ORIGINAL ARTICLE

EPIDEMIOLOGICAL STUDY OF MORTALITY AND SYMPTOMATIC MORBIDITIES AMONG MIC LEAK EXPOSED COHORT IN 1984: 24 YEARS OF EXPERIENCE

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ABSTRACT:BACKGROUND : An industrial disaster in form of Methyl Isocyanate and other toxic products leak occurred in Bhopal on night of 2nd /3rd December 1984 and led to death of about 2000 persons and 1000 cattle within 72 hours. Besides death, it led to multisystem/organ involvement, clinically evidenced by symptomatic morbidities (lungs/ eyes main target organs) besides other systems involvement. **METHODOLOGY**: To study mortalities and morbidities besides other objectives, a Prospective epidemiological study was planned through six community health clinics to follow the cohort of affected people living in gas affected area and a matched control living in distant are a through six monthly house to house survey. Interview of head of family or an adult respondent was taken on the visit. **RESULTS:** Over the 24 years of the data collection exercise reveals that after acute stage was over the mortalities came down to levels or lower than the national averages for matching age groups. However respiratory causes were the main reason for the mortalities, among both affected as well as control cohort. Respiratory, ophthalmic, gastrointestinal and skin morbidities attained a plateau since 1999, where all morbidities are occurring within 20%. However, morbidities in affected area are found to be higher than seen in control area. Experience suggests further in depth clinical studies among symptomatic.
KEY WORDS: Methyl Isocyanate, thermal inversion, mortalities, morbidities.
Short title: Long term Mortality and morbidity profile among MIC exposed.

INTRODUCTION: Bhopal, at altitude of 505 meter above sea level, located at longitude 77º12' – 77º40' eastern and latitude 23º07' -23º94' northern, spread over 284 sq. km. area with a population of6.72 lac (1981Census) with population density of 2355.2/sq.km. suffered a toxic gas leak disaster on the night of 2nd/3rd December 1984. The disaster occurred following an exothermic reaction between stored MIC and the water. This reaction released about27 Tons of MIC along with cyanide and other products of reaction.[1]The products of reaction escaped through 33 meter high vent gas scrubber in to outside cold (10-12ºC) atmosphere and continued till the reaction stopped by itself around 3.00AM on 3rd December 1984[2].Following the phenomena of thermal inversion the mixture of toxicants got condensed, settled down and started drifting in to surrounding communities along with the slow moving wind at speed of 10-12.km. per hour.[2] This gas leak led to death of estimated 2, 000 persons and 1, 000 cattle within 72 hours post disaster.[3] Initial autopsies indicated cyanide poisoning evidenced through "cherry red discoloration" of lung and MIC induced lung and other organ damage and later autopsies done four months to one year post disaster revealed diffuse interstitial pulmonary fibrosis (DIPF).[4]

Acute Morbidities among survivors indicated multi organ involvement. Kamat et al., studied 78 patients during acute phase and found that 79% had respiratory symptoms and 74% had

ophthalmic symptoms. [5]Mishra et al., during acute stage reported among 544 patients examined in OPD, 99% suffered with breathlessness, 95% with cough, 46% had choking and irritation, 25% had chest pain, 21% were listless, 16% suffered with hypersomnolence, 7% were brought in coma, 92% suffered with loss of appetite 52% had nausea and vomiting, 82 % had ronchi and crepts 80% had tachypnea, 54% had tachycardia and 2% had fever.[6] Kamat et al., found that 78% showed restrictive pulmonary impairment with reversible airflow obstruction, in 24% reduced oxygen uptake on exercise among 55% and raised levels of carboxyhaemoglobin, and methemoglobin.[7] Among 500 Chest radiographs of patients taken within 72 hours of gas disaster, 98% showed abnormalities of interstitial and alveolar lesions and destructive lesions of pre-existing lung diseases[8]At the time of the gas leak common complaints related to eyes were foreign body sensation, burning, excessive lacrimation, photophobia and blurring of the vision. On detail examination 60-70% had conjunctival and circumcorneal congestion with relatively little edema. A fair number of cases had superficial corneal ulcers, mainly involving central zone and inter-palpebral fissure.[9]

Looking in to severe multi organ damage observed in autopsies and in survivors and the unknown quantum and nature of toxicants as on date, a long term epidemiological study was launched to understand the morbidity status among the exposed population. The objectives of this study were a)To register cohorts in the affected and unaffected (control) areas and collect baseline data on socio-economic and demographic profiles and study the changes over a period of time in context of the exposure to the toxic gas. b) To observe mortality and morbidity in the registered cohorts and comparable control and establish a relationship with the grades of exposure of the affected population. c) To identify sub-cohorts for in-depth epidemiological, clinical and other studies and d) to establish linkages between various studies and with the studies on the affected population outside the cohort.

The present paper deals only with long term mortalities and symptomatic morbidities.

MATERIAL AND METHODS: It was observed that of 56 ward of Bhopal Municipal Corporation 36 (population- 559835) suffered toxic gas exposure while remaining 20 was declared (population- 334703) non-exposed.The affected area was divided in to three areas based on mortality rate experienced during 3-6 December 1984. The epidemiological study drew its ample form those areas and a population of 80021was sampled from those areas (Table-1)A population of15931 as control population was selected from localities located about 8 kms. away after matching it for their socioeconomic status.

The study was planned to be executed through six community health clinics. Each community health clinic was headed by an Assistant Research Officer (Medical)and three to four Research Assistants (RA); one each for one locality.Research Assistants were to enquire and record all the information regarding vital events, morbidity, mortality, pregnancy outcome within the registered cohort since last visit (almost six months back). The Assistant Research Officer was assigned to maintain quality control and carry out the functions of liaison and rapportbuilding, to provide primary health care and referral services, to record morbidity pattern through the clinics and support other research activities.

Six monthly data on vital events, mortality and symptomatic morbidity was being collected through house to house visit through interview of "Head" or "senior member" of the household. The morbidity data was collected on the basis of symptoms.A list of 40 symptoms was provided to the RA

for this purpose. The International Classification of Diseases was followed for coding the cause of death. All deaths were to be confirmed by Assistant Research Officer(ARO).

The generated information was being submitted to statistical unit on weekly basis for scrutiny.

Data validation exercises were in built in the study. These were planned to be conducted at field, pre analysis and analysis level. At Field level The ARO were supposed to verify all the work done by RAs. All the Families with morbidity and 10 % of the families without morbidity were visited by ARO to verify the accuracy of the collected morbidity data.100 % of the deaths in the cohort were supposed to be verified by ARO in accordance to the International Classification of the diseases. At Pre analysis level data was scrutinized at statistical unit for missing information, discrepancy and inconsistency. The data needed correction, if required was sent to the field. At analysis level during computer analysis the data was to be checked for duplication of information or any other inconsistency.

Data analysis was done manually as well as through computer. On completion of every six monthly survey, a report was generated. Present paper is culmination of the reports generated during 1996-2010.

OBSERVATIONS: Data of the study has been presented under four headings namely cohort progression, demographic and socio-economic profile, mortality and morbidity profile. The data for crisp presentation has been presented at five year interval in tables and on yearly basis in graphs.

1. **Cohort Progression-1985-2010:** To recapitulate, as mentioned that a cohort of 80, 021 in severely, moderately and mildly affected area (26382, 34964 and 18765 respectively) and 15, 931 in control area was assembled in 1985. However in year 2010, cohort of 16860 (5658, 6533 and 4669 from severely, moderately and mildly affected area respectively) and 5741 from control area was actually available for study. Over the years it has been observed that the proportional distribution of the population among available age groups in all areas fluctuated within narrow range.[10]

2. **Socioeconomic Profile:** over the period of 1986- 2010 educational status has improved in all areas and proportional literacy has increase up to secondary level.Per capita income in the affected as well as in control area too has improved 1986- 2010.

3.It is well known that Smoking is a strong contributor to the respiratory morbidities and the cancer hence, it was specifically monitored. It was found that over the period of study smoking has increase in affected area (except in severe area) and in control area and these findings are in agreement with that of population based Cancer Registry.[11]

Mortality:
   i. **Annual Mortality:** Immediate post exposure (4th -31st December 1984) mortality was very high i.e. 12.57/1000 for males and 11.6/1000 for females in severely affected area. Correspondingly in moderate area it was 0.71 and 0.56 and in mild area it was 0.1 and 0.22. It was higher to that observed in control area[12] (0.35 and 0.41respectively).

During 1985 to 1993 the annual mortality figures in severe area ranged between 7.4 -3.4, for males and 7.8-1.6 for females. For moderate area these figures ranged between 6.5-3.2 for males and 5.4-2.6 for females and in mild area 6.1-2.5 and 4.6-2.4 for females. In control area these figures

ranged 3.9 and 1.9 in males and 4.2 and 1.9 in females.[12] Generally a decreasing trend in death rates have been observed in all the areas. However, the death rates were observed to be higher in affected area in comparison to control.

In present study (1996-2010) Mortality rates most of the time were less than national crude urban death rate for the respective age group and period. This phenomenon was specially found comparable during 2002-2009.[13, 14, 15]However, death rates observed in 2010 reveal that except in severely affected area (5.48/1000) death rate werehigher in mildly (8.25/1000), moderately (8.11/1000) and control area (6.1/1000). This observation is probably the outcome of excessive higher age group representation in the cohort follow-up.

ii. Primary cause of death: The information on causes of death was included since 1986: cause of death analysis is based on 3978 death records collected during 1986-2010.Between the periods of 1986 to 2010 most common cause of death was observed to be respiratory in affected area followed by digestive and cerebro-vascular disorders. In control area too respiratory disorders were the most common cause of death though with lesser frequency, followed by digestive disorders and fever.

Morbidities: As mentioned earlier during the surveys information on morbidities were collected through a proforma enquiring about the forty symptoms. These symptoms were further re-grouped under the following systems: Respiratory morbidities, ophthalmic morbidities, Gastrointestinal Tract morbidities and skin morbidities.

Acute Stage Morbidities: During acute stage in all the three exposed areas 96-99% had both eyes and lung symptoms, while 74% suffered with gastrointestinal symptoms in severely exposed area, whereas in moderate and mild area it was 48 and 14% respectively. Morbidity related to skin was 1.2% in exposed area. The control area had very low morbidity during the same period

Chronic morbidities

Respiratory Morbidities: During acute stage 96.87% suffered with respiratory morbidities. In the severe area, the morbidity specific to lung for males were higher in all the follow-up periods compared to other two exposed and control area. Up to November 1988, there was no pattern in severe area, while in May 1991 there was an increase and later on a fall was noticed. The Respiratory morbidities came down from 96.87 in 1984 to 20.41, 16.99, and 16.46 % in severely, moderately, mildly affected area in comparison to 4.37% in control area. Since 1997, these morbidity rates are seen fluctuating between 20.31- 15.42% in severely, 15.43-9.63% in moderately 16.41-13.02% in mildly affected area. However, respiratory morbidity rates remained high in all affected areas in comparison to control area (0.06-4.37%) throughout 1984-2010. (Table- 2, fig-2)

Ophthalmic Morbidities: During acute phase in 1984 affected area experienced 98.50, 98.08 and 99.00% ophthalmic morbidities in severely, moderately and mildly affected area respectively in comparison to 0.07% experience by control area population. By 1996, ophthalmic morbidity rate came down to 16.60, 12.41 and 14.98% in the same areas in comparison to 4.31% observed in control area during the same period. These rates declined further and have been seen fluctuating

between 11.46-15.85% in severely affected area, between 9.00-11.07% in moderately affected area and 13.99-17.89% in mildly affected area in comparison to 2.84-3.43% in control area during 2005-2010. (Table- 3, fig-3).

Gastrointestinal morbidities: During acute phase in 1984, 73.53, 26.36 and 15% suffered with gastrointestinal morbidities in severely moderately and mildly affected areas in comparison to 0.01% in control area. However, within five years by 1991, these morbidity rates fell down to 7.99, 6.52 and 5.88% in the same areas in comparison to increased GI Morbidity rate of 5.80% in control area. Later since 1996 to till date, GI morbidity rates have been seen fluctuating 6.48-4.49, 5.21-3.29 and 4.56- 13.61% in severely, moderately and mildly affected area in comparison to 1.24-2.77% in control area. The peaks of rise in morbidity rates in mild area were further analyzed and it was found that these peaks relate to abdominal pain and gastritis.(Table- 4, fig-4)

Skin morbidities: Skin morbidities were observed in less than 1.82% in all area during acute phase observed in 1984, during acute phase no morbidity was reported in control area.Morbidity rates were marginally higher in all areas including control in 1996 which later except one peak in 1998 (2.24%) in severe area remained at the level or less than 1.63% in severe area and less than 1% in all areas including control. Since 2007 to till date even in severely affected area skin morbidity rate remained under 1%.(Table- 5).

DISCUSSION: Present study is the longest running epidemiological study on toxic gas disaster probably in world. In 2010, December it completed 24 years of data collection.Operating study of this magnitude for such a long time had its own challenges, like holding cohort, non-availability of comparable data for corresponding period, studies operating on same methodology etc. however the study did produce a wealth of data.

One of the most challenging tasks in operating a cohort study is to hold the cohort. And this study too suffered cohort loss. Of the original cohort (Table 1) only 5, 658, 6, 533 and 4, 669 from severely, moderately and mildly affected area respectively (total-16, 860) and 5, 741 from control area was actually available for study in 2010. In nut shell, study over a period of 25 years suffered a cohort loss of 79% in affected area and 64% in control area. The causes behind losses include shifting of the population to different places, marriage migration, shifting of young age cohort to older age one and subsequent removal by death.

Socio economic profile: Study noticed improvement in housing, per capita income and educational status of the population in affected as well in control population. However increase insmoking is a disturbing trend noticed in this study.

Mortality: The mortally rates were very high during the acute phase and later showed a decreasing trend with passage of time. In present study (1996-2010) mortality rates are less than the national crude death rate. Death rates observed during 2002-2009, bring out this fact more prominently. The study reveals main cause of mortality among gas affected as well control area as respiratory illness.

Morbidities:

Respiratory morbidities: Respiratory morbidities too have followed decreasing pattern. During acutestage in affected areas 96-98% people suffered with respiratory morbidities however by end of

ORIGINAL ARTICLE

7th year post exposure these morbidities came down to 20, 15 and 16% in severely moderately and mildly affected area and since 1998 have remained below 20 % till 2010.

Ophthalmic morbidities: were seen in 98-99% of the affected population during acute stage. This proportion came down to less than 16% in affected area in 1996 and since 1999 have remained under 20% till 2010.

Gastrointestinal tract morbidities: which started with 74, 26 and 15% in severely, moderately and mildly affected area respectively during acute stage came down to less than 8% in affected area by 1991 and since then have remained under same level till 2010 with occasional slightly higher peaks in all area. The mild area did show noticeable increase in morbidities i.e. up to 13% during 2004-2008. The cause of this rise was investigated and it was found that people started complaining excessively about gastritis abdominal pain. This could be possibly due to excessive self-medication for pain.

Skin morbidities showed consistent pattern of less than 2% in all areas in all times.

In summary, it can be said that in general the socioeconomic status of the cohort has improved over the years. And smoking is seen increasing the cohort which is a disturbing trend and a risk factor in aggravating the morbidities in already respiratory symptomatic population or even in normal cohort. Finding of present study reveal that mortality of the affected cohort is equal to that of normal urban Indian population. The study reveals Respiratory morbidities since 1998 and ophthalmic morbidities since 1999 have remained under 20%.GIT morbidities came down to 8% affected area by 1991 and since then have remained under same level till 2010. In nut shell it can be said that all the morbidity levels have been fluctuating fewer than 20% since 1999.However, all the morbidities in affected area are found to be higher than the morbidities seen in control area and require further studies at clinical level.

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ORIGINAL ARTICLE

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Area ward (Population) (Esti-1985)	Affected Zones (Population)(Esti-1985) Death rate/1000$	Wards no#	Localites#	Population Covered for acute stage study (Aug-Oct 1985)	Population for present study in 1986
Affected Wards-36 (559835)	Severe (34879) 21.98	13, 20	1, 2, 7, 8,	26382	19260
	Moderate (77239) 1.33	11, 08, 14, 45, 46	3, 4, 5, 6, 9, 10	34964	28261
	Mild (447717) 0.29	7, 9, 12, 44	11, 12, 13	18675	15185
Sub total	559835	11	13	80021	62706
Unaffected/ control Wards 20 (334703)	(334703)	54, 55, 36	14, 15, 16	15931	13526
Grand Total	894538	14	16	95952	76232
#under study, Esti- estimated), $ death rate 3-6December 1984					
Table-1: Affected area severity wise and population and sample for studies					

AREA	SEVERE			MODERATE			MILD			CONTROL		
VISITS	No.	No.	%	No.	No.	%	No.	No.	%	No.	No.	%
	Cont.	Morbid		Cont.	Morbid		Cont.	Morbid		Cont.	Morbid	
1984	24994	24213	96.87	33442	32802	97.45	18208	17958	98.62	15616	10	0.06
1991	8070	1632	20.23	13150	2012	15.30	6952	1147	16.49	7911	288	3.64
1996	10816	2207	20.41	14137	2402	16.99	9527	1568	16.46	7990	349	4.37
2001	6895	1202	17.43	9792	1133	11.57	6176	856	13.86	5133	136	2.65
2006	4961	835	16.83	5834	630	10.80	4814	675	14.02	5338	160	3.00
2010	5658	978	17.29	6533	641	9.81	4669	608	13.02	5741	147	2.56
Table-2: Respiratory Morbidities (1986-2010)												

ORIGINAL ARTICLE

AREA	SEVERE			MODERATE			MILD			CONTROL		
YEARS	No.	No.	%	No.	No.	%	No.	No.	%	No.	No.	%
	Cont.	Morbid		Cont.	Morbid		Cont.	Morbid		Cont.	Morbid	
1984	24994	24621	98.50	33442	32802	98.08	18208	18027	99.00	15616	11	0.07
1991	8070	950	11.77	13150	1583	12.03	6952	1062	15.27	7911	533	6.74
1996	10816	1795	16.60	14137	1754	12.41	9527	1428	14.98	7990	330	4.13
2001	6895	1055	15.29	9792	831	8.48	6176	804	13.02	5133	153	2.98
2006	4961	656	13.22	5834	595	10.20	4814	708	14.71	5338	183	3.43
2010	5658	897	15.85	6533	614	9.39	4669	653	13.99	5741	193	3.36
Table – 3: Ophthalmic Morbidities (1984-2010)												

AREA			SEVERE			MODERATE			MILD			CONTROL		
YEARS	No.	No.	%	No.	No.	%	No.	No.	%	No.	No.	%		
	Cont.	Morbid		Cont.	Morbid		Cont.	Morbid		Cont.	Morbid			
1984	24994	18379	73.53	33442	8817	26.36	18208	2733	15.00	15616	3	0.01		
1991	8070	645	7.99	13150	857	6.52	6952	409	5.88	7911	459	5.80		
1996	10816	649	6.00	14137	596	4.21	9527	743	7.80	7990	193	2.42		
2001	6895	351	5.09	9792	345	3.52	6176	569	9.21	5133	81	1.58		
2006	4961	256	5.16	5834	303	5.19	4814	508	10.55	5338	90	1.69		
2010	5658	295	5.21	6533	265	4.06	4669	442	9.47	5741	119	2.07		
Table 4 - Gastro intestinal tract morbidities (1984 – 2010)														

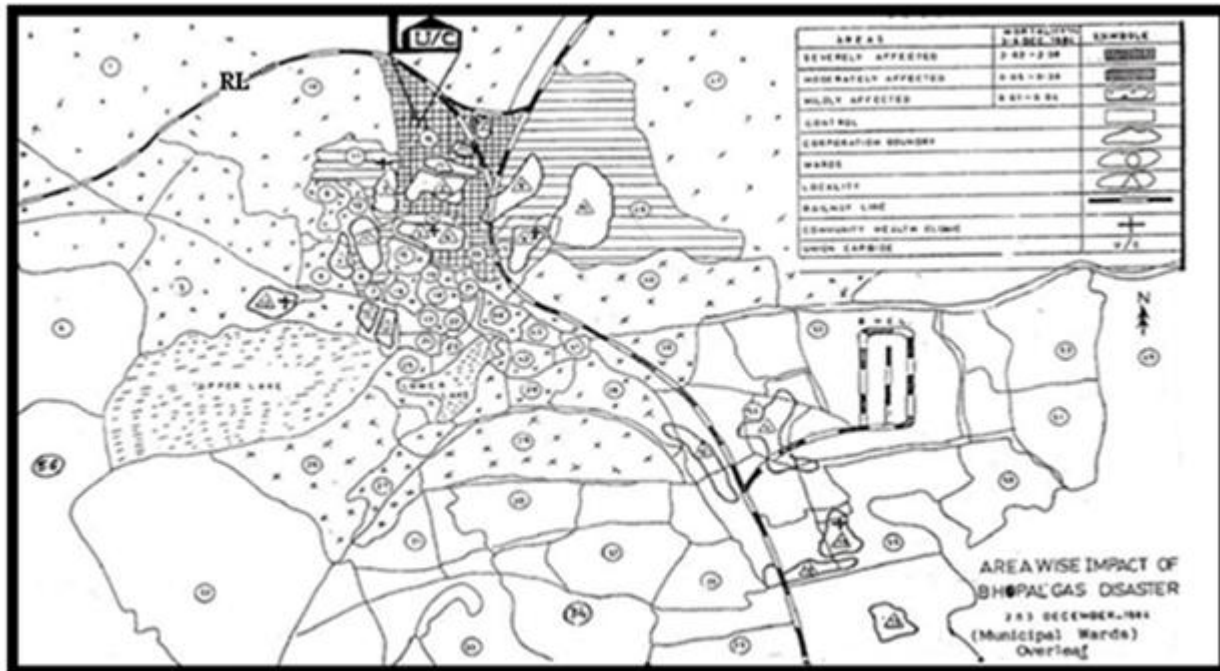| AREA	SEVERE			MODERATE			MILD			CONTROL		
YEARS	No.	No.	%	No.	No.	%	No.	No.	%	No.	No.	%
	Cont.	Morbid		Cont.	Morbid		Cont.	Morbid		Cont.	Morbid	
1984	24994	321	1.28	33442	610	1.82	18208	163	0.89	15616	0	-
1991	8070	189	2.34	13150	260	1.97	6952	60	0.86	7911	109	1.37
1996	10816	146	1.35	14137	101	0.71	9527	49	0.51	7990	29	0.36
2001	6895	73	1.06	9792	42	0.43	6176	8	0.13	5133	16	0.31
2006	4961	58	1.17	5834	34	0.58	4814	4	0.08	5338	14	0.26
2010	5658	50	0.89	6533	26	0.39	4669	26	0.56	5741	17	0.29
Table – 5: Skin morbidities (1984 – 2010)												

Fig.1 Affected area on the basis of Mortality (ICMR:Epidemiological study)

ORIGINAL ARTICLE

Fig:3. Ophthalmic Morbidities (1984 - 2010)

Fig: 4. GIT Morbidities (1984 - 2010)
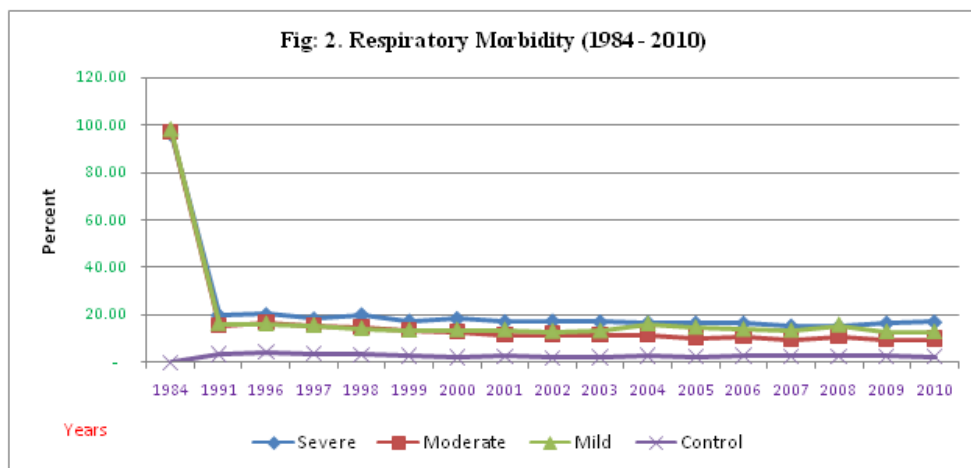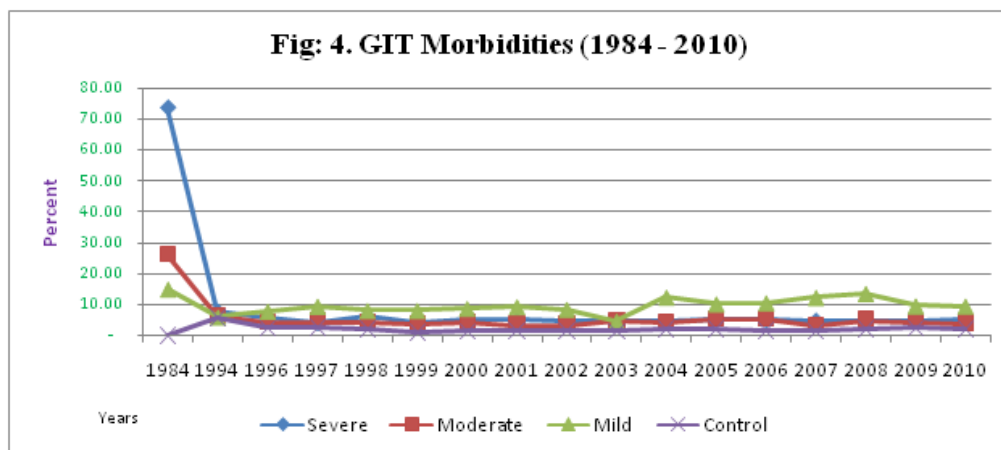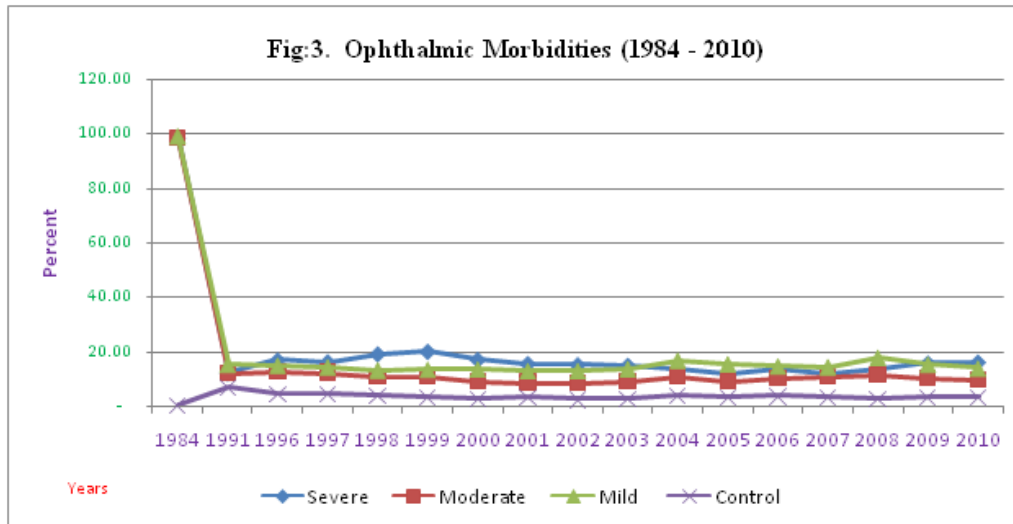
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