

Original Article

AN EPIDEMIOLOGICAL STUDY OF SYMPTOMATIC MORBIDITIES IN LOCALITIES AROUND SOLAR EVAPORATION PONDS AND BEHIND UNION CARBIDE FACTORY, BHOPAL

Brajendra Mishra¹, Nalok Banerjee², Sushil Singh³, S.C.Tiwari⁴

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Author's Affiliation:

¹Associate Professor and Head, Department of Community Medicine, Chirayu Medical College Bhopal, ²Head, National Institute of Research in Environmental Health (Indian Council of Medical Research, Bhopal, ³Scientist "C", National Institute of Research in Environmental Health (Indian Council of Medical Research) Bhopal, ⁴ Director, Department of Medical Education, Govt. of MP, Bhopal.

Correspondence:

Dr. Brajendra Mishra,
Email: drbmishra@yahoo.co.in

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ABSTRACT

Background: Following Toxic gas leak in 1984 from Union Carbide Ltd. India's Sevin manufacturing plant and resultant sudden closure, large number of chemicals were left unattended in plant premises. Concerned groups and population residing close by feared that these residual chemicals left over in plant and in solar evaporation ponds would percolate down to ground water and on consumption this toxic water would cause morbidities and may be mortalities among the population living in 14 localities settled around factory complex.

Methods and Procedures: Hence, an epidemiological study was planned to establish the cause and effect relationship between the allegedly present toxicants in water and the observed symptomatic morbidities. Tools like visit to the area, secondary data review on water analysis and cross sectional morbidities survey in population were used for this purpose.

Results: Through extensive review of literature it was found that there is no evidence to suggest that toxicants had reached either ground water or food chain in toxic doses. However, symptomatic morbidities survey did reveal statistically significant higher level of symptomatic morbidities among the resident living in affected localities in comparison to that of localities in control area.

Conclusion: From analysis it can be concluded that the higher symptomatic morbidities could be due to earlier toxic gas exposure, confounding effect of aging, poor socio economic standards and bad environmental / sanitation conditions found in slums, poor water quality at provider and consumer end and repeated misleading propaganda resulting in to self perceived morbidities.

Key Words: Methyl Iso Cyanate, Solar Evaporation Ponds, Sevin, Operation Faith

INTRODUCTION

Bhopal (longitude - 77.35° east, latitude- 23.25° north and altitude - 500-600 meters above sea level) capital city of Madhya Pradesh, India, suffered a major industrial catastrophe on the night of 2nd/ 3rd. December 1984. This disaster took place in a Carbaryl, a carbamate producing facility of Union Carbide India Ltd. (UCIL), following Methyl Iso Cyanate (MIC) gas leak. This disaster led to immediate death of about 2500 people living in the vicinity of the plant and a much large number of people survived to suffer with the long

term consequences of the disaster. Following the disaster and sudden closer of the UCIL plant and in absence of maintenance a large number of chemical inventories and waste products being collected in Solar Evaporation Ponds(SEP) during operative phase, were lying in factory and SEP premises in reportedly state of neglect. Concerned groups believed that these toxic chemicals would gradually seep out to the nearby localities, water bodies and to the ground water table thus would damage health of the people in long run. And to address this perception, Center for Rehabilitation Studies, department of Gas Relief and Reha-

bilitation, Govt. of M.P. requested department of Community Medicine to plan an epidemiological study.

OBJECTIVES

The Objective of this cross sectional concurrent symptomatic morbidity survey along with the secondary data review was to find out the cause and effect relationship between the allegedly present toxicants in water and symptomatic morbidities observed in population of 14 localities consuming this water.

MATERIAL AND METHODS

To conduct the above study following methodologies were used.

1. Development of study area identification of population and sample size for survey;
2. Review of available literature on a) toxic substances, b) Solar Evaporation Ponds, their structure and the contents, c) Soil structure, d) Drinking Water quality, e) Food chain and f) toxicants in human blood;
3. Field visits;
4. Concurrent symptomatic morbidity survey in affected localities and in matching control population

Development of study area identification of population

Study area consisted of the Union Carbide Factory, Solar Evaporation Ponds, and the 14 localities surrounding these premises (Fig-1) and a set of 6 matching control localities situated 10-14 kms. away on Bhopal- Hoshangabad road. The populations of gas affected localities and control localities were 26480 and 29655 respectively.

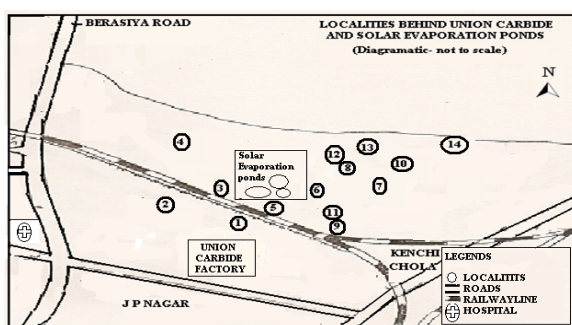


Fig 1: Study area: Union Carbide, Solar Evaporation Ponds and affected localities.

Previous six monthly symptomatic surveys conducted over last ten years by center of Rehabilitation Studies in affected and control area revealed that the symptomatic morbidities in affected area and control area ranged between 15.56%-25.42% and 7.55%-11.95% respectively¹. Based on this data, it was decided that survey of about 20% population in affected areas

would give an appropriate sample size for evaluation of current symptomatic morbidity status. Hence, it was decided to study about 5000 population each in affected and control localities. The affected localities had basically two type of sub population; one of above 24 years of age which experienced gas exposure in 1984 and exposure to allegedly contaminated water later on, while population up to 24 years of age population born after toxic gas disaster and was exposed to contaminated water only. For purpose of comparisons, population in control localities too were divided in similar sub groups (Table-1). The affected and control area was closely matched with each other in respect to socioeconomic status like both the areas are slums of self settled nature with almost similar water supply and drainage system. Their age, sex, religion education and occupation wise distribution is given in tables 2-6. Age and sex wise distribution of the population is given in table 2 and 3. Religion wise distribution is given in table no 4. Table no 4 reveals that proportionately higher number of Hindus live in control area while proportionately higher no of Muslims live in affected area. Education and wise distribution is given in table no 5 which reveal proportionately higher number of illiterate live in affected area and similarly comparatively higher proportion of no occupation population lives in affected area (table 6).

Review of available literature on a) toxic substances, b) Solar Evaporation Ponds, structure and contents, c) Soil structure, d) Water consumption, water quality, and e) Food chain and f) toxicants in human blood.

a). Toxic substances: from the review of literature it is found that Union carbide procured a large number of chemicals practically 22 in number during 15 years (1969-1984) of its operation. These chemicals were capable of polluting air, water and soil. These chemicals were procured in amounts ranging between 1mt. to 500 mt².

b). Solar Evaporation Ponds: These three structures were made in area covering 14 hectares (Fig-1). These ponds were built at the distance of 800 meters from the main plant. These were built by excavating 20 cm. of top soil and using it and the soil from surrounding area to make a bund around the excavated area. A special grade low density Black Polyethylene sheet as liner was laid down on the base as well as on the sides to prevent any seepage from the pond. Ends of the sheet were thermally sealed. 20 cm thick clay was spread over the liner film at the base for the better retention and as additional barrier against seepage. These solar evaporation Ponds were designed to receive neutralized acid waste water a mixture of chloride and Sulphate salts of Calcium, Sodium, Magnesium and traces of organics such as Alpha Naphthol, Carbaryl and other intermediates and solvents used in the manufacture of the pesticides. After closure of the factory in 1984, the ponds did not receive any waste water³. In 1990, on High Power Liquid Chromatography analysis of the Pond waters Car-

baryl, and Alpha Naphthol, Methylamine, Chloroform and Carbon Tetrachloride were not found. Sediments from Solar evaporation ponds I and II mainly contained Chlorides and Sulphates of Calcium and Sodium⁴. Again on examination of sediments of SEP by Toxic Characteristic Leaching Procedure Test (TCLP) as prescribed by the USEPA did not reveal presence of heavy metals, Carbaryl, Chloroform and Carbon Tetrachloride to designated sediment as hazardous⁵.

c). The Soil structure: Union Carbide factory is mainly built on Black cotton soil up to 2.0 meter and presence of clay mostly plastic in nature with Kankar below up to depth of 20-30 meters. This plastic clayey soil has more than 45% of the clay content. This clayey soil is highly impermeable and (Toxicant) would travel approximately at the rate of 36cm/year at the rate of 1×10^{-5} cm/Sec. It would take 23 years for the contaminants to reach the ground water table provided the leachets do not find a channel to migrate at faster rate⁶.

d). The water supply/ and Quality: It is observed that the localities under study (Affected/control) are of self settled nature with poor water supply and bad sewage/water/waste disposal systems. Hence, looking in to the fears of water contamination, Municipal Corporation, Bhopal/ Government agencies arranged to supply the potable water to the affected localities from the distant places: initially through tankers and later through the pipe lines from Rasalakhedi since 2006.

Investigators reviewed the reports available for the period of 1985-2006 and of the 13 times, six times water was found to be of potable quality and in remaining reports it was found to be free from the toxicants. The wastewater impounded in Solar Evaporation Ponds had not led to contamination of water environment within the area under study. It is reviewed that since 2006 water being supplied from distant Raslakhedi was slightly hard and had highly raised coliform and fecal Coliform count. It was not to be used as potable water⁷. Lastly, in 2010, 5 water samples were collected from within the Union carbide India Ltd. (UCIL) premises and 30 samples were collected from outside the UCIL premises. It was found that ground water in general is not contaminated due to seepage of contaminants from UCIL dumps⁸. Lastly at the intervention of Honorable Supreme court of India Central Pollution Control Board New Delhi instructed Indian Institute of Toxicological Research Lucknow to carry out the analysis of ground water, soil and sub soil from UCIL. The analysis was carried out during August -November 2013. In this water Lead levels were found above permissible limit and HC though found above permissible limit but the most toxic isomer of HCH(γ) was found within the permissible limit of drinking water. The report concluded that the water can be used for other purposes like cleaning, bathing, gardening etc⁹.

e). Toxic substances in food chain: the area under study is densely populated and nothing is grown or cultivated there, so it is unlikely that any toxic substance

present in the surface soil could have entered the food chain.

f). Toxicants in the Human blood: Nineteen years after the MIC leak in May 2005-06 National Institute of Occupational Health conducted a study to analyze the presence of DDT, HCH and Mercury in the blood/serum samples from the residents of the colonies around the UCIL premises and the Solar Evaporation Pond and the other part of the country. It found that there is no trend in respect to level of Pesticides like DDT and HCH in blood considering location of their residence from UCIL and the Solar Evaporation Pond, similarly mercury levels too were within range of normalcy¹⁰.

Field visits

Many field visits were conducted initially to gain the feel of the study area and later to conduct and supervise the survey by the research Assistants, Assistant Research Officers and the Investigators.

Concurrent symptomatic morbidity survey in affected localities and in matching control population

All residents (irrespective of their age, sex, religion, caste, creed or occupation) living in 14 affected localities/and 6 control localities mentioned earlier were included in concurrent symptomatic morbidity population survey of Toxic gas/water exposed pre designated affected and control localities. The population was asked to report symptoms (they were suffering with at the time of the survey) from the symptoms list of 48 symptoms practically covering every major physiological system of the body¹¹. Starting from the first house in the locality, every fifth house was surveyed till the required numbers of the people (about 5000) were surveyed in affected and control localities. In case the fifth house was locked or not available for the survey next house was surveyed and then again fifth house from the house surveyed last was taken as next house for survey. Once the house was selected all the members of the house were surveyed and enquired about the symptoms if any on the day of the survey. Attempt to correlate the symptoms with available records of the disease if any was made, but absence of record was not a criterion for exclusion from the study. Data entry was done under computer programmer and statistical analysis was done under supervision of a Professor of statistics.

OBSERVATIONS

Field visits

During the period of the study (2007-08) Investigators visited the localities many times before, during and after the study. It was observed that the localities were densely populated and there was no agricultural or horticultural cultivation in localities. There was no odor problem. Routine life in localities and the people always gave an impression of a lively slum with full of life. The area around the solar evaporation ponds too

was lush green with local wild grass and buffaloes were cooling off in the rain water lodged in solar evaporation ponds. However, investigators observed that local residents particularly young children and girls were digging toxic soil to be carried home thus, da-

maging protective layer of the barrier film (within which the toxic soil is contained either from the land fill or the solar evaporation pond/bund) for domestic kuccha construction and thus directly getting exposed to toxic material.

Table 1: Morbidity Distribution

Localities	Affected			Control		
	<24 yrs	>24 yrs	Total	<24 yrs	>24 yrs	Total
Age Group						
Population	3198	2230	5428	2864	2332	5196
Total. Morbid*	284 (8.88)	747 (33.49)	1031 (18.99)	63 (2.2)	198 (8.49)	261 (5.02)
Morbidities/ (Codes)#	No (%)	No (%)	No (%)	No (%)	No (%)	No. (%)
Respiratory (1,2,3,4,5,28,41)	84 (2.63)	309 (13.86)	393 (7.24)	18 (0.63)	51 (2.19)	69 (1.33)
Ophthalmic (19,20,44)	26 (0.81)	185 (8.3)	211 (3.89)	4 (0.14)	45 (1.93)	49 (0.94)
Gastroentologic (16,17,18,22,25,31,39)	76 (2.38)	262 (11.75)	338 (6.23)	3 (0.1)	30 (1.29)	33 (0.64)
Skin (23,43)	63 (1.97)	56 (2.51)	119 (2.19)	12 (0.42)	5 (0.21)	17 (0.33)
Mental (12,13,14,15,33)	31 (0.97)	131 (5.87)	162 (2.98)	4 (0.14)	56 (2.4)	60 (1.15)
Obst/Gyn (26,30,34)	13 (0.41)	32 (1.43)	45 (0.83)	1 (0.03)	11 (0.47)	12 (0.23)
Others (6,7,8,9,10,11,21,24,27,29,32,35, 36,37,38,40,42,45,46,47,48)	155 (4.84)	483 (21.66)	638 (11.75)	37 (1.29)	135 (5.79)	172 (3.31)

*An epidemiological Study of symptomatic morbidities in communities living around solar evaporation ponds and behind union carbide factory Bhopal, 2007-2008, p-62

*Chi-square statistics comparing > 24 yrs in affected area with < 24 yrs in same area and <24 yrs and >24 yrs in control area (Chi-square value= 0.128 df = 3, P <0.001)

Concurrent symptomatic morbidity survey in affected localities and in matching control population

Cross sectional concurrent symptomatic morbidity survey of 997 families in affected localities and 1126 families in control localities yielded required information on 5428 (under 24 years of age -3198 and above 24 years of age-2230) and 5196 (under 24 years of age - 2864 and above 24 years of age-2332) people in affected and control localities respectively. The prevalence of Symptomatic morbidities was 8.8 % among under 24 years, 33.49% among above 24 years in affected localities (over all 18.99%) and 2.20 % among under 24 years, 8.49% among above 24 years in control localities (over all 5.02%).

Table 2: Age wise distribution of population in affected and control population

Age	Affected Area (%)	Control Area (%)
0-14	1995 (36.75)	1656 (31.87)
15-59	3102 (57.15)	3280 (63.12)
60+	331 (6.01)	260 (5.00)
Total	5428	5196

It has been observed that Symptomatic morbidities were observed in higher proportion among above 24 years of age in affected localities in comparison to under 24 years of age in affected and under 24 and above 24 in control localities. Morbidities were significantly higher (P value <0.0001) among under 24 years of age in affected area in comparison to morbidities in control. (Table 1).

Table 3: Sex wise distribution of population in affected and control population

Sex	Affected Area (%)	Control Area (%)
Male	2896 (53.35)	2814 (54.16)
Female	2532 (46.65)	2382 (45.84)
Total	5428	5196

Table 4: Religion wise distribution

Religion	Affected Area (%)	Control Area (%)
Hindu	3830 (70.56)	4837 (93.09)
Muslim	1581 (29.13)	210 (4.04)
Christian	4 (0.07)	27 (0.52)
Sikh	0 (0.00)	32 (0.62)
Others	13 (0.24)	90 (1.73)
Total	5428	5196

Table 5: Education wise distribution

Education	Affected Area (%)	Control Area (%)
< 4 Years	371 (6.83)	373 (7.18)
Illiterate	1818 (33.49)	983 (18.92)
Literate	82 (1.51)	294 (5.66)
Primary	1767 (32.55)	1432 (27.56)
Middle	700 (12.09)	957 (18.42)
Secondary	549 (10.11)	799 (15.38)
College	140 (2.58)	306 (5.89)
Technical	1 (0.02)	52 (1.00)
Total	5428	5196

DISCUSSION

Present study was planned to find out the symptomatic morbidities among the resident population living in 14 localities surrounding the solar evaporation ponds

and the Union Carbide Factory and develop their correlation with allegedly toxic water (due to deposits in the solar evaporation ponds and toxic substances stored in Union Carbide Factory after its closure in 1984) being consumed by the residents. This study was conducted by using concept of cause and effect relationship under which cause ascertainment was done through review of available literature and morbidity load was evaluated by concurrent cross sectional morbidity survey as below:

Table 6: Occupation wise distribution

Occupation	Affected Area (%)	Control Area (%)
< 4 YEARS	371 (6.83)	373 (7.18)
NO. OCC	933 (17.19)	547 (10.53)
Professional	37 (0.68)	70 (1.35)
Sales	271 (4.99)	343 (6.60)
Farmers	1 (0.02)	4 (0.08)
Mines	2 (0.04)	0 (0.00)
Transport	103 (1.90)	80 (1.54)
Craftsman	729 (13.43)	749 (14.41)
Service	150 (2.76)	315 (6.06)
Armed Forces	31 (0.57)	21 (0.40)
House Wife	1029 (18.96)	915 (17.61)
Unskilled	109 (2.01)	75 (1.44)
Student	1638 (30.18)	1694 (32.60)
Occ. Unreported	24 (0.44)	10 (0.19)
Total	5428	5196

Ascertainment of the cause

From the review of the literature, it has been found that the inventory of 22 chemicals inside the factory premises was brought in over the 15 years of operation (1969-1984) to formulate product SEVIN. Hence, it is logical to believe that these chemical were unlikely to be ever present in such huge amount on the night of accident. One example is sufficed to prove the argument. The list mentions that 5 metric ton of MIC was procured between 1969 and 1984, but on the night of accident there was only 64 ton of MIC (42 tons of MIC in tank no. 610 which leaked out and 21 ton in tank no. 611 and 1 ton in tank no. 619 which was consumed to manufacture Sevin during Operation Faith on 16th- 22th December 1984) to avoid further catastrophe¹².

On visit it was found that the localities appeared to be like normal slums found anywhere and everywhere in India. The area was free from any type of odor and gave an impression of a lively slum with full of life, residents engaged in their routine life activities. The area around the solar evaporation ponds too was lush green with local wild grass and even one could see the green grass at the base of the solar evaporation ponds through lodged rain water.

From the review of the literature on Solar Evaporation Ponds it becomes clear that these were practically free from toxic substances. The water collected and examined over the 19 years on 13 occasions was found to be free from volatiles and toxic substance and at least on six occasions it was designated as potable. Possibly

this was due to two simple reasons: one is due to presence of black polyethylene sheet barrier and secondly the soil structure through which it would have taken about 23 years for the contaminants to reach the ground water. However, in 2013 the water was not found fit for consumption following presence of lead, Nitrate and HCH (α, β, δ) in above permissible limit. But one must remember that since 2006 outside water is being supplied to the affected localities. The localities under study were densely populated and there was no horticulture or agricultural practice so that toxicants could have entered the food chain. Lastly, on examination of blood of the residents from affected localities did not reveal presence of DDT, HCH and mercury in any excess when compared to level seen in blood of people living elsewhere.

Hence, in single line one can say that on the basis of available literature, cause for observed higher symptomatic morbidity in comparison to same in control area did not exist.

Significantly higher morbidities in affected localities

But all the same, symptomatic morbidities were observed in higher proportion in affected localities in comparison to symptomatic morbidities in control.

The reasons for such observations need explanation. Higher morbidities among > 24 yrs of age group possibly could be due to toxic gas exposure, confounding effect of aging and socioeconomically poor living conditions. Higher morbidities among under 24 years of age in affected localities were likely to be caused by confounding effect of socioeconomically poor living conditions. The affected localities were self settled slums with filth and dirt around, with practically no water disposal system, frequent intermixing of street runoff water with that of drinking water, abundance of mosquitoes and flies. In fact these localities were not fit for habitation by human beings of any class. Quality of piped water too is not fit for human consumption before treatment. Investigators themselves have found people collecting muddy water for drinking and domestic use. Besides these direct contributing factors one very important factor mentioned below may also be contributing to the higher symptomatic morbidities in affected localities. Many social groups are circulating certain documents in the study area, and convincing them to believe that chemicals once present in the Union Carbide premises are causing morbidities. This propaganda may be leading to increase in self perceived morbidities.

Lastly, epidemiological studies and their design have certain limitation and cannot answer the question fully, hence, authors recommend further studies to ascertain presence of chemicals (listed in this paper) in ground water/ food chain/water (minimum/maximum and permissible limit) and in human body (in toxic doses) along with proven pathway of travel of toxicants to human body and correlation with presenting clinical symptomatology with exclusion of role other factors causing similar symptomatology.

In summary, it can be concluded from the survey and review of the independent studies that the water from the affected localities and the water supplied from elsewhere to affected localities is free from the toxicants used in factory and per say there is no reason to correlate it with higher symptomatic morbidities among both age groups in affected localities. Higher morbidities observed in affected localities can be ascribed to confounding effect of aging, pervious toxic gas exposure, poor socioeconomic conditions prevailing in slum areas, poor water quality at providers and consumers end and to self perceived morbidities. The authors also recommend further biochemical/Toxicological experimental studies to develop one to one cause and effect correlation between alleged toxicants and clinical symptomatology.

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