Cancer Deaths in Agricultural Heartland
A Study in Malwa Region of Indian Punjab

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Cancer Deaths in Agricultural Heartland
A Study in Malwa Region of Indian Punjab

by

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Abstract

Indian state of Punjab is increasingly under focus for the increasingly incidence of cancer mortality as well as indiscriminate use of pesticides in agricultural practices. The study investigates cancer mortality, and its correlations with numerous variables, including demographic characteristics, cropping pattern and pesticide residues in soil and water.

Cancer mortality data for a period of five years (2002-06) was collected from 30 randomly selected villages in Malwa region of Punjab. 15 villages were selected from cancer prone “high risk” districts of Muktsar, Faridkot, Bathinda and Mansa, and the other 15 from “low risk” districts of Sangrur, Barnala, Moga and Firozpur. Cropping pattern was obtained and pesticide residues analysis conducted on composite soil and water samples from each village.

Cancer mortality has a direct correlation with gender (F = 6.25) and occupation (F=17.41) in SAS ANOVA test. “High Risk” districts had greater mortality than “low risk” districts (F=7.97). Mortality is increasing every year (F=12.25) in General Linear Model (GLM). Cancer mortality is positively correlated to cotton crop (Pearson correlation = 0.343) and negatively to rice crop (Pearson correlation = -0.355). The correlation between pesticide residues with cancer mortality is strong both in the case of water samples (0.583) and soil samples (0.531).

The greater incidence of female mortality compared to male mortality is contrary to global trends. Homemakers facing greater risk than farmers are a corollary of greater female mortality. The medium level correlation between cancer mortality with cropping is an indicator that cropping patterns needs to be re-examined. Correlation of pesticide residues with cancer is consistent with existing trends.

Correlation analysis has unearthed significant patterns in cancer mortality in the state, which has serious implication for policy planners.

Keywords: Punjab, cancer, gender, pesticide, occupation, Malwa, cotton, cropping pattern.

Acknowledgements

"To Sir With Love"

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But for them, my indiscretions and ignorance would have ensured that the thesis does not see the light of the day.

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1. Introduction

From famine to green revolution has been a long journey, traversed by many developing countries throughout the world. The previous century saw India, experiencing both famine as well as the green revolution. While the green revolution led to a significant decrease in hunger pangs of the teeming millions, it has also led to emergence of environmental problems, reminding one of the Byzantine proverb:

"He who has bread has many problems;
He who does not have bread has only one problem."

One of the scourges facing humanity in the 20th century was famine. It has been estimated that 70 million people died in the previous century due to famines (Deveruex 2000). Walker (1989) defines famine as "a socio-economic process which causes the accelerated destitution of the most vulnerable, marginal and least powerful groups in the community, to a point where they can no longer, as a group, maintain a sustainable livelihood".

In the Indian context, 22 major famines took place in British colonial India between 1770 and 1900 (Alamgir 1980). In the 20th century, the most notorious famine in India was the Bengal famine of 1943 resulting in 3 million deaths (Sen 1981). Even after Indian independence in 1947, the spectre of famine loomed large and in 1967 arrived the book "Famine 1975" predicting that India along with Haiti and Egypt "cannot be saved" from famine. The authors William and Paul Paddock even suggested the application of the medical "triage" system, leaving countries "can't be saved" nations like India to their own fate.

However, those very years (1966-67) also marked the beginning of the "Green Revolution" in India. All this helped India avert famine, and there has been no substantial famine in India since independence in 1947. This prompted USAID director, William Gaud to write, "These and other developments in the field of agriculture contain the makings of a new revolution. It is not a violent Red Revolution like that of the Soviets, nor is it a White Revolution like that of the Shah of Iran. I call it the Green Revolution" (Gaud, 1968).

Gurdev Singh Khush, one of the pioneers of the green revolution, credits the Green Revolution for averting famines. "Fortunately, large-scale famines, and social and economic upheavals, were averted, thanks to the marked increase in cereal-grain yields in many developing countries that began in the late 1960s"(Khush 2001).

The green revolution seemed to have overcome Malthusian predictions, when Normal Borlaug, in his Noble Prize acceptance speech, talked of two opposing forces, “the scientific power of food production and the biologic power of human reproduction” (Borlaug 1970).

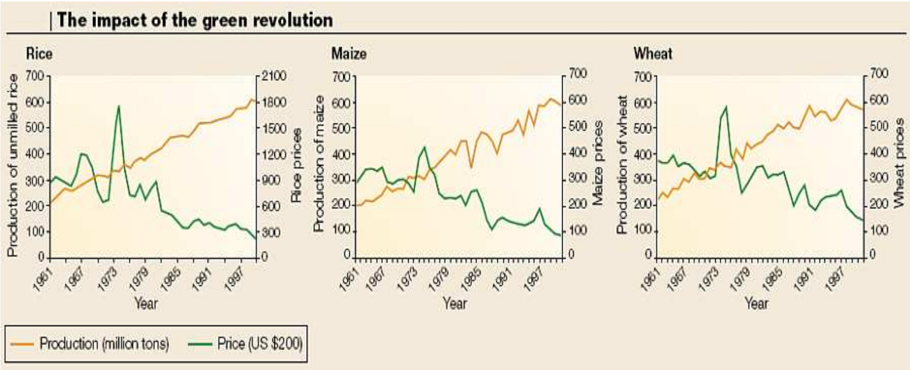


Figure 1: Green Revolution and increase in food production (1961-2000).
(Source: Khush, Gurdev Singh, Green revolution: the way forward, Nature Reviews, Volume 2, October 2001. p 816)

Scholars like Jeffrey Sachs (2005) feel that it was the green revolution that led to Asia acquiring a pivotal global role: “To me, the Green Revolution triggered Asia’s dynamism and an export-led revolution in manufacturing”.

In India, the forerunner of the “green revolution” was the state of Punjab. Scholars concede that the north-western state of “exemplifies the green revolution of the mid-1960s” (Murgai 1999). Coupled with high yielding varieties of food grains, technology, irrigation, chemical fertilizers and pesticides, the per hectare yield of wheat rose from 1104 kg per hectare to 2238 kg per hectare from 1965-66 and 1970-71; a period of just five years (Punjab 2005). Over the next three decades, cropping intensity continued to grow. From 126 percent in 1960-62, it reached 185 percent in 1996-97 and touched 189 per cent in 2004-05(ibid).

Table 1: Cropping Intensity in Punjab

Cropping Intensity (%)	Year
126	1960-62
185	1996-97
189	2004-05

(Source: Statistical Abstract of Punjab, 2005)

So successful was Punjab that it earned sobriquets like the “bread basket of India’’ and “India’s granary”. Although it occupies only 1.54 per cent of area in India, Punjab produces 22 per cent of wheat, 12 per cent of rice, and 13 per cent of cotton. The state has an area of only 50,362 square kilometres, but its world share for wheat and cotton production is 2 percent and that of rice is 1 per cent (Punjab 2006).

The green revolution has come under scrutiny even earlier; though the discourse of criticism has changed. Early scholars like Harry Cleaver (1972) had suggested that

American foreign aid in the form of inputs to Green Revolution was “an integral part of the postwar effort to contain social revolution” and to thwart specter of a communist revolution with food.

While the success of the Green revolution has been well documented and accepted; its consequences have come under considerable global scrutiny. Issues like environmental degradation (Conway et al 1991), separatist violence in Punjab (Corsi 2006; Weiss 2002) increase in class disparities, agrarian tensions arising out of wealthier farmers being favoured by markets, rural-urban migration, loss of biodiversity (Shiva 1989), petering out of productivity (Byerlee 2006), water issues like water logging, water overuse and changes in salinity (Gupta 2000) have been raised.

A frightening aspect that has recently emerged is the sudden spurt in deaths due to cancer.

Table 2: Mortality by cause (global)

Cause	Total	Male	Female
Cardiovascular diseases	29.3	27.2	31.7
Infectious and Parasitic diseases	19.1	19.4	18.8
Malignant neoplasms	12.5	13.3	11.6

(Adapted from “The World Health Report 2004 - Changing History”, 2004)

Cancer is not a single disease. It is a group of over 100 different and distinctive diseases. It has also been called the “misguided cell” (Prescott et al, 1982).

The National Cancer Institute describes cancer as “a term for diseases in which abnormal cells divide without control”. According to the Merck Manual (2006), cancer is “a cellular malignancy whose unique trait--loss of normal controls-- results in unregulated growth, lack of differentiation, and ability to invade local tissues and metastasize.”

Cancer is not a new disease, with the oldest documented cases coming from 1500 BC in Egypt, where details of eight kinds of breast tumours were recorded on a papyrus. Two papyri, “Edwin Smith papyri” and “George Ebers Papyri” describe medical conditions similar to cancer. Cancer has been found in skeletal remains of a woman from Bronze Age, while certain mummies of Incas from Peru indicate malignant melanoma. The ‘Father of Medicine’ Hippocrates is credited for coining the term cancer. He used the term ‘carcinos’ to describe non ulcer forming tumours and the term ‘carcinoma’ for ulcer forming tumours. The word carcinoma owes its origin from karkinoma, which means crab in Greek. Shimkin (1977) quotes Paul of Aegina to describe its etymology. Hippocrates named it since it had “the veins stretched on all sides as the animal the crab has its feet, whence it derives its name”.

The Greek phyisican and writer Galen (129 C.E.-ca 199) used the word 'oncos', derived from Greek ogkos (ογκος) which later led to present day word "oncology", the science of study of tumours.
Cancer causes 12.49 per cent of all deaths worldwide (WHO 2004) and is ranked as the third largest killer worldwide, below cardiovascular diseases, infectious and parasitic diseases, and much higher than HIV-AIDS.
Since cancer is a generic term describing almost 100 diseases, the mortality rates of each type of cancer are also different. Mortality rates vary not only among types of cancer but even geographically. WHO (2006) states that 70 per cent of all cancer deaths occur in low and medium income countries. It also postulates an increase in cancer deaths from 7.6 million in 2005 to 11.4 million in the year 2030 (0.15 per cent increase annually).

Table 3 : Global mortality due to Cancer (2005-2030)

Year	Mortality
2005	7.6 million
2015	9 million *
2030	11.4 million *

(*) = projections

(Adapted from WHO Factsheet N° 297, 2006)

The increase in global mortality is despite the fact that in the US, both cancer incidence rates and deaths rates of cancer have dropped (Jemal et al. 2004; Wingo et al. 1998)). On the other hand, countries like India are expected to see an increase in deaths due to cancer. WHO estimates that the percentage of cancer deaths in India will rise from 8 % in 2005 to 11.9 % in 2030.

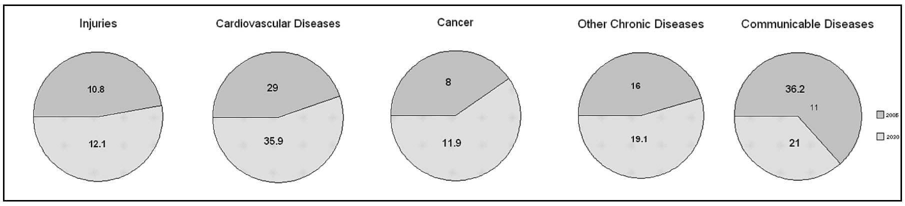


Figure 2: Major causes of mortality in India (2005-2030).
Values in brackets indicate percentage of deaths caused by the disease.
(Adapted from WHO Global Infobase)

In Punjab, the home of India's Green Revolution, news reports about cancer deaths first emerged in late 1990s when the media reported high cancer mortality in a few select villages. Village Gyana and Jajjal in Bathinda district hogged the limelight for being "cancer stricken" villages (Pandher 1999). The government was initially in a denial mode and even stated that "there have been no cancer deaths in Punjab" in response to a parliamentary question (Punjab 2003).

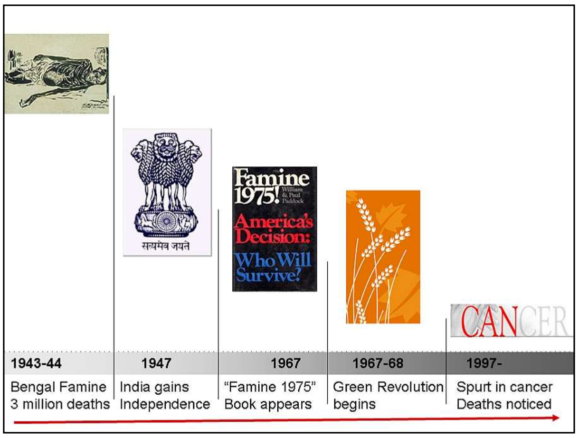


Figure 3: Timeline depicting chain of events leading to spurt in cancer

The denial mode did not last long, and a spate of reports and publications increased the focus on cancer mortality in Punjab.

The state's own agency, the Punjab Pollution Control Board commissioned the Post Graduate Institute of Medical Education and Research, Chandigarh to study the issue. The study report (PPCB 2005) revealed that the prevalence of confirmed cancer cases was 103 per lakh (100,000) Talwandi Sabo and 71 per lakh at Chamkaur Sahib blocks of Punjab.

The report, titled "An epidemiological study of cancer cases reported from villages of Talwandi Sabo Block, District Bathinda, Punjab" concluded that cancer deaths in Talwandi Sabo block were greater than those in Chamkaur Sahib "probably due to more use of pesticides, tobacco and alcohol". It further stated that "Limited studies show that in drinking water the levels of heavy metals such as As, Cd, Cr, Se, Hg were generally higher, and pesticides such as heptachlor, ethion and chloropyrifos were also higher in samples of drinking water, vegetables and blood in Talwandi Saho as compared to Chamkaur Sahib" (ibid).

Another report by Centre for Science and Environment (CSE 2005), "Analysis of Pesticide Residues in Blood Samples from villages in Punjab", had investigators concluding that out of 28 pesticides analysed, 15 were detected in blood samples as well.

The Atlas of Cancer in India (ICMR, 2003) has also reported a spurt in cancer deaths in Punjab, with incidence in Muktsar district growing from 30 cases in 2001 to 191 in 2002, while it rose from 19 to 144 in Faridkot during the same time period.

These reports, coupled with media scrutiny and increasing public awareness have now forced the state government to announce a series of steps to augment health facilities to tackle the scourge of cancer.

2. Study context and conceptual framework

Punjab, which was the torchbearer of the green revolution almost four decades ago, seems to be the first state in India which is suffering from the adverse consequences of green revolution as well. As more and more states in the country follow the agricultural practices adapted by Punjab, including hybrid seeds, pesticides and chemical fertilisers, fears are being expressed that “What happens in Punjab today could happen to the rest of the country tomorrow” (Philipose, 1998)

This study thus has implications not just for the state of Punjab, but also for India and South Asia in general, and for all those places where the green revolution took seed.

2.1. Problem statement and justification

Cancer, which has been described as a “lifestyle disease” is a disease of longevity, affecting developed countries more than developing ones. However, increase in longevity in developing countries, coupled with a decline in cancer mortality in developed countries due to better health practices and medical intervention, has implied that cancer is now emerging a major killer in developing countries as well. A spate of environmental factors contributes towards the development of cancer, apart from genetics and dietary factors. It is critical to understand the correlation of cancer with environmental factors, particularly in a local context. Carcinogens vary between geographical locations, since their prevalence often depends on local practices.

Understanding the interplay of local environmental factors and fatal diseases like cancer is crucial in ascertaining the factors that led to a spurt in cancer mortality. A correlation between environmental factors and diseases like cancer can also lead to “better” practices in not just the area under question, but also for other areas as well.

CORRELATION IS NOT CAUSATION:

The dictum, “Correlation does not imply causation” holds good for this study as well. Establishing a correlation between two variables does not imply that the cause has been established. As David Hume, the last of the triumvirate of “British empiricists” remarked “causation is the strongest associative relation”. Here the focus is on correlation and not causation.

Also the logical fallacy “*Post hoc ergo propter hoc*” (after this, therefore because of this) has to be considered in such a study. Just because a spurt in cancer mortality has followed the green revolution does not imply that the green revolution caused cancer.

2.2. Research Objectives

This study investigates the occurrence of cancer mortality in the “cancer belt” of Punjab.
Punjab, the grain bowl of India is now under focus for its increasing incidence of cancer deaths. Along with the increase in reported cancer deaths, excessive use of pesticides for over three decades has led to its water and soil being rendered suspect in a number of studies. Both the spurt in reported cancer deaths and increasing levels of pesticides in ground water and soil has been the focus of media reports.
The investigation analyses the possible correlation with pesticide residues in soil and water samples with cancer mortality. It also ascertains the variance of cancer with both gender and occupation. The variation of cancer mortality with crop patterns, and the temporal dimension of cancer mortality is also researched.

To achieve the research objective, the following specific objectives were formulated:

1. To investigate the incidence of cancer mortality in villages of Malwa region in Indian Punjab for a five year period from 2002-06.
2. To investigate relationship, if any, between cancer deaths and demographic characteristics of victims.
3. To ascertain the variation in cancer mortality and its correlation with cropping patterns.
4. To investigate the pesticide levels in soil and water samples in the study area.

To pursue the above stated objectives, the following research questions were formulated:

1. What is the correlation between cancer deaths and demographic parameters?
2. Is there a temporal dimension to cancer mortality?
3. What is the correlation between cancer and cropping patterns?
4. Is there a correlation between pesticide residues and cancer mortality in villages of Malwa region in Indian Punjab?

2.3. Research hypotheses

Based on the stated research questions, the following research hypotheses are formulated:

Hypothesis 1:

Hypothesis 1 seeks to ascertain whether there is a correlation between cancer mortality and gender.

$H1_0$: There is no correlation between cancer mortality and gender.

$H1_1$: There is a correlation between cancer mortality and gender.

Hypothesis 2:

Occupation could play a significant role in cancer mortality, with certain occupations having greater susceptibility to cancer than others.

$H2_0$: There is no correlation between cancer mortality and occupation.

$H2_1$: There is a correlation between cancer mortality and occupation.

Hypothesis 3:

Temporal dimension is investigated in the third hypothesis. This hypothesis seeks to investigate if cancer mortality is increasing every year.

$H3_0$: There is no correlation between cancer mortality and time.

$H3_1$: There is a correlation between cancer mortality and time.

Hypothesis 4:

Cropping patterns could have a bearing on cancer mortality. Agricultural practices associated with certain crops may be associated with greater cancer mortality.

$H4_0$: There is no correlation between cancer mortality and cropping patterns.

$H4_1$: There is a correlation between cancer mortality and cropping patterns.

Hypothesis 5:

Hypothesis 5 seeks to test whether pesticide residues in soil and water can be linked to cancer mortality.

$H5_0$: There is no correlation between cancer mortality and pesticide residues.

$H5_1$: There is a correlation between cancer mortality and pesticide residues.

3. Materials and Methods

3.1. Study Area

PUNJAB: The state of Punjab located in North West India, bordering Pakistan, extends from 29°32´ to 32°32´ North and 73°55´ to 76°50´ East. It is surrounded by the Indian states of Jammu and Kashmir in the north; the hilly state of Himachal Pradesh in the east; and by the state of Haryana and Rajasthan in the south. It covers a geographical area of 50,362 square kilometres and is one of the smallest states in India.

STUDY AREA: Socio-culturally, the state is classified into three regions -- Majha which is land between rivers Ravi and Beas; Doaba which lies between rivers Satluj and Beas; and Malwa, the region south of river Satluj. Our study area is located in the Malwa region, south of the river Satluj.

The study area comprises of eight districts of the Malwa region in Punjab namely, Sangrur, Barnala, Moga, Firozpur, Faridkot, Muktsar, Bathinda and Mansa.

Table 4: Location of Study Area

	Geographical Coordinates	
District	Latitude	Longitude
Sangrur	29° 43´ 25 " and 30° 41´ 41" North	75° 33´ 09" and 76° 12´ 40" East
Barnala	30° 08´ 17 " and 30° 36´ 28" North	75° 15´ 13" and 75° 43´ 56" East
Moga	30° 29´ 06 " and 31° 06´ 12" North	74° 54´ 12" and 75° 25´ 08" East
Firozpur	29° 55´ 36 " and 31° 10´ 58" North	73° 52´ 33" and 75° 09´ 19" East
Faridkot	30° 21´ 30 " and 30° 50´ 49" North	74° 28´ 15" and 75° 03´ 20" East
Muktsar	29° 53´ 31 " and 30° 40´ 43" North	74° 15´ 03" and 74° 49´ 32" East
Bathinda	29° 46´ 11 " and 30° 35´ 08" North	74° 37´ 49" and 75° 22´ 54" East
Mansa	29° 32´ 19 " and 30° 13´ 00" North	75° 09´ 49" and 75° 47´ 00" East

The entire study area lies between latitudes of 29° 32´ 19 " and 31° 10´ 58" North, and longitudes of 73° 52´ 33" and 76° 12´ 40" East.

The study area covers 22,175 square kilometres out of a total of 50,362 square kilometres area in the state. It includes 2102 villages out of 12959 villages of Punjab.

The study area covers 44 percent of the area of the state, though it covers only 16 percent of the villages. This is because villages in Malwa region, where the study area is located, are much larger in size than the villages in the rest of the state.

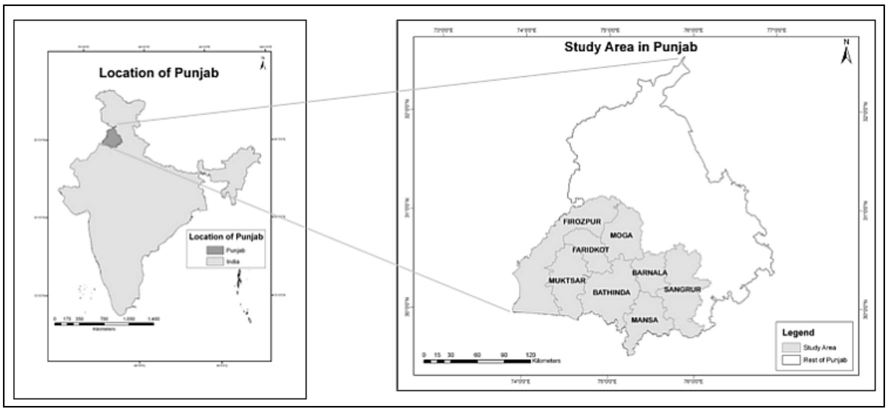


Figure 4: Location of the state of Punjab (left) and study area (right) comprising of eight districts in the Malwa region.

PHYSICAL GEOGRAPHY:

The state of Punjab is a part of the vast Indus plains (Uppal, 1978). Punjab is known as the land of five rivers, and in fact the very name, Punjab is derived from Persian words, *punj* (river) and *ab* (water). In ancient Indian epics the area was called *Panchanada*, the land of five rivers or *nadas*. When the Greeks occupied Punjab in fourth century BC, they called it ‘pentapotamia’ or the land of five (penta) rivers (potamia). Out of the five tributaries of the river Indus, namely Jhelum, Chenab, Ravi, Beas and Satluj, the first two are now in Pakistan, while the remaining three flow into Indian Punjab.

The drainage system of the state is formed by the three perennial rivers, Ravi, Beas and Satluj. Other drainage channels include seasonal rivers like the Ghaggar, White and Black Bein. Kiran Nala, Chakki River and Sakki Nala. Apart from these, various seasonal rivulets or *choes* originate in the Shiwalik hills. The natural gradient is generally from North-East to South-West (Manku 1998). Out study is restricted to the area south of the Satluj River.

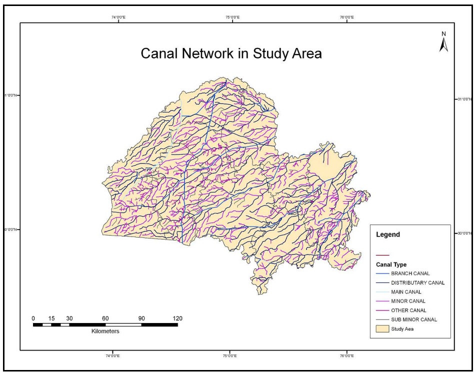


Figure 5: Canal Network in the Study Area. Punjab has about 4600 kilometres of canal and distributary network.

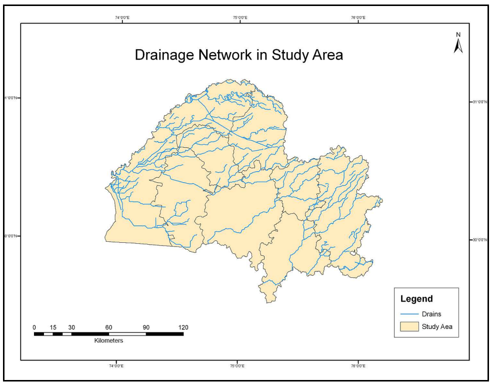


Figure 6: Drainage Network in the Study Area. The natural gradient is from the North-West to the South-East.

Physiographically, Punjab is divided into Shiwalik hills, piedmont sloping plains, alluvial plains, sand dunes, flood plains and palaeo channels. Geologically, Punjab is formed by alluvial deposits of various rivers flowing here. Stratigraphically, the Shiwaliks, piedmont and alluvial plans form three units in the state.

While hills are result of latest phase of Himalayan orogeny with deposits varying from upper Miocene to lower Pleistocene, the piedmont are formed due to coalescence of alluvial fans. Soils of Punjab show three states of development ranging from entisol and alfisol (Mavi et al, 2004). It is the alluvial plains comprising the quaternary sediments of Indus plain that forms the major part of our study area, apart from some portions of flood plains, palaeo channels and sand dunes.

The cropping pattern, since the days of Green Revolution has stabilised to a large extent. The Upper Bari Doab, Bist Doab and Satluj and Ghaggar plains follow rice-wheat alternate cropping patterns. In south west plains in the state, cotton often

replaces rice in the rice-wheat combination. Maize and sugarcane are also grown here.
All five crops, namely the three main crops of wheat, rice, cotton as well as the lesser popular maize and sugarcane, are grown in our study area.
With Himalayas in North and deserts of Rajasthan in South, three rivers and famous Indian monsoon influencing the climate, the state has flood plains, sub humid, semi arid and arid zones. Our study area has both semi arid and arid agro climatic zones. The temperature ranges from 0 C in winters to 47° C in summers. The state is characterized by hot summers, wet monsoons and cold winters.

Table 5: Land Use and Land Cover in Study Area

Land Cover / District	Built up land	Agriculture	Forest	Others	Total Area	No of Villages in District
Sangrur	183.75 (5.10)	3368.34 (93.41)	2.7 (0.07)	51.21 (0.14)	3606	591
Barnala	71.31 (5.04)	1318.71 (93.26)	2.35 (0.17)	21.63 (1.53)	1414	133
Moga	125.32 (5.61)	2061.9 (92.38)	0.02 (0)	44.76 (2)	2232	331
Firozpur	192.79 (3.66)	4889.17 (92.90)	2.34 (0.04)	178.7 (3.4)	5263	102
Faridkot	66.05 (4.47)	1372.61 (92.99)	16.08 (1.09)	22.76 (1.45)	1477	171
Muktsar	96.9 (3.68)	2458.3 (93.26)	0.31 (0.01)	80.49 (3.05)	2636	236
Bathinda	134.17 (3.97)	3086.71 (91.43)	61.82 (1.83)	93.3 (2.77)	3376	294
Mansa	81.04 (3.73)	1953.14 (89.97)	1.36 (0.06)	135.5 (6.23)	2171	244

(Adapted from Statistical Abstract of Punjab, 2006, Punjab)

(Figures in parenthesis are percentages of land cover within each district)

With Punjab being a predominant agricultural state, the area under forests is much lesser than the national average. 83 per cent (Punjab, 2006) of the total area in the state falls under agriculture, while only 5.7 per cent is forests (Punjab, 2006). Being a densely populated area, 5.94 percent of state comprises built up area; with rural built up area being 3.74 per cent and urban touching 2.08. Industrial built up area is negligible (0.12 per cent.).
The study area is more intensely cultivated than the rest of the state, particularly when compared to the Upper Bari Doab and Bist Doab areas. Consequently it has less area under forest cover as well. Mansa district has the lowest percentage of land under agriculture (89.97 %), while Bathinda has the most (91.43 %).

3.2. Research methodology

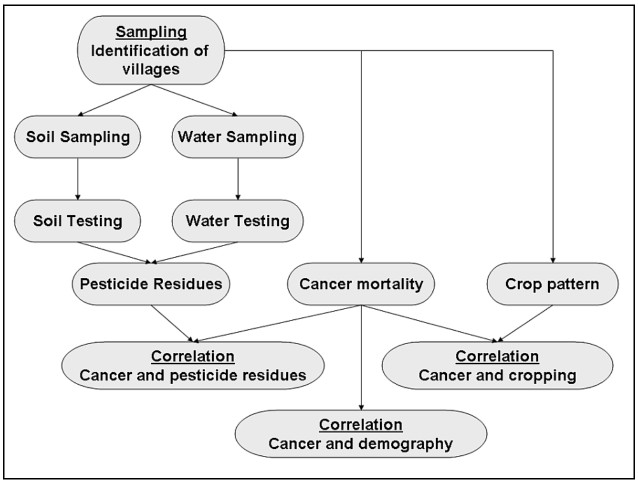


Figure 7: Flowchart depicting research methodology adopted during the study

3.3. Data collection

30 villages from eight districts of Malwa region of Punjab were selected for study. These selected villages are distributed among eight districts of Faridkot, Muktsar, Bathinda, Mansa, Sangrur, Barnala, Moga and Firozpur.

Half of the villages were chosen from what is known as the "high risk" zone of Punjab, areas which have reported higher incidence of cancer mortality. These 15 villages of "high risk" category were selected from the four districts of Faridkot, Muktsar, Bathinda and Mansa districts. The other 15 villages were selected from the "low risk" zone which is geographically contiguous with the "high risk" zone to enable a better spatial distribution and analysis of the problem. Hence, these 15 villages came from the districts of Sangrur, Barnala, Moga and Firozpur.

All these villages were selected on the basis of random sampling. For the purpose of selecting villages, two datasets were created – the first comprising of villages in the "high risk" category and the other comprising of villages in the "low risk" category. The random number generator function, RAND function [=RAND ( )] in Microsoft Office Excel 2003 was used to identify villages.

Field work began immediately after the identification of 30 villages in the study area. The years (2002-06), being the immediate five preceding years from the date of our study were selected for analysis, since they had the minimum time lag since the occurrence of cancer deaths. The year 2007 was omitted since the year was still mid way during the time of data collection.
The months of September-October 2007 were chosen for data collection.

Data collection involved three aspects; information on cancer deaths, collection of both soil and water samples and obtaining information on cropping patterns.

The primary data collection involved obtaining information on cancer deaths during the years 2002-06 in the villages in the study area. A bilingual form, in English and Punjabi, the vernacular prevalent in the region was created, for collecting information regarding the deaths.. The form included information regarding age, gender and occupation of the deceased (See Annexure 1: Data Collection Form). While data regarding cancer deaths was collected using this form, assistance was sought from officials posted at village, block and district level. The practice of maintaining a village deaths register by the village watchman (*chowkidar*), which began in Punjab in the year 1868 (Dyson 2001), proved to be exceptionally handy, since every death occurring in the village, natural or otherwise is recorded in this register (See Annexure 2: Village Deaths Register).

Soil and water samples were also collected from the 30 villages in the study area. Water was collected from hand pumps in all villages. Experts recommend that the water pump had to be running for at least half and hour to prevent any residuals from contaminating the sample. However, since all the hand pumps from which water samples were collected were found to be running, this problem was not encountered. Five samples of equal quantity were collected from each village and mixed together to prepare a composite sample.
Soil samples were collected from agricultural fields in all the villages. Care was taken to ensure that no soil sample was collected from near roadsides or near a water channel. Five samples of soil were collected from each village and mixed thoroughly to form a composite sample. An auger was used for collecting soil samples from all locations. Pesticide residues in both water and soil samples were analysed.

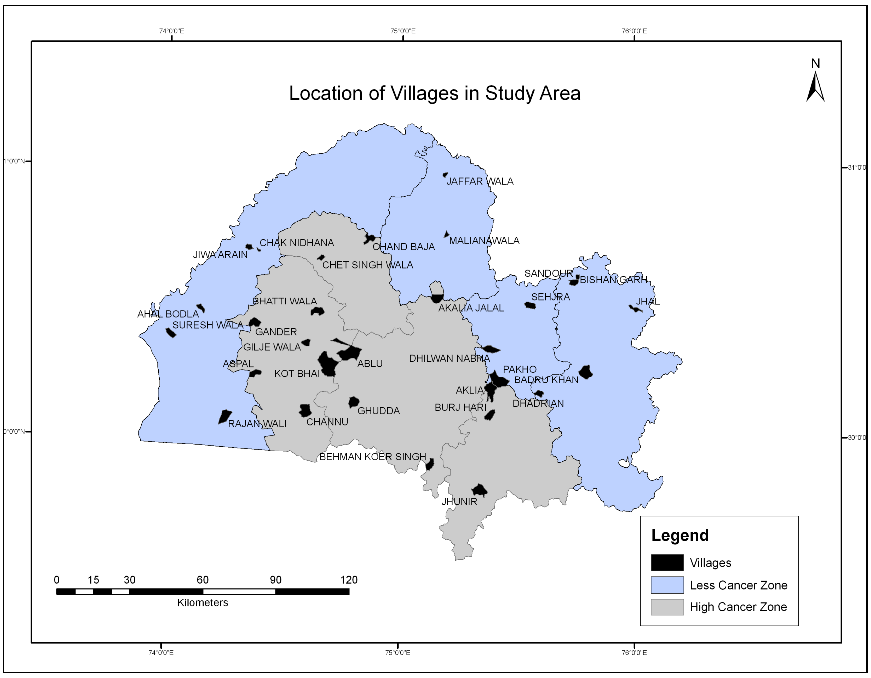


Figure 8: Location of all 30 selected villages in the study area

Punjab follows the two crop cycle, alternating between *kharif* and *rabi* crops.
The word *kharif*, means autumn in Arabic. Rice and cotton are the two major kharif crops that mature during summer and are harvested during autumn. At the time of field work, they had either been harvested or were being harvested. On the other hand, wheat is the predominant *rabi* of winter crop. *Rabi*, means spring in Arabic and the rabi crop is harvested during spring time, though it matures during winter. Details' regarding crop coverage for the study period in the selected villages was obtained from the department of planning, government of Punjab. Maps on crop coverage, as well as canal network, drainage network, soil type and village layers were obtained from the Remote Sensing Centre, Punjab Agricultural University, Ludhiana.
The cropping pattern available with the government details 15 different types of crops, apart from area under forest or fodder, in each village (See Annexure 3). Cancer is a disease that develops over a period of time, having a lag time of 20-30 years (Sullivan 1991). Since this years' crop would not have a bearing on cancer incidence in that village, average values of acreage of each crops in all the 30 villages for the period under study for the study period was calculated.

To obtain crop exposure of both cotton and paddy (rice), the per capita exposure was calcualated for each crop. Exposure levels for both crops were assumed to be similar, and a crop specific human exposure model was ignored due to lack of crop production data as well as absence of information on crop varieties sown during previous years. Though crop specific human exposure assessment (Kulhanek, 2004) is more accurate, the per capita method was adopted for analysis. As an alternative, the proportion of each crop in the total sown area in the village was also used for the analysis versus cancer mortality.

Cancer mortality was calculated for each village, for every year and for each gender and occupation, according to the two risk areas. For the purpose of classification of occupation, apart from the two major occupations of agriculture and homemakers, the remaining were classified into a joint third class and was titled “others”. This class included the employed (whether in government or private jobs), self employed (shopkeepers etc) and unemployed (e.g. students). Mortality was calculated for each year using the last available census data of 2001 and adjusting it for the annual population growth rate.
The mortality rate for each year, gender and occupational type was required for investigating the possible correlation of each type with cancer mortality.

3.4. Statistical Methods

Cancer mortality rates for each year in the study period were posited against demographic parameters to ascertain whether there is a correlation between the two. Three parameters were analysed -- gender, occupation and time (annual). Gender was divided into two classes -- male and female, while three occupational classes of agriculture, homemaker and others were selected. For temporal aspects, each of the five years under consideration (2002-06) was taken as one unit.
For these parameters (gender, occupation and time), repeated measures design was followed for ascertaining relations between cancer mortality and demographic parameters.
Repeated measures design is defined as one in which “more than one measurement is taken of at least one given variable for each subject” (Minke, 1997). It allows “testing of many research hypotheses, such as hypotheses that compare the same subjects under several different treatments, or those that follow performance over time” (Ibid).
The analysis of repeated measures involves data which consists of multiple measurements on experimental units. In this study, the experimental units, called subjects are the people who died of cancer, and longitudinal data is collected on how

measurements vary on a subject over time. Since data for a period of five years was collected, the procedure was akin to “repeated measures analyses”.
SAS (Statistical Analysis Software) system, a statistical package for business intelligence and predictive analysis was used for ascertaining analysis of variance. The SAS procedures of ANOVA, GLM and Mixed procedure were adopted.
Repeated measures ANOVA is used since all members of the random sample are measured under a number of different conditions. Using standard ANOVA is not ideal since the measurement of dependent variable is repeated.
GLM procedure of SAS is defined as a “general linear model”, and should not be confused with the usual “generalized linear model’. GLM procedure of SAS can fit regression, analysis of variance and analysis of covariance models by un-weighted or weighted least squares (Schabenberger, 2002). It can be used to compute the usual analysis of the random effects model that involves the computation of mean squares, expected mean squares and statistics to test hypothesis about the importance of individual variance components (Littell 2006).
The GLM procedure was useful in differentiating between various occupations while conducting correlation analysis.
The mixed procedure, which “contains both fixed and random effects” (Littell 2006), on the other hand is designed for models more general than the generalized linear models. The mixed procedure performs maximum likelihood interference in models with multiple random effects (mixed models) and nonlinear mean function. In the mixed analysis, all data can be used instead of ignoring subjects with missing data. It was beneficial for investigating the interaction of various fixed effects, like gender and time.
Cancer mortality was contrasted with the crop exposure pattern in the study area, particularly the winter crops of cotton and rice. Since the summer crop of wheat remains stable, the only variation that takes place is between rice and cotton. Hence a correlation analysis was performed on cancer mortality with both rice and cotton individually. A “paired t test” was also conducted on both rice and cotton to ascertain differences between the two. Regression analysis was performed on cancer mortality and crop exposure of two crops.
Cancer mortality was posited with the pesticide residues value, both for water and soil. A correlation analysis was performed on cancer mortality and both soil and water pesticide residues. A regression analysis was performed for cancer mortality vis-à-vis pesticide residues in both water and soil.

4. Results

4.1. Correlation of cancer mortality with demograpic parameters

Three separate procedures were run for ascertaining the correlation of cancer mortality with demographic parameters, namely ANOVA, Mixed procedure and GLM using SAS software.

ANOVA PROCEDURE

The ANOVA procedure resulted in F value for the model being 21.28 with a p value < .0001. (For statistical terms used in the study, refer to Annexure 10). Risk areas were divided into two classes, "high risk" and "low risk", while gender too had two classes ("male" and "female"). Occupation was divided into three classes, "agriculture", "homemaker" and "others".

The ANOVA results for gender yielded F value of 6.25 with a p value of 0.0126. Similarly the procedure resulted in F value of 17.41 for occupation, with a p value of <.001. For risk areas, the F value was 7.97 with a p value of 0.0049.

Table 6: ANOVA results for cancer mortality and demographic parameters

The ANOVA Procedure

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	28.351	2.577	21.28	<.0001
Error	88	107.531	0.121		
Corrected Total	899	135.882			

R Square	Coeff Var	Root MSE	Mortality Mean
0.209	235.196	0.348	0.148

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Risk	1	0.966	0.966	7.97	0.0049
Gender	1	0.757	0.757	6.25	0.0126
Occupation	2	4.216	2.108	17.41	<.0001
Gender*occupation	2	21.053	10.526	86.93	<.0001

GLM (GENERAL LINEAR MODEL):

The GLM procedure in SAS, resulted in F value of 10.73 for the model, with a p value <.0001. For risk areas, the F value was 6.73 with a p value of 0.0096. Gender yielded in F value of 5.28 and a p value of 0.0218, while occupation had a F value of 14.70 and p value of <0.0001. Since repeated measures were made for a period of five years (2002-06) in the study area, an analysis of temporal dimension was also carried out. The temporal variation ("year" factor) resulted in F value of 12.25 and p value of 0.0005.

Among the "occupation" class, Class 2 (homemaker) resulted in a t-value of 5.14, with a p value of <.0001. This was followed by Class 1 (agriculture) with a t-value of 1.07.

Table 7: General Linear Model for repeated measures design

The GLM Procedure

Source	DF	Sum of squares	Mean Square	F Value	Pr > F
Model	5	7.695	1.539	10.73	< .0001
Error	894	128.187	0.143		
Corrected Total	899	135.882			

R Square	Coeff Var	Root MSE	Mortality Mean
0.057	255.930	0.379	0.148

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Risk	1	0.966	0.966	6.73	0.0096
Gender	1	0.757	0.757	5.28	0.0218
Occupation	2	4.216	2.108	14.70	<.0001
Year	1	1.757	1.757	12.25	0.0005

Parameters		Estimate		Standard Error	t Value	Pr > | t |
Occupation	1	0.033	B	0.031	1.07	0.2837
Occupation	2	0.159	B	0.031	5.14	<.0001
Occupation	3	0	B	.	.	.
Year		0.031		0.009	3.50	0.0005

MIXED PROCEDURE:

The mixed procedure in SAS, which is beneficial for analysing two or more variance components, resulted in the combination of year, gender and occupation yielding a significant F value of 7.32, with a p value of 0.0007. Since repeated measures design is followed, the variance components and their interplay were effectively analyzed by the mixed model. Year*gender and year*occupation yielded low F values of 0.06 and 0.09 respectively, though analysis of year*gender*occupation had a higher F value.

Table 8: Mixed procedure for repeated measures

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Vill (risk*gender*occu)		0.012
Residual	Vill(risk*gend*occu)	0.107

Type 3 Tests of Fixed Effects

Effect	Num DF	F Value	Pr > F
Gender	1	1.29	0.2571
Occupation	2	0.98	0.3760
Gender*occupation	2	0.54	0.5851
Year*risk	1	0.06	0.8008
Year*gender	1	0.09	0.7632
Year*occupation	2	0.24	0.7842
Year*gender*occupation	2	7.32	0.0007

4.2. Correlation of cancer mortality with crops

Correlation analysis was performed using SPSS software on both rice and cotton exposure with cancer mortality. Results with both “per capita” crop exposure and “proportion” of crop in total sown area were similar. The human exposure model was preferred since the issue under investigation is human mortality.
The results of the correlation of cancer mortality with the cotton crop revealed a correlation value of 0.343 as contrasted to the correlation value of -0.355 for the rice crop.

Table 9: Correlation analysis of cancer mortality and cotton crop

	Mean	Std.Deviation	N
Mortality	.434	.231	30
Cotton exposure	.117	.107	28

		Mortality	Cotton exposure
Mortality	Pearson Correlation	1	.343
	Sig. (2-tailed)		.074
	N	30	28
Cotton exposure	Pearson Correlation	.343	1
	Sig. (2-tailed)	.074	
	N	28	28

Table 10: Correlation analysis of cancer mortality and rice crop

	Mean	Std. Deviation	N
mortality	.434	.231	30
Rice exposure	.176	.101	28

		mortality	Rice exposure
mortality	Pearson Correlation	1	-.355
	Sig. (2-tailed)		.064
	N	30	28
Rice exposure	Pearson Correlation	-.355	1
	Sig. (2-tailed)	.064	
	N	28	28

The Paired Sample T Test results yielded a t-value of 7.372 for “mortality-cotton exposure”, while it resulted in a t-value of 4.610 for “mortality-cotton exposure”.

Table 11: Paired T test

Paired Sample Correlations

		N	Correlation	Sig.
Pair 1	mortality & Cotton exposure	28	.343	.074
Pair 2	mortality & Rice exposure	28	-.355	.064

Paired Samples Test

		Paired Differences					**t**	**df**	**Sig. (2-tailed)**
		Mean	**Std. Deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**		**Mean**	**Std. Deviation**	**Std. Error Mean**
		Lower	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**
Pair 1	**mortality - Cotton exposure**	**.308**	**.221**	**.0418**	**.222**	**.394**	**7.372**	**27**	**.000**
Pair 2	**mortality - Rice exposure**	**.248**	**.285**	**.0539**	**.138**	**.359**	**4.610**	**27**	**.000**

Regression analysis for cotton resulted in an ‘R Square’ value of 0.117, compared to the value of 0.126 for rice crop. The F value for cotton was 3.457 compared to 3.739 for rice.

Table 12: Regression analysis for cancer mortality with cotton crop

Model	**R**	**R Square**	**Adjusted R Square**	**Std Error of the Estimate**	**Change Statistics**				
					R Square Change	**F Change**	**df1**	**df2**	**Sig. F Change**
1	0.343	.117	.083	.224	.117	3.457	1	26	0.074

Table 13: Regression analysis for cancer mortality and rice crop

Model	**R**	**R Square**	**Adjusted R Square**	**Std Error of the Estimate**	**Change Statistics**				
					R Square Change	**F Change**	**df1**	**df2**	**Sig. F Change**
1	0.355	.126	.092	.223	.126	3.739	1	26	0.064

4.3. Correlation of cancer mortality with pesticide residues

WATER SAMPLES: Correlation between cancer mortality and pesticide residues found in water samples yielded in a correlation value of 0.583.
The regression analysis of cancer mortality and pesticide residues in water gave a F value of 14.415 with an ‘R’ value of 0.583 and ‘R Square’ of 0.340.

Table 14: Correlation of cancer mortality and pesticide residues in water

Descriptive Statistics

	Mean	Std Deviation	N
Mortality	.420	.244	30
Residue	0.024	0.018	30

Correlations

		Mortality	Residue
Mortality	Pearson Correlation	1	.583**
	Sig. (2-tailed)		.001
	Sum of Squares and Cross products	1.729	0.075
	Covariance	.060	.003
	N	30	30
Residue	Pearson Correlation	.583**	1
	Sig.(2-tailed)	.001	
	Sum of Squares and Cross products	.075	.010
	Covariance	.003	0
	N	30	30

** Correlation is significant at the 0.01 level (2-tailed).

Table 15: Regression analysis for cancer mortality and pesticide residues in water

Model	**R**	**R Square**	**Adjusted R Square**	**Std Error of the Estimate**	**Change Statistics**				
					R Square Change	**F Change**	**df1**	**df2**	**Sig. F Change**
1	0.583	.340	.316	.202	.340	14.415	1	28	0.001

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	.588	1	.588	14.415	0.001
	Residual	1.141	28	0.041		
	Total	1.729	29			

SOIL SAMPLES: Correlation between cancer mortality and pesticide residues found in water samples yielded a correlation value of 0.531. The regression analysis of cancer mortality and pesticide residues in water yielded a F value of 10.976 with an ‘R’ value of 0.531 and ‘R Square’ of 0.282.

Table 16: Correlation of cancer mortality and pesticide residues in soil

Descriptive Statistics

	Mean	Std Deviation	N
Mortality	.420	.244	30
Soil Residue	0.841	.319	30

Correlations

		Mortality	Residue
Mortality	Pearson Correlation	1	.531**
	Sig. (2-tailed)		.003
	Sum of Squares and Cross products	1.729	1.200
	Covariance	.060	.041
	N	30	30
Residue	Pearson Correlation	.531**	1
	Sig.(2-tailed)	.003	
	Sum of Squares and Cross products	1.200	2.960
	Covariance	.041	.102
	N	30	30

** Correlation is significant at the 0.01 level (2-tailed).

Table 17: Regression analysis for cancer mortality and pesticide residues in soil

Model	**R**	**R Square**	**Adjusted R Square**	**Std Error of the Estimate**	**Change Statistics**				
					R Square Change	**F Change**	**df1**	**df2**	**Sig. F Change**
1	0.531	.282	.256	.211	.282	10.976	1	28	0.003

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	.487	1	.487	10.976	0.003
	Residual	1.242	28	0.044		
	Total	1.729	29			

5. Discussion

CANCER MORTALITY AND DEMOGRAPHIC PARAMETERS

Both gender and occupation have a significant correlation with cancer mortality rates in the study area.

5.1. Gender variation

For analysing the difference in male and female mortality, an analysis of variance is performed by adopting the repeated measures ANOVA procedure.
The F test, which assesses the statistical comparison between variations in two data sets, clearly shows a strong variation with gender.
The ANOVA procedure yielded F value of 21.28 for the model, and a p value of <.0001indicating a high degree of distance between the two genders, male and female. Within the model, the F value was 6.25 with a p value of 0.0126 for gender analysis, implying a high level of variance between the two genders.

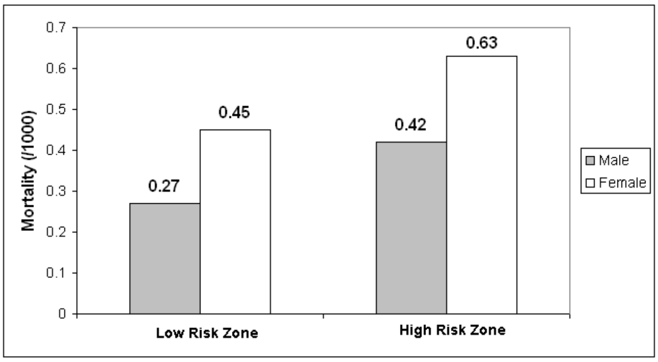


Figure 9: Mortality variation among males and females in high and low risk zone

Apart from variance in gender mortality, it is evident that female mortality is greater in both high risk and low risk areas, and this phenomenon is not concentrated in one zone alone.
Hence the first hypothesis (**H1$_0$**) that there is “no” variance between the two genders is rejected, and the alternative hypothesis (**H1$_1$**) that there is “a” variance between the two genders is accepted.

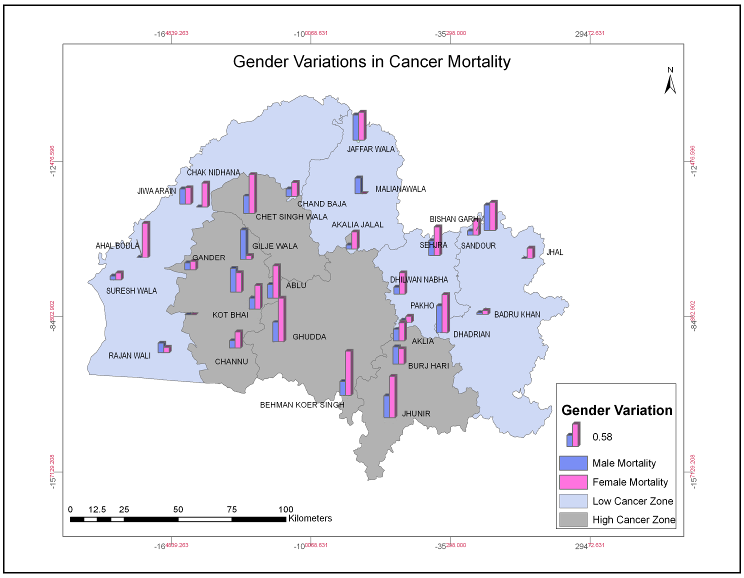


Figure 10: Variation of gender with mortality

SIGNIFICANCE OF RESULT:

Contrary to global trends, in the study area, more females are dying of cancer than males.

According to global health report "close to one third more men die of cancer than women" (WHO, 2003). Global estimates of mortality (Shibuya et al 2003) reveal that in all regions "mortality was much higher in males while incidence were almost the same due to relatively good prognosis of breast and cervix cancers compared to common cancers among males such as liver and lung cancers". This is true of the WHO subregion South East Asia Region which includes India as well.

Table 18: Cancer mortality in World and South Asia Region

Gender	Male	Female
Estimated deaths* global	3901.9	3132
Estimated deaths SearD# subregion	450.1	425.0

(*)Deaths are in thousand

(#)SearD subregion includes Maldives, India, Bangladesh, Bhutan, Myanmar, Nepal, and Democratic People's Republic of Korea

(Adapted from Shibuya, 2003)

The result is significant when contrasted to the global trend. It appears shocking since females face an adverse sex ratio not only in all the villages in the study area, but also in India in general (Sen 2003). An adverse sex ratio and the spectre of "missing females" should imply that fewer females should be dying of cancer; if all other variables are assumed to be same. The causes of high mortality in females needs to be ascertained and requires further investigations.

However, higher mortality of females in Punjab may not be restricted to cancer alone. A study on coronary heart disease in village Pohir in Ludhiana district in Punjab, close to the study area, indicates a similar trend. The study (Wander et al, 1994) revealed that the prevalence of coronary heart disease among females (37.3/1000) was higher than in males (25.6/1000). This study was however restricted to one village of Punjab only.

A further analysis of the data reveals that females die of cancer at slightly younger age than males. In case of cancer, the average age of death of females is 50.41 years compared to males where it is 51.64. In Punjab, life expectancy of males is 68.4 years, while for females it is 71.4 years, according to the census figures of 2001.

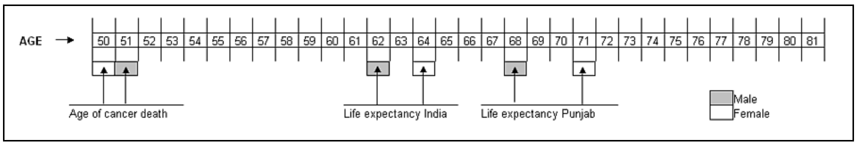


Figure 11: Comparison of life expectancy with age of cancer death

POSSIBLE EXPLANATIONS:

While the data does not reveal any confirmative evidence on the reasons for greater cancer mortality among females, some possible explanations are offered for this disturbing trend:

(1) Non Smoking Culture: Globally, more males die of cancer than females and this is widely attributed to smoking habits. Lung cancer is the largest killer among all types of cancer, estimated to be caused by smoking in 87 per cent of the cases (NCI, 2007). However lung cancer is relatively less prevalent in Punjab. In the dataset, lung cancer accounts for only 6.9 per cent of cancer deaths among males in the study area, ranking much lower than stomach cancer, leukaemia, and cancer of the oesophagus.

Table 19: Cancer Mortality according to Type (males)

Cancer type	% occurrence
Lung	6.9
Stomach	11
Leukaemia	20
Oesophagus	28.8

This trend is similar to the earlier study conducted by the Punjab Pollution Control Board (2005), where lung cancer was missing from the top five types of cancer.

A major reason for the lack of lung cancer could be found in the socio-religious interplay in the state of Punjab.
The religious sanction against smoking among the adherents of Sikh religion could be a reason for relative low levels of lung cancer.
A fundamental doctrine of Sikhism is non-use of tobacco and non-smoking, which is prescribed in the Sikh "Code of Conduct" (SGPC, 2006). Punjab is the only geographical location in the world where adherents of Sikh religion are in a majority, accounting for 59.9 per cent of the population (Singh, 2004).
This has led to Punjab having lowest rate of tobacco use among North Indian states (Jindal et al. 2005). A cross sectional household survey across 26 states in India, which found a median prevalence of male smoking at 30.6 per cent, confirmed that Punjab has the lowest male smoking rate in the country rated at 13.9 % (Rani 2003). This could imply that lesser males are dying of cancer, rather than more females dying of cancer.
(2) Literacy Rates: There could be a relationship between differential literacy rates between males (75.2 %) and females (63.4 %) and mortality, since cancer awareness and literacy levels should have a relationship.
(3) Gender Bias: Relationships between masculinity and its ecological context with psychological well being have been documented in Punjab (Yim and Mahalingam 2006), and this could account for a bias against females. The nutritional status of females has been found wanting in Punjab (Sidhu et al. 2005, Vartika Saxena et al. 2000) and this could further be a cause of greater mortality.
(4) Kitchen Smoke: Kitchen smoke could be an important contributing factor leading to greater cancer mortality among women. Behera (2006) identifies biomass fuel exposure as a principal risk factor in cancer among females.
(5) Lack of medical facilities: The entire study area is bereft of a cancer hospitaland the nearest speciality hospitals are located in Ludhiana (164 kms from Bathinda city, the heart of Malwa region) or at Chandigarh (210 kms from Bathinda city). In many cases, people travel to neighbouring state of Rajasthan.
Given the fact that females suffer more from breast and uterine cancer, lack of female medical professionals and absence of cancer hospital may compound the situation for them. Gender barriers to female medical health care have been reported in other parts of South Asia (Mumtaz et al. 2003).
(6) Incidence and Mortality: The difference between cancer incidence and cancer mortality could be a factor. Although evaluation of mortality from morbidity and vice-versa has been attempted (Lundberg 1973, Damiani 1983), the lack of region specific survival data is a major limitation for such a model (Mathers et al, 2001).

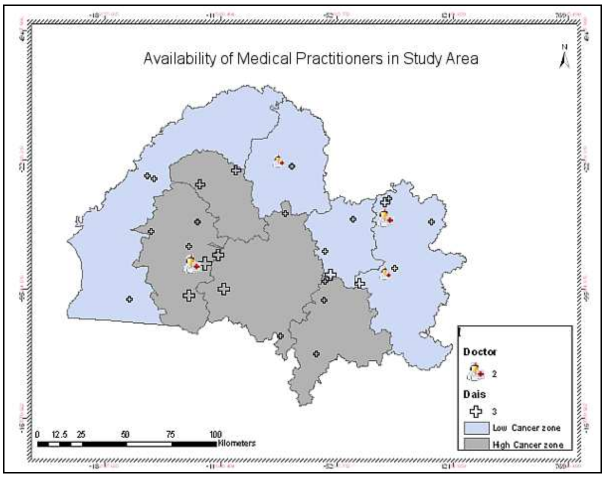


Figure 12: Availability of doctors and midwives (dais) in villages in study area. Only 4 of 30 villages have a qualified doctor in the village.

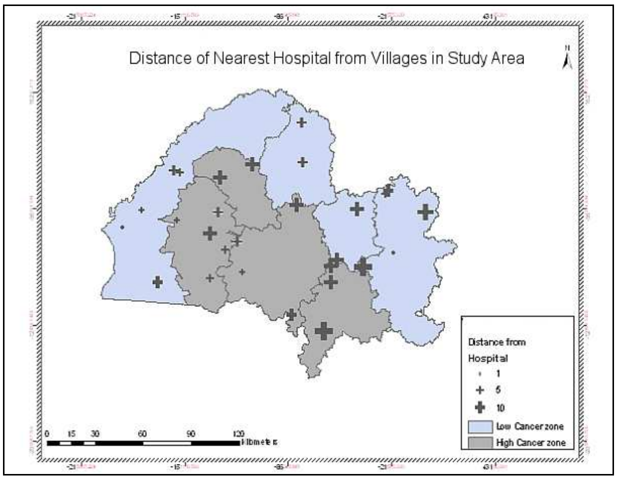


Figure 13: Availability of medical facilities in the villages in study area. For 3 of the 30 villages, the nearest hospital is over 20 kilometres away

Only 4 of the 30 villages had a qualified doctor (figure 12). None of them had a Primary Health Centre, though half of them had a health sub centre. For three of the villages, the nearest hospital (25 bedded general hospital) is more than 20 kilometres away (figure 13).

5.2. Occupational variation

There is a strong correlation between cancer mortality and occupation. The correlation is stronger than the correlation between cancer mortality and gender. The F value derived in the ANOVA procedure of 17.41 has a p value of less than 0.0001 indicating a strong correlation between occupation and cancer mortality. Also it indicates a greater statistically predictive capability in the regression framework.

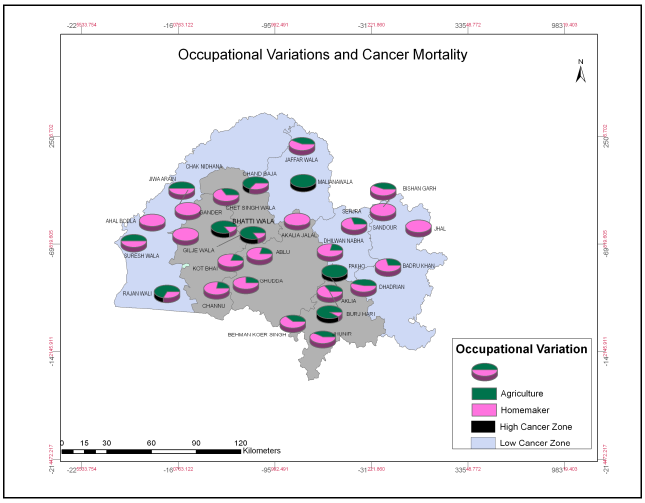


Figure 14: Occupational variation and cancer mortality

There is a certain intra occupational variation as well, with homemakers being at the greatest risk followed by those following agriculture and others respectively.

In the GLM procedure, the category 1 in Occupation (farmers) results in a t-value of 1.07 and a p value of 0.2837. However, category 2 of homemakers has a t-value of 5.14 and p value of <0.0001. This leads to conclusion that homemakers are more prone to cancer deaths than other occupations.

Hence the hypothesis (**$H2_0$**) that there is "no" correlation between cancer mortality and occupation is rejected, and the alternative hypothesis (**$H2_1$**) that there is "a" correlation between cancer mortality and occupation is accepted.

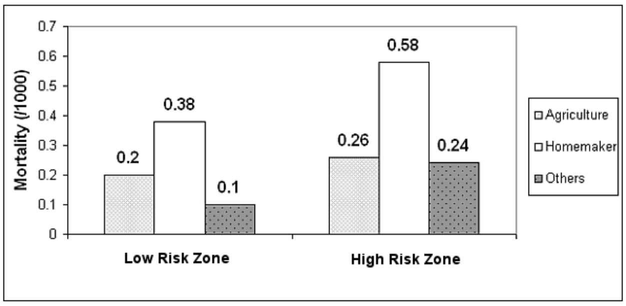


Figure 15: Variation of mortality with occupation (by risk areas)

The issue of correlation between cancer mortality and those involved in agriculture has been contentious. Studies have indicated that agriculturists have a greater risk than the general population for cancers of prostate, skin, brain, skin, myeloma, leukaemia, Hodgkin's disease, and non Hodgkin's myeloma (Blair 1992; Pearce 1990; Blair 1991; Blair 1995).

On the other hand, farmers have often been found to be less prone to certain other types of cancer (Blair 1985; Blair 1982; Lee 2002) due to healthy working habits, less exposure to pollution and lesser smoking. Farmers have been found to have lower risk in "smoking-related cancers, cancers associated with an urbanized way of life" (Pukkala 1997).

While lesser smoking in Punjab could be one of the reasons for lesser death among farmers (predominantly male), the correlation of homemakers and cancer mortality is both surprising and astonishing.

GENDER-OCCUPATION INTERPLAY:

Gender and occupation are closely related in Punjab. In the ANOVA procedure, the F value of gender*occupation was a whopping 86.93 with a p value less than 0.0001. The fact that occupation is often a corollary of gender is reflected in the study area as well.

The mixed procedure in SAS indicates that the combination of year, gender and occupation results in F value of 7.32, with a p value of 0.0007. This is significant since the F value indicates that interaction of year*gender*occupation as a random effect also accounts for the correlation. However more significant is the impact of variables, gender and occupation on mortality. While gender has an F value of 6.25 and p value of 0.0126, and occupation has an F value of 17.41 and p value of <0.0001, the combination of both gender and occupation results in an F value of 86.93 with p value of <0.0001.

Occupation is closely related to gender in South Asia, more particularly so in India and Punjab.
The participation rate of females in agriculture in Punjab is only 4.28 percent (Dhillon 1995), which is way behind southern state of Andhra Pradesh (95 %) and Tamil Nadu (24 %) as well as the central state of Maharashtra (29 %). However the role of females in other farm activities is considerably higher.
In our study area, an abnormally high percentage of females are homemakers. Though it is possible that they contribute towards agriculture activities, their dominant activity is confined to the household and hence they are classified as homemakers. 11 per cent of the female sample were categorised as agriculturists, compared to 57.7 per cent males.
Interestingly there are no male homemakers in the entire sample.

Table 20: Classification of occupation with gender (%)

Gender	Agriculture	Homemaker	Others
Male	57.7	0	42.3
Female	11	83.5	5.5

Table 20 clearly indicates that gender and profession, particularly that of homemakers are intricately linked. There are no males performing the job of homemaker in the sample, while whopping 83.5 per cent females are homemakers. It implies that the combination of gender and occupation is more significant in ascertaining mortality rates.

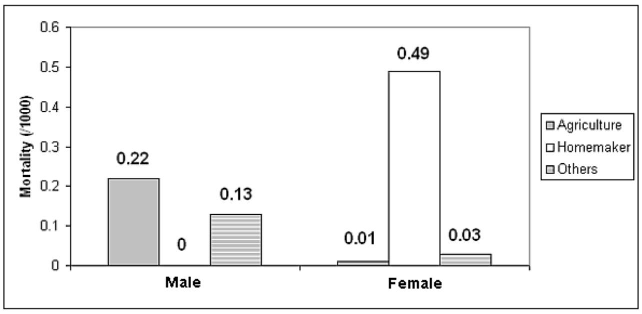


Figure 16: Variation of mortality rate with occupation (by gender)

5.3. Temporal dimension in cancer morality rates

Cancer mortality is increasing every year in the study area. The temporal dimension is an important factor in the study, since it indicates that the problem is acquiring serious dimensions and mortality is showing an uptrend.

In the GLM procedure in SAS, the F value for the variable `year' was 12.25 with a p value of less than 0.0005. This indicates that cancer mortality has been showing an increase during the five year period under study. Barring the year 2004, which showed a dip in mortality rates, each year has shown a progressive increase. Plotting the mortality rate for five years in each of the 30 villages also suggests a rise, but the cumulative plot (Figure 17) provides a very definitive result. The annual variation for various combinations of gender and occupation in both high risk and low risk zones is also plotted (Figure 19).

The F value for annual variation is much higher than the values for gender. The high value assumes importance, since there is always a “lag time” for cancer to develop. This could be a pointer of things which could follow in subsequent years.

Hence the hypothesis (**$H3_0$**) that there is “no” correlation between cancer mortality and time is rejected and the alternative hypothesis (**$H3_1$**) that there is “a” correlation between cancer mortality and time is accepted.

This is in consonance with both global and Indian statistics. World Cancer Report (Stewart 2003) estimates an increase in global cancer incidence and mortality, with incidence increasing by 50 % by the year 2020. This is despite a decrease in cancer mortality in a few developed countries like the United States of America (ACS 2007) and in parts of Western Europe (Coleman, 1993).

Studies have shown that incidence and mortality of certain types of cancer is increasing; while in other types it is declining (Hoel 1992). However, this study concentrates only on overall cancer mortality, and hence individual cancer types are not analysed for their relative increase or decline.

Estimates that the share of cancer in overall mortality (Figure 2) would increase are clearly reflected in Punjab.

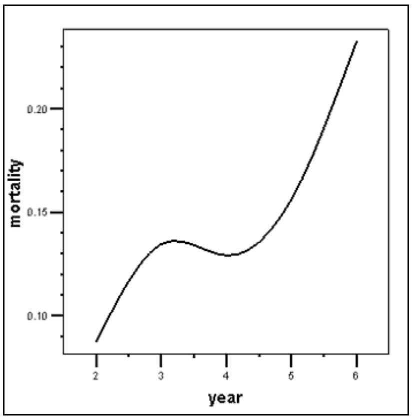


Figure 17: Temporal variation of cancer mortality rates across study area

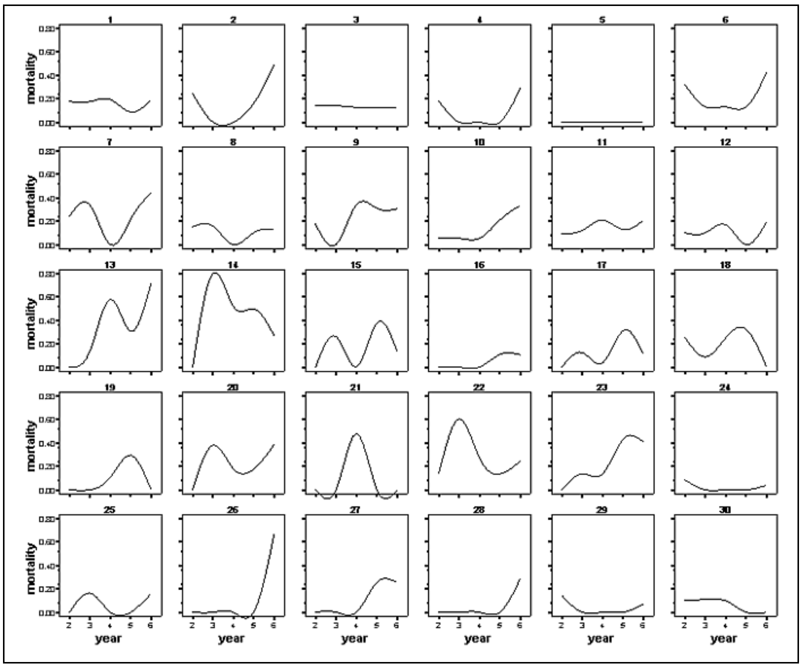
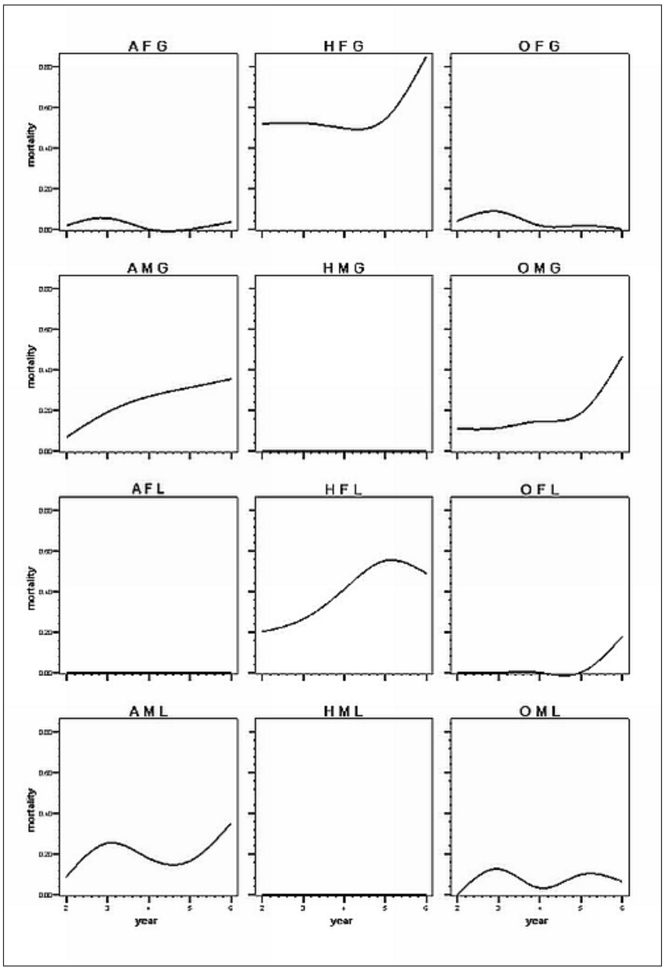


Figure 18: Annual variation of mortality across each of 30 villages



Legend
A – Agriculture H – Homemaker O - Others
F – Female M - Male
L - Low Risk Area G – Greater/High Risk Area

Figure 19: Temporal variation of cancer mortality across a combination of factors:risk areas, gender and occupation

5.4. Risk Zones

Cancer mortality is found to be higher in “high risk” districts of Muktsar, Faridkot, Bathinda and Mansa as compared to “low risk” districts of Sangrur, Barnala, Moga and Firozpur. The SAS ANOVA procedure results in F value of 7.97 for Risk with a p value of 0.0049.

Hence, the segmentation of “high risk” and “low risk” districts is adequate and proper. High Risk areas show a greater incidence of cancer mortality (0.49/1000) as compared to low risk area (0.35/1000).

The media description of “high risk” districts as “cancer belt” of Punjab however needs further investigation, since incidence and mortality in the other parts of the state are not available for comparative analysis.

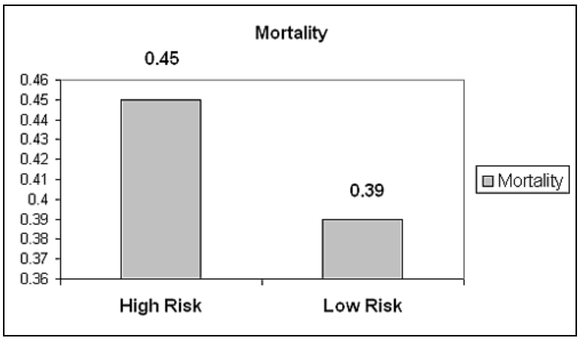


Figure 20: Comparison in mortality rates (/1000) in high and low risk areas

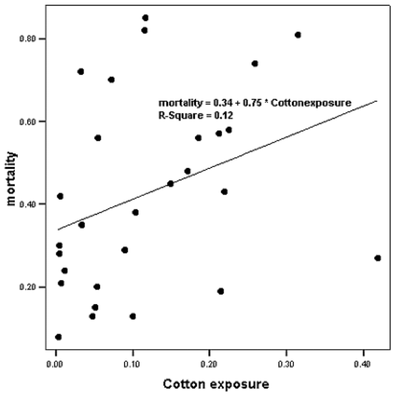
5.5. Cancer mortality and crop patterns

Cancer mortality is linked to the cropping pattern in the state, though the correlation is of medium significance. Correlation between per capita cotton crop exposure and cancer mortality yields a value of 0.343. While this is not a very high value, a pattern emerges when it is contrasted with the rice crop. The correlation for the paddy (rice) crop results in a value of (-) 0.355. Hence it indicates that a village where cotton is grown extensively has far more chances of cancer. On the other hand, a village with rice crop has a lesser probability of cancer.

The Paired Sample T Test conducted on both cotton and rice also results is a t-value of 7.372 for “mortality-cotton exposure”, while it resulted in a t-value of 4.610 for “mortality-cotton exposure”, testifying that chances of cancer mortality are greater wit cotton crops as compared to rice or paddy.

The regression lines as shown in Figures 20 and 21 for cotton and rice respectively repeats the same story. Regression analysis for rice yields an ‘R Square’ value of

0.13, compared to the value of 0.12 for cotton crop. The F value for rice is 3.739 compared to 3.457 for cotton. The values are of medium significance. Hence though it cannot be asserted that cancer mortality and cropping patterns exhibit a very strong correlation, it does point towards a relationship when both cotton and rice crops are contrasted against each other.



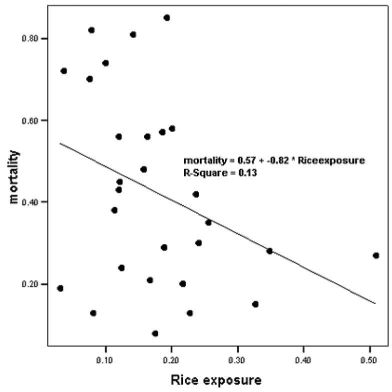


Figure 21: Regression pattern between cancer mortality and cotton exposure (left)
Figure 22: Regression pattern between cancer mortality and rice exposure (right)

Hence the research hypothesis (**H4**$_0$) that there is "no" correlation between cancer mortality and cropping patterns is rejected and the alternative hypothesis (**H4**$_1$) that there "is" a correlation between cancer mortality and cropping patterns is accepted.

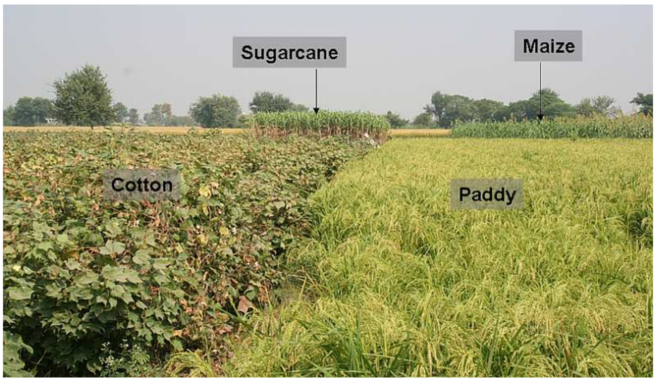


Figure 23: Crop pattern observed during fieldwork.
Cropping pattern can be very complex with the same field having 4 types of crops. The photograph, clicked on October 19, 2007 during fieldwork reveals that while cotton is about to be plucked, the paddy crop is yet to mature. Sugarcane is not ready, and maize has been sown.

COTTON CROP AND PESTICIDE LINKAGE:

It has been reported that in cotton areas in India, during an average spraying session, “a farmer is directly exposed to pesticides for three to four hours at a time through leaking spray equipment, dripping plants and wind drift” (Mancini 2005).

Since cotton crop requires more pesticide applications than paddy, inhabitants in the cotton growing area have a greater risk of exposure to pesticide than those living in non cotton areas. In a study in Andhra Pradesh, 50 female cotton growers reported 323 events ranging from symptoms of mild poisoning to hospitalisation in just one cotton season (ibid).

The linkage between cropping pattern and cancer could be traced to the degree of pesticide usage for each crop.

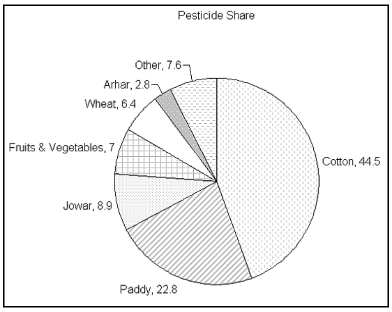


Figure 24: Crop wise consumption of pesticides in India reveals that the cotton crop is the single largest pesticide consumer. (Figures next to crop indicate percentage consumption). **(Adapted from ICRA Industry Sector Analysis Insecticides/Pesticides, 2005)**

Cotton, paddy, vegetable and fruits are responsible for 80 % of the pesticide consumption in India, with white cotton alone accounting for 44.5 % followed by rice (22.8 %). However, acreage under cotton crop is almost one fifth of the area under paddy (five year average) (CACP, 2006). Cotton covers a mere 5 per cent of the land under crops in the country (CACP, 2006), and yet it consumes almost half of India’s pesticide.

5.6. Cancer mortality and pesticide residues

Cancer mortality tends to increase with increase in pesticide residues both in water and soil. The correlation with pesticide residues in water (0.583) is slightly stronger than that with soil (0.531). However both of them are significantly correlated with cancer mortality.

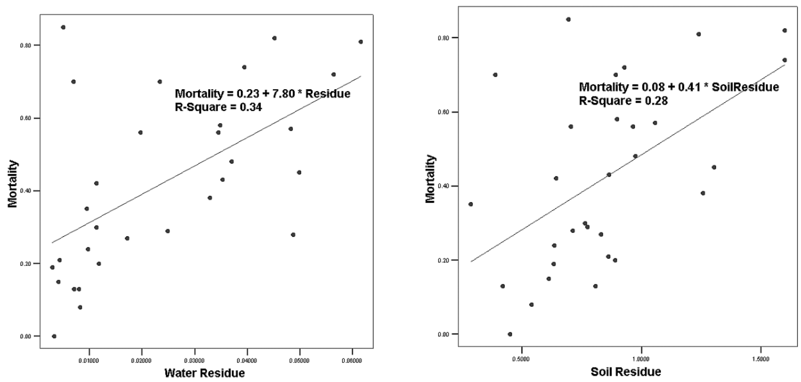


Figure 25: Variation of cancer mortality with pesticide residues in water (left) and soil (right). Residues are measured in parts per million (ppm), while mortality is per thousand.

The correlation of pesticide residues with cancer mortality is evident from the Pearson correlation values in both water and soil. Regression analysis too reveals the same pattern. In case of pesticide residues in water, the ‘R Square’ value is 0.340 and F value is 14.415, both of which indicate a good correlation. In the case of pesticide residues in soil, ‘R Square’ value is 0.282, while the F value is 10.976. This too suggests a good correlation, albeit it is marginally less than the correlation with pesticide residues in soil samples.

Hence the hypothesis (**$H5_0$**) stating that “there is no correlation between cancer mortality and pesticide residues” is rejected and instead the hypothesis (**$H5_1$**) that “there is a correlation between cancer mortality and pesticide residues” is accepted.

Pesticide residues in water arise from two sources – leaching in ground water as well as canals. The source of drinking water in the study villages varies between tube wells and canal water. In the case of tube wells, the water is rarely treated before use and is often consumed directly after drawing it from the well. Canal water is treated in a plant in the village, but in most cases, an old antiquated elementary sand filtration based plant is the only installation in the village. Hence water is rarely treated for pesticide residues in the entire study area.

The consequences of occurrence of pesticide residues in soil are dependent on both pesticide and soil type. Amount of organic matter in soil, texture of soil and its ph value influence the leaching properties of soil. Soil Leaching Potential (SLP) too varies according to soil type. Pesticide properties like persistence (often measured in half life terms), rate of application, method of application and binding properties of pesticide are also critical in arriving at leaching rates.

Further analysis of pesticide residues requires intensive analysis on both soil and pesticide types.

The occurrence of pesticide residuals is in consonance with other studies in the state as well as other parts of India.
PPCB (2005) confirmed presence of heptachlor in tap and ground water in Punjab. It had also detected pesticide residues in cauliflower, carrot, potato, grapes, bottle gourd and apple gourd.
Human milk samples analysed in 2004 indicated the presence of DDT and HCH (Kalra et al). Similarly, an analysis of commercial milk and butter samples in Ludhiana district indicated the presence of DDT and Lindane (Battu et al., 2004). Studies have found DDT and BHC residues in food samples at levels higher than those reported from developed countries (Singh 1998; Kashyap 1994). However by 2006, DDT and HCH residues levels in wheat have been found to be decreasing from previous levels (Toteja 2006).
Organochlorine residues have been detected in freshwater fish species in Punjab (Kaur, 2007). Pesticide residues have also been discovered in poultry feed, chicken muscle and eggs in a select poultry farm in Punjab (Aulakh 2005). In India, pesticide residues have been found in cold drinks and bottled mineral water as well (CSE, 2006).
Pesticide residues have been found even in neighbouring state of Haryana. Kumari (2008) reported that in tube well water, 80 per cent of samples reported pesticide residues above the regulatory limits.
A more serious revelation is an ongoing study analysing DNA mutations. Preliminary findings from a yet to be published study in Punjab indicate genetic mutations in blood samples of 65 per cent of the people tested. The study has not yet established what has caused the genetic mutations (Timmons, 2007)

Consumption patterns of pesticide in India differ with the rest of the world. In India, over three fourths of the pesticide usage comprises insecticides, with herbicides and fungicides falling way below the global norm.

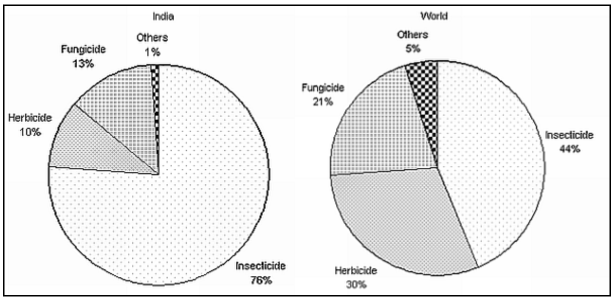


Figure 26: Comparisons in consumption patterns of pesticide usage in India and rest of the world. **Adapted from Saiyed, Bhatnagar and Kashyap (2003)**

And within India, there is a state and region level variation in consumption. The state of Punjab, though one of the smallest in terms of geographical area, is the largest consumer of pesticide in the country. (For comparison of area of state and pesticide consumption, see Annexure 7)

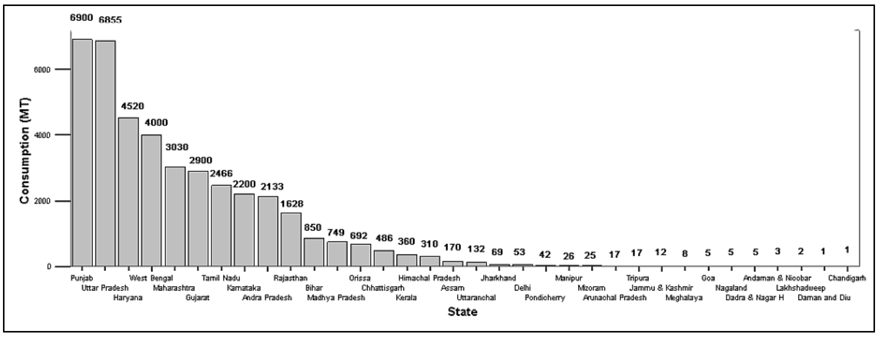


Figure 27: State wise pesticides consumption in India (2004-05) indicates that Punjab is the highest consumer (6900 MT) in the entire country.

(Adapted from, Pesticides, Residues & Regulation in India, Humboldt University Berlin, 2007)

In the year 2004-05, Punjab consumed 6900 metric tonnes of pesticides, a figure that is startling, since it is one of the smallest states in India. Other states like Andhra Pradesh and Uttar Pradesh have significantly reduced their pesticide consumption over the years, in Punjab; there has been no such trend. Decline in pesticide consumption in the state of Andhra Pradesh has been 413.70 %, compared to 18.3 % in Uttar Pradesh over a 10 year period.

The net result being that consumption patterns of pesticides in Punjab seem to have ultimately led to a preponderance of pesticides in water, soil, food and even in milk and blood samples.

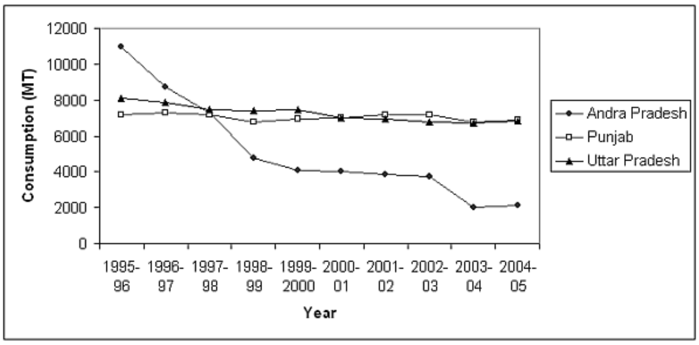


Figure 28: Comparative consumption of pesticides in 3 Indian states over the past 10 years. (Adapted from, Pesticides, Residues & Regulation in India, Humboldt University Berlin, 2007)

5.7. Significance of the study

- The significance of the study is not restricted to the study area or to the Indian state of Punjab alone. Since the Green revolution took seed in the rest of South Asia as well, the consequences being faced by people in Indian Punjab could serve as a warning signal to the rest. As is often remarked, “What happens in Punjab today could happen to the rest of the country tomorrow” (Philipose, 1998), the study points towards consequences that could appear in the rest of India.
  Similar consequences have already appeared not just in neighbouring Indian states but in neighbouring countries also.
  In the state of Haryana, contamination levels in samples of butter and ghee (clarified butter) in the cotton belt in rural areas have been found to more than urban areas (Kumari 2005). In the bordering state of Rajasthan, organochlorine pesticide residues have been found in dairy products in Jaipur. In Pakistan, endocrine disrupting pesticides have been identified as a leading cause of cancer among rural people in the country (Ejaz 2004).
- The revelation that more females are dying than males is an indicator that a more holistic approach is needed rather than a pure biological approach citing greater life expectancy for females. It also throws open new questions regarding the issue of gender versus cancer.
- The association of cropping patterns with cancer suggests that a new approach is required in agricultural policy. To avoid a monoculture wheat-rice cycle, the state government had been actively promoting a crop diversification scheme (Punjab 2002) asking farmers to move away from rice towards alternate crops. Rise and fall of water tables (PSCST 2007) was also cited as another reason to move away from rice. With cotton proving to be a mixed blessing, the state government needs to come up with better *kharif* crop alternatives.
- Indiscriminate pesticide usage combined with an absence of regulations limiting its use could have far reaching adverse consequences. The case of Andhra Pradesh, which effectively reduced its pesticide consumption by a whopping 413 % in 10 years, could be a beacon for other states, particularly Punjab.

5.8. Limitations of study

- The study does not investigate incidence of cancer and concentrates on mortality. In the absence of a detailed cancer registry, it is difficult to ascertain incidence of cancer from mortality. Mortality rates may or may not be similar to incidence rates. Hence a definitive conclusion on cancer incidence cannot be ascertained.
- Heavy metals like arsenic and mercury, apart from industrial pollutants, both of which are known carcinogens, were not analysed in the study.
- Cancer is a combination of nearly 100 types of diseases. Incidence rates of different types of cancer vary with geographical locations. Here cancer is being studied in totality, rather than analyzing different types of cancer.
- Cropping pattern is complex at the micro level, with one farmer often planting different crops in the same field. Similarly one village could have just one crop or a combination of various crops, with the decision to sow a particular crop depending on many factors, like past performance, available of seeds and fertilizers as well as weather conditions. Hence a firm estimate of the cropping pattern is difficult to ascertain.
- Different carcinogens are responsible for different types of cancer. Each pesticide and soil variety has its own characteristics which affect leaching properties. The study did not analyse individual pesticides and their individual carcinogenic effects.
- Floating population, particularly of farm labour was not ascertained. Most farm labour in the study area is migratory; working in Punjab during the agriculture season and returning back to their states at the end of the harvest season. Incidence and mortality of cancer in migratory population was not ascertained. However, this factor may be similar for all villages under study.

6. Conclusions and Recommendations

6.1. Conclusions

The beginning of the 20th century saw India struggling with food shortages and famine. The herald of the 21st century has India grappling with issues concerning the environment.

The study, conducted in India's grain basket of Punjab focussed on grim facet of cancer, a disease which is deeply rooted in environmental practices and lifestyle habits. Rural areas of Punjab are increasingly coming into focus for the spurt in cancer mortality.

The study did not try and ascertain causes of cancer, but merely looked into correlation. It concludes that there is a definite increase in cancer mortality in rural areas. Specifically, the findings of the study are:

- There is a direct correlation between cancer mortality and gender. The study comes to an appalling conclusion that more females are dying of cancer than males. This is in total contrast to global trends where mortality rate in females is much lesser than males. The conclusion is also contrary to expected results, since it was assumed that mortality among males would be higher.
- There is a very significant correlation between occupation and cancer mortality. More homemakers are dying due to cancer than farmers and those involved in other professions. This could be a direct corollary of the fact that cancer mortality among females is higher than males.
- There is a significant correlation between cancer mortality and time. Cancer mortality is increasing every year and more people are dying of cancer than previously. Given the fact that there is a "lag time" in cancer incidence, mortality rates could increase further in the coming years.
- There is a medium level correlation between cropping pattern and cancer mortality. Areas under cotton crop indicate a positive correlation with cancer mortality, while areas under paddy/ rice reveal a negative correlation with cancer mortality.
- There is a significant correlation between pesticide residues in soil and water with cancer mortality.

6.2. Recommendations

- CANCER HOSPITAL: The Malwa region urgently needs a cancer hospital. The absence of a specialized cancer hospital in the region amounts to criminal neglect on the part of the state government, since the region has witnessed a large number of cancer deaths, People in the region have to travel to far off places for treatment, be it Chandigarh or even Bikaner district in the neighbouring state of Rajasthan. The state government needs to take immediate measures to construct a cancer hospital in the region.
- FEMALE HEALTH PROFESSIONALS: Female health care needs greater focus since more females are dying due to cancer. Considering the fact that the society is not yet egalitarian when it comes to gender, the health department of the state needs to depute more female health professionals in the region. This would facilitate access of patients, particularly female, to medical services for consultation and advice.
- PESTICIDE FREE VILLAGES: The state of Andhra Pradesh has shown that areas hitherto known for huge pesticide consumption can be converted into pesticide free zones. Numerous villages in Andhra Pradesh have been declared “pesticide free” under the Non Pesticidal Management (NPM) scheme (see Annexure 9). It is recommended that the Punjab government should initiate a scheme to ensure that at least some villages are brought under the scheme and made pesticide free. The state government could also consider awarding such villages with cash or grants to implement such a scheme.
- AWARENESS CAMPAIGN: A state wide awareness campaign is needed to convince farmers of the deleterious affects of excessive pesticide usage. It was observed that farmers use excessive amounts on pesticide under the impression that greater the pesticide, lesser would be the chances of pest attack.
- BEST PESTICIDAL PRACTICES: Agricultural universities, agriculture scientists and environmental groups need to formulate a “best” practice for use and application of pesticides. Farmers and those involved in pesticide usage often apply pesticide without taking due precautions and are often bereft of protective gear.
- WATER TREATMENT PLANTS: Water treatment plants in villages are based on the antiquated sand filtration system. The practice of drawing water from wells for both drinking and household purpose results in people

consuming untreated water, which is hazardous to their health. The state government needs to invest heavily into water treatment to avoid a potential disastrous situation.

- CANCER REGISTRY: The state of Punjab lacks a cancer registry. Data on cancer incidence and mortality is not available on a state wide basis. Hospitals maintain their own records, but each hospital serves people from both within and outside the state. In light of this, there is an urgent need to create a state wide cancer registry.
- VILLAGE DEATHS REGISTER: The age old practice of maintaining a village deaths register, though a very useful tool has its limitations. The cause of death in many cases is mentioned as "*achanak*" (sudden). This is often done to avoid complications in filling up the death register, since recording an unnatural death requires more paper work. It is suggested that it should be made mandatory for the village watchman (*chowkidar*) to describe the name and type of disease in the village deaths register (See Annexure 2).
- AGRICULTURE FIRES: Agriculture fires were witnessed all over the region during the field work. Since they are potentially harmful and can act as carriers of pesticides, it is recommended that a state wide consensus needs to be arrived on its ban (See Annexure 8).
- NEED FOR MORE INTENSIVE STUDY: The subject, particularly of greater mortality among females, pesticide linkage to cancer, and possible correlation with cropping patterns needs a state wide more intensive and detailed study. This study is a mere speck in investigating the grim spectre of cancer in Punjab.

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8. Annexures

Annexure 1: Data Collection Form

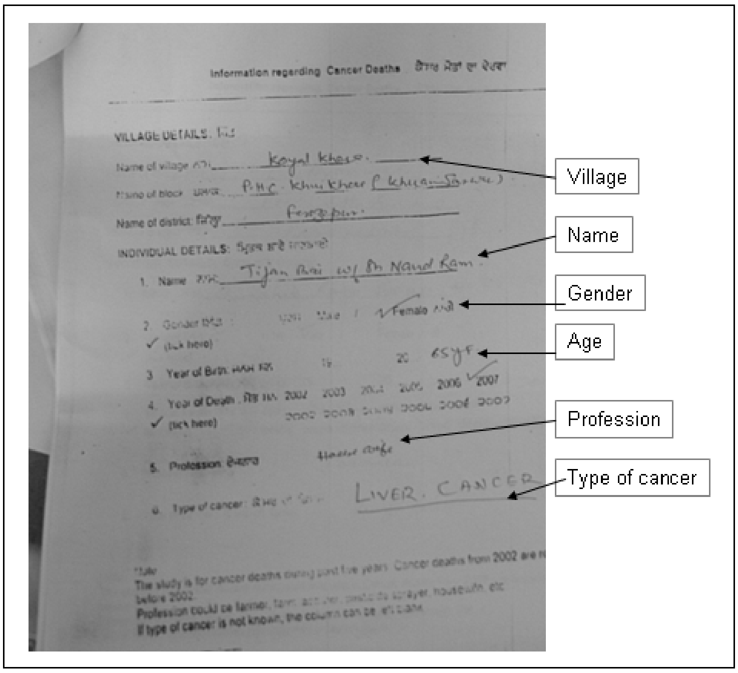


Figure 29: Sample data collection form.

Annexure 2: Village Deaths Register

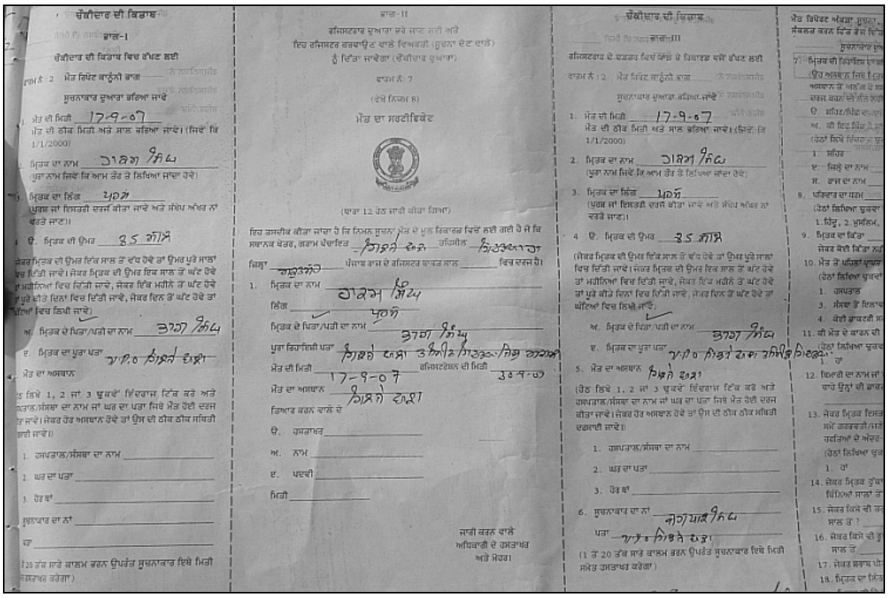


Figure 30: A sample page from the deaths register in one of the villages in the study area in Punjab.

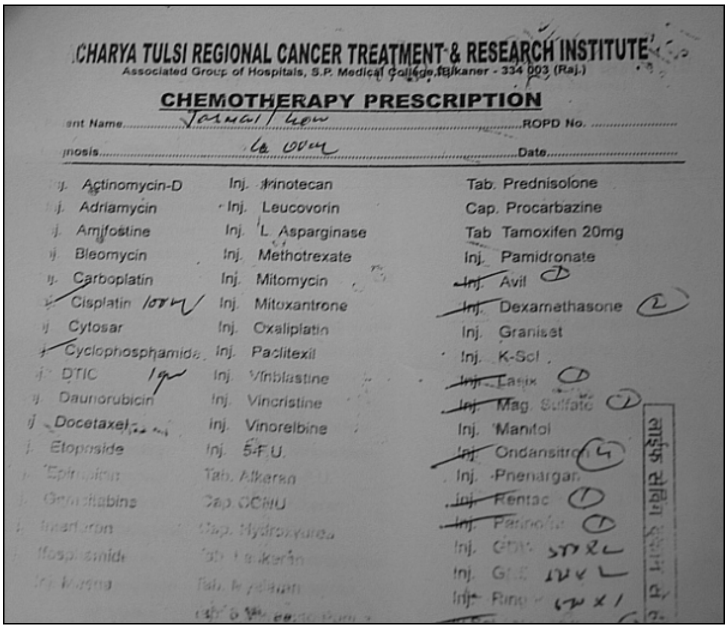
Annexure 3: Cancer data collected from one of the villages in the Study Area

Table 21: Demographic data of cancer victims during 2002-06 in village Kotbhai in Gidderbaha block in Muktsar district

Name	M	F	Birth	Death	Age	Profession	Cancer type	Village name	District
Gurdial Kaur		F	1947	2002	55	homemaker	breast	Kotbhai	Muktsar
Jagir Kaur		F	1947	2002	55	homemaker	breast	Kotbhai	Muktsar
Titar Singh	M		1950	2002	52	agriculture	brain	Kotbhai	Muktsar
Raghbir Kaur		F	1938	2002	64	homemaker	breast	Kotbhai	Muktsar
Angrez Kaur		F	1967	2002	35	homemaker	brain	Kotbhai	Muktsar
Jasmel Kaur		F	1942	2002	60	homemaker	brain	Kotbhai	Muktsar
Gurmej Kaur		F	1945	2003	58	homemaker	stomach	Kotbhai	Muktsar
Suresh Rani		F	1955	2003	48	homemaker	uterus	Kotbhai	Muktsar
Balwinder Kaur		F	1953	2003	50	homemaker	blood	Kotbhai	Muktsar
Joginder Singh	M		1945	2003	58	farm labourer	throat	Kotbhai	Muktsar
Surjit Kaur		F	1943	2003	60	homemaker	blood	Kotbhai	Muktsar
Dalip Kaur		F	1935	2003	68	homemaker	blood	Kotbhai	Muktsar
Mukhtiar Singh	M		1938	2004	66	mistry	throat	Kotbhai	Muktsar
Suresh Rani		F	1964	2004	40	homemaker	bone	Kotbhai	Muktsar
Swarna Rani		F	1956	2004	48	homemaker	skin	Kotbhai	Muktsar
Gopal Das	M		1950	2004	54	shopkeeper	bone	Kotbhai	Muktsar
Dalip Kaur		F	1937	2004	67	homemaker	brain	Kotbhai	Muktsar
Roop Chand	M		1953	2004	51	electrician	brain	Kotbhai	Muktsar
Jarnail Kaur		F	1957	2004	47	homemaker	breast	Kotbhai	Muktsar
Goshan	M		1970	2004	34	agriculture	blood	Kotbhai	Muktsar
Surjit Kaur		F	1952	2005	53	homemaker	stomach	Kotbhai	Muktsar
Kartar Singh	M		1948	2005	57	agriculture	prostate	Kotbhai	Muktsar
Harbans Kaur		F	1964	2005	41	homemaker	bone	Kotbhai	Muktsar
Mohinder Singh	M		1952	2006	54	agriculture	stomach	Kotbhai	Muktsar
Kulwant Singh	M		1996	2006	10		stomach	Kotbhai	Muktsar
Surjit Kaur		F	1957	2006	49	homemaker	brain	Kotbhai	Muktsar

Annexure 4: Hospital record of one of the patients obtained during field work

Figure 31: Chemotherapy prescription of one of the victims who died of cancer. The prescription is from a hospital in Bikaner in Rajasthan district.



CHARYA TULSI REGIONAL CANCER TREATMENT & RESEARCH INSTITUTE
Associated Group of Hospitals, S.P. Medical College, Bikaner - 334 003 (Raj.)

CHEMOTHERAPY PRESCRIPTION

ent Name.................... ROPD No. ....
nosis.................... Date....................

j. Actinomycin-D	Inj. Irinotecan	Tab. Prednisolone
j. Adriamycin	Inj. Leucovorin	Cap. Procarbazine
j. Amifostine	Inj. L. Asparginase	Tab Tamoxifen 20mg
j. Bleomycin	Inj. Methotrexate	Inj. Pamidronate
j. Carboplatin	Inj. Mitomycin	~~Inj.~~ Avil
j. Cisplatin	Inj. Mitoxantrone	~~Inj.~~ Dexamethasone
j. Cytosar	Inj. Oxaliplatin	Inj. Granisat
j. Cyclophosphamide	Inj. Paclitexil	Inj. K-Scl
j. DTIC	Inj. Vinblastine	~~Inj. Lasix~~
j. Daunorubicin	Inj. Vincristine	~~Inj. Mag.~~ Sulfate
j. Docetaxel	Inj. Vinorelbine	Inj. Manitol
j. Etoposide	Inj. 5-F.U.	~~Inj.~~ Ondansitron
	Tab. Alkeran	Inj. Phenargan
	Cap. CCNU	~~Inj. Rentac~~
		~~Inj.~~
		Inj.
		Inj.
		Inj.

Annexure 5: Field work photographs

Figure 32: Hand pumps used by people for drinking water. In image 3, notice the rusting of hand pump caused due to water quality.

Annexure 6: Cropping Pattern

Village	Area				Area under different crop pattern (Hect.)															
												Other Crops				Area under Midterm Crops			Area under Specific Crops	
	Total Area	Area under Forest	Net sown Area	Total sown Area	Wheat	Rice	Cotton	Sugarcane	Maize	Other Cereals	Oil seeds	Vegetables	Non-Vegetables	Fodder	Area under Horticulture	Rape seed	Sunflower	Other	Medicinal Plants	Other
AALAM WALA	1843	0	1619	3240	1291	1080	304	5	0	26	25	37	0	236	33	0	203	0	0	0
ASPAL	1199	0	1034	1766	555	520	109	80	0	26	30	14	0	210	143	0	79	0	0	0
AULAKH	732	0	650	1272	531	287	262	0	0	19	26	9	0	94	7	0	37	0	0	0
BAAM	2008	0	1790	3703	875	775	979	9	0	78	29	141	0	342	190	0	285	0	0	0
BANGCHIRI	1287	0	1173	2259	825	775	207	0	0	15	13	11	0	379	0	19	15	0	0	0
BHAGWANPURA	1213	0	1065	1990	671	603	216	0	0	103	87	105	0	154	9	19	23	0	0	0
BHULERIAN	745	0	678	1365	513	316	194	0	0	23	13	7	0	112	50	45	92	0	0	0
BODIWALA KHARAK SINGH	1099	0	1018	1978	993	421	419	22	0	65	18	12	0	265	4	7	52	0	0	0

Figure 33: Cropping pattern in Punjab villages. This abstract is from Muktsar district.

Annexure 7: Pesticide Consumption in Punjab vis-à-vis other states

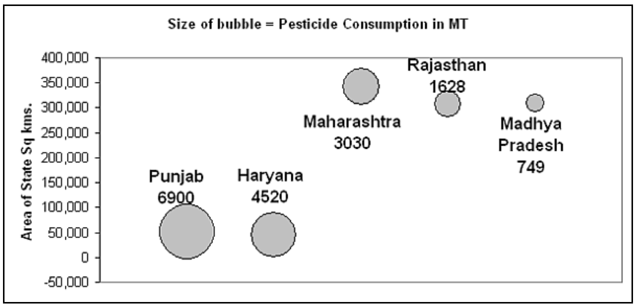


Figure 34: Comparison of size of states and corresponding pesticide consumption.

Annexure 8: Agriculture Fires

Agriculture fires are prevalent all over Punjab immediately after the harvest season. These are not accidental, but deliberate fires set up by farmers. The motive of the fire is to clear the fields once they have been harvested; fire being the cheapest way to level fields, compared to hiring costly labour.

Wheat and paddy stubble is set on fire, and once the fire raises the field to the ground, a tractor is used to plough the soil. Akin in one respect to the slash and burn cultivation known as *jhum* cultivation (Ramakrishnan 1992), this practice has reached epidemic proportions in Punjab. However, unlike tradition tribal *jhum* cultivation, the farmers sow grains on the same field during the next season.

It has been estimated that in 2005, "nearly 5504 sq. km area has been estimated to be under wheat crop residue burning and 12,685 sq. km under rice crop residue burning" (Badrinath, 2006).

A MODIS image from Aqua satellite of Punjab reveals the extent of prevalence of agriculture fires. NASA, while releasing the image, stated that "although the fires are not necessarily hazardous, such widespread burning can have a strong impact on weather, climate, human health, and natural resources" (NASA, 2003).

The question whether these fires could be related to cancer incidence needs to be probed. While cigarette smoke is accepted as a causative factor for cancer, studies on fire smoke and cancer have also pointed towards a possible correlation.

In a study in fire-fighters in San Francisco in USA, Beaumont et al (2007) concluded that "increased risks of death from oesophageal cancer and cirrhosis and other liver diseases may have been due to fire-fighter exposures".

An increase in testicular cancer among fire-fighters has been found both in New Zealand (Bates et al, 2001) and Germany (Stang, 2003). Bates (2001) reported that "complex organic mixtures from combustion emissions are genotoxic and carcinogenic in animal and in vitro assays". Band et al (1990) , who investigated occupational cancer risks with a population based cancer registry concluded that "The magnitude of the cancer risks from the complex organic mixtures in man depends on the degree of the exposure, the types of the compounds contained in the mixtures, and the concentrations of these biologically active compounds present in the combustion emissions."

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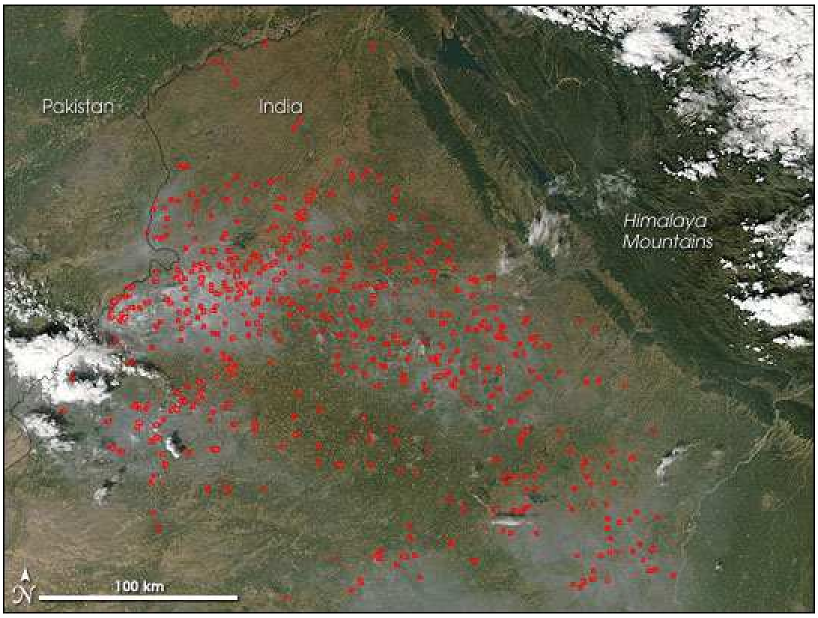

Figure 35: Fires in Northwestern India. An Aqua-MODIS image (Image courtesy NASA).

Figure 36: An example of an agricultural field set on fire after the crop harvest. Picture clicked by author.

Annexure 9: Non Pesticidal Management

The Non Pesticidal Management (NPM) programme followed in the Indian state of Andhra Pradesh was carried out over a 10 year period (1991-2005). It was conducted with the assistance of three donors:

1. European NGOs:
    a. Hivos, Netherlands (www.hivos.nl/english)
    b. Action for World Solidarity, Germany (www.en.aswnet.de)
2. Local NGO : Centre for Sustainable Agriculture (CSA)
3. State Government Initiative: Society for Elimination of Rural Poverty (SERP) (www.velugu.org)

The village Punnukala in Khamman district of Andhra Pradesh was selected for the project. The village previously followed a monoculture cotton crop cultivation. Excessive pesticide usage had resulted in pests developing resistance, apart from being responsible for adverse consequences on human health including poisoning. High costs of pesticide usage led to indebtness among farmers as well.
The launch of NPM meant implementing changes in agricultural practices like encouraging deep ploughing, using bonfires and light traps to attack moths, using sticky boards in field to attract insects, hand removal of leaves found infested with insect eggs, pheromone traps, biological pesticides like *neem* seed-kernel extracts and
chilli–garlic extracts. Extract from cow dung and urine was also used to control aphids and leafhoppers. Trap crops like castor and marigold were also planted to lure insects.
The village *panchayat* also passed a resolution declaring the village to be pesticide free and anyone not following NPM would be fined. The State Bank of India (SBI) developed a micro credit model for the area.
The NPM experiment resulted in

- Restoring ecological balance of the fields
- Improvement in health of farmers
- Lesser medical expenses for farmers
- More jobs for farm workers

(Source: Non Pesticide Management in Andhra Pradesh, India.
ftp://ftp.fao.org/sd/sda/sdar/sard/ipm-india.pdf (accessed Jan 10, 2008)

Annexure 10: Statistical Terms used in study

ANOVA: ANOVA corresponds to a determination of the fluctuations observed in a sample, and their dependencies.
F-test: In comparing two independent samples of size N1 and N2, the F Test provides a measure for the probability that they have the same variance. The estimators of the variance are s_1^2 and s_2^2. Their ratio $T = s_1^2 / s_2^2$, which follows an F Distribution with $f_1 = N_1 - 1$ and $f_2 = N_2 - 1$ degrees of freedom.
T-test: A test statistic T follows Student's distribution, and can be compared to its quantiles for three different hypotheses.
Correlation coefficient: The correlation coefficient between two random variables X_i and X_j is covariance divided by the square root of the product of the variances. It has the range (-1 to 1) and vanishes for independent variables.
Degrees of Freedom: The number of degrees of freedom describes how many redundant measurements exist in an overdetermined system, and allows one to predict the probability density function of the minimum of the sum of squares in least squares fitting.
Regression: A technique for finding mathematical relationships between dependent and independent variables.
Linear regression: It is a special case of the least squares method. In its simplest case, regression corresponds to a straight line fitted to measurements all characterized by the same variance

Source: Bock Rudolf K., and Krischer W., 1998. The Data Analysis BriefBook 1998, by Rudolf K. Bock & Werner Krischer, Springer

Annexure 11: List of pesticides known for their carcinogenity *

Chemical	Cancer Classification
2-Benzyl-4-chlorophenol	Group C–Possible Human Carcinogen
Acephate	Group C--Possible Human Carcinogen
Acetamide	Group C--Possible Human Carcinogen
Acetochlor	Suggestive Evidence of Carcinogenic Potential
Acifluorfen sodium	Likely to be Carcinogenic to Humans at High Doses Not Likely to be Carcinogenic to Humans at Low Doses
Alachlor	Likely to be Carcinogenic to Humans at High Doses Not Likely to be Carcinogenic to Humans at Low Doses
Amitraz	Suggestive Evidence of Carcinogenic Potential
Asulam	Group C--Possible Human Carcinogen
Benfluralin	Suggestive Evidence of Carcinogenicity but Not Sufficient to Assess Human Carcinogenic Potential
Benomyl	Group C--Possible Human Carcinogen
Benthiavalicarb-isopropyl	Likely to be Carcinogenic to Humans
Bifenthrin	Group C--Possible Human Carcinogen
Bioallethrin	Suggestive Evidence of Carcinogenicity but Not Sufficient to Assess Human Carcinogenic Potential
Boscalid	Suggestive Evidence of Carcinogenicity but Not Sufficient to Assess Human Carcinogenic Potential
Bromacil	Group C–Possible Human Carcinogen
Bromoxynil	Group C–Possible Human Carcinogen
Buprofezin	Suggestive Evidence of Carcinogenicity but Not Sufficient to Assess Human Carcinogenic Potential
Butachlor	Likely to be Carcinogenic to Humans at High Doses
Cacodylic acid	Group B2--Probable Human Carcinogen
Captafol	Group B2--Probable Human Carcinogen
Captan	Likely at prolonged, high-level exposures but not likely at dose levels that do not cause cytotoxicity and regenerative cell hyperplasia
Carbaryl	Likely to be Carcinogenic to Humans
Carbendazim (MBC)	Group C–Possible Human Carcinogen
Chlordimeform	Group B2--Probable Human Carcinogen
Chlorfenapyr	Suggestive Evidence of Carcinogenicity but Not Sufficient to Assess Human Carcinogenic Potential
Chloroaniline, p-	Group B2--Probable Human Carcinogen
Chlorothalonil	Group B2--Probable Human Carcinogen
Chlorthal-dimethyl (DCPA)	Group C–Possible Human Carcinogen
Clodinafop-propargyl	Suggestive Evidence of Carcinogenic Potential
Clofencet	Group C–Possible Human Carcinogen
Clofentizine	Group C–Possible Human Carcinogen
Cocamide Diethanolamine	Likely to be Carcinogenic to Humans
Cyanazine	Group C–Possible Human Carcinogen

Chemical	Cancer Classification
Cypermethrin	Group C–Possible Human Carcinogen
Cyproconazole	Group B2--Probable Human Carcinogen
Daminozide	Group B2--Probable Human Carcinogen
Dichlorvos	Suggestive Evidence of Carcinogenicity but Not Sufficient to Assess Human Carcinogenic Potential
Diclofop-methyl	Likely to be Carcinogenic to Humans
Dicofol	Group C–Possible Human Carcinogen
Dicrotophos	Suggestive Evidence of Carcinogenicity but Not Sufficient to Assess Human Carcinogenic Potential
Difenoconazole	Group C–Possible Human Carcinogen
Dimethenamid	Group C–Possible Human Carcinogen
Dimethipin	Group C–Possible Human Carcinogen
Dimethoate	Group C–Possible Human Carcinogen
Dimethoxane	Suggestive Evidence for Carcinogenicity in Humans
Dinoseb	Group C–Possible Human Carcinogen
Dithianon	Suggestive Evidence of Carcinogenic Potential
Diuron	Known/Likely
Epoxiconazole	Likely to be Carcinogenic to Humans
Esbiothrin	Suggestive Evidence of Carcinogenicity but Not Sufficient to Assess Human Carcinogenic Potential
Ethaboxam	Suggestive Evidence of Carcinogenic Potential
Ethalfluralin	Group C–Possible Human Carcinogen
Ethoprop	Likely to be Carcinogenic to Humans
Ethylene thiourea (ETU)	Group B2--Probable Human Carcinogen
Fenbuconazole	Group C–Possible Human Carcinogen
Fenoxycarb	Likely to be Carcinogenic to Humans
Ferbam	Likely to be Carcinogenic to Humans
Fipronil	Group C–Possible Human Carcinogen
Flonicamid	Suggestive Evidence of Carcinogenicity but Not Sufficient to Assess Human Carcinogenic Potential
Fluazinam	Suggestive Evidence for Carcinogenicity in Humans
Fluometuron	Group C–Possible Human Carcinogen
Fluthiacet methyl	Likely to be Carcinogenic to Humans
Folpet	Group B2--Probable Human Carcinogen
Furiazole	Likely to be Carcinogenic to Humans
Furmecyclox	Group B2--Probable Human Carcinogen
Haloxyfop-methyl	Group B2--Probable Human Carcinogen
Hexaconazole	Group C–Possible Human Carcinogen
Hexythiazox	Group C–Possible Human Carcinogen
Hydramethylnon	Group C–Possible Human Carcinogen
Hydrogen cyanamide	Group C–Possible Human Carcinogen
Imazalil	Likely to be Carcinogenic to Humans

Chemical	Cancer Classification
Iprodione	Likely to be Carcinogenic to Humans
Iprovalicarb	Likely to be Carcinogenic to Humans
Isophorone	Group C–Possible Human Carcinogen
Isoxaben	Group C–Possible Human Carcinogen
Kresoxim-methyl	Likely to be Carcinogenic to Humans
Lactofen	Likely to be Carcinogenic to Humans at High Does, Not likely at low doses
Lindane	Suggestive Evidence of Carcinogenicity but Not Sufficient to Assess Human Carcinogenic Potential
Linuron	Group C–Possible Human Carcinogen
Malathion	Suggestive Evidence of Carcinogenicity but Not Sufficient to Assess Human Carcinogenic Potential
Mancozeb	Group B2--Probable Human Carcinogen
Maneb	Group B2--Probable Human Carcinogen
Mecoprop-P	Suggestive Evidence of Carcinogenicity but Not Sufficient to Assess Human Carcinogenic Potential
Mepanipyrim	Likely to be Carcinogenic to Humans
Mercaptobenzothiazole, 2-	Group C–Possible Human Carcinogen
Metaldehyde	Suggestive Evidence of Carcinogenic Potential
Metam sodium Metam potassium	Group B2--Probable Human Carcinogen
Methidathion	Group C–Possible Human Carcinogen
Methyl isothiocyanate	Group B2--Probable Human Carcinogen
Metiram	Group B2--Probable Human Carcinogen
Metofluthrin	Likely to be Carcinogenic to Humans
Metolachlor	Group C–Possible Human Carcinogen
Metrafenone	Suggestive Evidence of Carcinogenic Potential
MGK 264	Group C–Possible Human Carcinogen
MGK Replellent 264	Group B2--Probable Human Carcinogen
Molinate	Suggestive Evidence of Carcinogenicity to Humans
MON 4660	Likely to be Carcinogenic to Humans
Nitrapyrin	Likely to be Carcinogenic to Humans
Norflurazon	Group C–Possible Human Carcinogen
Orthosulfamuron	Suggestive Evidence of Carcinogenic Potential
Oryzalin	Likely to be Carcinogenic to Humans
Oxadiazon	Group C–Possible Human Carcinogen
Oxadixyl	Group C–Possible Human Carcinogen
Oxyfluorfen	Group C–Possible Human Carcinogen
Oxythioquinox	Group B2--Probable Human Carcinogen
Parathion, ethyl-	Group C–Possible Human Carcinogen
Pendimethalin	Group C–Possible Human Carcinogen

Chemical	Cancer Classification
Penoxulam	Suggestive Evidence of Carcinogenicity in Humans but Not Sufficient to Assess Human Carcinogenic Potential
Pentachloronitrobenzene (PCNB)	Group C–Possible Human Carcinogen
Pentachlorophenol	Group B2--Probable Human Carcinogen
Permethrin	Likely to be Carcinogenic to Humans
PHMB	Suggestive Evidence of Carcinogenicity but Not Sufficient to Assess Human Carcinogenic Potential
Phosmet	Suggestive Evidence of Carcinogenicity but Not Sufficient to Assess Human Carcinogenic Potential
Phosphamidon	Group C–Possible Human Carcinogen
Piperonyl butoxide	Group C–Possible Human Carcinogen
Pirimicarb	Likely to be Carcinogenic to Humans
Prochloraz	Group C–Possible Human Carcinogen
Procymidone	Group B2--Probable Human Carcinogen
Prodiamine	Group C–Possible Human Carcinogen
Pronamide	Group B2--Probable Human Carcinogen
Propachlor97)	Likely to be Carcinogenic to Humans
Propanil	Suggestive Evidence of Carcinogenicity but Not Sufficient to Assess Human Carcinogenic Potential
Propargite	Group B2--Probable Human Carcinogen
Propiconazole	Group C–Possible Human Carcinogen
Propoxur	Group B2--Probable Human Carcinogen
Pymetrozine	Likely to be Carcinogenic to Humans
Pyraflufen ethyl	Likely to be Carcinogenic to Humans
Pyrethrins	Suggestive Evidence of Carcinogenicity but Not Sufficient to Assess Human Carcinogenic Potential
Pyrimethanil	Group C–Possible Human Carcinogen
Pyrithiobac-sodium	Group C–Possible Human Carcinogen
Resmethrin	Likely to be Carcinogenic to Humans
S-Bioallethrin	Suggestive Evidence of Carcinogenicity but Not Sufficient to Assess Human Carcinogenic Potential
s-Metolachlor	Group C–Possible Human Carcinogen
Spirodiclofen	Likely to be Carcinogenic to Humans
Sulfosulfuron	Likely to be Carcinogenic to Humans
TCMTB (Busan 72)	Group C–Possible Human Carcinogen
Tebuconazole	Group C–Possible Human Carcinogen
Tebufenpyrad	Suggestive Evidence of Carcinogenicity but Not Sufficient to Assess Human Carcinogenic Potential
Telone	Group B2--Probable Human Carcinogen
Terbutryn	Group C–Possible Human Carcinogen
Terrazole	Group B2--Probable Human Carcinogen

Chemical	Cancer Classification
Tetrachlorvinphos	Likely to be Carcinogenic to Humans
Tetraconazole	Likely to be Carcinogenic to Humans
Tetramethrin	Group C–Possible Human Carcinogen
Thiabendazole	Likely to be Carcinogenic to Humans Doses; not likely at low doses
Thiacloprid	Likely to be Carcinogenic to Humans
Thiazopyr	Group C–Possible Human Carcinogen
Thiodicarb	Group B2--Probable Human Carcinogen
Thiophanate-methyl	Likely to be Carcinogenic to Humans
Tolyfluanid	Likely to be Carcinogenic to Humans
Tralkoxydim	Suggestive Evidence of Carcinogenicity but Not Sufficient to Assess Human Carcinogenic Potential
Triadimefon	Group C–Possible Human Carcinogen
Triadimenol	Group C–Possible Human Carcinogen
Triallate	Group C–Possible Human Carcinogen
Tribenuron methyl	Group C–Possible Human Carcinogen
Tribufos	Likely to be Carcinogenic to Humans Doses; not likely at low doses
Trichlorfon	Likely to be Carcinogenic to Humans Doses; not likely at low doses
Tridiphane	Group C–Possible Human Carcinogen
Trifluralin	Group C–Possible Human Carcinogen
Triflusulfuron-methyl	Group C–Possible Human Carcinogen
Triforine	Suggestive Evidence of Carcinogenicity but Not Sufficient to Assess Human Carcinogenic Potential
Triphenyltin hydroxide (TPTH)	Group B2--Probable Human Carcinogen
UDMH	Group B2--Probable Human Carcinogen
Uniconazole	Group C–Possible Human Carcinogen
Vinclozoli	Group C–Possible Human Carcinogen
Zeta-Cypermethrin	Group C–Possible Human Carcinogen
Ziram	Suggestive Evidence of Carcinogenicity but Not Sufficient to Assess Human Carcinogenic Potential Likely to be carcinogenic to Humans

* (source: Chemicals Evaluated for Carcinogenic Potential, 2007. Science Information Management Branch Health Effects Division Office of Pesticide Programs, U.S. Environmental Protection Agency)