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Study of Health Hazards of Using Endosulfan in the Food Sector: A Fuzzy Analisis

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Abstract

Endosulfan a well known pesticide has been used to preserve fruits, vegetables, pulses and food grains from infesting pests in the farming sector. Even after harvesting they are sprayed with it to avoid rotting. This pesticide enters into the body of human being through inhalation, skin and also by consumption of these food materials. This has a hazardous impact on the health conditions of anybody who comes in contact with it. The various effects caused by this organo-chlorine pesticide is analyzed by making use of the simple Fuzzy Cognitive Maps [FCMs].

Key words: FCM, Endosulfan, Hidden Pattern, Fixed Point, Limit cycle.

1. Introduction

In this paper the study of the hazardous impact of organo-chlorine based-pesticide Endosulfan on the health of people is presented by making use of Fuzzy Cognitive Maps [FCMs]. As the data obtained through the pilot survey was an unsupervised one; FCM was employed, as it is the best suited mathematical model which in addition gives the hidden pattern of the problem under investigation.

This paper is divided into four sections. The first one is introductory in nature. Section two gives information about the various aspects related to the pesticide Endosulfan. In three we make use of this model to study the health hazards suffered by humans due to endosulfan. Two expert opinions (one an environmental expert and other a medical expert) are employed here

to get the FCM models. Finally the last section gives the conclusion based on the study.

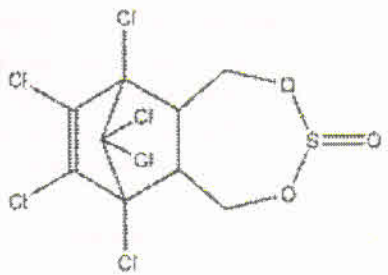
In 1965, L.A. Zadeh introduced a mathematical model called Fuzzy Cognitive Maps. After a decade in the year 1976, political scientist R. Axelord[26] used this fuzzy model to study decision making in social and political systems. Then B. Kosko[11] enhanced the power of cognitive maps considering fuzzy values for the concepts of the cognitive map and fuzzy degrees of interrelationships between concepts. FCMs can successfully represent knowledge and human experience, introduced concepts to represent the essential elements and the cause and effect relationships among the concepts to model the behavior of any system. It is a very powerful tool, which is used in numerous areas such as social, economical, medical fields, etc. illustrated by W.B.Vasantha Kandasamy[21-3].

The hidden pattern is found as follows: Let $C_1, C_2, \ldots, C_n$ be the nodes of an FCM, with feedback. Let M be the associated adjacency matrix. Let us find the hidden pattern when C_1 is switched on. When an input is given as the vector $X_1 = (1, 0, 0, \ldots, 0)$, the data should pass through the relation matrix M. this is done by multiplying X_1 by the matrix M. Let $X_1M=(a_1, \ldots, a_n)$ with the threshold operation that is by replacing a_i by 1 if $a_i > r$ and a_i by 0 if $a_i < r$ (r is a suitable positive integer). We update the resulting concept. The concept C_1 is included in the updated vector by making the first coordinate as 1 in the resulting vector. Suppose $X_1M \rightarrow X_2$ then consider X_2M and repeat the same procedure. This procedure is repeated till we get a limit cycle or a fixed point[11-2].

2. Introduction to the Pesticides Endosulfan:

Pesticides[1,2] are a class of biocide which is normally utilized for thwarting, wiping out or alleviating any pest. A pest[15] can be defined as any living species which is invasive or prolific, detrimental, troublesome, noxious, destructive, a nuisance to either plants or animals, human or human concerns, livestock, human structures, wild ecosystems etc. The term pesticide includes all of the following: insecticide, herbicide, rodenticide, germicide, antimicrobial, animal repellent, insect repellent, termiticide, avicide, fungicide, disinfectant, sanitizer, and insect growth regulator. Although there are benefits to the use of pesticides, some also have negative effects, such as potential toxicity to humans and other living species. It is in fact a broader term, as pesticides are also used for non-agricultural purposes. There are 234 pesticides registered in India. Out of these, 4 are WHO Class Ia pesticides, 15 are WHO Class Ib pesticides and 76 are WHO Class II pesticides, together constituting 40% of the registered pesticides in India.

Endosulfan also called as *Benzoepin, Endocel, Parrysulfan, Phaser, Thiodan* and *Thionex* is an off-patent organo-chlorine pesticide whose molecular weight is 406.93, molecular formula is $C_9H_6O_3Cl_6S$ and its structural formula is represented as follows



Its IUPAC name is 6,7,8,9,10,10-Hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3 - benzodioxathiepine-3-oxide. Endosulfan[4] has been used in farming around the planet to manage insect pests including whiteflies, aphids, leafhoppers, Colorado potato beetles and cabbage worms. Due to its distinctive mode of action, it is immensely valuable in resistance management; however, as it is not specific, it can negatively impact populations of beneficial insects. It is, however, considered to be moderately toxic to honey bees, and it is less toxic to bees than organophosphate insecticides[10.12].

Endosulfan is one of the most dangerous pesticides on the market today, responsible for many fatal pesticide poisoning incidents around the world[6]. It is reported for its acute toxicity, potential for bioaccumulation, and role as an endocrine disruptor. As a result of its threats to human health and the environment, a global ban on the manufacture and use of endosulfan was negotiated under the Stockholm Convention in April 2011.

3. Study of Health Hazards of Using Pesticides in Food Processing Using Fuzzy Cognitive Maps (FCMs):

In this paper we analyse herein the effect of endosulfan as a pesticide sprayed on agricultural plants while growing in the farmlands to preserve them from pests, and also on the harvested vegetables, fruits, etc., to keep them from rotting until it reaches the customers. We list the following impact in the health of the public who consume these vegetables fruits etc., by making use of FCM [11] introduced by Bart Kosko in the year 1986 to study this problem. This work is based on expert's opinion. Further as the information and the data we obtain are only an unsupervised one we are justified in using FCMs model[17.19.20].

Endosulfan has affected human health under various categories and they are listed by the experts which as follows:

C_1 : Toxicity
C_2 : Endocrine Disruption
C_3 : Reproductive and Developmental Effects
C_4 : Carcinogenicity
C_5 : Environmental Contamination
C_6 : Bio Accumulation

C_1 : Toxicity

Endosulfan is acutely a neurotoxin to human beings. Symptoms of acute poisoning include hyperactivity, tremors, convulsions, lack of coordination, staggering, difficulty breathing, nausea and vomiting, diarrhea, and in severe cases, unconsciousness. Doses as low as 35 mg/kg have been documented to cause death in humans,[6] and many cases of sub lethal poisoning have resulted in permanent brain damage[7]. Farm workers with chronic endosulfan exposure are at risk of rashes and skin irritation.

C_2: Endocrine Disruption :

Endocrine system involves the structure and functioning of Pituitary gland, Thyroid gland, Adrenal gland, Islets of Langerhan, Reproductive glands, etc., present in any living organism. Endosulfan is a known endocrine disruptor[3]. Numerous *in vitro* studies have documented its potential to disrupt hormones related to reproductive and developmental

toxicity, especially among males. A number of studies have documented that it acts as an anti-androgen.[24]

C_3: Reproductive and Developmental Effects :

Several studies have documented that endosulfan can also affect human development. Its exposure delays sexual maturity among boys decreases the levels of testosterone, and cryptorchidism.[5.9.16]

C_4: Carcinogenicity :

Endosulfan is not listed as known, probable, or possible carcinogen by the EPA, IARC, or other agencies. No epidemiological studies link exposure to endosulfan specifically to cancer in humans, but *in vitro* assays have shown that endosulfan can promote proliferation of human breast cancer cells.[7.8.14]

C_5: Environmental Contamination :

Endosulfan is a ubiquitous environmental contaminant. It is semi-volatile in nature and persistent to degradation processes in the environment. Endosulfan is subject to long-range atmospheric transport, *i.e.,* it can travel long distances from where it is used. Thus, it occurs in many environmental domains.[18]

C_6: Bio Accumulation :

Accumulation of the pesticide endosulfan by means of food, water, air, etc., in living organisms is called as bioaccumulation of endosulfan.[13] This process may lead to genetic disorder. It may lead to epileptic effect and paralysis.

The related directed graph given by the 'an environmental scientist' is represented in Figure 1.

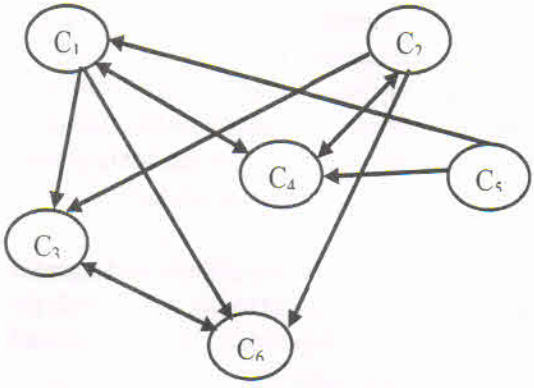


Figure 1: Graph given by an Environmental Expert

The connection matrix associated with the above graph given in Figure 1.

$$\begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \end{array} \begin{array}{c} \begin{array}{cccccc} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 \end{array} \\ \begin{bmatrix} 0 & 0 & 1 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \end{bmatrix} \end{array}$$

The related connected matrix M of the directed graph, serves as the dynamical system of the model.

A. Let $X_0 = (1\ 0\ 0\ 0\ 0\ 0)$ where only the node **Toxicity** is in the 'On State' all the other nodes

are in the 'Off State'.

The effect of X on the dynamical system M is given by $X_0M \mapsto X_1$ where '$\mapsto$' denotes the resultant state vector which has been updated and threshold.

$$X_0M = (1\ 0\ 0\ 0\ 0\ 0)M \mapsto (1\ 0\ 1\ 1\ 0\ 1) = X_1$$
$$X_1M = (1\ 0\ 1\ 1\ 0\ 1)M \mapsto (1\ 1\ 1\ 1\ 0\ 1) = X_2$$
$$X_2M = (1\ 1\ 1\ 1\ 0\ 1)M \mapsto (1\ 1\ 1\ 1\ 0\ 1) = X_3$$

We get $X_2 = X_3$, thus the hidden pattern of the state vector X_0 which is the fixed point, in which all the states except the **Environmental Contamination** is on the 'On State'.

B. Let $Y_0 = (0\ 0\ 0\ 1\ 0\ 0)$ where only the node **Carcinogenicity** is in the "On State" while all the other nodes are in the 'Off State'.

The effect of Y_0 on the dynamical system M is given by

$$Y_0M = (0\ 0\ 0\ 1\ 0\ 0)M \mapsto (1\ 1\ 0\ 1\ 0\ 0) = Y_1$$
$$Y_1M = (1\ 1\ 0\ 1\ 0\ 0)M = (1\ 1\ 1\ 1\ 0\ 1) = X_3$$

We get $Y_1 = X_3$, the hidden pattern is the fixed point in which all the states except the **Environmental Contamination** is on the 'On State'.

C. Let $Z_0 = (0\ 0\ 0\ 0\ 1\ 0)$ where only the node **Environmental Contamination** is in the 'On State' and all the other nodes are in the 'Off State'. The effect of Z on the dynamical system M is given by

$$Z_0M = (0\ 0\ 0\ 0\ 1\ 0)M \mapsto (1\ 0\ 0\ 1\ 1\ 0) = Z_1$$
$$Z_1M = (1\ 0\ 0\ 1\ 1\ 0)M = (1\ 1\ 1\ 1\ 1\ 1) = X_3$$

We get hidden pattern in which all the nodes turns into 'On State', which clearly justifies environmental contamination can lead to all the health hazards listed by the expert.

D. Let $A_0 = (0\ 0\ 0\ 0\ 0\ 1)$ where only the node **Bio-Accumulation** is in the 'On State' while all the other nodes are in the 'Off State'. The effect of A_0 on the dynamical system M is given by

$$A_0M = (0\ 0\ 0\ 0\ 0\ 1)M \mapsto (0\ 0\ 1\ 0\ 0\ 1) = A_1$$
$$A_1M = (0\ 0\ 1\ 0\ 0\ 1)M = (0\ 0\ 1\ 0\ 0\ 1) = A_2$$

We get $A_1 = A_2$, where the hidden pattern is the fixed point. Bioaccumulation has a direct impact on reproductive and developmental effects.

The second expert **'a medical expert'** feels that the node toxicity need not be included but added three more attributes other than that are listed.

D_1: Endocrine Disruption

D_2: Reproductive and Developmental Effects

D_3: Carcinogenicity
D_4: Environmental Contamination
D_5: Bio Accumulation
D_6: Loss of Immunity
D_7: Mental Disorders
D_8: Rashes and Skin Irritation

D_1 and D_5 have been discussed as C_2 to C_6 in the earlier; now D_6, D_7 and D_8 are described in a line or two.

D_6: Loss of Immunity :

Endosulfan was found to cause immune suppression and increase vulnerability to infection.[10] Often this expression is accompanied by atrophy of major lymphoid organs. It has been suggested that increased apoptotic cell demise leading to altered T-B cell ratios, and loss of regulatory cells in grave numbers leads to perturbations in immune function.

D_7: Mental Disorders :

Studies on the individuals health status exposed to endosulfan indicates that 0-30 year age group had recorded the highest cases of mental retardation with 74.5% male and 74.1% female.[1]

D_8: Rashes and Skin Irritation :

It was reported that with prolonged exposure to *endosulfan* led to the risk of *rashes and skin irritation* among plantation farmers[12].

The directed graph given by the second expert is as follows:

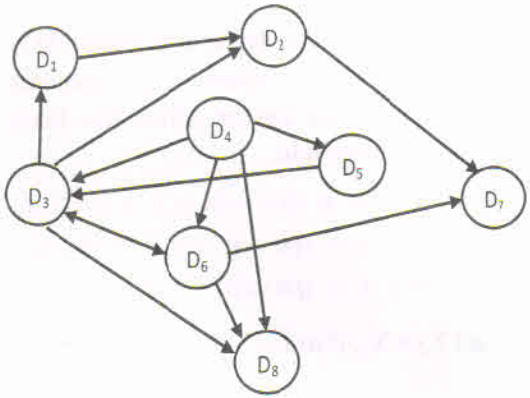


Figure 2: Graph given by Medical Expert

The connection matrix associated with the graph given in Figure 2 is presented below

	D_1	D_2	D_3	D_4	D_5	D_6	D_7	D_8
D_1	0	1	0	0	0	0	0	0
D_2	0	0	0	0	0	0	1	0
D_3	1	1	0	0	0	1	0	1
D_4	0	0	1	0	1	1	0	1
D_5	0	0	1	0	0	0	0	0
D_6	0	0	1	0	0	0	1	1
D_7	0	0	0	0	0	0	0	0
D_8	0	0	0	0	0	0	0	0

The related connected matrix M of the graph serves as the dynamical system of this FCM model

I. Let $A_0 = (1\,0\,0\,0\,0\,0\,0\,0)$ be the state vector where only the node **Endocrine Disruption** is in the 'On State' while all the other nodes are in the 'Off State'. The effect of A on the dynamical system M is given by $A_0 M \mapsto A_1$ where represents the resultant state vector which has been updated and thresholded.

$$A_0M = (1\ 0\ 0\ 0\ 0\ 0\ 0\ 0)M \mapsto (1\ 1\ 0\ 0\ 0\ 0\ 0\ 0) = A_1$$
$$A_1M = (1\ 1\ 0\ 0\ 0\ 0\ 0\ 0)M \mapsto (1\ 1\ 0\ 0\ 0\ 0\ 1\ 0) = A_2$$
$$A_2M = (1\ 1\ 0\ 0\ 0\ 0\ 1\ 0)M \mapsto (1\ 1\ 0\ 0\ 0\ 0\ 1\ 0) = A_3$$

We get $A_2 = A_3$, the hidden pattern which is the fixed point in which **Reproductive and Developmental damage** and **Mental Disorders** becomes 'On State'.

II. Let $B_0 = (0\ 1\ 0\ 0\ 0\ 0\ 0\ 0)$ where only the node **Reproductive and Developmental Effects** is in the 'On State' while all the other nodes are in the 'Off State'. The effect of B_0 on the dynamical system M is given by

$$B_0M = (0\ 1\ 0\ 0\ 0\ 0\ 0\ 0)M \mapsto (0\ 1\ 0\ 0\ 0\ 0\ 1\ 0) = B_1$$
$$B_1M = (0\ 1\ 0\ 0\ 0\ 0\ 1\ 0)M \mapsto (0\ 1\ 0\ 0\ 0\ 0\ 1\ 0) = B_2$$

We get $B_1 = B_2$, the hidden pattern which is the fixed point in which only **Mental Disorder** becomes 'On State'.

III. Let $C_0 = (0\ 0\ 0\ 1\ 0\ 0\ 0\ 0)$ where only the node **Environmental Contamination** is in the 'On State' and all the other nodes are in the 'Off State'. The effect of C_0 on the dynamical system M is given by

$$C_0M = (0\ 0\ 0\ 1\ 0\ 0\ 0\ 0)M \mapsto (0\ 0\ 1\ 1\ 1\ 1\ 0\ 1) = C_1$$
$$C_1M = ((0\ 0\ 1\ 1\ 1\ 1\ 0\ 1))M \mapsto (1\ 1\ 1\ 1\ 1\ 1\ 1\ 1) = C_2$$
$$C_2M = (1\ 1\ 1\ 1\ 1\ 1\ 1\ 1)M \mapsto (1\ 1\ 1\ 1\ 1\ 1\ 1\ 1) = C_3$$

We get hidden pattern in which all the nodes turns into "On State".

IV. Let $D_0 = (0\ 0\ 1\ 0\ 0\ 0\ 0\ 0)$ where only the node **Carcinogenicity** is in the 'On State' and all the other nodes are in the 'Off State'. The effect of D_0 on the dynamical system M is given by

$$D_0M = (0\ 0\ 1\ 0\ 0\ 0\ 0\ 0)M \mapsto (1\ 1\ 1\ 0\ 0\ 1\ 0\ 1) = D_1$$
$$D_1M = (1\ 1\ 1\ 0\ 0\ 1\ 0\ 1)M \mapsto (1\ 1\ 1\ 0\ 0\ 1\ 1\ 1) = D_2$$
$$D_2M = (1\ 1\ 1\ 0\ 0\ 1\ 1\ 1)M \mapsto (1\ 1\ 1\ 0\ 0\ 1\ 1\ 1) = D_3$$

We get hidden pattern in which all the nodes turns into 'On State' except **Environmental Contamination** and **Bioaccumulation**. Similar result is also obtained when node **Loss of Immunity** is at 'On State'.

V. Let $E_0 = (0\ 0\ 0\ 0\ 1\ 0\ 0\ 0)$ where only the node **Bioaccumulation** is in the 'On State' and all the other nodes are in the 'Off State'. The effect of E_0 on the dynamical system M is given by

$$E_0M = (0\ 0\ 0\ 0\ 1\ 0\ 0\ 0)M \mapsto (0\ 0\ 1\ 0\ 1\ 0\ 0\ 0) = E_1$$
$$E_1M = (0\ 0\ 1\ 0\ 1\ 0\ 0\ 0)M \mapsto (1\ 1\ 1\ 0\ 1\ 1\ 0\ 1) = E_2$$
$$E_2M = (1\ 1\ 1\ 0\ 1\ 1\ 0\ 1)M \mapsto (1\ 1\ 1\ 0\ 1\ 1\ 1\ 1) = E_3$$
$$E_3M = (1\ 1\ 1\ 0\ 1\ 1\ 1\ 1)M \mapsto (1\ 1\ 1\ 0\ 1\ 1\ 1\ 1) = E_4$$

We get hidden pattern in which all the nodes turns into "On State" except Environmental contaminant. The observations from the study of the both the experts given by the FCMs model is given in the section on conclusion[22.23.25].

4. Conclusion

It is clear that when **Toxicity** exists, then in due course all the other attributes except **Environmental Contamination** are in 'On mode'. It can be inferred that similar outcome is observed when **Carcinogenicity** is on the 'On mode'. When C_3 is the On state it discloses interesting information that when **Environmental Contamination** is switched on then all the other attributes becomes active *i.e.*, the environmental contamination leads to all damages to the greatest extent. When **Bio-accumulation** is on an active mode then it results in lasting **Reproductive and Developmental** effects. From (I) it is clear that when **Endocrine Disruption** is present then in due course **Reproductive and Developmental** damage and **Mental Disorders** gets into 'On State'. It can be inferred from (II) that when **Reproductive and Developmental Effects** is on the 'On State' then it leads to the **Mental Disorder** of the next generation. It is obvious that (III) gives interesting information that when **Environmental Contamination** is switched on then all the other attributes becomes active *i.e.*, it also damages the environment to a greatest extent. It is understood from (IV) that **Carcinogenicity** may lead to **Endocrine Disruption, Reproductive and Developmental Effects, Loss of Immunity, Mental Disorders** and **Rashes and Skin Irritation.** Finally from (V) it can be concluded that when **Bio-accumulation** is on an active mode then all the nodes are into 'On State' except **Environmental Contamination**.

From this study, it is proved beyond doubt that spraying of Endosulfan on the food products derived from farm sector until it reaches the hand of consumers brings about drastic impact on the health of human beings when they are involved in consuming it. When FCM model is employed it is observed that when Endosulfan is utilized as a pesticide then certainly in the longer run it will definitely cause Toxicity, Endocrine disruption, Reproductive and Developmental effects, Environmental contamination and even Cancer. So it is highly imperative on the part of officials to come out with a policy decision in the immediate ban of employing this dreadfully harmful Endosulfan in preserving the crops at the level of cultivation, harvesting, storing, marketing and selling. It is unfortunate the government records raise in cancer among the people on one side and prompting the use of such chemicals the contamination of which leads to cancer on the other side is questionable.

It is unfortunate to note that although the harmful and disastrous effects of Endosulphan have been well documented and inspite of the

Supreme Court of India ordering a complete ban on Endosulpha, the Government has not banned it expect in the states of Kerala and Karnataka. Such a dual standard and absolute hypocrisy of the state exposes a callous disregard for the lives of its people. While more than so nations have banned this poisonous pesticide, it is still being used in cotton and cashew plantations in India, It appears that a sustained struggle is required to force the manufacturers of this pesticides to totally shut shop[27,28].

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