Europe, and to make a realistic estimate. The analysis is based on 535 unique accident descriptions (of which 107 were fatal accidents) from seven accident databases covering the nine-year period from 1984 to 1992. The majority (70%) of the accident descriptions identified were found in one source only.<sup>15</sup>

But, so far no study has been conducted in the fireworks industries for the past 10 years. In this paper, the authors have analysed the accident causes for the past decade. So, this analysis will be useful to fireworks manufacturing industries to avoid the fire and explosion accidents due to the various reasons.

## **2. FIREWORKS MANUFACTURING:**

### **2.1 PROCESSES IN FIREWORKS INDUSTRY**

In a fireworks industry, different chemicals like fuels, oxidisers, ignitor, sand and special effect chemicals are mixed thoroughly. All the mixing operations are done manually. Wooden trays with brass meshed bottoms are used to sieve the chemicals to get a homogeneous mixture.<sup>16-17</sup> Here the major causes of accidents are impact, friction, static electricity charges and human errors. The mixed chemicals are filled into the tubes or loading into the required boxes.

Charcoal, other chemicals and water are made into paste and is applied on cotton wicks. After drying, the wicks are cut to required size and fitted suitably on the crackers and other fireworks. The fuses are inserted and allowed to dry. For drying the products, specially prepared

platforms are used. Usually the procedures are dried twice in the production line, once after fixing the fuse and secondly after finishing the products. Dust accumulation and overheating may cause accidents.

Fireworks after drying are packed in small boxes manually. Later these boxes are bundled together. Warning slips are placed in large bundles. The day's production is stored locally and in the evening, they are sent to the main stores. Push carts and trucks are used to transfer the goods within the factory and to warehouses. Here, careless handling, impact loading, over loading and dragging of materials roughly may lead to accidents.

## 2.2 UNSAFE ACTS WHICH LEAD TO ACCIDENT

Because of all the chemicals are flammable in nature, any source of ignition, which will turn into untoward incidents. To avoid the source of ignition, electricity is not allowed inside the working shed. In addition, some of the measures are usage less quantity of chemicals, avoidance of friction between the chemicals, proper house keeping, frisking, following proper handling procedures, experienced supervision etc. Here, some of the human errors which lead to accidents in fireworks factories are summarised as follows:<sup>18-19</sup>

- |  |   |
|--|---|
| Create friction during handling of chemicals                               | Leave the unused chemicals without proper disposal                      |
| Rubber mat has not been used on the floor                                  | Unclean the room if spilled chemicals are in the ground                 |
| Instead of using brass rod, iron rod is used                               | Carry with match box and easily flammable items                         |
| Throwing cigarette bud   | Create disturbance during the working                                   |
| Drag the materials roughly   | Use of chappals with iron nails   |
| Without cleaning of sand particles in their foot, enter into the work shed | Carrying iron materials with them                                       |
| Handling huge quantity of chemicals at a time                              | Not maintaining the correct drying time with respect to the environment |
| Carrying huge quantity of materials  | Usage of iron knife for fuse cutting                                    |
| Improper stacking / unstacking of chemical filled rings / cap papers       | Over loading of chemicals during the filling                            |
| Handling of decomposed (Heat released)                                     |   |

- |   |  |
|---|--|
| chemicals                                   | for the crackers.                          |
| Working at low lighting                     | Improper cutting of roll caps              |
| Working under sweating condition            | Dragging of roll caps                      |
| Weighing of chemicals by iron weigh balance | Working in open place                      |
|   | Improper storage of semi finished products |
|   | Horse play inside the shed.                |

### **3. MATERIALS AND METHODS:**

#### **3.1 Data sources**

The accident data of the fireworks accidents for the past fourteen years (1994 – 2008) were collected from the chief Inspectorate of factories, Chennai, Tamilnadu, India. The total number of accidents were 193 and fatalities were 216. The data were analysed for the reasons to which the accidents were occurred. From the data, the month, year & time of accidents, victim's age & sex and the place of accidents were taken. Then the data are entered in the MS Excel format and graphs were plotted against all the variables. The results were charted in table 1 & table 2 as below:

Table 1 Accident victims based on the age & Sex

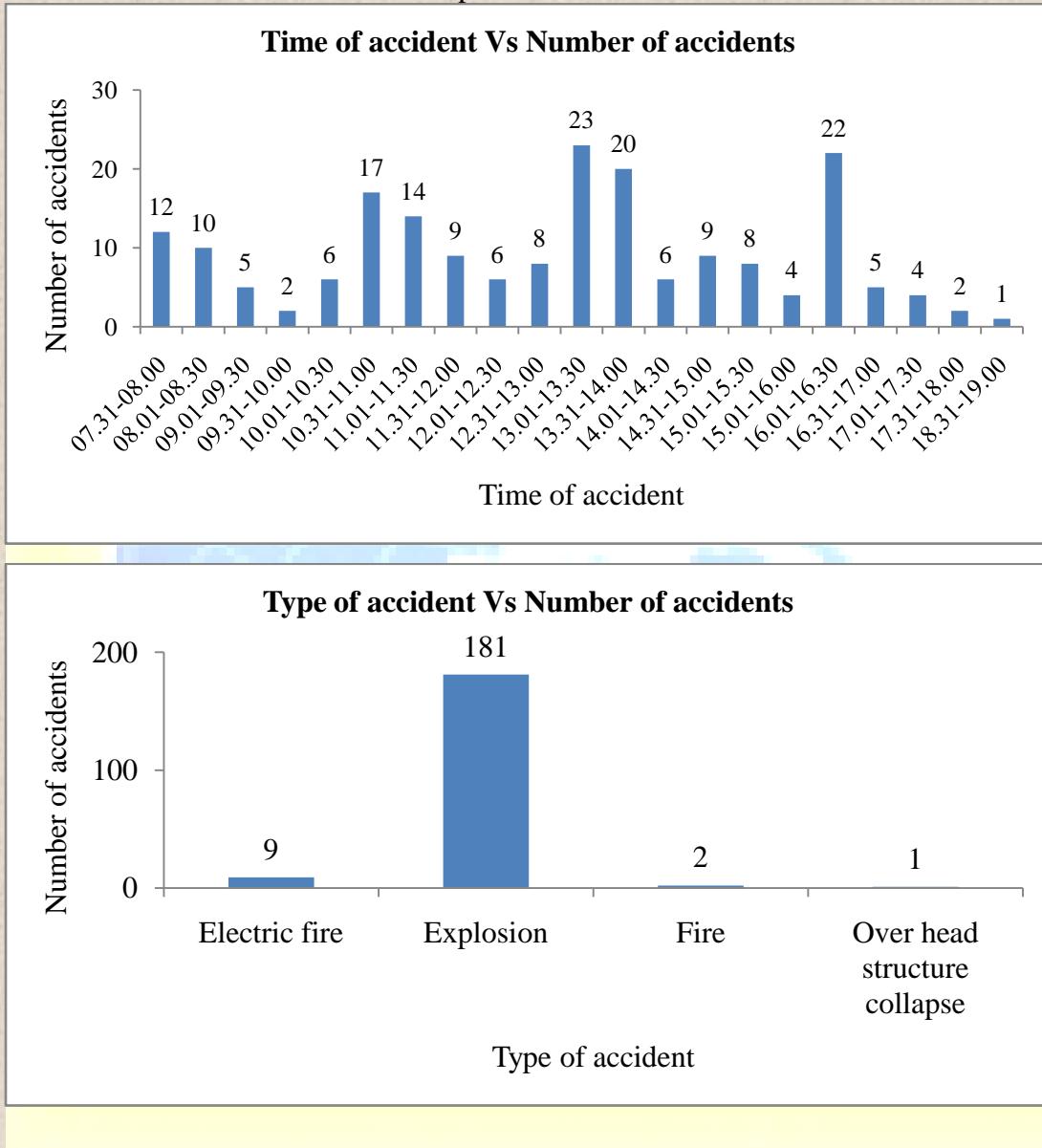
Age limit	Male	Female	Total
Below 20	3	4	7
21 – 30	50	14	64
31 – 40	40	19	59
41 – 50	27	17	44
Above 50	24	18	42
Total	144	72	216

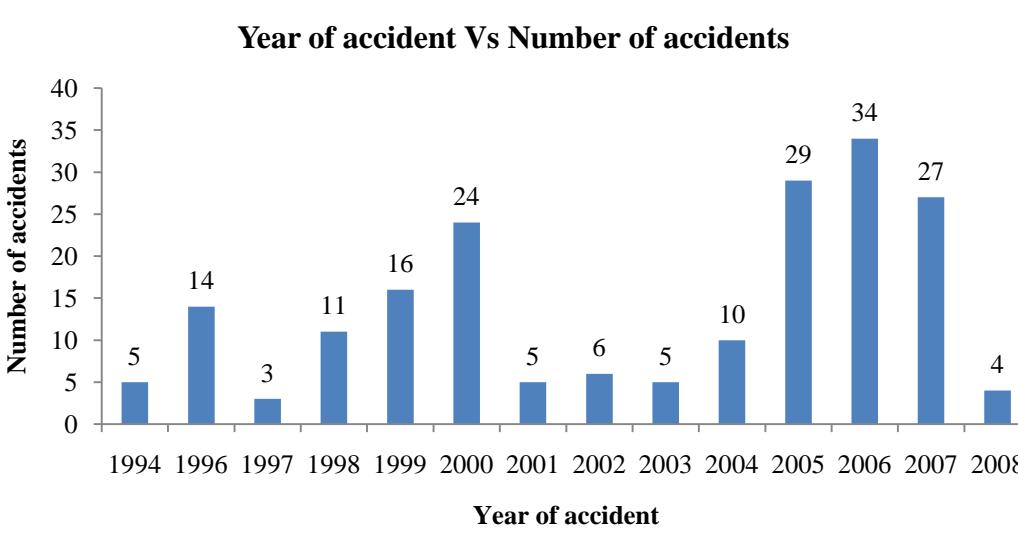
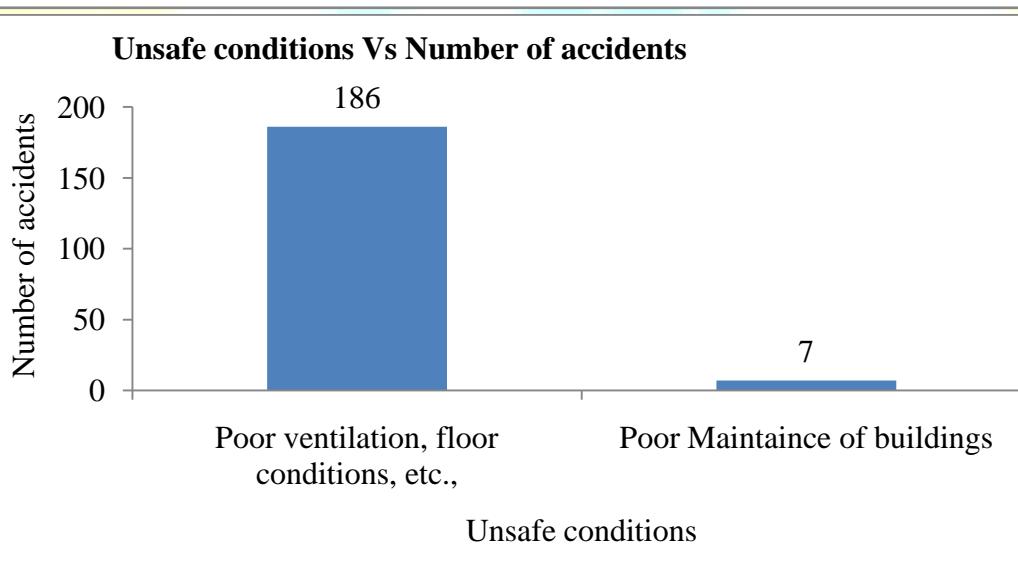
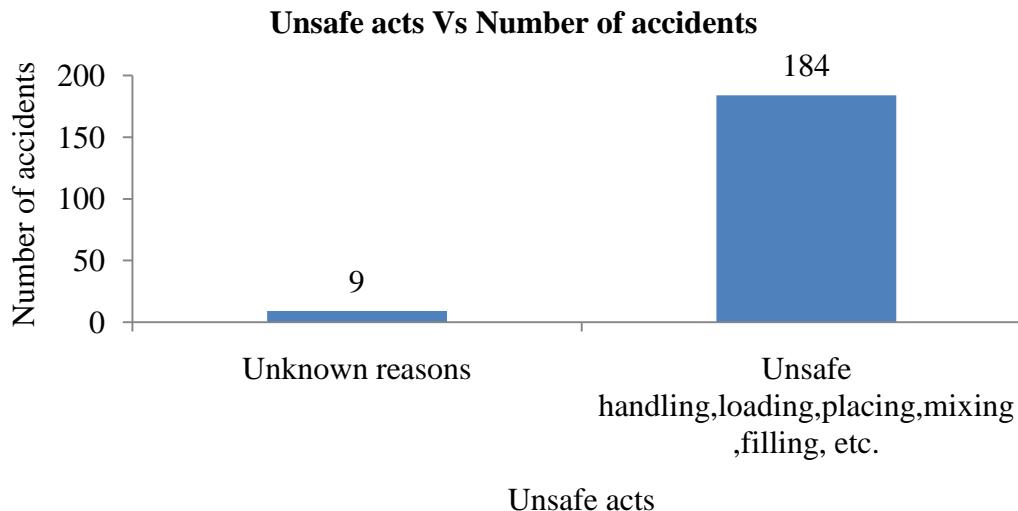
Table 2 Accident victims based on the process

Process	Nos.
Filling	45
Drying	7
Roll cap manufacturing	29
Fuse cutting	9
Waste burning	11
Packing	11
Weighing of chemicals	4
Carrying chemicals	15
Mixing	12
Fuse fixing	7
Fancy	39
Lightning	13
Testing of samples	14
Total	216

#### 4. RESULTS:

The data were converted and presented in the chart format as below:





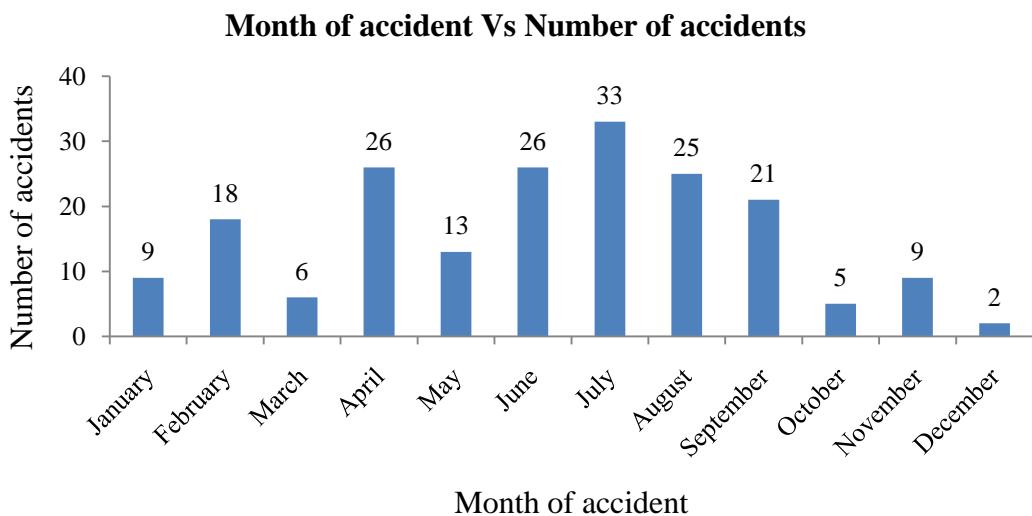
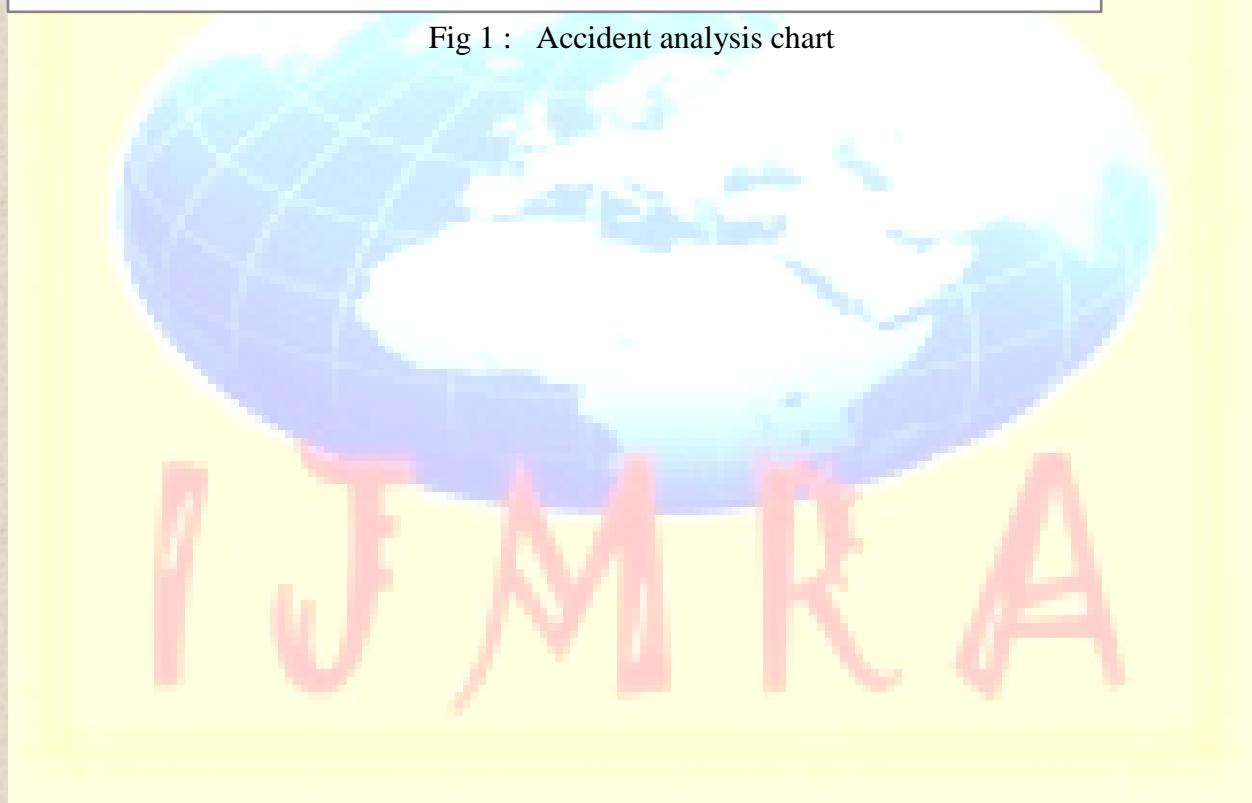


Fig 1 : Accident analysis chart



## **5. DISCUSSION:**

In the fireworks industries, it has been reported that most of the accidents took place in the sections of filling and fancy. In these two sections only, labours are handling the chemicals in the powder form.

During filling of chemicals, air borne dusts were accumulated in the room and which leads to dust explosion. Also the reasons for the fatal accidents may include mishandling of chemicals, carelessness of workers and over filling of chemical in a single stroke. Mishandling leads to intense friction that would produce massive heat generation, eventually resulting in explosion.

In fancy fireworks manufacturing, the chemicals are prepared into the slurry and made into the ball shaped chemicals to perform the aerial display. So, the chemicals are mixed with appropriate quantity of water, which leads to decomposition. Correct drying time and well ventilation shall be maintained to avoid the heat accumulation. Here, even small ignorance leads to fire accidents.

A statistics shows that out of 216 victims of fire accidents, 43 casualties took place during 1 to 2 pm, 31 deaths in between 10 am and 11.30 am, 22 workers lost their lives in between 4 pm and 4.30 pm. The result shows that the accident took place at the time of morning tea, evening tea and lunch only.

In explosives manufacturing industries, constant supervision must be necessary to avoid accidents. As the fireworks manufacturing units had no electricity, automatic warning systems could not be implemented. The golden rules that no chemicals had left unattended. But during the normal leisure hours like tea and lunch time, labours involvement in the works had considerably reduced.

It should be noted that out of 193 accidents, explosion is the root cause for 183 accidents and the remaining others may be accounted to electric fire and building collapse. All the fireworks products mean for joyful to give loud noise. In the place of manufacturing, lots of finished and semi-finished products are available. So, all the fire accidents leads to explosion and their consequence effects will be leads to collapse of buildings.

Due to unsafe acts of the workers, 184 accidents occurred out of 193 and for the remaining 9 fatalities reasons are yet to be explored. Even though there is great part by the government and the organisation, the safety lies in the hands of the employees. They have to follow the safety norms scrupulously without violating the norms. This can only be achieved by the whole hearted involvement of the employees. This could be achieved by educating the employees and a study, survey and analysis is needed to know the awareness of the employees. Continuous monitoring of the employers activity to check their unsafe acts and training them appropriately will lead to avoidance of the accidents. Also, maintenance of the safe conditions like adequate space, good ventilation and levelled floor lead to avoidance of accidents. This will create an environment where everyone at every level in the organization will increase their commitment and their involvement in making the workplace injury free.

59 fatalities occurred out of 216 in the month of June and July. In India, Deepawali is the popular regional festival, which the people are enjoyable by bursting the crackers to show their joy. **Deepavali**, usually celebrated between mid-October and mid-November in India. Owing to the huge demand of fireworks for this function, employers insist to produce more than the normal during the months of June and July. So, more chances of bypassing the safety rules in these times may be the main reasons for more accidents.

The another inference from the graph that the unsafe acts which already referred in the previous section lead to 95% of the accidents.

## **6. SAFE CONDITIONS TO PREVENT THE ACCIDENTS:**

- Separate places for different types of chemical mixture for the process of mixing and filling
- Name boards for each process to be displayed.
- Utensils used for one type of mixture should not be used for other type of mixture
- Wear rubber shoes while at work
- Do not carry matches
- Doors are made of woods fitted with non ferrous hinges
- Doors shall be open outwards

- Least quantity of chemical composition in working places (not more than the prescribed limit)
- Room shall be well ventilated to reduce the probability of dust explosion
- Fireworkproducts are never to be dragged roughly
- Fire buckets never being used for other purpose
- Fire buckets shall be filled with dry sand
- Display safety posture ( for uneducated workers)
- All rooms have minimum of two fire exits.
- The doors of any two manufacturing shed should not face each other to prevent the spread of fire in case of explosion.
- Floor should be covered with electrically conducted rubber mat
- Space between the buildings shall be minimum 10 meters
- Space between the drying platforms and other rooms shall be 18 meters
- Distance between mixing and filling sheds shall be 18 meters
- Suitable mound / screen shall be provided around mixing or filling rooms. The mound should be RCC, 22.5 cm thick, or brickwork with 34 cms. thick and 1.5 to 2 meters from the shed
- Dipped fuse thread should not be overlap each other
- Wooden knob and brass cylinder should only use for making stars (colour balls).
- Wooden hammer should be used for ramming chemicals into the tube of rockets.

## **7. CONCLUSION:**

In order to develop a successful health and safety programme, it is essential that there must be strong management commitment and strong worker participation in the effort to create and maintain a safe and healthy workplace. An effective management addresses all work-related hazards, not only those covered by government standards.

Safety regulations must be established in all the firework factories. These rules must include the maximum amount of chemicals that can be handled at one time and an absolute prohibition on smoking while making firework. The firework workers should focus exclusively on making firework in order to avoid carelessness resulting in rough handling. The firework

should not be exposed to direct sunlight while drying outdoors, especially in the summer. Firework making should be suspended in lightning storms that can result in short-circuit.

The resting hours such as tea time and lunch time, firework work being suspended so as to relax the workers.

The analysis clearly shows that the accidents are held mostly due to human error. An effective safety management with the proper training and education for the workers may prevent the accidents considerably. The strong technical measures like automatic warning system, automatic chemical handling methods, adequate fire prevention & protection systems would definitely help to reduce the accidents effectively. Also top management commitment to prevent accidents will be the important one.

## **REFERENCES:**

- Azhagurajan.A., 2005. Study on explosive waste disposal with a case study on fireworks waste. *Journal of Industrial Pollution control* 21, 43-50.
- Brock.H.,1949. A history of fireworks. George.G.Hararap Co. Ltd. London.
- Chelladurai.A. 1987, *Fireworks – Principles and Practice – Tips to an Amateur – Do's and Don'ts*. Standard fireworks, Sivakasi.
- Ghosh,K.N., 1987, *The Principles of Fireworks*. H.Khatsuria, Sivakasi.
- Sekar.T., et. al., 2010, Planning of industrial estate for fireworks industries in Sivakasi. *International Journal of Engineering Science and Technology* 2, 2207-2217.
- Xibahenanli., 2010, Analysis on occupational-related safety fatal accident reports of China, 2001–2008. *Safety Science* 48 , 640-642.
- ElisabettaRenni, Elisabeth Krausmann, Valerio Cozzani., 2010. Industrial accidents triggered by lightning. *Journal of Hazardous Materials* 15, 42-48.
- Valerio Cozzani, MichelaCampedel, ElisabettaRenni, Elisabeth Krausmann., 2010. Industrial accidents triggered by flood events: Analysis of past accidents. *Journal of Hazardous Materials* 15, 501-509.

- Xu-Lin Chen, Yong-Jie Wang, Chang-Rong Wang, De-Lin Hu, Ye-Xiang Sun, Shou-Sheng Li., 2002. Burns due to gunpowder explosions in fireworks factory: A 13-year retrospective study. *Burns* 28, 245-249.
- Carol, S., Vilchez,J. A., J. Casal., 2002. Study of the severity of Industrial accidents with hazardous substances by historical analysis. *Journal of Loss Prevention in the Process Industries* 15, 517-524.
- Ester Galli., 1999. A sociological case study of occupational accidents in the Brazilian petrochemical industry *Accident analysis & Prevention* 31, 297-304.
- Zoe Nivolianitou, MyrtoKonstandinidou, ChristouMichalis., 2006. Statistical analysis of major accidents in petrochemical industry notified to the major accident reporting system (MARS). *Journal of Hazardous Materials* 137, 1-7.
- Byung Yong Jeong., 1997. Characteristics of occupational accidents in the manufacturing industry of South Korea. *International Journal of Industrial Ergonomics* 20, 301-306.
- AndrisFreivalds, Alison B. Johnson., 1990. Time-series analysis of Industrial accidents data. *Journal of Occupational accidents* 13, 179-193.
- PalleHaastrup, Hans Rømer., 1995. An analysis of the database coverage of Industrial accidents involving hazardous materials in Europe. *Journal of Loss Prevention in the Process Industries* 8, 79-86.
- Azhagurajan.A., 1999, Principles of safety control (PSC) Application in fireworks, Proceedings of the National Seminar on Fireworks Safety 99". MepcoSchlenk Engineering College, 116-119.
- Prem.D.R., 2000, Law of arms and explosives with rules, Ashoka law house, New Delhi.
- Rajathilagam.N.,Dr.Sundarapandian.P., 2009, Enhancing the safety consciousness in hazardous industries. Third concept, An International journal of ideas. 23, 51-54.
- Subramanian.V., 2000, The Indian Factories act, 1948, Madras Book agency, Chennai.