Regression Model for the People working in Fire Work Industry- Virudhunagar District

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Abstract: Fireworks industry is well known to be a hazardous industry. Starting from the initial stage of manufacturing, storage and transportation, risk to life and property is high. 90% of the Indian fireworks are situated in Virudhunagar district. Due to direct contact with hazardous substances lead poisoning, ulcers, damage to central nervous system are some major problems faced by these people. This paper reviews the hazards faced by the workers working in match box and fireworks industry. Regression model is used to analyze the data collected.

Keywords: Fireworks industry, hazardous chemicals, prediction equation, regression equation.

Introduction:

Occupational health and safety is about preventing people from being harmed by work or becoming ill from work by taking adequate precautions and providing a safe and healthy work environment [28].These incidents cause human suffering, loss of production and high medical cost. According to Regulation of Hazardous chemical substance (1995) HSC means toxic, harmful, corrosive, irritant substance where an occupational exposure limit prescribed/not prescribed but which creates a hazard to health [1]. Working with chemical or in a industry poses many risks including causing the following diseases, injuries- chemical burns, asthma, allergies, irritant contact dermatitis, allergic contact dermatitis, skin infection, skin injuries, skin cancers, reproductive problems, even death [20]. Accidents and ill health can ruin lives and affect business if output is lost [21]. All risks in the workplace must be identified and assessed for control measures [23]. The people who might be harmed should be decided, risks must be evaluated and precautionary measures should be recorded and implemented [17]. Frequent review and updations should be followed [25]. Using chemical or other hazardous substance at work place can put people's health at risk causing diseases including asthma, dermatitis or cancer. A worker's skin may be exposed to hazardous chemicals through direct contact, immersion or splashes. The main danger of harmful dusts is that it can be inhaled. They can also cause burns or eye damage due to eye splashes [26].

There are around 750 factories and 80,000 workers employed in Virudhunagar district. 90% of the Indian fireworks industry is situated in Virudhunagar district [2]. Fireworks are made of pyrotechnic chemical which are capable of emitting heat, light, sound and gas [3]. Charcoal is the commonly used fuel in the industry [22]. Oxidizing agents like chlorates and per chlorates are used to make the firework burn. Reducing agents like sulphur, regulators, colouring agents like strontium, barium, copper and binders are used to make the fireworks [4] [11] [12]. Flash powder mixture is a combination of aluminium powder and potassium chlorate. Sometimes potassium chlorate is replaced by potassium perchlorate. Potassium nitrate, sulphur and aluminium powder are mixed in 5:2:3 ratio with 2% boric acid [10]. Aluminium powder and potassium perchlorate are the two components of the pyrotechnic industry mixed in 3:7 Other metal nitrates including barium, strontium are also used [5]. All widely used flash powder mixtures are sensitive to shock, friction and electrostatic discharge [27]. Modern pyrotechnic practices call for never to use sulphur in a mix containing chlorate salts [14]. This makes flash powder dangerous to handle as it can cause severe hearing damage and amputation injury even when sitting in open [16]. Flash powder of any formulation should not be

mixed in huge quantities by amateur pyrotechnicians [24].

Unsafe acts and unsafe conditions are the main reasons for these accidents [3]. Inhalation of aluminium dusts causes pulmonary diseases [7]. The phosphorous used in match box industries also has severe effects on human. There are several forms of phosphorous white, red and black phosphorous. White phosphorous is highly dangerous. It causes skin burns. While burning it may cause damage to liver, heart and kidneys [8]. Potassium perchlorate affects the thyroid gland. A case of grave's disease with potassium perchlorate for 22 years without ill effect is identified. Some studies suggest that has pulmonary toxic effects as well [9]. Workers exposed to perchlorate were found to have a significant systolic blood pressure rise when compared to the workers who were not exposed to perchlorates. At a presentation it has suggested that environmental exposure to perchlorate in pregnant women with hypothyroidism may be associated with significant risk of low IQ in their children [10]. Workers had cases of chronic headaches, dizziness and ulcers due to high level of exposure of Mn during the manufacturing process. Workers didn't wear masks or gloves while working, and hence respiratory tract was deducted as a possible source of entry of the metal into the body.[13] Elemental sulphur is non toxic but many simple sulphur derivatives cause damage to human. Globally sulphuric substances can have the following effects on human health. Neurological effects and behavioral changes, disturbance to blood circulation, heart damage, effect on eye and eye sight, reproductive failure, damage to immune system, hearing defects. [8]

Figure 1 below shows the composition and effects of chemicals used in fireworks. [15] [19]

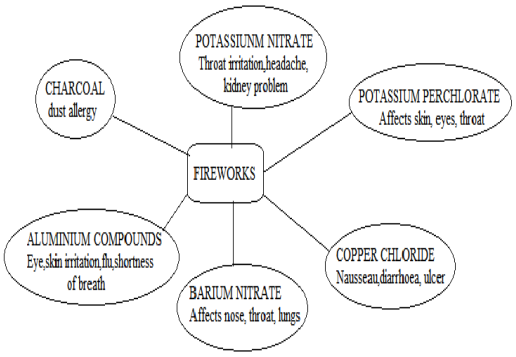


Fig 1:Composition of fireworks and its effects

Case study on presence of potassium perchlorate in fireworks:

Samples are collected from 15 different fire work industries and the quantity of potassium perchlorate are measured and tabulated where x= mass of firework (in milligram/square cm) and y= potassium perchlorate (in milligram/ square cm). x is independent variable while y is the dependent variable.

S.No	Mass (x)	Potassium perchlorate(y)
1	161.8	82.4
2	106.5	51.5
3	118.9	54.6
4	64.2	30.9
5	89.4	47.2
6	100.8	46.3
7	131.7	66.2
8	111.6	54.3
9	97.6	49.6
10	118.7	59.3
11	86.3	45.1
12	238.4	100.3
13	54.2	25.9
14	342.5	193.5
15	68.3	34.2

This data is analyzed for the presence of outliers. Outliers are unusually small or large data value. There are observations which are distinctly different from other observation. It may occur due to mistake in coding, wrong entry or extraordinary event. The researcher must decide whether the unusual data should be represented in the study or not. Outliers should be given careful attention to determine the reasons for large fluctuation between observed and predicted response. [41]The box plot diagram can be used to detect whether the outlier is extreme outlier or mild outlier.[12]

54.2, 64.2, 68.3, 86.3, 89.4, 97.6, 100.8, 106.5, 111.6, 118.7, 118.9, 131.7, 161.8, 238.4, 342.5

Median, lower quartile and upper quartile are calculated.

$median\ M = 106.5,$

$Lower\ quartile\ L_q = 86.3,$

$Upper\ quartile\ U_q = 131.7$

$Inter\ quartile\ range\ iqr = U_q - L_q = 45.4$

$1.5 * iqr = 68.1\ and\ 3 * iqr = 136.2$

$U_q + 1.5 * iqr = 131.7 + 68.1 = 199.8$

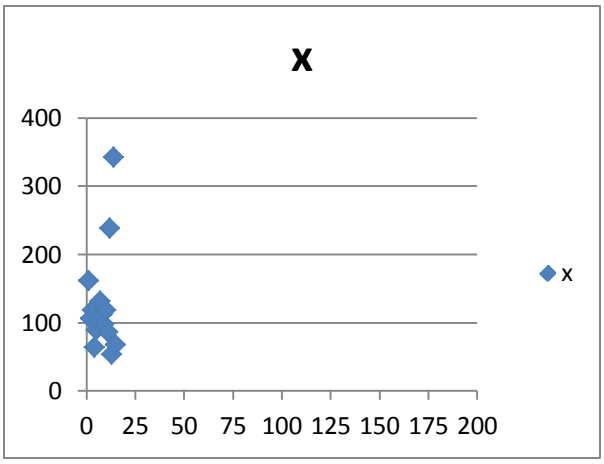
$L_q - 1.5 * iqr = 86.3 - 68.1 = 18.2$

Therefore 238.4 and 342.5 are the outliers in the upper end and there are no outliers in the lower end.

$U_q + 3 * iqr = 131.7 + 136.2 = 267.9$

Therefore 342.5 is the extreme outlier and 238.4 is the mild outlier.

The scatter diagram (figure 2) of the independent variable x is shown below.



Finally the decision maker decides whether to include or exclude the outlier point by analyzing the errors. By this method we get the prediction equations with better accuracy.

Case (i): All the 12 samples are included for getting the prediction equation by regression formula:

$$\sum_{i=4}^{15} x_i = 1503.7 \ , \sum_{i=4}^{15} y_i = 752.8,$$

$$\sum_{i=4}^{15} x_i^2 = 264880.6 \ , \sum_{i=4}^{15} x_i y_i = 135345.8$$

$$b = \frac{n\sum_{i=4}^{15} x_i y_i - \left(\sum_{i=4}^{15} x_i * \sum_{i=4}^{15} y_i\right)}{n\sum_{i=4}^{15} x_i^2 - \left(\sum_{i=4}^{15} x_i\right)^2}$$

$$\therefore b = 0.54$$

$$a = \frac{\sum_{i=4}^{15} y_i - b\sum_{i=4}^{15} x_i}{n}$$

$$\therefore a = -4.49$$

The regression equation is $y_i = a + bx_i = -4.49 + 0.54\, x_i$

Now use the first three observations to find predicted values.

$when\ x_{1=}161.8\ , the\ predicted\ value\ of\ y_1 = 82.31\ while\ the\ observed\ value\ is\ 82.4$

$when\ x_{2=}106.5\ , the\ predicted\ value\ of\ y_2 = 52.64\ while\ the\ observed\ value\ is\ 51.5$

$when\ x_{3=}118.9\ , the\ predicted\ value\ of\ y_3 = 59.30\ while\ the\ observed\ value\ is\ 54.6$

From the observed and predicted values, errors or residues are calculated.

$e_1 = -0.09, e_2 = 1.14, e_3 = 4.70$

Case (ii): All the samples except mild outlier (except 238.4) are considered for getting the prediction equation by regression formula:*

$$\sum_{i=4}^{15^*} x_i = 1265.3 \ , \sum_{i=4}^{15^*} y_i = 652.5$$

$$\sum_{i=4}^{15^*} x_i^2 = 208046.01 \ , \sum_{i=4}^{15^*} x_i y_i = 111434.3$$

$\therefore b = 0.58$ and $a = -7.63$

The regression equation is $y_i = a + bx_i = -7.63 + 0.58\, x_i$

Now use the first three observations to find predicted values.

$when\ x_{1=}161.8\ , the\ predicted\ value\ of\ y_1 = 86.54\ while\ the\ observed\ value\ is\ 82.4$

$when\ x_{2=}106.5\ , the\ predicted\ value\ of\ y_2 = 54.35\ while\ the\ observed\ value\ is\ 51.5$

$when\ x_{3=}118.9\ , the\ predicted\ value\ of\ y_3 = 61.57\ while\ the\ observed\ value\ is\ 54.6$

From the observed and predicted values, errors or residues are calculated.

$e_1 = 4.14, e_2 = 2.85, e_3 = 6.97$

Case (iii): All the samples except extreme outlier (except 342.5) are considered for getting the prediction equation by regression formula:*

$$\sum_{i=4}^{15^*} x_i = 1161.2 \ , \sum_{i=4}^{15^*} y_i = 559.3,$$

$$\sum_{i=4}^{15^*} x_i^2 = 147574.3 \ , \sum_{i=4}^{15^*} x_i y_i = 69072.08$$

$b = 0.40, a = 8.48$

The regression equation is $y_i = a + bx_i = 8.48 + 0.40\, x_i$

Now use the first three observations to find predicted values.

$when\ x_{1=}161.8\ , the\ predicted\ value\ of\ y_1 = 73.41\ while\ the\ observed\ value\ is\ 82.4$

$when\ x_{2=}106.5\ , the\ predicted\ value\ of\ y_2 = 51.22\ while\ the\ observed\ value\ is\ 51.5$

$when\ x_{3=}118.9\ , the\ predicted\ value\ of\ y_3 = 56.20\ while\ the\ observed\ value\ is\ 54.6$

From the observed and predicted values, errors or residues are calculated.

$e_1 = -8.99, e_2 = -0.28, e_3 = 1.60$

*Case (iv): In the samples both the mild outlier and extreme outlier are excluded (except 238.4 and 342.5)*for getting the prediction equation by regression formula:*

$\sum_{i=4}^{15^*} x_i = 922.8$, $\sum_{i=4}^{15^*} y_i = 459$, $\sum_{i=4}^{15^*} x_i^2 = 90739.76$, $\sum_{i=4}^{15^*} x_i y_i = 45160.56$

$b = 0.50, a = -0.44$

The regression equation is $y_i = a + bx_i = -0.44 + 0.50\, x_i$

Now use the first three observations to find predicted values.

$when\ x_{1=}161.8\ , the\ predicted\ value\ of\ y_1 = 80.81\ while\ the\ observed\ value\ is\ 82.4$

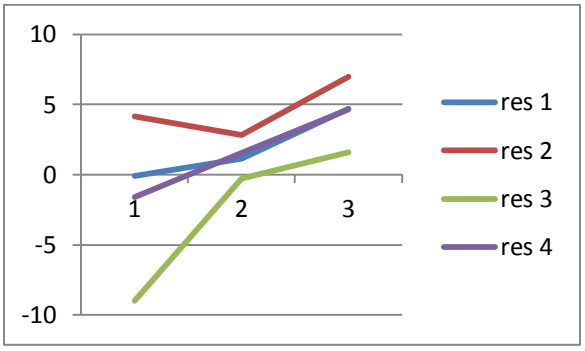
$when\ x_{2=}106.5\ , the\ predicted\ value\ of\ y_2 = 53.04\ while\ the\ observed\ value\ is\ 51.5$

$when\ x_{3=}118.9\ , the\ predicted\ value\ of\ y_3 = 59.27\ while\ the\ observed\ value\ is\ 54.6$

From the observed and predicted values, errors or residues are calculated.

$e_1 = -1.59, e_2 = 1.54, e_3 = 4.67$

The solution for regression equations were got using excel solver. The graph below (figure 3) shows the slope of the residue line in the four cases including and excluding outliers. The decision maker can decide whether to include or exclude the sample to get accurate prediction equation. From the graph below we can find that the slope of residue 4 is more constant when compared to other residue lines. Therefore excluding the mild outlier and extreme outlier, the decision maker gets the better prediction equation.



Suggestion and Conclusion:

The process can be automated or the materials can be handled mechanically. Proper training on the risk of chemicals of which they use in the work place can be promoted. Awareness about personal hygiene, proper protective equipment like gloves, apron can be provided and training for usage of latest protective equipment should be given. A thorough study about the workers in Virudhunagar district has been undergone and the prediction equation for the presence of potassium perchlorate in 15 different firework industries has been formed. The prediction equation are brought by the regression equation by excluding and including the outlier points to achieve the nearest prediction equation.

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