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Reducing the Risk of Pesticide Residues in the Groundwater: A Case Study of Punjab

Sajjad Ahmad Baig[1*], Muhammad Usman Awan[1], Irfan Ahmad Baig[2], Muhammad Abrar[3]
[1] IQTM, Punjab University Lahore; [2] MNS Agriculture University Multan; [3] LBS, GC, University Faisalabad
*E-mail: sajjad.baig@hotmail.com

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Abstract

The objective of this study was to reduce the risks of pesticide residues in groundwater, through the use of Good Agriculture Practices (Gaps) the data (primary) were collected with the help of two pretested questionnaires. SQC (Statistical Quality Control) tools and Hazard Identification Based System were used on data, for the determination of the risk from different activities, related to pesticide usage. It was observed that induction of risk assessment and the principle of quality management at an early stage of the food supply chain which would increase the efficiency of farming and also decreased the different types of hazards, related to the agricultural activity

Keywords: Pareto analysis, Fishbone diagram, Risk assessment, Pesticide residues

Introduction

The agricultural industry has started to acknowledge something that rest of the global industry has recognized for quite some-time before, i.e., the use of quality management systems. (There is need of the quality management and risk management in the field of agriculture on the basis of numerous reasons and risks such as eroding margins in an increasingly competitive global marketplace, consumer concerns for the environmental quality as well as for the security concerns. Therefore, in the food supply chain, there is a need for early identification of hazards, at the farm level, in order to prevent them to be the health risks. (Rathore. Et al., 2017; Marvin *et al.*, 2009). Hazards stand for impending dangers. The hazard, associated with a potentially toxic substance causes toxicity which occurs by the potential exposure to the substance while a food hazard is defined as a biological, chemical or physical agent in, the food, causing an adverse health effect". (Sander,1999). The hazard of pesticide is the potential for injury or the degree of danger, involved in using a pesticide under a given set of conditions. Pesticide hazard occurs at the following stages:

a. Manufacturing and formulation,
b. Application of pesticides, and
c. Consumption of treated products

With regard to agriculture, we should take steps for the prevention and reduction of these hazards, which depend on their uniqueness, behavior and point of entry into the environment as well as the hazard analysis approach which are good tools for assessing risks and Good Agricultural Practices (GAPs), are good strategies for mitigating them. (Jank, & Rath, 2017; Marven et al., 2009).

Pesticide waste and residues are damaging the quality of water soil and food which are ultimately destroying the human health and extremely disturbing the environmental sustainability. The poisonous pesticide has become a growing concern across the globe, particularly, in the developing countries. As estimated, about 99 % of the poisonous pesticide occurs in the developing countries which are fatal to the health of human beings; although, these countries consume only 20 to 25 % of all pesticides. Small farmers, with overwhelming poverty, prevailing among them, are often most vulnerable to pesticide exposure and poisoning. The high incidence of pesticide poisoning, among small-holders, can also be related to the faulty pesticide-practices and the high toxicity of pesticides. The chances of poisoning are on the increase with the increasing usage of dangerous pesticides (Damalas, & Khan, 2017;. Wesseling *et al.,* 1997; WHO, 1990; Dinham, 1993).

These insecticides can find their way into the ground-water, through leaching, channeling (downward percolation), direct spillage and wind-drift, etc. A costly and very slow solution to the problem of groundwater, pollution is pumping, so it is better to work hard to make efforts not to contaminate ground-water, in the first place (Goss *et al.*, 1997). In Pakistan, Praveen and Masud (1987) had detected some chlorinated insecticides, in the drinking- water for cattle from Karachi; while Jabber *et al.,* (1993), had determined the residues of cyhalothrin, monocrotophos, and endrin in shallow ground-water of Faisalabad. In the near past, pesticide residues had been detected in ground-water, in various localities, in Pakistan, in the areas where pesticides, were being used extensively (Anwar *et al.*, 2000; Tariq *et al.,* 2004). Surface-water was also contaminated with the pesticide-residues (Ali, et al., 2018; Ahad *et al.*, 2006,). Cotton-growing-areas in the southeastern Punjab and Sind were especially affected, (Jabbar *et al.,* 1993; Ahad *et al.*, 2001; Tariq *et al.*, 2004)

Quality Management Systems (QMSs), allow the producers to focus on the customer's requirements and subsequently strengthen the supply-chain through control of the operations and processes. The various advantages extend over to the debate on food security. So, the concepts and different basic tools of TQM (Total Quality Management) can be used in agriculture for increasing the quality of the primary product, and farm performance without producing adverse effects on the environment(Nuryani *et al.,*2016). However, conceptually, TQM has no universal definition (Imran et al., 2019.Different tools of the TQM can also be used to determine the causes of pesticide-residues in ground-water.

The previous studies ignore the role of farmers i.e.ill practices, and wrong attitudes towards the pesticide-usage, due to the overuse, misuse and inappropriate application of pesticide, it affects the total environment in shape of residues in the food chain and also pollutes the soil and ground-water. (Abhilash, 2009; UN/DESA, 2002). In this part, efforts have been made to illuminate those management practices which could be the possible reasons for the accumulation of pesticide residues in the ground-water and could be regarded as a basis to the concept of Good Agricultural Practices (GAPs) for the pesticide-usage. These GAPs are general procedures to reduce hazards, related to the product and environmental-safety at the farm level. The different quality standards (HACCP; ISO 2200) require the safety of primary products as well as of the environment at the farm level as the prerequisite for the implementation of these standards.

The use of Good Agricultural Practices (GAPs) during production, harvesting, sorting, packaging, and storage operations for crop-production, is a way to prevent the accumulation of pesticide-residues beyond a certain critical limit. The important areas for implementing a GAPs-program are persistent practices, related to the land-use, adjacent land-use practices, water-quality and its use, soil-fertility management and practices, related to pesticide-usage, pest, wildlife, farmers' hygiene, and sanitary facilities, etc.

In order to reduce the risks, associated with agricultural production, it is necessary; first assess the potential hazards in the production environment. When the potential sources of contamination in ground-water have been identified, the control measures and practices should be adopted to reduce or eliminate their hazards. The intent of this research paper was not only to determine the detailed pesticide management practices but also to evaluate the farmer's knowledge about pesticides and their attitude towards the safety procedures for this pesticide usage. So that the farmers can be cultured and trained about the various areas of concern, in light of these findings.

Methodology

Total Quality Management (TQM) is a" management philosophy and a set of associated quality improvement techniques that have been used initially by Japan's People and then through out western world. (Shafiq, Lasrado, & Hafeez,2017).By using TQM viewpoints and techniques, businesses start continuous upgrading across all operations by seeking to discover the reasons for poor quality performance and customer service and implementing methods to reduce and eliminate the causes of poor quality.

Fundamental to the TQM viewpoint is the theme of defect prevention versus defect detection. Traditionally, the quality control efforts have concentrated on detection of defects through inspection after the product is manufactured. This process results into rework and waste. Under the TQM philosophy, the quality control is an on-going activity throughout the entire process cycle: it focuses on understanding the causes of problems and seeks to reduce or eliminate their impact in the most cost-effective manner. By making use of employee familiarity with work problems, TQM taps into the creative capabilities for find out solutions of the problems. Total Quality Management focuses on people: it encourages the formation of teams and empowerment of employees. Pollution can be taken as inefficiency or defect within a process that results into poor environmental performance for a company. The tools and philosophies of TQM can be used to improve the environmental performance by eliminating the waste or reducing its impact.

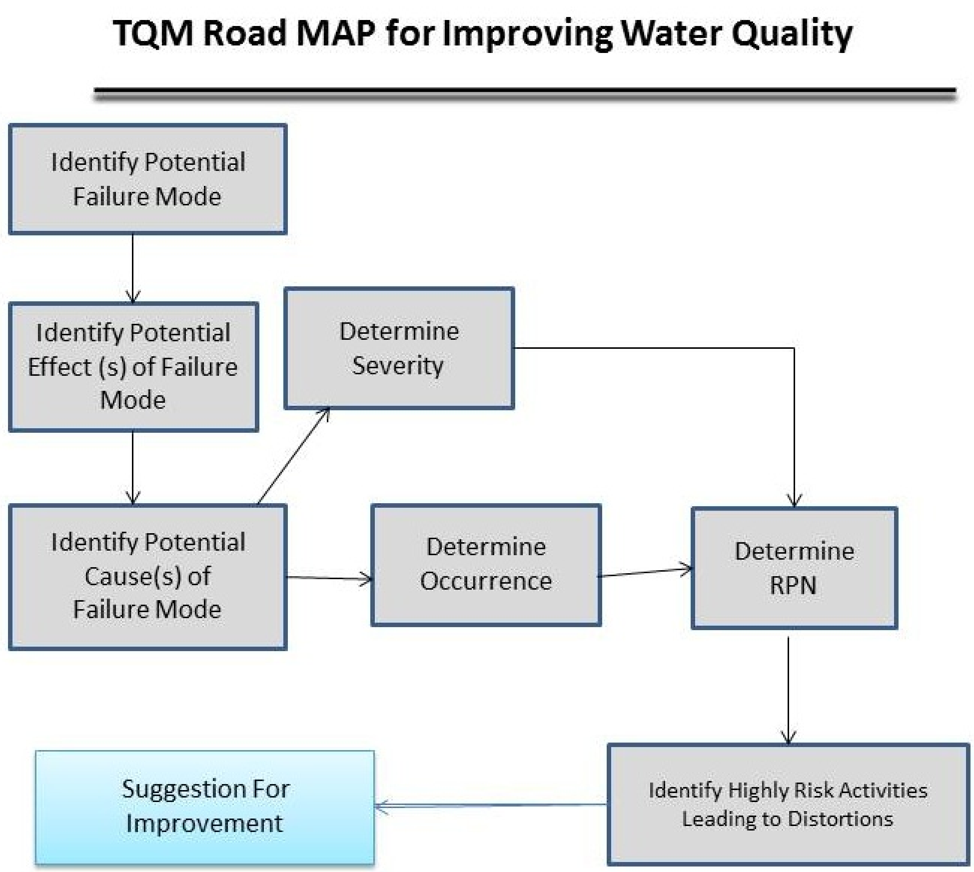

Figure 1: Flow diagram identifying the critical points of TQM base Approach.

The application of these tools and philosophies to improve environmental performance is known as Total Quality Environmental Management (TQEM). The most of the TQM methods, used by manufacturing industries to solve quality problems can be applied in problem-solving tool in the agriculture sector. These simple tools have proven effective in dramatically reducing problems in the industry In this section; we used a model based on Total Quality Management (TQM) concept to suggest improvement of the water quality which is deteriorated due to the pesticide usage.

The model for carrying out the risk and vulnerability analysis is based on TQM theories. The main focus is on identifying hazardous events, a risk evaluation matrix, and identifying risk reduction options. In this research, a fish-bone diagram, Pareto-analysis, and a Hazard Identification Based System had been used for the evaluations of adverse effects of the different practices, related to the pesticide-usage on the ground-water. The hazard risk analysis increasingly provided the foundation for practical risk rating systems as well as the regulatory guidance and the requirements for documents, used in the international trade, food safety, and health risk assessment work. These systems assign ratings, such as, "high," "medium," or "low", to express the dimensions of exposure and potential harm and then combine these component-ratings to determine an overall rating of risk, to be used as an input for decision-making for reducing the identified problem.

Results and Discussion

Cause and Effect Diagram

A cause-and-effect diagram or a fish-bone diagram is a graphical representation to determine the root causes of quality problems. In this diagram, the major causes of the ultimate problem are grouped and broken down into detailed sources (Russell and Taylor, 2000). Ishikawa-diagram was invented by Dr. Kaoru Ishikawa, a Japanese Quality Control, and worker. The cause and effect diagram is a problem-solving instrument that provides a systematic method of looking into the problem and their potential causes. It is often called as the fish-bone diagram, owing to its resemblance to fish-skeleton (Varzakas and Arvanitoyannis, 2007). In another study, the fishbone diagram offers an appropriate theoretical framework for a visual representation and technological analysis of complex factors of major innovations over time

A cause-and-effect diagram is a powerful tool of a TQM because it supports actions and principles, vital to the successful implementation of total quality. The cause-and-effect diagram is a powerful quality control tool which increases the total qualityin the following ways: it promotes the efficient involvement of associates; it avoids problems from recurring; it creates continuous improvement; it is a fundamental activity in problem-solving and corrective action. Cause-and-effect is a graphic presentation with the major branches reflecting on the categories of causes. A cause-and-effect analysis stimulates and broadens thinking about potential or real causes and facilitates further examination of the individual causes. Because every idea can find a place on the diagram, a cause-and-effect analysis helps to generate consensus about causes. It helps to focus the attention on the process, where a problem is occurring, and also allows a constructive use of facts, revealed by reported events. However, it is important to remember that a cause-and-effect diagram is a structured way of expressing the causes of a problem to find out practices of farmers which are more related to the pesticide-residues in the ground-water. Fish-bone diagram (A type of cause and effect diagram) has been used in the study. The cause and effect diagram is used to explore the potential and real causes of a problem. It encourages a group effort, to understand a problem properly and to find out solutions. For constructing a fish-bone diagram, the first step is the identifying of a problem. In this study the main focus on the problem of pesticide-residues in ground-water. In this way, we can identify the possible causes of the problem. In this part, only those management practices of the farmers had been considered which were causing pesticide-residues, in groundwater, ignoring other environmental factors such as the groundwater level, soil texture, related to the pesticide-usage. With the help of Focus group discussions with agricultural scientists and quality management experts, major causes of pesticide-residues were identified. These causes were arranged into groups (4M, i.e., Man, Method, Machine, Material) and all the other causes recorded on the diagram, in boxes, parallel to the main line, connected them to its line with slanting arrows, giving special attention to problem identification and its risk formalization.

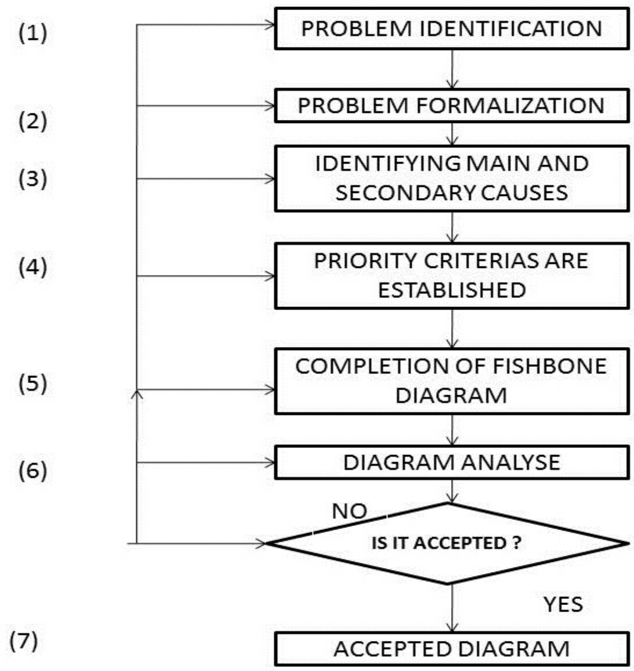

Figure 2. Flow diagram for identifying the critical points

In this way, the fish-bone diagram was drawn out. After a brain-storming session, fifteen causes of the pesticide-residues were identified, in the ground-water which were enlisted in four groups as below:

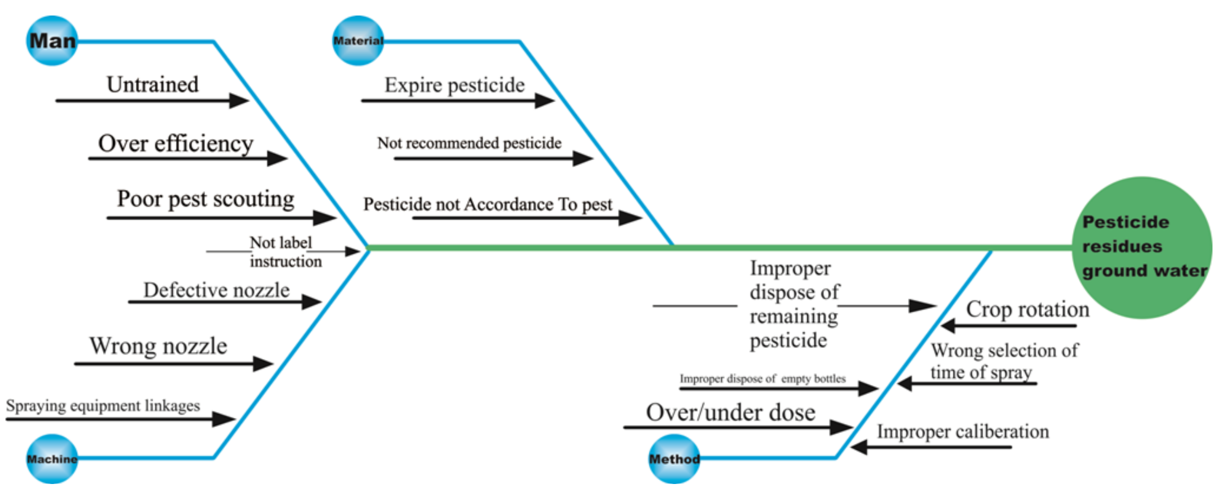

Figure 3. Fish Bone Diagram for Pesticide Residues in Groundwater.

Pareto-Analysis

For understanding of processes, there is need of having of the knowledge of seven basic Quality Control (QC) tools, which are used, in problem identification so that they can be improved by using a systematic approach (Herbert *et al.,* 2003). These tools are largely quantitative and help answer the questions, associated with them:

(1) Process flow-charting – what is one?
(2) Pareto-analysis– which are the big problems?
(3) Cause-and-effect analysis – what causes the problem?
(4) Histograms – what does the variation look, like?
(5) Check-sheets/tally-sheets – how often does it, occur?
(6) Scatter-diagrams – what are the relationships between factors?
(7) Control charts – which variations are to be controlled and how?

Pareto analysis is a Quality Control (QC) tool that classifies the data and arranges it in descending order from the highest frequency of occurrences to the lowest frequency of occurrences. The total frequency is equated to 100 percent. The “important few” things occupy a large amount (80 percent) of cumulative percentage of incidents and the “useful many” occupy only the remaining 20 percent of occurrences. The risk- identification process is supported by the brain-storming sessions and the use of Pareto- charts. A Pareto-chart is used to summarize and display the relative importance of the differences between various groups of the data graphically. In this case, this involves the assessment of the relative importance of risks to enable prioritizations. (Bystrom, 2003).

For the investigation of the frequency of different awful management practices, which were causing pesticide-residues, a questionnaire was used as a data collecting tool. The questionnaire for pesticide-exposure assessment was developed with the help of the staff of the University of Agriculture, Faisalabad and District Agriculture Offices. During the development of a questionnaire, all the points which had been described in a Fish-bone diagram were considered as the potential activities of pesticide residues in the ground-water. The questionnaire and its contents were reviewed by the pesticide specialists (Technical sale Officers of the area[1]). The questionnaire was pre-tested in the field. After incorporating the necessary changes, in the light of a pre-testing feed-back, the final-questionnaire was approved for further study.

Field research was done in four districts of Punjab for understanding the general trend of pesticide-usage, in the area. The primary research tool was the collection of data through face to face interviews (with the help of a structured questionnaire), supported with the field observations. The questionnaire consists of two parts. In the first part, we got general information, and in the second part, we got information on the occurrence of different activities, related to pesticide usage.

Random sampling design was employed to represent the research population. With the help of local agricultural offices, the areas were mapped, in these districts where both vegetables and cotton were grown.. In the concerning areas, interviews were taken from only those farmers with at least 3 acres of land, under cultivation.

Area-community, Agricultural-Profile

In this community, a total of 200 people from the two districts were interviewed. Out of these 167 were married; while, 33 were unmarried. The age of the respondents was ranged from 17 years to 63 years. However, the most of the respondents were between 20 to 40 years of age. The majority of persons were uneducated (48.5%), and only 12%, of them, had at least 10 years of

[1] Technical Sale Officers are the representative of the pesticide companies in the area

schooling. Majority of the respondents had less than 12 acres and they, used conventional method for the cultivation of land. Table 1 presents area community and agriculture profile.

Table 1: Area-Community Agriculture-Profile

Total Inter-viewed(N) N=200				
Age	Below 20 30(15%)	Between 20 to 40 128(64%)	Above 40 42(84%)	
Education (No of Schooling Years)	0 Years of Schooling 97(48.5)	1-5 Years of Schooling 71(35.5)	6-10 Years of Schooling 24(12%)	Above 10 years of Schooling 8(4%)
Marital Status	Married 167(83.5)	Un married 33(16.5)		
Land Holding	Up to 6 acres 115(57.5%)	6 acre to 12 acres 70(35%)	More than 12 acres 15(7.5%)	

Figures in parenthesis show the percentage value

Table 2: Possible Causes of Groundwater Contamination and their Frequencies

Sr.No	**Cause**	**frequency**	**Percentage**	**Commutative Percentage**
1	Poor Training	131	18	18
2	Poor Pest Scouting	81	12	30
3	The absence of Crop Rotation	69	10	40
4	Leakages of Spraying Equipment	63	9	49
5	Over/under Dose	61	9	58
6	Wrong Nozzles	45	7	65
7	Over Efficiency	44	6	71
8	Improper dispose of bottles	41	6	77
9	Wrong Selection of Time of spray	41	6	83
10	Defective Nozzles	37	5	88
11	Do not Follow Label Instruction	33	5	93
12	Pesticide not accordance the pest	15	2	95
13	Expire Pesticide	14	2	97
14	Banned Pesticide	12	2	99
15	Improper dispose of Remaining Pesticide	5	1	100

For constructing the Pareto chart, we got information about the frequency of occurrence of the different wrong practices, related to the pesticide usage and the arranged the data from more frequent to the less frequent event. The Table 2 and Figure 4 showed that poor training, poor pest scouting, crop rotation and leakages of equipment are some “vital few” events which can pollute the ground-water In the Pareto-analysis, “poor training regarding the pesticide-usage”, was found to be the most frequent cause of ground-water contamination with pesticide residues. There was no need of training of the farmers for pesticide-spraying in the areas. Poor pest-scouting was another big issue. Due to the poor pest-scouting, farmers were unable to determine the threshold point of a pest. That's why, they failed to determine the right time of spraying.

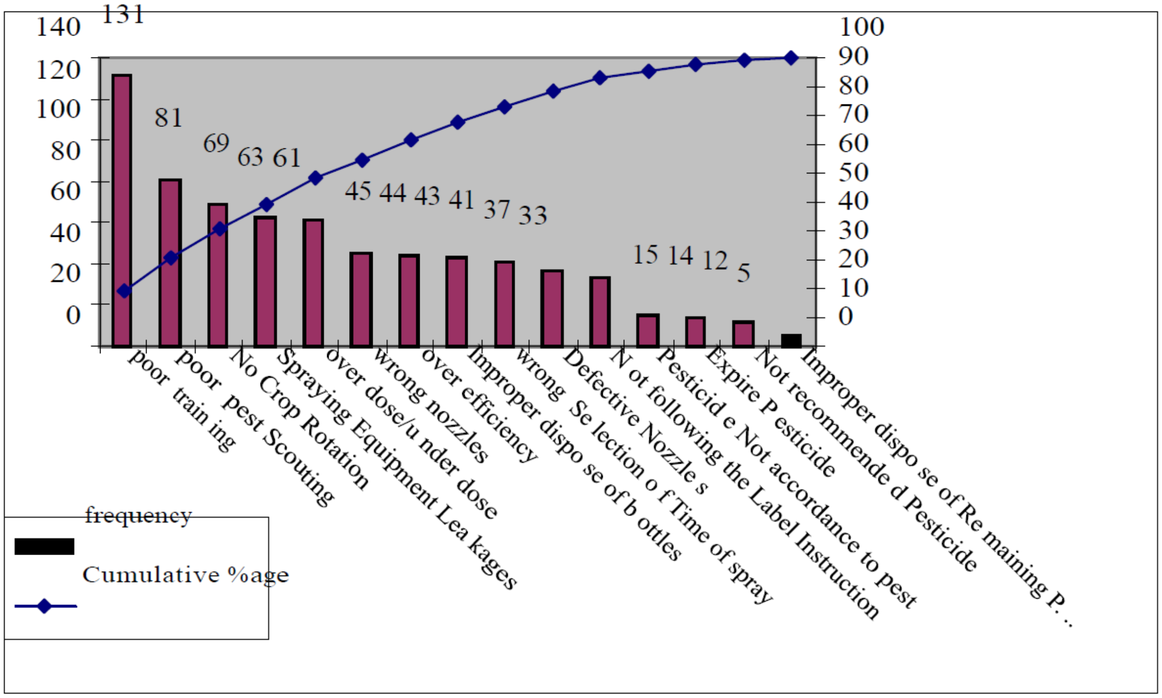

Figure 4. Pareto-Chart

Hazard Identification Based System (Qualitative Analysis).

KLP food supply chains are compulsory (Marvin *et al.*, 2009). Qualitative analysis has a wider elucidation, in social science studies. In this method, the collection of data is done with interviews, questionnaires, and analyzing conversations. This method provides a lot of information to the researcher for gathering the required data. The Qualitative Risk Analysis is the process of assessing the impact and probability of the identified risks how to priorities them according to their effect, on the project, if realized. The result serves, as a guide for the choice of critical risk responses. A by far the most, common approach to qualitative risk analysis is the use of impact/probability matrices. It may be called as "The Preliminary Hazard Analysis (PHA)," which requires the assessment of two factors for the desired hazard, the likelihood that the hazard, i.e., will occur and the severity if it does occur (Varzakas and Arvanitoyannis, 2007). This approach is also called an expert-judgment, as these are based on the qualitative estimates of the probabilities and impact/probability matrix that can be extended, so that, each level of impact or Probability is defined qualitatively or quantitatively. Quantitative definitions allow the calculation of expected risk values

Risk value = Impact * Probability

Risk analysis typically involves identifying the risks, assessing their probabilities and impacts, ranking them and screening out the minor risks (Emblemsva and Kjolstad, 2002). Here, it suffices to acknowledge that this crucial step requires experience, knowledge and creativity. So, for the ranking of causes (for their impact) on the ground-water quality, another questionnaire was developed. This time, the respondents were the agriculturist scientists, agricultural officers and the teachers of the Agriculture University Faisalabad. The cause (risk-activity) having a maximum adverse impact on the ground-water quality, was assigned maximum numbers and the cause (risk-activity) with a minimum adverse effect on the ground-water, was assigned minimum number. Table 3 showed the assigned scores and associates risk severity. On the basis of the responses, recorded from respondents, a different "risk-activity" score from 1 to 5 categories, as mentioned below was arranged.

Table 3: Assign the Score (severity) of Different Activities.

Category	Score	Severity	Event
1	1-3	Minor	Over Efficiency,
2	4-6	Low	Poor Training, Pest Scouting, Wrong Nozzles, Spraying Equipment Leakages
3	7-9	important	Wrong Selection of Time
4	10-12	Hazardous	Defective Nozzles, Expire Pesticide
5	13-15	Severe	Not Recommended Pesticide

Table 4 showed that "not recommended pesticide" most sever activity while Over Efficency is a minor acitvit, regarding the severity.

Table 4: Over-All Risk Value Table.

Sr. No.	Activity	Risk Likelihood Determination (Probability)	Severity	Score	Risk Level
1	Poor Training	4	3	12	High Risk
2	Poor Pest Scouting	3	1	3	Low Risk
3	Crop Rotation	2	1	2	Low Risk
4	Spraying Leakages Equipment	2	2	8	Moderate Risk
5	Over/under Dose	2	2	4	Low Risk
6	Wrong Nozzles'	2	2	4	Low Risk
7	Over Efficiency	2	3	6	Moderate Risk
8	Improper Dispose of Bottles	2	4	8	Moderate Risk
9	Wrong Selection of Time of Spray	2	3	6	Low Risk
10	Defective Nozzles	2	4	8	Moderate Risk
11	Following Label Instruction	2	4	8	Moderate Risk
12	Pesticide not Accordance the Pest	1	4	4	Low Risk
13	Expire Pesticide	1	4	4	Low Risk
14	Recommended Pesticide(using)	1	5	5	Moderate Risk
15	Dispose of Remaining Pesticide	1	4	4	Low Risk

Table 5. Over All Risk, Rating Matrices

Impact					
probability	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Very High	5	10	15	20	25
High	4	8	12	16	20
Medium	3	6	9	12	15
Low	2	4	6	8	10
Very low	1	2	3	4	5

Where Low risk is represented by white color, moderate with gray color and high risk is shown by pink color.

Table 5 showed that maximum score has been given to poor training, which showed that poor training was a serious problem. In Bangladesh Robinson *et al.*, (2007) studied the behavior rice farmers, he concluded that the trained farmer more likely recognize natural enemies to pests than untrained farmers and also performed environmental friendly activities during farming. Over Dosing, Improper disposal of bottles, defective nozzles, and using of un-recommended pesticides were moderate risks.

Proposed Training Approach

One of the important finding of the present study is that inappropriate use of f pesticides has led to large economic losses and threats to human and animal life health. The finding is also supported by many other studies like (Azeem (2000);, and Ahad, *et al*,. (2001).To overcome the problem and avoid pesticide residual accumulation in soil, primary products and water, a comprehensive training program, regarding the pesticide handling, use and IPM is an important tool. A comprehensive and effective training program to encompass the desired parameters and achieve the quality objectives in pesticide usage is being proposed as under:

Farmers Training Program

The proposed training model is consisted of three module, aims at creating a deeper understanding of the essential interactions of agro-ecosystems as well as on ecological farming, with the particular emphasis on safe use of chemical pesticide([Berg, *et al*,. 2004). The Pesticide management practices of farmers are likely to change as a result of the proposed training process. Knowledge based learning methodologies are being proposed for improving the practical approaches of the farmers for taking balanced decisions under difficult and changing circumstances. The eventual goal of this training approach is to achieve a considerable improvement in the crop and pest management methods and promote best agricultural Practices of the farmers for sustainable crop production.

SMART Objectives of the Proposed Training Approach are:

- Specific to the Training Need Assessment
- Measureable in terms of specific targets
- Achievable by using the existing financial and technical resources
- Relevant to the sector specific goals
- Time-bound to make them meaningful and measureable

Modules of Proposed Training Approach:

Following three training modules have been designed to be included in the comprehensive training program, largely designed for the farmers but not limited for the farmers as other persons, including the farm labour, small pesticide retailers.

1. IPM

2. Safe Pesticide use
3. Good Spraying Practices

Integrated Pest Management (IPM)

IPM module is presented below in Figure 6. The goal of the Integrated Pest Management is to manage pests effectively, economically and safely. Pest management usually involves suppressing pests up to an acceptable level. IPM has the potential to increase effectiveness, reduce cost and make pest control safer. IPM means “better integration of good farming practices.

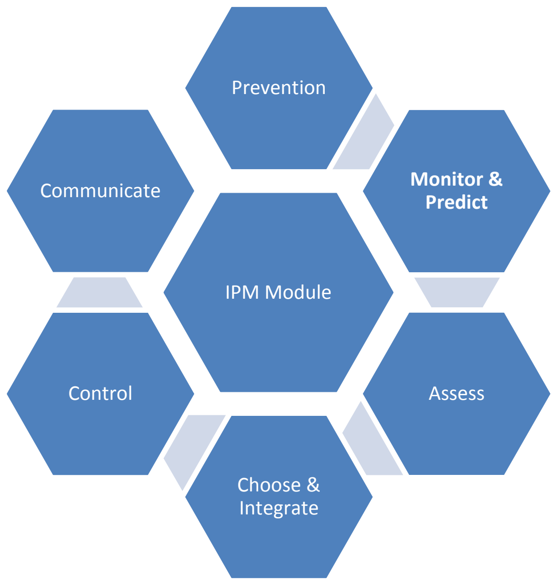

Figure 6. Intergated Pest Management Module

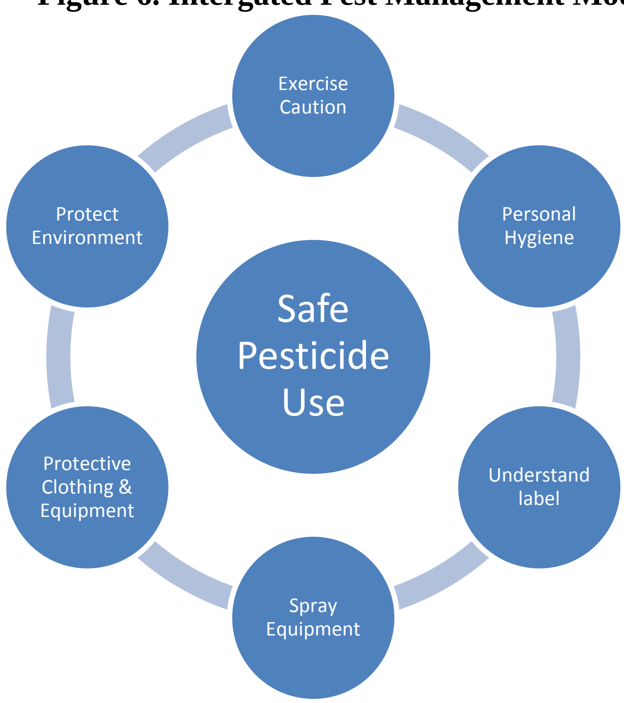

Figure 7. Safe Pesticide Use Module

Safe Pesticide Use Module:

Second module is regarding the Safe Pesticide Use (SPU) as presented below in Figure 7 . The module is mainly degined to create awareness in the target group, regarding the hazardous aspects of the pesticides and develop capacity in the target group to protective human health, surroundings and environment from the pesticide residual contamination.

Good Spraying Practices

Third module covers the overall techniques for having an effective spray and post spray management practices to minimize the pesticide residual accumulation. Fig 8: below summarize the different aspects of the third module

Figure 8. Good Spraying Practices

Conclusions

The conclusions were based on author's initial work, which involved knowing present condition of farming by doing a process mapping; the causes of problem can be identified where they existed. After knowing the problem, the different quality tools can be used to rectify them and suggestions can be generated for improvement. The main problem of the Pakistanis farmers, was "training for the pesticide-usage". The most of the farmers believed that the usage of pesticide was so simple; they could learn it without the help of any institute. So, it is the responsibility of the government to make arrangements for the training of farmers as well as for producing awareness of the pesticide-usage and good agricultural management practices which not only decrease the cost of production but also increase the quality of primary products, farmer health and environment. The introduction of QMS tools in the Agriculture is a new idea in Pakistan; it will be used in other activities of agriculture. Therefore, the incorporation of Agriculture with the Quality Management System is considered imperative, and Pakistani Government should introduce the protocol of "good agricultural practices "(GAPs) for Agriculture sector by using of the concept of ISO 22000 and HACCP. Good Agricultural Practices are "practices that address environmental, economic and social sustainability for on-farm processes, and result in safe and quality food and non-food agricultural products".

The four 'pillars' of GAPs (economic viability, environmental sustainability, social acceptability and food safety and quality) are included in the most private and public sector standards but the scope which they actually cover varies widely.

The concept of Good Agricultural Practices may serve as a reference tool for deciding, at each step in the production process, on practices and/or outcomes that are environmentally sustainable and socially acceptable. The implementation of GAPs should also contribute to Sustainable Agriculture and Rural Development.

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