International Journal of Education and Science Research Review
E-ISSN 2348-6457
Volume-2, Issue-4 August- 2015
www.ijesrr.org Email- editor@ijesrr.org

Failure Mode and Effect Analysis of Polluting Factors in Human Health Using Fuzzy Logic

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ABSTRACT

Failure mode and effects analysis (FMEA)—also "failure modes," is one of the first systematic techniques for failure analysis. It was developed in the context of reliability in the late 1950s to study problems that might arise from malfunctions of the systems. It involves reviewing as many factors, components, assemblies, and subsystems as possible to identify failure modes, and their causes and effects. In real life situation the classical theory is insufficient to covers up the deficiency caused due to the uncertainty in sampling, collection of data and variation in data. Fuzzy logic covers up the deficiency caused due to the grading in membership function. Present paper aims at generating an algorithm to screen out any failure mode and its effect that consists of different failure causing factors having different weights. In this process of screening we shall first obtain the possibility of occurrence of that failure mode and then compare this possibility with the critical value (CV) taken in that problem. If the possibility of failure mode is larger than the critical value (CV), then this failure mode is taken for final expert system analysis otherwise it is dropped.

KEYWORDS: Fuzzy Logic, Membership function, Failure Mode Effect Analysis, Fuzzification, Defuzzification, Matlab Software.

1 INTRODUCTION:

With the growth in the size of cities, rapid economic development, industrialization, increasing traffic and higher levels of energy consumption, air pollution has been aggravated. Despite the vast improvements in health globally over the past several decades, environmental factors remain a major cause of sickness and death in many regions of the world. The movement of people into urban areas together with an increase in smoke due to unplanned urban and industrial development has led to the problem of air pollution. The main factors contributing to urban air quality deterioration are:

(i) Growing industrialization (ii) Increasing vehicular pollution (iii) Small scale industries (iv) The domestic pollution

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Environmental Pollution is the release of harmful environmental contaminants, or the substances so released. Generally the process needs to result from human activity to be regarded as pollution. Even relatively benign products of human activity are liable to be regarded as pollution, if they precipitate negative effects later on. The major form of pollution includes:

(i) AIR POLLUTION: -

Air pollution is a chemical, physical (e.g. particulate matter), or biological agent that modifies the natural characteristics of the atmosphere.

(ii) WATER POLLUTION: -

The water quality monitoring results indicate that organic and bacterial pollution continue to be pre-dominant source of pollution in our aquatic resources.

(iii) SOIL CONTAMINATION: -

Soil contamination is the presence of man-made chemicals or other alteration of the natural soil environment.

(iv) RADIOACTIVE CONTAMINATION:

Radioactive contamination is the uncontrolled distribution of radioactive material in a given environment.

(v) NOISE POLLUTION: -

Noise pollution usually called environmental noise in technical venues, is displeasing human or machine created sound that disrupts the environment.

Since the present paper is devoted to the fuzzy logic aspect analysis of air polluting factors in human health, it would be proper at this juncture to look into the status air- pollutants.

(a) Suspended Particulate matter (SPM) (b) Sulphur dioxide (c) Nitrogen dioxide
(d) Respirable Suspended Particulate Matter (RSPM)

In the air polluting factor the air quality is normally classified into four broad categories based on an Exceedence Factor, which in calculated as follows:

$$\text{Exceedence Factor (EF)} = \frac{\text{(Observed annual mean concentration of criteria pollutant)}}{\text{(Annual standard for the respective pollutant and area class)}}$$

The four air quality categories are:

- Critical pollution (C): When $EF > 1.5$;
- High Pollution (H): When $1.0 < EF \leq 1.5$;
- Moderate Pollution (M): When $0.5 < EF \leq 1.0$; and
- Low Pollution (L): When $EF \leq 0.5$.

It is obvious from the above categorization, that the first two categories, that is, critical and high pollutions are actually violating the standards, although, with varying magnitude. Those, falling in the third category are considered to be meeting the standards presently but likely to violate the standards in future, if pollution continues to increase and is not controlled. However, the locations in low pollution category have a rather pristine air quality and such areas are to be maintained at low pollution level by way of adopting preventive and control measures of air pollution. : The average air quality in India for industrial and residential areas is presented in table 1 according to National Ambient Air Quality Standards (NAAQS).

AMBIENT AIR QUALITY IN INDIA DURING THE YEAR 2003

Pollution level	Annual Mean Concentration Range ($\mu g/m^3$)				
	Industrial (I)			Residential (R)	
	SO_2 & NO_2	RSPM	SPM	SO_2,NO_2 & RSPM	SPM
Low (L)	0-40	0-60	0-180	0-30	0-70
Moderate (M)	40-80	60-120	180-360	30-60	70-140
High (H)	80-120	120-180	360-540	60-90	140-210
Critical (C)	>120	>180	>540	>90	>210

Table 1

2 CLASSIFICATIONS AND FUZZIFICATION OF POLLUTING FACTORS:-

(a) CLASSIFICATION OF FACTORS CAUSING POLLUTION: -

The failure of any working system may be caused due to several factors. These factors may not play equal role in system failure but may have different importance. We have in the earlier sections, already gone through several factors that are responsible for pollution. These factors also have different contributions in causing pollution. We characterize them as low, Moderate, High and Critical. Theses factors differ with each other in the sense that their effects in the pollution of the system are different.

(b) FUZZIFICATION OF FAILURE CAUSING FACTORS: -

These precipitating factors may be fuzzified by associating adequate fuzzy set to these factors. This facilitates in quantifying the contribution of a particular factor by a fuzzy number.

Let f_i be the factor, causing the failure of a system. Then this factor may be fuzzified as below.

$$f_i(x)=\begin{cases}0 & for\ x\le a\ \ or\ x\ge d\\ \dfrac{x-a}{b-a} & for\ a\le x\le b\\ 1 & for\ b\le x\le c\\ \dfrac{d-x}{d-c} & for\ c\le x\le d\end{cases}$$

where x denote the crisp value of factor *i*. This factor *i* may be assigned any other fuzzy number i.e. triangular / trapezoidal fuzzy number or fuzzy number of any other type. The fuzzification of these factors depends on the nature of occurrence during any experimental or functioning mode.

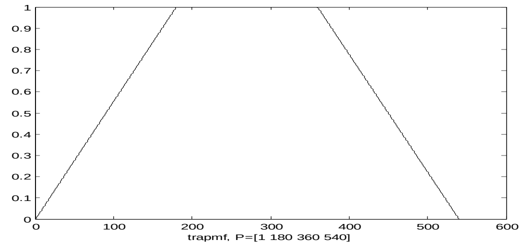
In our study we have classified these factors as (i) Critical factors (ii) High factors (iii) Moderate factors and (iv) Low factors

In the present paper these factors have been fuzzzified on assigning them trapezoidal fuzzy numbers of distinct shapes. The shapes of these fuzzy numbers depend on the nature of the involved factor i.e. what sort of behaviour it imparts with the change in their numerical value. Fuzzification of the failure causing factors in this study has been done in the following manner.

(i) SUSPENDED PARTICULATE MATTER: -

The suspended particles of matter in air can be considered lying in the range {0- 540 $\mu g/m^3$}. The fuzzification of this factor is done using Matlab function given below,

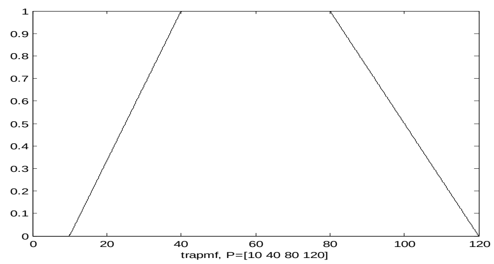
```
x=0:0.1:540;
y=trapmf(x,[0 180 360 540]);
plot(x,y)
xlabel('trapmf, P=[0 180 360 540]'
```



(ii) OXIDES OF NITROGEN: -

The Oxides of nitrogen of the air polluting factors can be fuzzified on the scale having the range {0-120 $\mu g/m^3$ } using Matlab

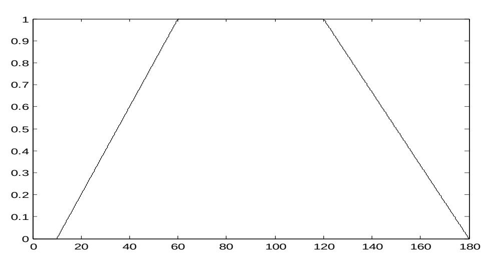
x=0:0.1:120;
y=trapmf(x,[10 40 80 120]);
plot(x,y)
xlabel('trapmf, P=[10 40 80 120]')



(iii) **RESPIRABLE SUSPENDED PARTICULATE MATTERS (RSPM): -** T

he Respirable Suspended Particulate Matters has the numerical values from 60 $\mu g/m^3$ to 180 $\mu g/m^3$ and the expression for the fuzzification of this factor on the given range is given as

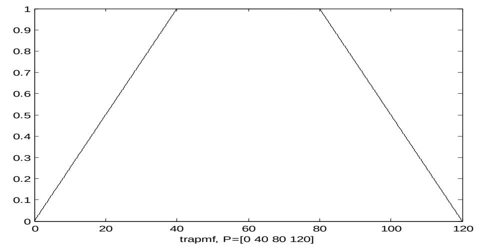
x=0:0.1:180;
y=trapmf(x,[10 60 120 180]);
plot(x,y)
xlabel('trapmf, P=[10 0 120 180]')



(iv) **SULPHUR DI-OXIDE: -**

In a manner similar to previous cases, this factor can also be fuzzified by assigning the trapezoidal fuzzy set defined on the universal set {0- 120 $\mu g/m^3$ }.

x=0:0.1:120;
y=trapmf(x,[0 40 80 120]);
plot(x,y)
xlabel('trapmf, P=[0 40 80 120]')



3 MEASURE OF FAILURE CAUSING FACTORS:

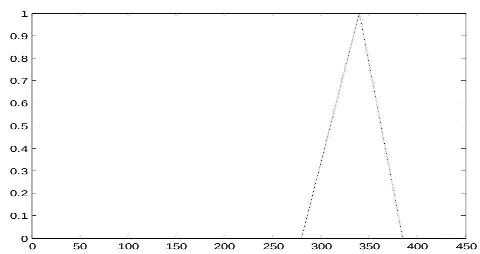
In the present paper we study the functioning of polluting factors. The factors causing effect on human health are classified as below.

(i) Critical (ii) Very High (iii) Moderate and (iv) Low factors

(I) CRITICAL FACTORS: -

Now it is not easy to take any of the above fuzzy numbers for our purpose. Rather we have to find out a fuzzy number that can cover all these fuzzy numbers. That can be obtained by using the technique mentioned above for getting best-approximated fuzzy number. We get the best-approximated fuzzy number for our purpose as given below:

x=0:0.1:425;
y=trimf(x,[280 340 385]);
plot(x,y)

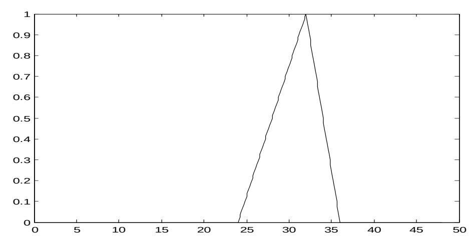


(II) VERY HIGH FACTORS: -

As defined above, another factor that has been put in the family of High factors is nitrous oxide. For pollution free air, the value of nitrous oxide ranges from 29-42 $\mu g / m^3$. Here during our operation three fuzzy numbers "*about 32", "about 36"* and *"about 40"* are assigned to this factor. Suppose these three fuzzy numbers can be defined by the following expression and fig. 4 gives the pictorial form of these fuzzy numbers.

With the similar approach as mentioned above, we can find out a single fuzzy number from these three fuzzy numbers. This fuzzy number thus obtained can be defined by the following expression and shown in fig.

x=0:0.1:48;
y=trimf(x,[24 32 36]);
plot(x, y)

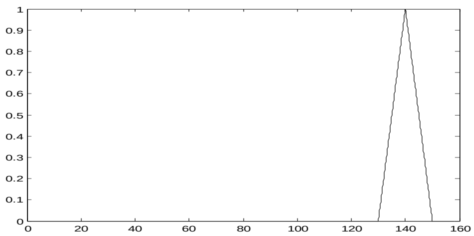


(III) MODERATE FACTORS:

We have to find out a single fuzzy number, out of these fuzzy numbers i.e a fuzzy number that may represent these three fuzzy numbers to best approximation. Following expression is used to express this fuzzy number:

x=0:0.1:160;
y=trimf(x,[130 140 150]);
plot(x,y)

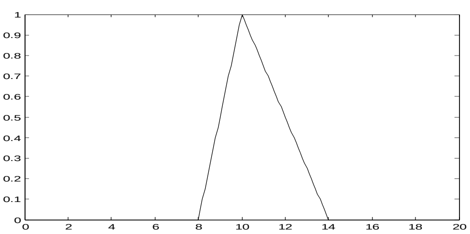
This fuzzy number can be shown as below.



(IV) LOW FACTORS:

Using the same approach as earlier we can get a best fuzzy number from these three fuzzy numbers for the computational purpose. This fuzzy number is defined as below and shown by the following figure.

x=0:0.1:20;
y=trimf(x,[8 10 14]);
plot(x,y)



The factors involved in the present work were assigned some appropriate fuzzy numbers. But it is not possible to consider all linguistic terms of a particular factor for computational purpose. So we obtain a unique fuzzy number for each factor by using the technique of best approximation. Also during the computation the value of these factors cannot be taken in the form of a fuzzy number. Thus we have to defuzzify the fuzzy numbers associated to each failure-causing factor to attain the crisp value for these factors.

4 FUZZIFICATION OF WEIGHTS OF THE FAILURE FACTORS:

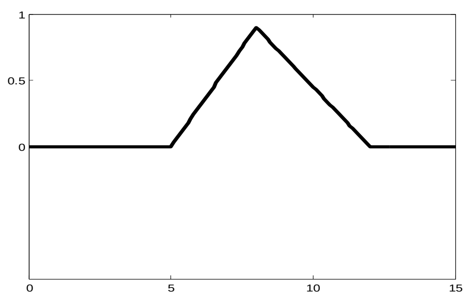
Various failure causing factors involved in the operation of the above system has different role. So the weight of these factors cannot be avoided during the computation of possibility of occurrence of different modes. Now selection of weights of various factors can be obtained by using the historical data available to the fuzzy expert system. As we have earlier mentioned that the weight of these factors are usually available in the form of linguistic terms. Therefore assigning a crisp number to these weights would be impractical, and we shall have to associate a fuzzy set to these linguistic terms. In our present work, these factors have been divided in following four categories:

(i) Critical (ii) Very High (iii) Moderate (iv) Low factors

All these factors have different weights in the failure of the system Let the weight of these factors is denoted as w_c, $w_{h,}$, $w_{mo,}$ w_l. In present paper, using fuzzy expert system the value of these factors are given in the form of linguistic terms, *"low", "moderate", "high", "very high"*. The appropriate fuzzy set can be assigned to the linguistic terms by using various membership functions. The linguistic terms *"very high", "high", "moderate", "low",* are assigned to the weights of decisive, specific, momentous, and related factors respectively. The fuzzy sets (numbers) assigned to these linguistic terms are defined as below and shown in the figure

x=0:0.1:15;
y=trimf(x,[5 8 12]);
plot(x,y)
xlabel('trimf, P=[5 8 12]')
xlabel('trimf, P=[5 8 12]')
plot(x,mf,'LineWidth',3);
set(gca,'YLim',[-1 1],'YTick',[0 .5 1])
x1 = defuzz(x,mf,'centroid')
x1 = 8.3333

This value gives the crisp number for critical value.

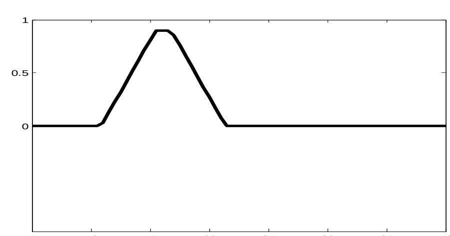


5 POSSIBILITIES OSSIBILITY OF OCCURRENCE OF DIFFERENT FAILURE MODES: -

Weights of these factors are shown in fig. 4.13. Possibility of a particular failure mode in which the weight of Critical, High, Moderate and Low factors is in accordance to table is given as.

Pos (Failure mode) = $\left[w_c * f_{SPM}(x) + w_h * f_{NO_x}(x) + w_{mo} * f_{RSPM}(x) + w_l * f_{SO_2}(x) \right]$

x=5:0.5:40;
y=trapmf(x,[10.865 15.466 16.775 21.364]);
plot(x,y)
xlabel('trapmf, P=[10.865 15.466 16.775 21.364]')
mf = trapmf(x,[10.865 15.466 16.775 21.364]);
plot(x,mf,'LineWidth',3);
set(gca,'YLim',[-1 1],'YTick',[0 .5 1])
x1 = defuzz(x,mf,'centroid')
x1 = 16.1161



On comparing this fuzzy number thus obtained for Possibility of the failure mode using fuzzy ranking method we get that this fuzzy number is greater than the fuzzy number given for critical value. Thus this particular failure mode should be included in our final expert system analysis.

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