# Ergonomic Risk Mitigation Techniques For Improving Industrial Safety In Crackers And Fancy Fireworks Sector

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## Abstract

The fireworks industry, predominantly based in the Sivakasi region of Virudhunagar district, plays a significant role in regional employment. This study explores occupational health concerns, particularly ergonomic risks, in fireworks production units such as those manufacturing standard crackers and decorative fireworks. Workers often endure physically demanding postures and repetitive tasks that contribute to musculoskeletal stress and discomfort. The objective of the study is to evaluate and minimize the risks associated with improper body mechanics in these work environments. To achieve this, ergonomic assessments were conducted in two different sectors of the fireworks industry using validated evaluation tools such as the Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA). These tools were applied to determine risk levels and prioritize interventions. After the data collection phase, workers participated in brainstorming sessions to share their perspectives and complete structured questionnaires aimed at capturing the extent of physical discomfort experienced during routine tasks. The feedback revealed significant ergonomic strain in multiple operational phases. The results indicated specific body postures and task repetitions that could lead to chronic injury if unaddressed. Using both qualitative insights and quantitative analysis, the study proposed targeted ergonomic interventions. These suggestions are intended to reduce injury risks and enhance workplace safety standards. The research highlights the need for sustainable ergonomic solutions in traditional manufacturing setups.

**Keywords:** Ergonomic hazards, Fireworks industry, RULA, REBA, Risk assessment, Occupational safety

## 1. Introduction

The investigation was carried out in Sivakasi fireworks sectors. Morethan 100 workers are employed in day shifts alone in that fireworks sector. The company contains supervisors, quality checkers and workersinvolvedinthe production of various crackers and fancy items. The various process involved in making crackers that are Rolling, Cutting, Pasting, Sand filling, Chemical filling, Threading, and packing assembly sections. In these various sections, different types of workers are involved in different activities based on the working domain specializations.[1] Evaluated the performance of the different tasks of workers in the brick manufacturing industry. They observed workers continuously performedawkward posture in the brick manufacturing process and feeling the discomfort in nature. In this analysis, they used the same tool RULA and REBA for a Brick manufacturing industry. But in this research same tool applied for a fireworks industry to monitor the performance of the worker'sobservations. The difference of the brick manufacturing that is related to all manual handling operationsis carried in human body parts and the brick manufacturing industry is not in the hazardous category. In this survey assessment the fireworks industry involved in very high impact hazardous in nature [2]. The Corresponding Flow diagrams show the working flow of fireworks industries (figure 1).

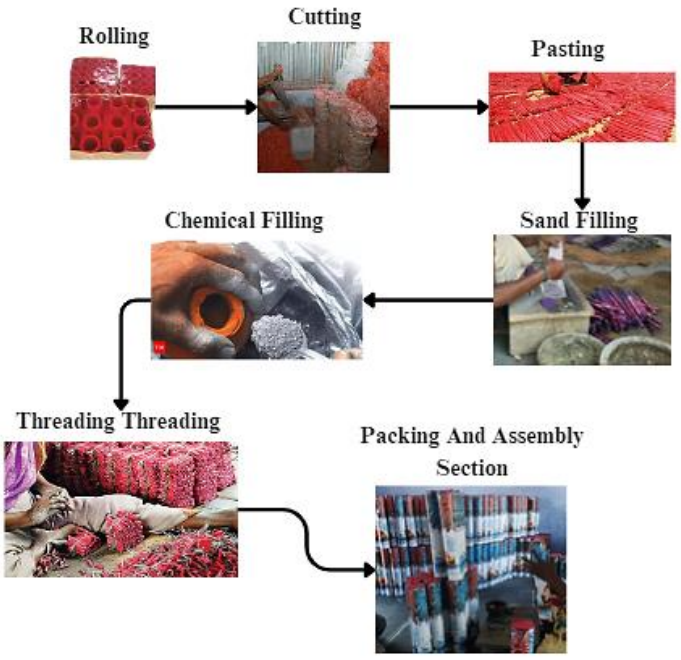


*Figure1. Process Carried out In Fireworks*

The evaluation assessment in the Leather Manufacturingunit. Theyinitially identify the problems faced with leather units and listed out. The problems identified the Work-relatedMSD (Muscular Skeletal disorder). So they decided to use the RULA and REBA Tool for analysis purposes. After getting the various information from the survey and evaluation assessment and identify the problems and categorize the risk based on the work postures of each worker employed in those leather units. In theseassessments. [3] Case study on SSI (Small scale industries) analysis of the work body postures and assessments using REBA Techniques alone. So the implications represent the analysis of the result in only one ergonomics tool. So the result is not reflective properly in all stages. So that comparative techniques are mostly used to give better results from one to one method [4]. The conceptual design methods of work postures analyses using Virtual software's mode using RULA and REBA analysis. The research ideas state that the performance actions are taken for this analysis purpose and make an effective result obtained to identify the awkwardposture in fireworks industries [5] The method of genomics analysis in their various domain that can able to identify the awkward postures of workers in various fields.

In this analysis the author able to develop the ergonomic invention methods used for industrial survey assessment purposes. The outcome of the review more number of methods employed in ergonomicsfields to determinetheawkward postures.[6] The hazards identification and consequences of hazards encountered in fireworks industries. They concentrated only on accident statistics values. Based upon the result they concluded mostly hazards occurred due to human error and unawareness only. But they didn't conduct any surveyassessments. In this analysis, the survey assessmentsdeploy discuss the behavior-based performance of each worker employed in fireworks industries.[7] The Accident data analysis for a fireworks industry for the various process using the safety management concepts JHA(Job Hazard Analysis).From this method, they analyze the handing operations and consequences of hazards encountered in fireworks industries. [8] The awkward postures of car drivers and the linkage of pressures in and around the traveling. In this survey, they conclude the proper sitting postures and strategies following the ergonomics postures. [9] Develop a work based sampling method for construction workers to mitigate the repetitive motions in the workplace by using the different approaches of the PATH Method.[10] Compared the outcomes of ergonomics parameters in different operation of four sawmill machinery jobs. They identify the qualitativedata's implications using various

ergonomics assessment tools respectively.[11] Case study on ergonomic studies for investigating the Work-related Muscularskeletal Disorder problemsfaced by the Sawmill workers located in Indian countries to evaluate the Postures scores using the RULA and REBA Techniques. [12] Investigate an Exposure of ergonomics using the system design approaches.[13] Evaluate the ergonomics postures and awkwardpostures in virtual Manufacturing sectors to identify the reliability outcomes from the ergonomics assessments.[14] The assessments of assessing the physical exposures of work-related Muscular skeletal Disorder Problems based on postures analysis techniques.

[15] The evaluation of ergonomics postures inside the industrial workstations to identify the physical and Ergonomics problems inside the workplace.Ergonomic analysis related to Muscular skeletal disorder hazards faced by workers in the two sawmills located in Karnataka states of the southern part of India. In this analysis, various ergonomics hazards are identified using various posture tools analysis. [16] The work posture assessment in a forging industry to evaluate the potential ergonomic factors in small scale Industries.In this fireworks consist of various units that are deeply viewed the worker's manual handling is recorded in the form of a photograph in an investigation survey from each section of the two manufacturing units. In this work, various sections process and awkward postures investigations are discussed below with the sample evidence of the above ergonomics problems.

Initially, the Investigation was conducted in each firework industry located in Sivakasi area zones. The analyzer of the investigation is initially concentrated in the area of wise potential zones. Fireworks consists of various sections that contain the manufacturing the firecrackers and fancy items In the Rolling process workers are mostly are rolled paper tubes with black powder (also called gunpowder). They might also be filled with flash paper and a fuse. When you light the fuse of a firecracker, the fire burns along the fuse. So from this analysis mostly the workers have faced back pain problems over a long time they bend to fill the chemical powder in the filling paper so it can lead to back pain and also the finger also twisted over a prolonged period. These effects will cause serious ergonomics problems and they will perform the awkward postures in the workplace. The sample evidence took from the fireworks are shown below from one of the fireworks units (figure 2).

*Figure 2 Work postures activity1*

The analysts are moved to the next sections in each fireworks unit's worker's posture analysis to the cutting section. The cutting sections playa major potential incident due to the wrong working postures in each of the fireworks units. In this cutting sections workers are performed different styles need to finish the work as soon as possible. This will create serious ergonomic problems like muscle problems as well as upper arm abduction and lower arm abduction in each of the cutting units of fireworks sectors. The sample proof of each firework is shown below Figure 3 and 4.

*Figure 3 and Figure 4 Work postures activities (2 And 3)*

## 2. Problem identifications and case study assessments:

On the other hand, the assessor or reviewer conducts Physical assessment in two fireworks manufacturing sectors located in Sivakasi and virudhunagar fireworks zones. He must able to make a detailed plan assessment in each of the worker's performance and working postures based on the locations that they are employed in a particular workplace. In this lieu of this, the firework industry hazards are classified into many types in the manufacturing process. They are,

- Rolling process
- Cutting process
- Pasting process
- Sand filling process
- Chemical filling process
- Threading process
- Packing And Assemble process

Firework process and identify the hazards

*Table 1 Problems Encountered in Fireworks*

| **Fireworks process** | **Problem Identifications** | **Hazards Encountered** |
|---|---|---|
| Rolling | Finger Amputations. | Ergonomics and Manual Material Handling |
| Cutting | CTS (Carpel tunnel Syndrome) | |
| Filling | Finger Amputations. | |
| Packing And Assembly | Carelessness | |

A serious potential incident happened in fireworks routinely in and around the Sivakasi and virudhunagar locations.[17] Conducted the case study review regarding the works exposures of risks from the fireworks manufacturing sectors**.** Detailed analysesof these incidents in various investigations in various views.[18] Conducting the case assessment and started to plan to implement and construct the Industrial estate for the

fireworks industries based on the worker's attitude and to make changes in the behavioral changes among the fireworks workers (table 1). The scenario states that the manual material handling and unawareness that will lead to creating serious ergonomics hazards happened inside the workplace. In this work various types of recent fireworks accidents are taken for investigation purposes and also common fire accidents occurred recently and compared with the two accidents in statistical analysis that will create a serious impact than common accidents. Because the worker's death and material loss are higher than the common accidents that happened in fireworks. Detailed various media that have published daily news through newspapers recently. The data are collected and tabulated in year wise and the death rate.[19] Conducted the physical survey in the fireworks industries and collecting the many incidents data that can be encountered during the year 2010 and 2011 based on this survey they suggest the disaster implementation programs in the fireworks sectors (table 2)

*Table 2 Accident Statistics In Fireworks Recent Years*

| **Sl. No.** | **Year** | **Types of accidents** | | **Number of injuries** | |
|---|---|---|---|---|---|
| | | Firework | Common | Firework | Common |
| 1 | 2020 | Sivakasi | Road accident | 30 | 25 |
| 2 | 2019 | Sivakasi | Fire in bunk | 15 | 15 |
| 3 | 2018 | Sivakasi | Fire (Oil store) | 21 | 6 |
| 4 | 2017 | Virudhunagar | Chemical industry | 25 | 20 |
| 5 | 2016 | Virudhunagar | Fire (Rail) | 27 | 15 |

**2.1 Sample Incidents Encountered in Fireworks:**

Case Assesmment1:

In Sivakasi, near thekakkivadanpatti village, the leading fireworks can be manufacturing fancy fireworks and crackers products.In this fireworks, more than 30 rooms and more than 100 workers are employed for manufacturing the firework. One day afternoon fancy model mixed with chemical process friction with one another on fire suddenly happen. One room is completely collapsed and damaged, in the accident, another 2 rooms are minor damaged. In this

accident, 12 workers are injured and more than 30 workers are deaths because of continuously the workers are employed in shift due to the demand products of crackers. Management-focused only production and profits. Due to the workers facing the physical hazards encountered in the fireworks workplace that leads to the death of one worker and got severe potential injury by other workers.

Case Assessment 2:

One of the fireworks industriesis fire accidentshave happened. Near the Sivakasi, Fireworksis produced the fancy model crackers and it is from the friction of the mixing the chemical process. Suddenly catch the fire and it is the process of fancy model of firecrackers. They are produced by the chemical mixing process and from the friction. Near the 2 clocks from the friction 4 rooms are collapsed and more than 5 rooms are minor accidents. In this accident are nearly 21 workers are injured and 1 worker is dead. Because the industry is not following proper rules and regulations. Also from the case study investigated the workers got finger amputation problems continuously in rolling sections all workers are faced with serious Ergonomics hazards encountered in that place.

Case Assessment 3:

During the process of the firework industry, fire accidentshave happened in Sivakasi. The process of firework accidentshas happened because fireworks industries are not following the rules and regulations properly. In this accident are 6 workers are injured. After getting a survey from the incident preparation from the workers it is observed that in cutting units CTS can occur continuously from the worker's fingers. It leads to accidents and an explosion inside the cutting units.

Case Assessment 4:

Near the sattur, chinnakampatti village firework industries are in the running process. More than 225 workers are produced the crackers. While mixing the chemical process friction is formed and suddenly catch the fire. Due to the continuous enforcement by the management leads to the catch fire in mixing sections. It is also referred that serious potential type of ergonomics hazards takes place in these particular sections. In this accident they are more than 2 rooms are collapsed and more than 10 rooms are minor accident are happened. Particular one room

crackers are catching the fire and it is exposed. In this accident, 15 workers are injured and more than 1 worker has died.

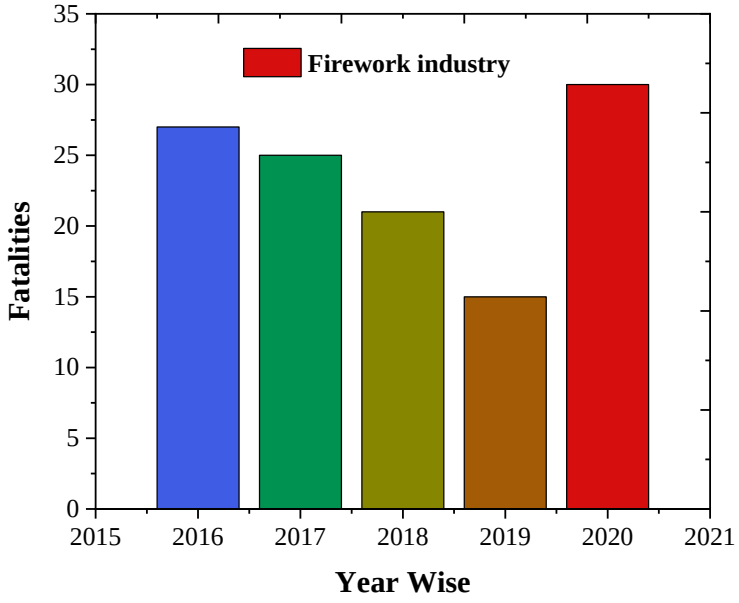


*Figure 5 Analysis of Fireworks Incidents in the Recent Years*

In this above graph shows that year-wise fatalities occurred in fireworks industries from the last five years. Till from 2016 the number of incidents occurred crossed 5 to 10. In 2017 gradually it increases from above 25 in range it shows the no safety precautions can be taken on the 2017$^{th}$ year. While in the 2018 year it can be decreased by the serous enforcement can be taken by the government that can reduce the Fatalities from 25 to 20. Simultaneously in 2019 also the injuries can be decreased compared from the previous year (figure 5). In other views 2020 drastically the number of increases and till it reaches the peak value of 30 incidents that happened in the current year. So it is a very serious type of problem the number of incidents can be increased. So that only the investigator decided to select the fireworks to investigate the serious potential problem and able to minimize the number of incidents. Not only identify the problems also deeply investigate the origin of creating incidents in the fireworks.

## 3.Methodology

In this work basically, ergonomics studies are carried out under each of the fireworks manufacturing units. [20] Apply various tools like RULA, REBA, WERA,etc to solve the ergonomics analysis problems and case studies.[21] Introduce new framework structures to solve the design basis problems involved in the ergonomics factors [22] Compared the two ergonomic assessments tools and suggesting the suitable recommendations. Therefore more Ergonomics assessment tools are used by the researchers as well as industry experts also. Based on the above problems here RULA and REBA assessment tools were used by the case study investigations. The case studies are selected based on the potential problems faced by the workers on a daily rotation basis. Especially in more number of crackers demands workers faced ergonomic problems in the daily work routine. Let us detailed discussed the methodologies that are explained.

Form this methodologyinitially study all the industrial processes and manufacturing details of each fireworks location. [23] Compare the ergonomics assessment tools to evaluate the ergonomics problems encounter among the workers.[24] Evaluate the actions of the posture using the RULA and REBA Techniques for small scale industries. [25] The research literates and evaluate the work postures and awkward postures using the REBA Techniques. Afterinitial screening, the process based on the initial studies compare all the hazards evaluate and the posture of workers of the two fireworks units located near the fireworks industries. The identification of potential areas based on the severity and frequency of the accidents already happened inside the industries (i.edata's collected by the company officials and management). After that only potential types of areas are classified. Aftercollecting all the concerneddata of fireworks assessment data are going to proceed based on each potential area from each fireworks unit. The Fireworks units are screen only working postures because here the problem is the Ergonomics manual material handling process in the fireworks units (figure 6).

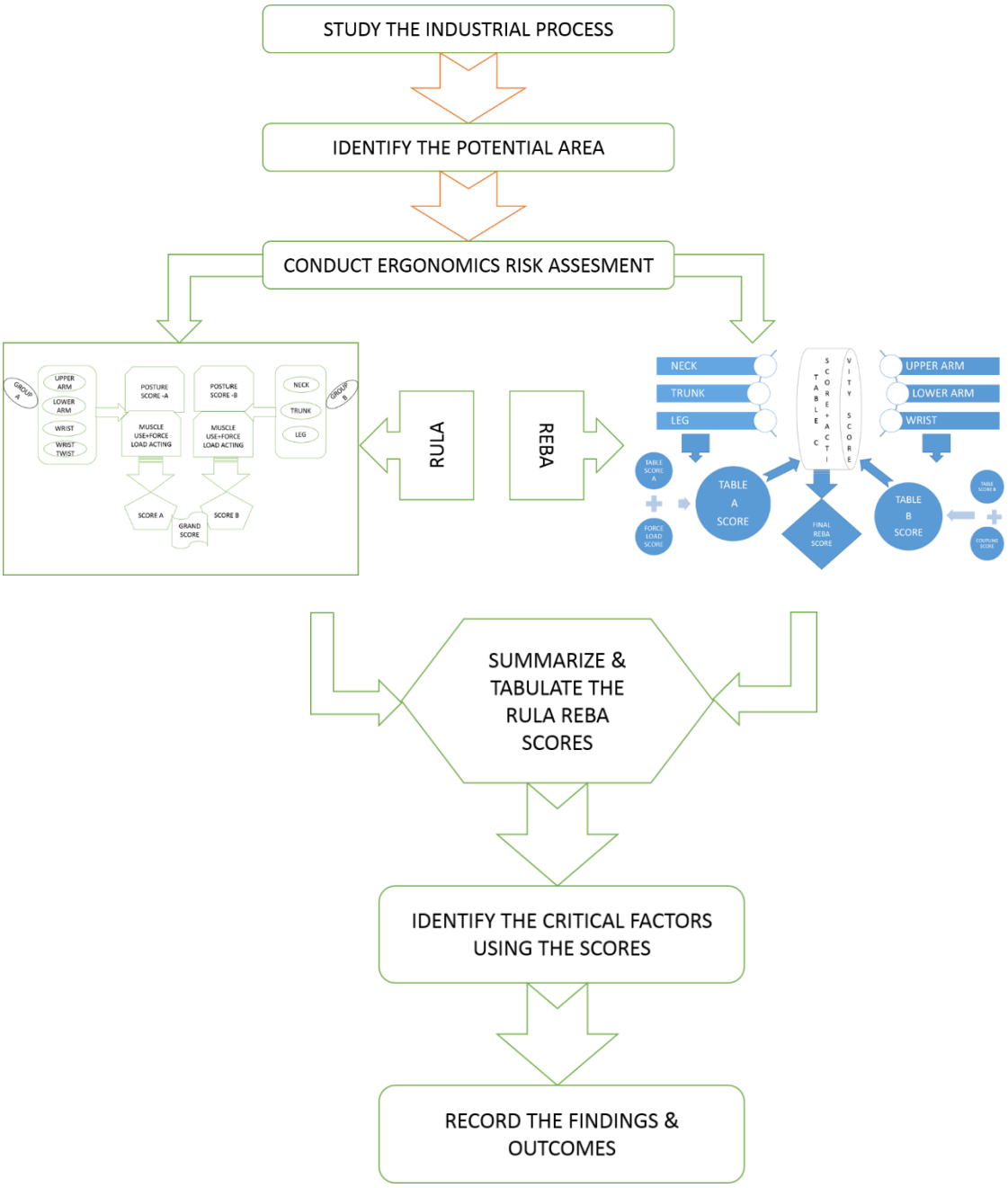


*Figure 6 Ergonomics Assessment Flow diagram*

### *3*.1 Applications of RULA measured the awkward postures of the human body:

In RULA (Rapid Upper Limb Assessment) the upper parts of the body were only taken for the evaluation assessment of awkward postures performed by the workers in each of the fireworks units. The methodology is common for all the two fireworks only performance of the

worker's performance is different. As Per the assessment procedures the following parts of the body arescreened by the assessor. The corresponding RULA Modified procedures are shown below inthe figure 7.

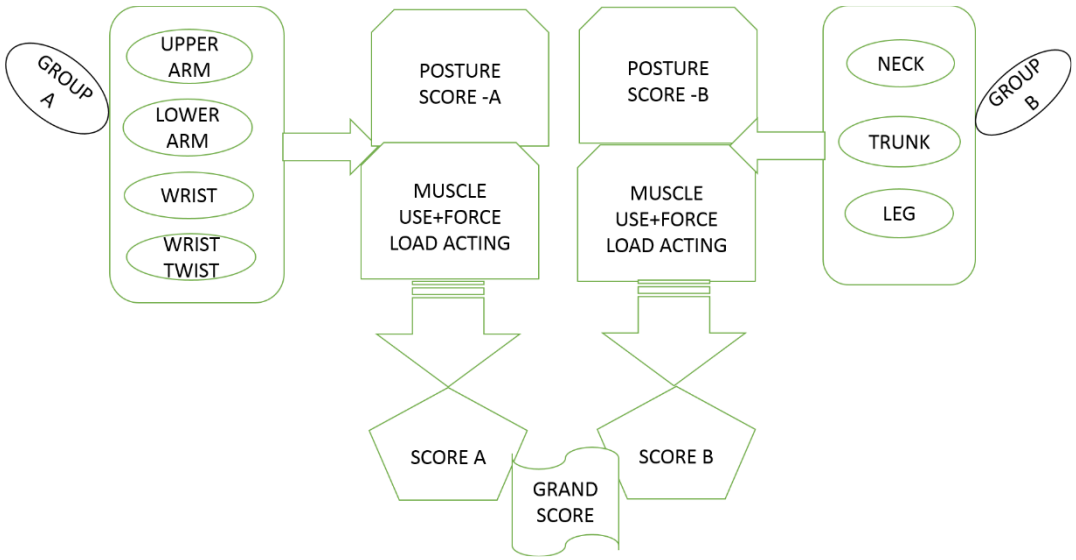


*Figure 7 RULA Assessment Modified Model in Firework evaluation*

Initially, the assessments are split into two different groups namely Group A and Group B. The Group A Contains the Arms and writs positions scores (i.e Lower and Upper arms scores, Normal Wrist and wrist twist scores) all the arm scores are together integrated. The posture score A has derived the arms and wrist twist score. eventually, the muscle use score and material handling limits are noted in the form of lbs. after that it will give and calculation of Score given in table 3, 3A to C.

*Table 3 RULA Table Score Evaluation Methodology Procedures*

| S.No | Body Parts | Awkward position limits and parameters | Final Score Evaluation Procedures |
|---|---|---|---|
| 1 | Upper Arm | -20 to 20 , >20,20-40,40-90,90(all values in degrees) | Table A Upper arm Score |
| 2 | Lower Arm | 60-100,0-60, 100 flexion, (all values in degrees) | Table A Lower arm Score |
| 3 | Wrist position | 0,0-15,> 15 (all values in degrees) | Table A Wrist position scores |
| 4 | Wrist Twist | Mid-Range-1,Twisting range-2 | Table A Wrist twist scores |
| 5 | Muscle weight handling positions | Postures based on static and Material Handling ranges | Look up Posture Score in Table A |
| 6 | Final postures | Evaluationlimits of Table A And C Score | Calculation of Postures from Table C |

*TABLE-3A Arm-Wrist Postures Values*

| Upper Arm | Lower Arm | Wrist | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | | 2 | | 3 | | 4 | |
| | | Wrist Twist | | Wrist Twist | | Wrist Twist | | Wrist Twist | |
| | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 3 | 3 |
| | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 |
| | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 4 | 4 |
| 2 | 1 | 2 | 3 | 3 | 3 | 3 | 4 | 4 | 4 |
| | 2 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 |
| | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 1 | 3 | 3 | 4 | 4 | 4 | 4 | 5 | 5 |
| | 2 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 |
| | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 |
| 4 | 1 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 |
| | 2 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 |
| | 3 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 5 |
| 5 | 1 | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 7 |
| | 2 | 5 | 6 | 6 | 6 | 6 | 7 | 7 | 7 |
| | 3 | 6 | 6 | 6 | 7 | 7 | 7 | 7 | 8 |
| 6 | 1 | 7 | 7 | 7 | 7 | 7 | 8 | 8 | 9 |
| | 2 | 8 | 8 | 8 | 8 | 8 | 9 | 9 | 9 |
| | 3 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |

*TABLE-3B Trunk-Leg Posture scores*

| | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Legs | | Legs | | Legs | | Legs | | Legs | | Legs | |
| Neck | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| 1 | 1 | 3 | 2 | 3 | 3 | 4 | 5 | 5 | 6 | 6 | 7 | 7 |
| 2 | 2 | 3 | 2 | 3 | 4 | 5 | 5 | 5 | 6 | 7 | 7 | 7 |
| 3 | 3 | 3 | 3 | 4 | 4 | 5 | 5 | 6 | 6 | 7 | 7 | 7 |
| 4 | 5 | 5 | 5 | 6 | 6 | 7 | 7 | 7 | 7 | 7 | 8 | 8 |
| 5 | 7 | 7 | 7 | 7 | 7 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| 6 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 9 | 9 | 9 | 9 | 9 |

*TABLE-3C Trunk-Leg Posture scores*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7+ |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 |
| 2 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 3 | 3 | 3 | 3 | 4 | 4 | 5 | 6 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 4 | 3 | 3 | 3 | 4 | 5 | 6 | 6 |
| 5 | 4 | 4 | 4 | 5 | 6 | 7 | 7 |
| 6 | 4 | 4 | 5 | 6 | 6 | 7 | 7 |
| 7 | 5 | 5 | 6 | 6 | 7 | 7 | 7 |
| 8+ | 5 | 5 | 6 | 7 | 7 | 7 | 7 |

### 3.2 Applications of REBA measured the awkward postures of the human body:

This type of Assessment continuously deals with the entire body working postures performed during the workplace. The assessor completely points out the actions of the body postures of the workers in each of the fireworks sectors. Similarly,the same procedures are followed like RULA assessment the same as REBA Assessments. Similar kind of actions takespalace to deal with the various awkward working postures. The Corresponding Methodology is shown in the figure 8 below.

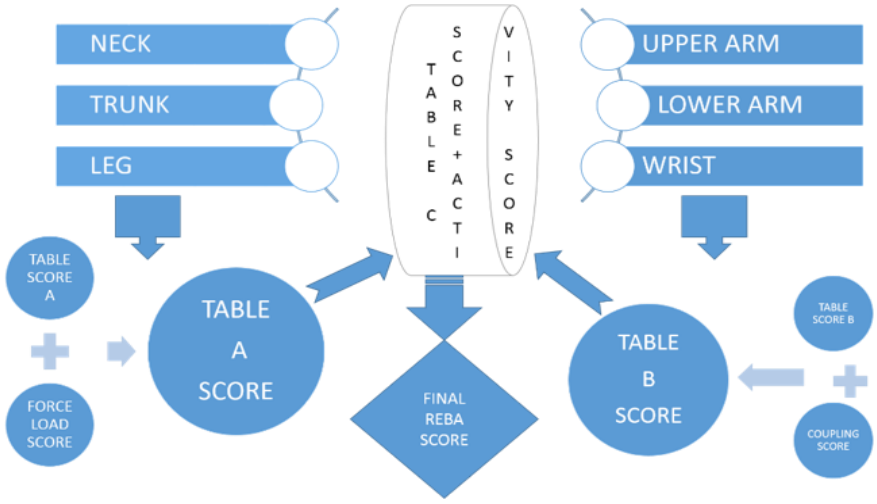


*Figure 8 REBA Assessment Modified Model in Firework evaluation*

The basic procedures of REBA analysis are divided into two sides of body postures namely known as Neck, Trunk and leg are the basic postures analyzedon one side. On the other side parallels the hand-arm, finger twist rotation isanalyzedon another side they are all compared and together calculated the working postures scores are derived from the two sides of the working postures scores analysis. Similarly,the same Table 4, A and Table B and C Scores are

calculated based on the working awkward postures of workers of each fireworks sector so that it can easily compare the risk evolved from the workers from the analysis tool REBA assessment.

*Table 4 REBA Table Score Evaluation Methodology Procedures*

| **S.No** | **Body Parts** | **Awkward position limits and parameters** | **Final Score Evaluation Procedures** |
|---|---|---|---|
| 1 | Neck | 20, 20 side bend, 20 Twisted (all values in degrees) | Neck Score noted in Table |
| 2 | Trunk | 0,20,20-60.>60 (all values in degrees) | Trunk Score noted in Table |
| 3 | Leg | 0,30,30-60,>60 (all values in degrees) | Leg Score noted in Table |
| 4 | Upper Arm | -20 to 20 , >20,20-40,40-90,90(all values in degrees) | Upper Arm Score noted in Table |
| 5 | Lower Arm | 60-100,0-60, 100 flexion, (all values in degrees) | Lower Arm Score noted in Table |
| 6 | Wrist | 0,0-15,> 15 (all values in degrees) | Wrist Score noted in Table |
| 7 | Muscle weight handling positions | Postures based on static and Material Handling ranges | Look up Posture Score in Table A |
| 8 | Coupling Score | 0,1,2,3,4,5 (Based on the workers performance Condition) | Look Table C from the postures score |
| 9 | REBA Score | Table C Score | Activity score from Table C |

*Table-4a Trunk-Leg Postures Scores*

| Table A | Neck | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Legs | 1 | | | | 2 | | | | 3 | | | |
| | | | | | | | | | | | | | |
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| | 1 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 3 | 3 | 5 | 6 |
| Trunk | 2 | 2 | 3 | | 45 | 3 | 4 | 5 | 6 | 4 | 5 | 6 | 7 |
| Posture | 3 | 2 | 4 | 5 | 6 | 4 | 5 | 6 | 7 | 5 | 6 | 7 | 8 |
| Score | 4 | 3 | 5 | 6 | 7 | 5 | 6 | 7 | 8 | 6 | 7 | 8 | 9 |
| | 5 | 4 | 6 | 7 | 8 | 6 | 7 | 8 | 9 | 7 | 8 | 9 | 9 |

**TABLE-4B Upper and Lower Arm Postures Scores**

| Table B | Lower Arm | | | | | | |
|---|---|---|---|---|---|---|---|
| | Wrist | 1 | | | 2 | | |
| | | | | | | | |
| | | 1 | 2 | 3 | 1 | 2 | 3 |
| | 1 | 1 | 2 | 2 | 1 | 2 | 3 |
| | 2 | 1 | 2 | 3 | 2 | 3 | 4 |
| Upper | 3 | 3 | 4 | 5 | 4 | 5 | 5 |
| Arm | 4 | 4 | 5 | 5 | 5 | 6 | 7 |
| Posture | 5 | 6 | 7 | 8 | 7 | 8 | 8 |
| | 6 | 7 | 8 | 8 | 8 | 9 | 9 |

**Table 4C Consolidated postures and Table scores**

| Score A (Score from Table A | Table C<br>Score B, (Table B Value + Coupling Score) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |

| + load force score | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 7 | 7 |
| 2 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 | 6 | 7 | 7 | 8 |
| 3 | 2 | 3 | 3 | 3 | 4 | 5 | 6 | 7 | 7 | 8 | 8 | 8 |
| 4 | 3 | 4 | 4 | 4 | 5 | 6 | 7 | 8 | 8 | 9 | 9 | 9 |
| 5 | 4 | 4 | 4 | 5 | 6 | 7 | 8 | 8 | 9 | 9 | 9 | 9 |
| 6 | 6 | 6 | 6 | 7 | 8 | 8 | 9 | 9 | 10 | 10 | 10 | 10 |
| 7 | 7 | 7 | 7 | 8 | 9 | 9 | 9 | 10 | 10 | 11 | 11 | 11 |
| 8 | 8 | 8 | 8 | 9 | 10 | 10 | 10 | 10 | 10 | 11 | 11 | 11 |
| 9 | 9 | 9 | 9 | 10 | 10 | 10 | 11 | 11 | 11 | 12 | 12 | 12 |
| 10 | 10 | 10 | 10 | 11 | 11 | 11 | 11 | 12 | 12 | 12 | 12 | 12 |
| 11 | 11 | 11 | 11 | 11 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |

## 4.Case Study

The Investigation and survey assessment are conducted in two different fireworks manufacturing sectors having more than 100 workers are employed in various fancy and firecracker productions. During the process, they have only a one-day shift alone. The serious problem physical and manual material handling hazards are identified by the assessor it leads to serious ergonomic hazards encountered inside the workplace. the consequence and effects that will create serious fatigue illness to the workers even it will create serious types of fire hazards also due to they will continue the same task during the entire shifts. The workers are also physiologically weak from mental illness. This is also one of the critical conditions that will cause an accident inside the workplace. In this assessment evaluation sample assessment is taken for the worker's performance of each worker in fireworks of each section already discussed above. The assessor planned to investigate two directions due to the effective input and output checking for a trail investigation carried out in each section followed by the two methodologies RULA and REBA. The methodologies are criticallymaking note down each performance of

workers'awkward posture also. After the deep investigation of the assessor, the assessment was carried out in two ways one is before implementation and after implementation. So this methodology followed and checking prominent improvement from the various working posture analysis. Let us discussed in each of the fireworks RULA and REBA analysis are below.

### 4.1 RULA Assessment in Fireworks

Initially, already methodology is shown for an effective plan work the assessor measures the effectiveness of management effortless and worker's behaviors in fireworks 1 and 2 simultaneously based on the awkward postures measurements in each fireworks sector. In each step, the assessments can be taken in a step by step procedures. The Corresponding table 5 shows the risk assessment scores for the process involved in fireworks. The risk scores notonly measurement of single workers because different workers have different behaviors to perform each task in the workplace. So the RULA Assessments are identified the different awkward postures performance ata different level in each unit. Measurementis also categorized into two levels before and after implementation. Because it shows the stability and accuracy of each implementation of ergonomics assessments.

*Table 5 Before Implementation of RULA Scores*

| **Sl.No.** | **Activity** | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | W9 | W10 | **Total Score** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Rolling process | 5 | 6 | 5 | 7 | 5 | 5 | 6 | 7 | 7 | 6 | 59 |
| 2 | Cutting process | 7 | 7 | 6 | 5 | 7 | 5 | 5 | 6 | 6 | 5 | 59 |
| 3 | Pasting process | 5 | 6 | 5 | 6 | 7 | 5 | 7 | 5 | 6 | 6 | 58 |
| 4 | Sand Filling process | 6 | 5 | 6 | 7 | 5 | 5 | 7 | 6 | 7 | 5 | 59 |
| 5 | Chemical Filling process | 7 | 6 | 5 | 7 | 6 | 7 | 7 | 6 | 7 | 7 | 65 |
| 6 | Threading process | 6 | 7 | 6 | 7 | 5 | 7 | 6 | 7 | 5 | 5 | 61 |
| 7 | Packing process | 6 | 7 | 6 | 7 | 5 | 7 | 6 | 5 | 5 | 7 | 61 |

The observer can conduct survey assessments in the workplace based on the scores it can't be decided whether the ergonomics hazardsencountered in the workplace. It would be observed based on the RULA Score from before the implementation process. As Per the ethical rule collect some of the inference and records from the workers regarding the posture assessments and working activities. So that only it can be frame a clear picture and make observationsto implement the RULA Recommendations from the observed workplace. The Corresponding table 6 shows that Activity and Inference observations of workers and assessors are shown below. This observation is only applicable for only RULA Techniques because in fireworks mostly all the types of processing techniques can be carried out by workers in sitting postures only. To analyses the similar standing postures by using the REBA Techniques. Only the sitting postures are given more importance for the analysis purpose by using the RULA Techniques.

*Table 6 RULA Observation and Inferences*

| SNO | ACTIVITY | WORKERS INFERENCE | ASSESSOR OBSERVATION |
|---|---|---|---|
| 1 | Rolling Process | The workers feel too hard continuously and handling of fuse cutting is difficult to manage in the workplace | Finger Wrist Twist causes discomfort |
| 2 | Cutting Process | The worker recorded his feedback constantly his cutting work can be processed due to he feels the discomfort with his continuous pain in the hand | Finger Ligaments and leads to CTS(Carpal Tunnel Syndrome) |
| 3 | Pasting Process | The workers are continuously worked so that he feels very discomfort physically his hands are very tried. | It leads to causes the Upper arms or upper limbs of each hand can be abducted due to his continuous process. |
| 4 | Sand Filling process | The workers feel his discomfort with his continuous fillings process using with his/her hands | It leads to the upper arm and wrist twist abduction problems |

| | | | |
|---|---|---|---|
| 5 | Chemical Filling process | The workers were made to discomfort on his/her continuous exposures and pain by using fingers. | Causes Finger amputations |
| 6 | Threading process | The workers have exposures in forehand parts continuously get discomfort while working in Threading Process. | Causes Hand Ligaments |
| 7 | Packing process | The upper arms of shoulders are continuously getting exposures. | Causes Upper arm abduction and shoulder ligaments. |

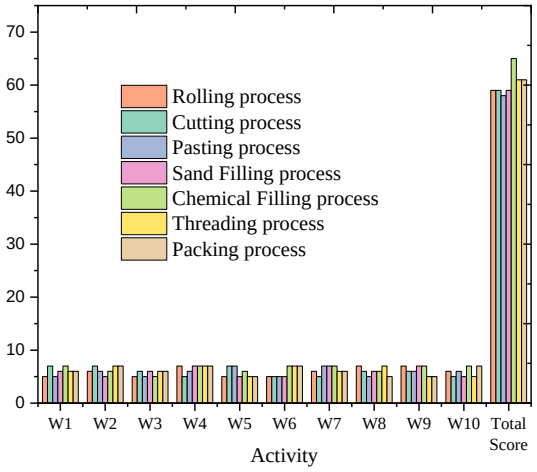


*Figure 9 Analysis of RULA Score Weightages*

An InitialAssessment of the RULA tool various observations are notedduring the ergonomics studies carried out in the way of the following inference that is strongly recommended by the observer. The observers initiate the following deficiencies while carrying out the RULA Tool. Workers are not following the basic safety rules inside the workplace due to the workforce and work demand (figure 9). The Survey assessments are carried out in three months of these fireworks workplace. Due to the seasonal time of Manufacturing the management is employed the workers continuously without given any break and even some of the workers are continuing their shifts for the extra wages reasons. The management will decide to encourage and keep as support of workers they earn a lot of profits during that seasonal time. On another hand, some of

the surveys were already discussed in the problem identification part, due to in presence of worker's minds, attitudes changes that createawkward postures. So this kind of awkward postures will lead to encountered various accidents inside those two fireworks workplaces. The observer will strongly give various implementations of fireworks to change over the awkward postures and behaviors based attitudes inside the workplace.

| S.No. | Activity | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | W9 | W 10 | Total Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Rolling process | 1 | 2 | 1 | 3 | 1 | 1 | 2 | 3 | 3 | 2 | 19 |
| 2 | Cutting process | 3 | 3 | 2 | 1 | 3 | 1 | 1 | 2 | 2 | 1 | 19 |
| 3 | Pasting process | 1 | 2 | 1 | 2 | 3 | 1 | 3 | 1 | 2 | 2 | 18 |
| 4 | Sand Filling process | 2 | 1 | 2 | 3 | 1 | 1 | 3 | 2 | 3 | 1 | 19 |
| 5 | Chemical Filling process | 3 | 2 | 1 | 3 | 2 | 3 | 3 | 2 | 3 | 3 | 25 |
| 6 | Threading process | 2 | 3 | 2 | 3 | 1 | 3 | 2 | 3 | 1 | 1 | 21 |
| 7 | Packing process | 2 | 3 | 2 | 3 | 1 | 3 | 2 | 1 | 1 | 3 | 21 |

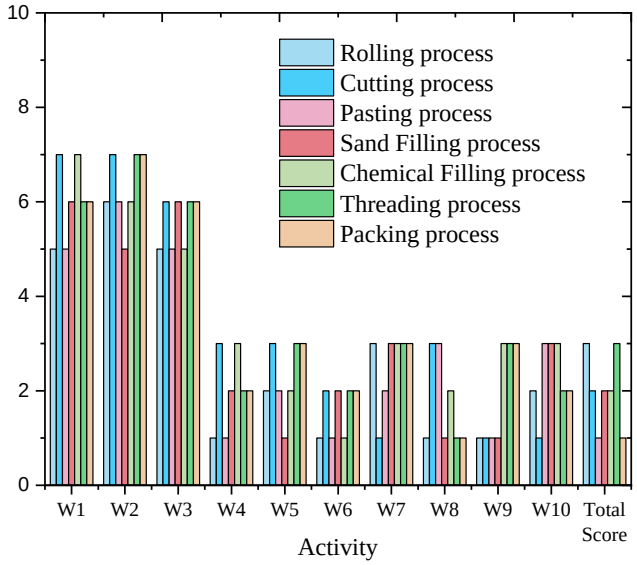


*Figure 10 Analysis of RULA Scores in after Implementation*

In this assessment taken in before and after assessment periods, exposures identify the ergonomics deficiencies present in the workplace that has been recorded in the format of assessment scores (figure 10). Based on the scores each risk can be highlighted and categorized based on the potential factors associated with each activity. The RULA Tool identifies theawkward postures in the fireworks sector 1 (figure 11). Similarly, the correspondingimplementation can be discussed below in results deeply with new implementation suggestions suggested by the assessors in a regularized manner that can be followed by the worker's daily basis. After the implementation process, the causes of ergonomics risk can be minimized and reduced to safe level zones (table 7).

*Table 7 comparing both implementations (before and after) for RULA*

| **Sl. No.** | **Before Implementation** | **After Implementation** |
|---|---|---|
| 1 | 59 | 19 |
| 2 | 59 | 19 |
| 3 | 58 | 18 |
| 4 | 59 | 19 |
| 5 | 65 | 25 |
| 6 | 61 | 21 |
| 7 | 61 | 21 |

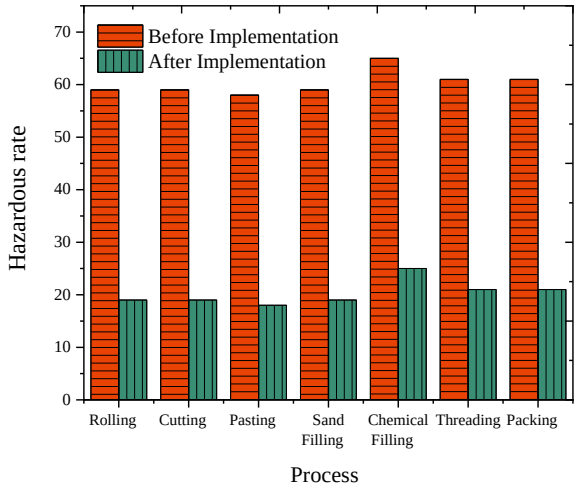


*Figure 11 Comparison analysis for RULA Weightages (Before and After Implementations)*

### 4.2 REBA Assessment in Fireworks

Similarly the measurements of worker's behaviors in REBA assessment also very high potential in nature. The whole body working postures are taken into account in REBA Assessments. The Entire body working actions are monitored deeply by the assessor of each activityinside the fireworks1 (figure 12). The same process can be continued in the before and after the implementation of REBA analysis is performed using the various implementation methodology is discussed in the results. In Total 10 Numbers of workers are tested for screening level process in REBA Analysis as same as RULA Analysis. After calculating the risk scores of each activity are consolidated in the table 8 as before and after the implementation of ergonomics improvements in the fireworks sector 1.The corresponding scores are tabulated below.

*Table 8 Before Implementation of REBA Scores*

| Sl.No. | Activity | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | W9 | W 10 | Total Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Rolling process | 6 | 5 | 5 | 7 | 5 | 6 | 7 | 7 | 5 | 7 | 60 |
| 2 | Cutting process | 7 | 7 | 5 | 6 | 7 | 5 | 5 | 6 | 5 | 5 | 58 |
| 3 | Pasting process | 5 | 6 | 5 | 5 | 6 | 7 | 5 | 5 | 6 | 7 | 57 |
| 4 | Sand Filling process | 6 | 5 | 5 | 5 | 6 | 7 | 5 | 7 | 7 | 6 | 59 |
| 5 | Chemical process | 7 | 7 | 6 | 6 | 6 | 7 | 5 | 6 | 7 | 6 | 63 |
| 6 | Threading process | 6 | 5 | 7 | 5 | 5 | 6 | 7 | 5 | 7 | 5 | 58 |
| 7 | Packing process | 6 | 5 | 7 | 5 | 7 | 6 | 6 | 7 | 5 | 5 | 59 |

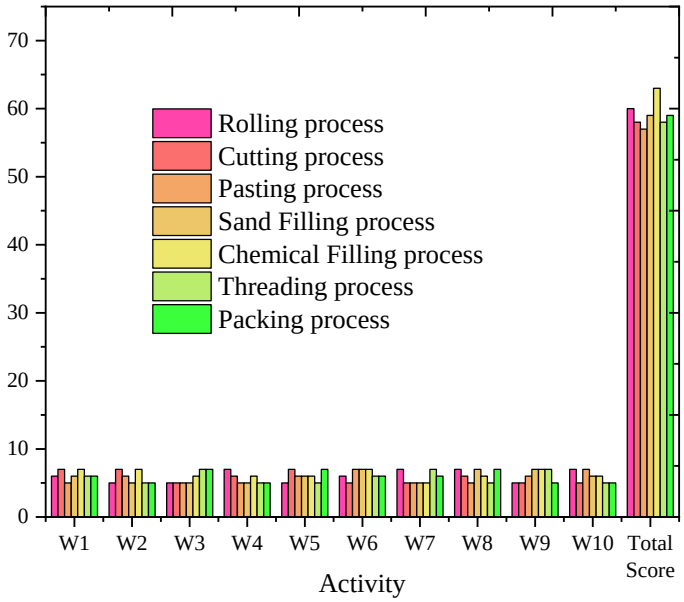


*Figure 12 REBA Before Implementation consolidated Scores*

### 4.3 Inference-Observation of REBA Tool:

In this above REBA Tool states that the initial setup of areas Rolling, Cutting, and Pasting process will scores only low because in this area more potential hazards are not encountered because it is not repetition and important activities so it scores below 60 in ranges only. On other hand from the sand filling, Chemical, Threading areas more potential hazards and award postures can be encounter so that only the worker's mind will change and also attitudes change due to the repetitive in motion. Not only the motions of workers postures also his area involved in chemical handling so the chemicals that react continuously and have to create a very awkward environment working with the workers so the scores can be drastically increased from 60 to 63 ranges. As Per OSHA Standards it is not a permissible level in nature, this area have to follow more monitoring process so that only scores can become into the safe level zone of about 20 to 30 in natures (figure 13). The observerdecided to mitigate the hazards and scores to a safe level some using the various implementation can be startedalreadybefore the Implementation of the RULA Process (table 9 and 10).

*Table 9 After Implementation of REBA Scores*

| Sl.No. | Activity | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | W9 | W10 | Total Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Rolling process | 2 | 1 | 1 | 3 | 1 | 2 | 3 | 3 | 1 | 3 | 20 |
| 2 | Cutting process | 3 | 3 | 1 | 2 | 3 | 1 | 1 | 2 | 1 | 1 | 18 |
| 3 | Pasting process | 1 | 2 | 1 | 1 | 2 | 3 | 1 | 1 | 2 | 3 | 17 |
| 4 | Sand Filling process | 2 | 1 | 1 | 1 | 2 | 3 | 1 | 3 | 3 | 2 | 19 |
| 5 | Chemical process | 3 | 3 | 2 | 2 | 2 | 3 | 1 | 2 | 3 | 2 | 23 |
| 6 | Threading process | 2 | 1 | 3 | 1 | 1 | 2 | 3 | 1 | 3 | 1 | 18 |
| 7 | Packing process | 2 | 1 | 3 | 1 | 3 | 2 | 2 | 3 | 1 | 1 | 19 |

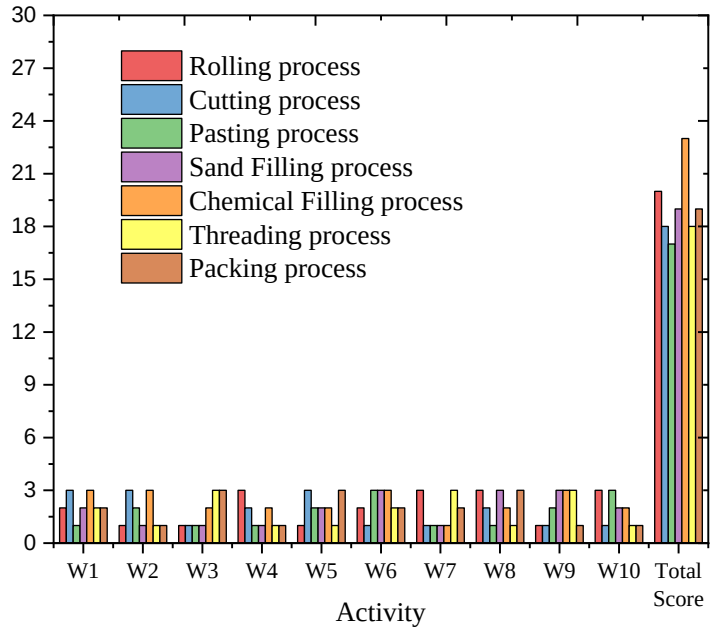


*Figure 13 Packing Process Weightages*

*Table 10 comparing both implementations (before and after) for REBA*

| Sl. No. | Before Implementation | After Implementation |
|---|---|---|
| 1 | 62 | 22 |
| 2 | 59 | 19 |
| 3 | 57 | 17 |
| 4 | 59 | 19 |
| 5 | 58 | 18 |
| 6 | 59 | 19 |
| 7 | 62 | 22 |

## 5. Ergonomic Recommendation Intervention Practices:

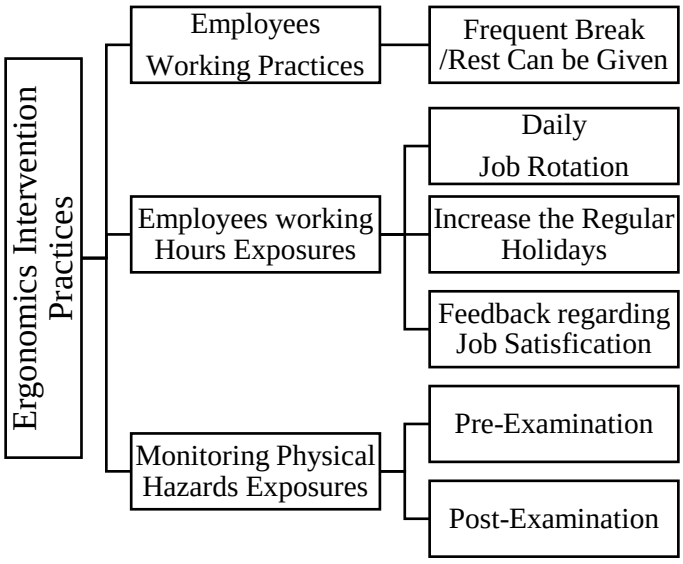


*Figure 14 Ergonomics Intervention Framework Implementations*

The Ergonomic Intervention Practices that can be implemented in the workplace of fireworks carry over the three types of methodology that should be followed to insist on the employees and employers in the workplace. After conducting the case studies and Interview techniques the assessors can able to identify the suitable method to identify the root cause and

consequences of this incident. From this above observation the incident analysis can preach about the framework ergonomic intervention practice model can be framed and it can be implemented in the workplace. Each observation and the postures scores are evaluated from the RULA and REBA Methodology. The Model of Ergonomics intervention practices can be given in the above figure 14.

The Ergonomics Practices are categorized into three parts of the implementation and improvement of the postures that can be performed by each worker. From this value, the risk and working methodology can be categorized. The Management can decide to given frequent breaks to the workers while working in potential hazards exposures section especially in hazardous workingsections. In exposures of workers in the workplace can be recommended practices report to that management of fireworks higher officials follow daily job rotation can be implemented to overcome and mitigate the ergonomics problems inside the industries. It also gives motivate the employees and reduces the physical discomfort in that work that has given the holidays for the workers that they feel very discomfort inside the workplace. It is one of the Behavior cultures can be improved in the way to reduce physical hazards. Regularly conducting the brainstorming sessions to the workers regarding the physical discomfort exposures in the workplace.

The final Implementation and Intervention practices show that the periodical medical examination for each worker. The management will plan medical monitoring such as fever, cough, ortho problems,etc to the workers. The management will arrange the specialized Nero medical officer to investigate the workers' health and submit the report to the management for the screening and analysis purposes. After the detailed screening, the selected employees were identified for detailed medical investigations. Same as that investigations can be repeated in the two categories like Pre-examination and Post examination. The conduction of two medical examinations gives the outcomes of the ergonomics implementation practices in the workplace. It is used to measure the accuracy and significance of each examination medical report of each worker in that fireworks sections.

## 6. Conclusion

The comparative method shows the accuracy and Potential evaluation of awkward postures performed by each worker in different timings followed in the fireworks. The

assessments pf Ergonomics factors are one of the predetermined causes of physical hazards such as Stress, Strain and fatigue to the workers employed in fireworks industries. This Investigation analysis is the framework assessments of each fireworks worker to identify the awkward and wrong working postures. The model of RULA and REBA analysis can be used as benchmark Tool evaluation for assessing the Physical hazards causes and consequences of potential factors that are presented in the fireworks workplace. They are similar tools that can be used to assessing potential threats and awkward postures. The Ergonomics Tools can be used very vast and wide to apply in the industrial engineering and safety domain. The following Physical hazards and Ergonomic hazards that cause the awkward postures are identified using the RULA and REBA Methods clearly and their corresponding Ergonomic Intervention Practices can be implemented in that fireworks workplace with the different practices based on the working postures evaluation scores. The work can be extended to the different manufacturing sectors with different ergonomic analysis with their corresponding ergonomics evaluations.

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