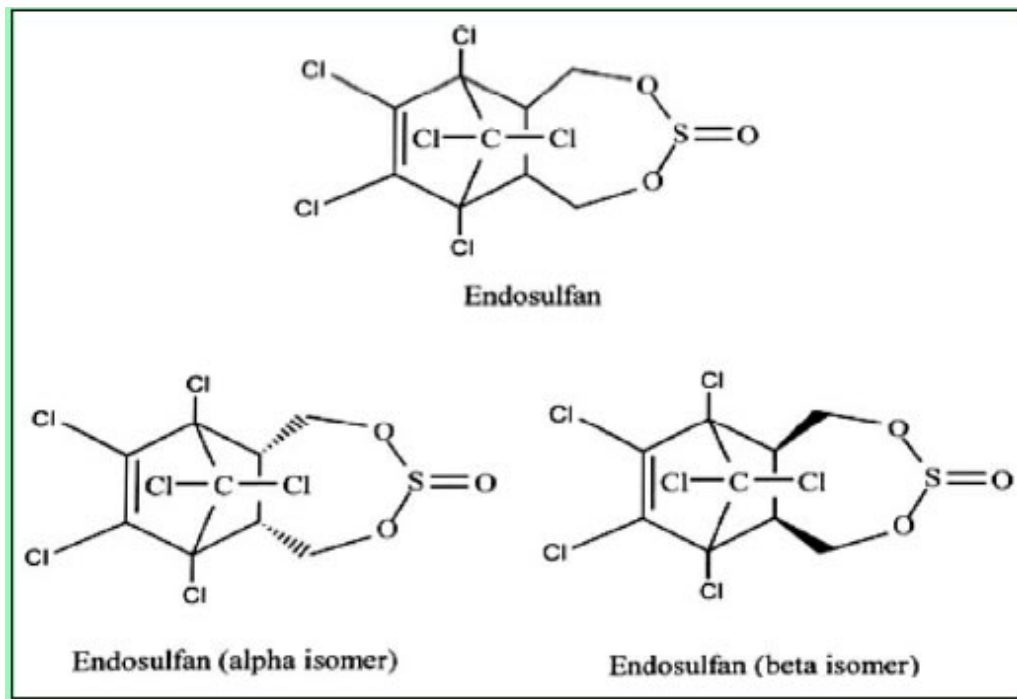


INTRODUCTION

“So far as the laws of Mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality” Albert Einstein

Endosulfan is an insecticide which was first introduced in 1950's and is commonly known by its trade name Thiodan. It is a chlorinated hydrocarbon insecticide and acaricide of the cyclodiene subgroup which acts as a poison to a wide variety of insects and mites on contact. Endosulfan is a derivative of hexachlorocyclopentadiene and is chemically similar to aldrin, chlordane and heptachlor. Specifically, it is produced by the Diels-Alder reaction of hexachloro cyclopentadiene with *cis*-butent-1, 4-dial and subsequent reaction of the adduct with thionyl chloride. Technical Endosulfan is a 7:3 mixture of stereoisomers, designated α and β . α and β -Endosulfans are conformational isomers arising from the pyramidal stereochemistry of sulfur. α -Endosulfan is the more thermodynamically stable of the two, thus β -Endosulfan irreversibly converts to the α - form.



Even before 2000 BC, humans have utilized **pesticide** to protect their crops. The earlier history of pesticides use is discussed in Muller and Korte, (1975) that DDT is an effective insecticide.

The first generation of pesticides introduced over 75 years ago includes the Organochlorine compounds (OC) and Organophosphorous (OP). Later they become unacceptably persistent in the environment, although at the time of their introduction, they seemed to be promising candidates. In **1940s**, manufacturers began to produce large amounts of synthetic pesticides and their use became widespread (Daly *et al.*, 1998). Pesticide use has increased 50-folds since 1950 and 2.3 million tons of industrial pesticides are now used every year (Miller, 2002). Seventy-five percent of all pesticides in the world are used in developed countries, but use in developing countries is in an increasing trend (Miller, 2004).

Endosulfan is used in agriculture worldwide to control insect pest, including whiteflies, aphids, leafhoppers, Colorado potato beetles and cabbage worms. It also kills many types of mites, ticks and also **taste flies**. Because of its unique mode of action it is useful in controlling insects that have become resistant to other forms of insecticide. **However**, its major drawback is that it is **non-specific**, it kills all insects, whether they are harmful or beneficial (such as honeybees). It is used extensively in India and the US in crops such as cotton, **potatoes, tomatoes**, mangoes, cashews and apples, but its use in the US is gradually being phased out. It is an extremely effective insecticide and one of the most toxic pesticides on the market. It is believed to be responsible for many fatal pesticides poisoning incidents around the world (Pan Magazine 2006). It is extremely toxic to environment, human, domestic and wild animals.

IMPACTS OF ENDOSULFAN

ENVIRONMENTAL IMPACT OF ENDOSULFAN

Endosulfan sulphate will be present in the environment as a result of the use of Endosulfan as an insecticide. Even small concentrations of chemicals in the environment can find their way into organisms, accumulate in food chains leading to higher doses causing problems. If Endosulfan sulphate is released to water, it is expected to absorb to the sediment and may bio concentrate in aquatic organisms. Photolysis may not be an

important process based on the stability of thin films of Endosulfan sulphate exposed to light >300nm. Endosulfan standard was not found degraded in standard screening tests using settled domestic waste water as in columns. However, Endosulfan sulphate has been reported to bio degrade when exposed to mixed cultures from a sandy loam soil. If a pollutant is soluble in water, it will be excreted by the organism and so Endosulfan. Endosulfan does not easily dissolve in water and so Endosulfan is not excreted and is causing damage. It does not stick to soil particles readily. The transport of this pesticide is most likely to occur if Endosulfan is attached to soil particles in surface runoff. Large amounts of Endosulfan can be found in surface water near areas of application. It may also be found in surface water at very low concentrations and can be detected in the air at minute levels. In raw river water at room temperature and exposed to light, both isomers disappeared in four weeks during the experiments conducted in California. A breakdown product first appeared within the first week. The breakdown in water is faster (five weeks) under neutral conditions than at more acidic conditions (five months). Under strongly alkaline condition, the half-life of the compound is one day. Endosulfan and Endosulfan residues have been found in numerous food products at very low concentrations. They have been detected in vegetables, in tobacco, in various sea foods and in milk. Because of its abundant usage and potential transport, Endosulfan contamination is frequently found in the environment at considerable distances from the point of its original applications (Man Singh and Wilson, 1995 and Miles and Pfeuffer, 1997).

FATE IN HUMANS AND ANIMALS

Clinical signs of acute exposure to Endosulfan include salivation, hyperactivity, respiratory distress, diarrhea, tremors, hunching and convulsions (WHO,2004) Other effects of Endosulfan exposure include tremors, convulsions, nausea, diarrhea, unconsciousness, permanent brain damage, coma, and death. Endosulfan has been detected in the air in schools at levels exceeding levels-of-concern for young children derived from EPA (Environmental Protection Agency) data. New research suggests that mothers who lived near applications of Endosulfan during the first trimester of their pregnancy are more likely to have children who develop autism. The pesticide is a suspected “endocrine disruptor” and is associated with reproductive and developmental effects such as miscarriages,

reduced sperm quality and count, impairment of sexual organs and delayed sexual maturity. Endosulfan's endocrine disrupting properties also increase the risk of breast cancer in humans. Studies suggest that young animals are more sensitive to the effects of Endosulfan than mature animals. Endosulfan is also found in food supplies, drinking water, and in the tissues and breast milk of pregnant mothers. Improper application and handling of Endosulfan have been linked to congenital physical disorders, mental retardations and deaths in farm workers and villages in developing countries.

In India, Kasaragod is a district in Kerala state once known for its greenery. Today Kasargod is haunted by diseases and tragedy. Aerial spraying in the cashew plantation spread along the district. Here the pesticide is sprayed on trees with the nozzle of the pump directed skywards. The person engaged in spraying gets affected almost instantly. The diseases are the side effects of Endosulfan, a deadly pesticide, sprayed in these plantations. Even despite the fact that Endosulfan is banned now, for 26 years Kerala Government sprayed the deadly pesticide in government owned cashew plantations under Plantation Corporation of Kerala (PCK). While about 500 deaths since 1995 have been officially acknowledged as related to the spraying of Endosulfan, the insect killer was sprayed aerially using helicopters. As the plantations are mostly in mountainous areas, the pesticide drains and get washed down the slopes during rains into drinking water below. Consuming this water will result in diseases ranging from physical deformities, cancer, birth disorders and damage to the brain and nervous system. The study of Endosulfan effects (<http://godsowncountrys.wordpress.com/fight-for-ban-Endosulfan/>) showed larger abnormalities such as mental retardation, cancer and the infertility in the victims.

A study conducted by the National Institute of Occupational Health (NIOH) on the health hazards of Endosulfan spraying in Kasargod in 2001 had found that the pesticide is the cause of a number of health problems among school children living in the exposed area. These children had significantly lower intelligence level and a very high incidence of various sexual disorders. (The Hindu, 26.11.2010). The following pictures are the Endosulfan victims from Kasaragod.



The Hindu (2009)



T. Sruthi in 2006
Environmental Justice Foundation (2006)



T. Sruthi in 2016 daijiworld (2016)

T.Sruthi of Kasargod has been suffering from physical disability due to the after affects of insecticide sum-
acaricide, Endosulfan. She has succeeded in getting admission into homeopathic medical college at
Bengaluru. Chief Minsiter of Kerala declared to give 4 lakhs for her studies.



Sharanya developed Cerebral Meningitis on the 28th day after her birth (Swelling in the head) (Children of Endosulfan Down to Earth, February 28, 2001)

In Kerala, about 613 children of the eight Gramma panchayat in Palakkad district have been found to be living victims of the banned pesticide Endosulfan. More than 600 children below 14 years of Muthalamada in Chittur Taluk of Palakkad are suffering from the illness caused by the aerial spraying of the pesticide Endosulfan. S.Guruvayurappan, coordinator (South India) of the non-profit Wildlife Protection Society of India (WPSI) reported thousands of butterflies were dying every day in the mango orchards due to excessive use of Endosulfan. “The pesticide

use in this area makes the place a graveyard for the wildlife and its ecosystem,” wrote Guruvayurappan in a letter to the forest and agriculture departments and the chief minister in 2005. “We got reports of reptile and monkey deaths and dogs, goats and cows giving birth to young ones with twisted limbs,” he said. The next year the Calicut University Teacher Education Centre, the nonprofit Environment Protection Group and WPSI conducted a detailed study of 550 families in Muthalamada. Researchers found members of 174 families had serious health problems. Many children were suffering from severe birth deformities, Cerebral Palsy, mental disorders, skin diseases, vision loss and cancer and many women were found infertile. Most of the victims hail from low income families. Muthalamada, in Palakkad district known as the Mango City of the State, turns to be a toxic hub because of heavy use of pesticides by some mango farmers. The pesticide is a known carcinogen, neurotoxin and genotoxin (damages DNA); the Insecticides Act of 1968 recommends restricted use of Endosulfan. The Stockholm convention, a global treaty to protect human health and the environment has declared Endosulfan a persistent organic pollutant and then 73 countries have banned its use. A handful countries like India, China, and Israel, however, oppose its ban (*India still in Endosulfan denial*, Down to Earth November 15, 2010). The following are Endosulfan victims from Muthalamada, Palakkad.



Sakthi vel has Psoriasis and his mother (top) developed leprosy (Down to Earth December 31, 2010)

After seeing the difficulties faced by the victims of Endosulfan in Palakkad and Kasargod districts of Kerala, I have opted to study the causes for using Endosulfan, the effects of Endosulfan and to find control measures to stop Endosulfan by applying mathematical models of FCM (Fuzzy Cognitive Maps). Also, it is a current issue and even now the surviving victims are struggling and fighting for their rights from the Government. As, I hail from Palakkad I have been observing Endosulfan tragedy occurred in Muthalamada, Kollengode and Attappady. By this first hand experience, I could collect data, informations from the victims and hospitals and many relevant articles from journals and newspapers. A sample survey of 101 people in Kerala (Palakkad and Kasaragod) was conducted. They were interviewed using a questionnaire relevant to the topic. The data collected from these people using the linguistic questionnaire is transformed into fuzzy data. Being a Mathematics student, I have converted this real life problem mathematically and derived solutions and conclusions for this current issue by various methods of FCM.

As the environment is getting more complicated, effective decision-making is more desired. Decision-makers are always obliged to assess a complex and confusing situation,

identify the causal relationship of a problem, decide the appropriate solution, and ensure an effective action plan. Their effectiveness depends largely on the ability to think logically about the cause-effect relationship and they make decisions according to this analysis. That is, to take meaningful decisions or actions in a problem with **the** complex situation requires an essential understanding of the cause-effect relationship within the problem. FCM can successfully represent the knowledge and human experience, introduced concepts to represent the essential elements and the cause and effect relationship among the concepts to model the behavior of any system.

Fuzzy Cognitive Map (FCM) is a well established technique for prediction and decision **making**, especially for situations where fuzziness and uncertainty exist. Cognitive Maps, which are precursors of Fuzzy Cognitive Maps, were first introduced in 1976 by a political scientist named Robert Axelrod (Axelrod, 1976), who used it to represent knowledge as an interconnected, directed bilevel logic graph. They were presented as a tool to help analyze systems that include concepts interrelated by complex relationship. Ten years later, in 1986, Kosko (Kosko, 1986) introduced Fuzzy Cognitive Maps. FCMs are fuzzy-graph modelling approaches based on **the** expert's opinion. This is the non-statistical approach to study the problem with imprecise information. FCM is the best suited tool when the data is an unsupervised one. Fuzzy Model can be used in applied mathematics, to study **the** social and psychological problem and also used by doctors, engineers, scientists, industrialists and statisticians. Moreover, Fuzzy Cognitive Map utilizes learning techniques, which have implemented in Neural Network Theory. This model is well suited to get a clear representation of the knowledge to support **the** decision making process and assist in the area of computational intelligence, which involves the application of soft computing methodologies even though the given inputs are vague, uncertain and even contradictory in nature. We have used FCM and its advanced version which is called as Induced Fuzzy Cognitive Map (IFCMs) introduced by Pathinathan (2006, 2007). IFCMs are a fuzzy-graph modelling approach based on expert's opinions. This is **non**-statistical approach to study the problems with imprecise information. This model has also become very essential that plays a vital role in several real world problems like various infectious diseases (cancer, tuberculosis, **migration**, etc.), student's life in rural area, and problems of private employees in their day-to-day life etc.

AIM AND OBJECTIVE OF THE STUDY:

- ❖ To learn and apply various types of FCM (Fuzzy cognitive maps) models such as FCM, CFCM and IFCM to real life problems which are faced by people living in the area where Endosulfan is used as pesticide in agriculture.
- ❖ To define a new model MFCM (Maximum fuzzy cognitive maps), to apply MFCM to the problem under consideration and to compare the result with that of the other models of FCM.
- ❖ To suggest remedial measures to come out of the ill effects of Endosulfan.
 - ❖ Promote organic, ecological and natural agriculture
 - ❖ Protection of Environment
 - ❖ Develop Eco-Tourism
 - ❖ Involvement of NGO organization
 - ❖ Educated younger generation to enter agriculture
 - ❖ Improve the online information service for non chemical pest management
 - ❖ Start of vocational training centers, including awareness generation programme, job orientation courses for the welfare of women and child.
 - ❖ Promote the support of Government and research Institutions
 - ❖ Organize different types of environmental awareness programmes

The research work is divided into three parts to study **the** causes, effects and preventive measures on the use of Endosulfan in Kerala through various types of FCM models. The analysis is done from the linguistic questionnaire from 101 pesticide Endosulfan victims from the area of Kasargod and Palakkad districts in Kerala.

The deliberations in the research work include the following topics:

1. Introduction to Endosulfan, CETD matrix, fuzzy cognitive maps and different types of fuzzy cognitive maps

2. Identifying the causes for using Endosulfan
3. Estimation of the reasons for various effects of Endosulfan
4. Suggesting preventive measures to eliminate using Endosulfan

Chapter I describes the usage of deadly fertilizer Endosulfan, environmental impact of Endosulfan and its ill effects on human beings, wild and domestic animals. A detailed report on the usage of Endosulfan in Kasargod and Palakkad districts in Kerala is also given. In the second section the various models of FCM are presented and the methods of their applications to social problems are highlighted.

In **Chapter II**, an algebraic approach to the problem of determining the age group of victims affected by Endosulfan is dealt with. To study the overall age group victims of Endosulfan, four types of matrices namely Initial raw data matrix, average time dependent data matrix (ATD), Refined Time dependent data matrix (RTD) and Combined Effective Time Dependent data matrix (CETD) are applied. From the questionnaires of 101 victims of Endosulfan, the following concepts are selected for this study. X_1 – Skin diseases, X_2 – Handicapped, X_3 – Eyesight disorders, X_4 – Defects in sex hormone, X_5 – Kidney, liver, heart disease, X_6 – Mentally Retarded, X_7 – Growth retardations, X_8 – Epilepsy, Cerebral Palsy, It is concluded that the maximum Endosulfan victims are from the age group of 0-20 only. Few people between the age group 20-60 are also affected. Endosulfan was sprayed since 1980. The effects of Endosulfan were found in Kasargod and Palakkad from 1990 only. The children born after 1990 were the victims of the residues of Endosulfan in the land and water. Hence people of age below 20 to 25 are the main victims of the chronic effect of spraying Endosulfan. The infants are affected as they are breastfed by mothers, who work in the field where Endosulfan is sprayed, having Endosulfan residues in their milk. The school going children are exposed to the aerial spraying of Endosulfan and by the drinking water from the open well which is left uncovered during the aerial spraying of Endosulfan. The teenage and adolescent group victims have acquired these diseases since birth and had severe physical and mental retardation. The higher age groups are less affected due to the immunity level. The data collected from hospitals in Kasargod and Muthalamada revealed that the diseases X_1 to X_8 occur mainly due to the usage of Endosulfan in the field.

In **Chapter III**, an analysis is conducted to predict the causes for using Endosulfan in agriculture using the methods of various FCMs. From the questionnaire the concepts for predicting the causes for using Endosulfan in agriculture are determined by expert's opinion. The concepts considered for calculation in this chapter are

- C₁ - Population Increase
- C₂ - Increase in food production
- C₃ - Cheap cost of Endosulfan
- C₄ - Easy availability of Endosulfan
- C₅ - Better yield
- C₆ - Need for pest control
- C₇ - Illiteracy
- C₈ - Unawareness on ill effects of Endosulfan
- C₉ - Less knowledge of any other non chemical alternative
- C₁₀ - Non involvement of social organizations
- C₁₁ - Indifference or negligence of Government with farmers.

The justification for each concept is discussed in section 3.2. In section 3.3, the mathematical approach of FCM is given. This method is most simple and an effective one as it can analyze the data by directed graph and connection matrices. A directed graph and the connection matrix $M = (a_{ij})$ of FCM are formulated with $a_{ij} = 0$, if $C_i \not\rightarrow C_j$ and $a_{ij} = 1$, if $C_i \rightarrow C_j$. A state vector P^i is defined such that, one concept C_i (say) is in "ON" state and the remaining are in "OFF" states. Accordingly, as the vector P_1^i having 1 in i^{th} place and 0 in other places is introduced and the product $P_1^i M$ of P_1^i and M is calculated. The resulting vector P_2 is modified by assigning 1 if the values of the entries are >1 and keeping 1 in the i^{th} place always. Then $P_2 M$ is calculated and threshold is obtained at each stage until the two consecutive vectors become equal. Finally the fixed point having some entries 1 and the remaining 0 is obtained. It is concluded that the concepts corresponding to the entries having 1 in the fixed vector are impactful for the concept C_i .

FCMs have several advantages of various fuzzy models. The main advantage of this method is that it is simple, easy to handle and based on the expert's opinion. It also helps to work when the data is unsupervised. This fuzzy model helps us to find out the hidden

pattern of any type of given problem in any situation. As we have eleven concepts to be analyzed a computer program C++ (Appendix III(b)) is used to find the **interrelation**, among the concepts.

After applying FCM model, it is concluded that for the concepts C_4, C_8, C_{10} , the fixed point $(1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1)$ is obtained in the 2nd step itself. **Hence**, these 3 concepts are considered to be major causes for using Endosulfan in agriculture even though all other concepts also get the same fixed point $(1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1)$ expressing the interdependence among them. So by FCM model it is predicted that all the 11 concepts are the causes for using Endosulfan in agriculture of which *easy availability of Endosulfan* (C_4), *no awareness on **the** ill effects on Endosulfan* (C_8) and *non involvement of social organization* (C_{10}) are more impactful.

Section 3.4 is devoted to the study of **the** application of CFCM model. A finite number of FCMs can be combined together to produce the joint effect of FCMs. This method is called Combined Fuzzy Cognitive Maps. The connection matrices A,B,C,D are drawn from the responses given by four experts (i)an agriculture officer (ii)an NGO (iii)a doctor (iv)a village administrative for the same set of eleven concepts discussed in section 3.2. A C++ computer program is written and applied (Appendix III(c)) to obtain the results. Let $S=A+B+C+D$ be the matrix. To derive the conclusion, the same methodology of FCM is applied to S where the threshold is done in different way. If an entry after multiplication is ≤ 2 then the value 0 is assigned and if it is ≥ 3 the value 1 is assigned.

Finally, in CFCM model, all the state vectors get fixed points. The concepts $C_3, C_4, C_7, C_8, C_9, C_{10}, C_{11}$ have fixed points as $(1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1)$ from which it is concluded that these concepts have impact on all eleven concepts. Whereas C_1, C_2, C_5, C_6 have $(1\ 1\ 0\ 0\ 1\ 1\ 0\ 0\ 0\ 0\ 0)$ as fixed point, stating that these concepts have dependency only among them. These concepts have no impact on other concepts. The results obtained in this model CFCM give more details than that of FCM. In FCM model, it is seen that all concepts are dependent and hence all have the impacts on all other concepts. But in CFCM model, it is well differentiated that the concepts C_1, C_2, C_5, C_6 have interdependencies and have no impact on other **concepts**, whereas the concepts $C_3, C_4, C_7, C_8, C_9, C_{10}, C_{11}$ have impact on all the 11 concepts.

In section 3.5, another type of Fuzzy model which is a modified version of FCM called induced FCM (IFCM) is applied. The method is same as that of FCM until P_2 is calculated. Then, each component in P_2 vector is taken separately and multiplied with matrix M . Among these vectors, the vector which has the maximum number of 1's for the first time is considered as Q_2 . Then the same procedure is repeated as done for P_2 until a fixed point is obtained.

Implementing the method of IFCM to the problem under consideration and using a C++ computer program (Appendix III(d)) the following conclusions are obtained:

1. All the concepts get the same fixed point (01100100111) which is the vector corresponding to the concept C_4 . The triggering pattern of all the concepts also reveal that C_4 – *easy availability of Endosulfan* is the terminal node. If any one of the causes is switched on to ON state, C_4 goes ON State. Hence “*easy availability of Endosulfan* is the main cause related to all the concepts.
2. The limit point corresponding to C_4 (0 1 1 0 0 1 0 0 1 1 1) highlights that attribute C_2 , C_3 , C_6 , C_9 , C_{10} , and C_{11} (i.e the concepts corresponding to 1 in the vector) which seem to be the major causes for using Endosulfan in agriculture.
3. The triggering pattern shows that:
 - i. C_1 & C_2 are **related**, i.e population increase gives rise to increase in food productivity.
 - ii $C_4 \rightarrow C_{10} \rightarrow C_4 \rightarrow C_4$. reveals that C_{10} - *non involvement of social organization* plays the role of intermediary node.
 - iii The relation of C_6 & C_2 implies that pest control is needed to improve the food productivity.
 - iv. C_7 & C_9 are connected i.e illiteracy is the major cause for having poor knowledge of any other non chemical alternatives

Based on the conclusions some remedial **measures** are suggested **at** the end of the chapter

But to deal with unsupervised data, IFCM model **predicts** the appropriate results when **compared** with FCMs model. The IFCM method clearly defines the terminal node which is

more critical one and also shows the intermediary node which helps us to analyze the given problem. But IFCM model has a couple of limitations also. This model consists of a lengthy procedure of calculation which is not suitable for calculation with matrices having higher number of rows and columns. Second, this manual calculation is fully based on the expert's opinion. So, it may lead to personal bias.

In section 3.6, a new model namely the **Maximum Fuzzy Cognitive Maps (MFCM)** is defined and applied in the present work. It involves the least number of steps yielding more accurate values. The row having maximum number of 1's occurring for the first time in the connection matrix M , is identified as R_1 and each component in the R_1 vector is taken separately and the product of it with matrix M is calculated and thresholded. Then the vector which has maximum number of 1's is identified and named as R_2 and R_2M is calculated and thresholded. The procedure is repeated until a fixed point is obtained. A C++ computer program (Appendix III(e)) is framed to work the above method. The above discussed algorithm of the given problem is focused on the node C_4 (0 1 1 1 0 1 0 0 0 1 1) finally. The above fixed point is nothing but the 4th row of the casual connection matrix M after thresholding. i.e. *easy availability of Endosulfan*. We conclude that this factor is the most impactful factor in this study, even though many attributes are present. The other interdependent attributes having an impact on the cause for using Endosulfan in agriculture are C_2 , C_3 , C_6 , C_9 , C_{10} and C_1 which are the places in which 1 is present in the fixed point. This is the same fixed point we have arrived in IFCM. Highlights of the model MFCM introduced newly are:

- While working with IFCM model, 11 trials are performed and got various fixed points where as in MFCM model, there is only 1 trial giving the main fixed point.
- MFCM model consumes less time and focuses only on a particular fixed point, unlike getting various fixed points leading to vagueness. Hence this model is much suitable to work for the unsupervised data to find the most impactful factors.

The objective of **Chapter IV** is to analyze the reasons for various effects of pesticide Endosulfan using different fuzzy models FCM, CFCM, IFCM and MFCM. Here the following 12 different concepts are chosen to be the reasons for the effects of Endosulfan in human, wildlife and Environment.

- C₁ - Exposure to Endosulfan when spraying in agriculture field
- C₂ - Consuming Endosulfan sprayed vegetables, oil/seeds,
- C₃ - Lack of precaution and treatment
- C₄ - Pollution of water source (river, pond) by Endosulfan
- C₅ - Land becoming infertile with the poor yield
- C₆ – Residual effects of Endosulfan in land
- C₇ - Air pollution by Endosulfan
- C₈ - Residues in the blood sample of **breastfed** children
- C₉ - Endosulfan exposed domestic animals, earth worms, Micro orthoposes, rabbits, rats.
- C₁₀ - Endosulfan contaminated water living fish, crab, frog.
- C₁₁ - Endosulfan affected **environmental** exposure to beetles, butterfly and birds
- C₁₂- Long term exposure to Endosulfan causing cancer, kidney, skin diseases, Neuro behavioral problems and infertility.

In section 4.3, the FCM model is implemented to study the reasons for various effects of Endosulfan. A C++ computer program (Appendix III(f)) is used to find the fixed point. It is concluded for all the concepts from C₁ to C₁₂ the same fixed point (1 1 1 1 1 1 1 1 1 1 1 1) is obtained in the 2nd or 3rd step. Hence all these concepts are considered to be major reasons for the effects of Endosulfan.

So we conclude that getting exposure to the spraying of Endosulfan and consuming Endosulfan sprayed vegetables lead to neurological disorders, congenial birth defects, chromosomal abnormality, cancer and at the end even death. Lack of and avoiding treatment may lead to adverse effects. Pollution of water resources, infertility of land and air pollution are the major environmental effects. The effects will remain in the land for years and blood samples of children having residues of Endosulfan will make the future generation affected by the deadly poison Endosulfan.

In section 4.4, the CFCM model is implemented to study the problem under consideration. A C++ computer program (Appendix III (g)) is written and applied. In CFCM model all the state vectors get the same fixed point (1 1 1 1 1 1 1 1 1 1 1). This indicates all the concepts have **an** interrelationship among them as in **the** FCM. The concepts

C_1 and C_{10} get the fixed point in the 3rd step itself. Hence

C_1 - Exposure to Endosulfan when spraying in agriculture field

C_{10} - Endosulfan contaminated water living fish, crab, frog have more impact on all 12 concepts where as the concepts $C_3, C_4, C_7, C_8, C_9, C_{11}$ and C_{12} get fixed point much earlier than the concepts C_2, C_5 and C_6 .

In section 4.5, applying next model IFCM, a C++ computer program (Appendix III(h)) is used to find out the triggering patterns. It is concluded that all the concepts have the same impact ie, the same fixed point (0 0 1 1 1 1 1 1 1 1 1) which is the vector corresponding to the concept C_1 . Hence, the interrelationships between the attributes reveal that C_1 -*Exposure to Endosulfan when spraying in agriculture* is the terminal node. The limit points corresponding to C_1 (0 0 1 1 1 1 1 1 1 1 1) highlights that attribute $C_3, C_4, C_5, C_6, C_7, C_8, C_9, C_{10}, C_{11}, C_{12}$ which seem to be the major reasons for the various effects by Endosulfan in agriculture.

The triggering pattern of C_1 and C_2 shows that C_8 is the **intermediary** concept (i.e) C_1 exposure to Endosulfan when spraying in agriculture and C_2 consuming Endosulfan sprayed vegetables, oil/ seeds will give the residues of Endosulfan in the blood sample of **breastfed** children, ie. the women living in the Endosulfan contaminated area will pass on the effect of Endosulfan to their children **with** their milk.

In section 4.6, the newly defined MFCM model is applied, a C++ computer program (Appendix III(i)) is also framed to work the above method. We arrive at a fixed point (1 0 1 1 1 1 1 1 1 1 1). The above fixed point vector is nothing but the first row of the casual connection matrix M after thresholding. That is, C_1 *exposure to Endosulfan when spraying in agricultural field*. We can conclude that this factor as the most impactful factor in this study even though many attributes are present. The other interdependent attributes

having an impact on the reasons for various effects by Endosulfan in agriculture are C_1 , C_3 , C_4 , C_5 , C_6 , C_7 , C_8 , C_9 , C_{10} , C_{11} and C_{12} which are the places in which 1 is present in the fixed point.

The measure to eliminate the use of pesticide Endosulfan and to eradicate the harmful effects of Endosulfan are suggested in the **last chapter V**. From the expert's opinion, the following 16 concepts for measures to stop using Endosulfan are listed.

- C_1 - Prohibition or restriction of production, use, import and export of Endosulfan
- C_2 - Use lower risk alternative pest control practices
- C_3 - Strengthen agricultural chemical control act
- C_4 - Adopt organic, ecological and natural agriculture
- C_5 - Voluntary cancellation and phase out of all existing Endosulfan
- C_6 - Promote online information service for non chemical pest management
- C_7 - Use crop rotation, inter cropping, field sanitation and mechanical methods
- C_8 - Use insecticides derived from natural plants extracts, natural soaps, neem, lemon grass
- C_9 - Give awareness about the ill effects of Endosulfan
- C_{10} - Give severe punishment for using Endosulfan
- C_{11} - Support of Government and research Institutions
- C_{12} - Involve NGO organizations
- C_{13} - Educated younger generation to enter agriculture
- C_{14} - Give free organic pesticides to farmers
- C_{15} - Improve the status of farmers by giving incentives and loans by the Government
- C_{16} - Award the informer on Endosulfan

In section 5.3 the FCM method is applied to the problem under study. A C++ computer program (Appendix III (j)) is used to find the fixed point. In FCM model, the fixed point (1 1 1 1 1 1 1 1 1 1 1 1) is obtained in the 2nd or 3rd step for all concepts. All the concepts are interrelated. Hence all these concepts are considered to be major measures to stop the usage of Endosulfan with respect to FCM model.

Section 5.4 is devoted to the study of **the** CFCM model application. A C++ computer program (Appendix III(k)) is written and applied. In CFCM model, all the concepts get the fixed point **(1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1)** is obtained in the 2nd or 3rd step. So all 16 concepts are the major measures to stop the usage of Endosulfan.

In section 5.5, the method IFCM is adopted to analyse the problem. A C++ computer program (Appendix **III (l)**) is used to find out the triggering patterns. The IFCM expresses that all the concepts except C_{15} have the direct impact to the same fixed point **(1 0 1 1 1 1 1 1 1 1 1 1 1 0 1 0 1)** which is the vector corresponding to the concept C_2 . Hence, the interrelationships between the attributes reveal that C_2 -“*Use lower risk alternative pest control practices.*” is the terminal node. The triggering pattern $C_2 \rightarrow C_9 \rightarrow C_2 \rightarrow C_2$ implies that C_9 -*Give awareness about the ill effects of Endosulfan* plays the role of intermediary node. The limiting point corresponding to $C_2(1 0 1 1 1 1 1 1 1 1 1 1 1 0 1 0 1)$ highlights that attribute $C_1, C_3, C_4, C_5, C_6, C_7, C_8, C_9, C_{10}, C_{11}, C_{12}, C_{14}, C_{16}$ which seem to be the major measures to stop the usage of Endosulfan in agriculture.

The triggering pattern shows that C_2 and C_9 are related. ie, Giving awareness about the ill effects of Endosulfan to the farmers will result in the usage of lower risk alternative pest control practices.

Section 5.6 deals with the application of MFCM to the study. A C++ computer program (Appendix III(m)) is also frame to work the above method. In MFCM model we arrive at a fixed point **(1 1 1 1 1 1 1 1 1 1 1 1 0 1 0 1)**. This fixed point vector is nothing but the second row of the casual connection matrix M after thresholding. That is, “*Use lower risk alternative pest control practices*”. **It can be concluded that this factor is the most influential one in this study, even though many attributes are present.** The other interdependent attributes having **an** impact on the estimation of the measures to stop the usage Endosulfan in agriculture are $C_1, C_2, C_3, C_4, C_5, C_6, C_7, C_8, C_9, C_{10}, C_{11}, C_{12}, C_{14}$ and C_{16} which are the places in which 1 is present in the fixed point. This is the same fixed point we have arrived in section 5.5.

Measures to be taken to stop using Endosulfan from our study

C_1 - Prohibition or restriction of production, use, import and export of Endosulfan

- C₂ - Use lower risk alternative pest control practices
- C₃ - Strengthen agricultural chemical control act
- C₄ - Adopt organic, ecological and natural agriculture
- C₅ - Voluntary cancellation and phase out of all existing Endosulfan
- C₆ - Promote online information service for non chemical pest management
- C₇ - Use crop rotation, inter cropping, field sanitation and mechanical methods
- C₈ - Use insecticides derived from natural **plant** extracts, natural soaps, neem, lemon grass
- C₉ - Give awareness about the ill effects of Endosulfan
- C₁₀ - Give severe punishment for using Endosulfan
- C₁₁ - Support of Government and research Institutions
- C₁₂ - Involve NGO organizations
- C₁₄ - Give free organic pesticides to farmers
- C₁₆ - Award the informer on Endosulfan

Some recommendations are given in the Summary and Conclusion of the thesis. These were collected from the study made by reading many articles, journals, news papers, the people living in the area where Endosulfan is sprayed and mainly from the mathematical analysis conducted during the work using various FCM models including the newly introduced MFCM model.