

A critique of the epidemiological studies on health in allegedly endosulfan-affected areas in Kasaragod, Kerala

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Conference of Parties to the Stockholm Convention in its fifth meeting held at Geneva in April 2011 added endosulfan to the United Nations' list of persistent organic pollutants to be eliminated worldwide¹. Endosulfan, a widely used insecticide, is targeted for elimination from the global market by 2012. Health problems in Kasaragod district in Kerala, where endosulfan was aerially sprayed for two decades, was the focal point of an international campaign that culminated in the global ban of the insecticide². Circumstances link the alleged health problems in Kasaragod district to the aerial application of endosulfan.

The Government of Kerala instituted an Expert Commission headed by A. Achyuthan and the National Human Rights Commission instituted the National Institute of Occupational Health (NIOH) to investigate into the issue separately. The Achyuthan Commission and the NIOH³ that studied the issue in 2001 and 2002 respectively, recommended a detailed epidemiological survey in the area. The survey was conducted only in 2010. This study was undertaken by Prabhakumari and co-workers from the Calicut Medical College (CMC), Kerala. A report of this study was submitted to the Prime Minister by the Minister for Health and Family Welfare, Government of Kerala. A partial report of this study, when published by the Delhi-based Centre for Science and Environment (CSE) on their website⁴ (Note 1), gained publicity all over the world and was filed before the Supreme Court of India. Thanks to the Right to Information (RTI) Act, we received a copy of the original research report⁵, submitted to the Government of Kerala. Another epidemiological study was conducted by Embrandiri *et al.*⁶ during 2008–09 in five affected Panchayaths, involving 1000 respondents.

Our critique of the CMC study is based on both the study reports. The methodology and other aspects of the study are critically analysed here.

Calicut Medical College study

Methodological issues

Research design: The CMC study is a comparison of the health problems of 1000 families of Bovikkanam Village in Muliya Panchayath affected by the pesticide application, with that of 850 families in Banam Village in Kodombelur Panchayath where no pesticide was applied. However, the people of Bovikkanam and Banam are not comparable as they are dissimilar socially and economically. The Muslim population in North Malabar is socio-economically backward⁷. The population of Muslims in Banam is only 15% and that of Bovikkanam is 45%. This difference is reflected in the food habits as well as the health and educational status of the people in these areas. Eleven Panchayaths in Kasaragod district are affected by the aerial spraying of endosulfan. However, it is stated in the report that 'one Panchayath—Muliya, with large number of victims was selected randomly' (p. 6)⁵ (emphasis added). A well-designed study based on adequate number of representative samples would have yielded unequivocal and conclusive results. Evidently, no attempt was made in this direction.

Operationalization of parameters: The various parameters of health studied were not properly defined. For example, there are many types of liver diseases, including infective jaundice. It is not clear which types of liver diseases were included. Without providing working definition of a parameter, it cannot be studied clearly.

Pesticide residue analysis: Endosulfan residues in the blood plasma of 41 subjects from 11 Panchayaths were analysed. However, no attempt was made to compare these values with those from the reference population, which is intriguing. Thus it is impossible to make comparisons and draw valid conclusions with regard to this important parameter under study. Gas chromatography (GC) was

used for the analysis of pesticide residues. However, mass spectroscopy (MS) was not done to confirm the results. The Government of India has made it mandatory to confirm the analytical values with MS in the laboratories under the All-India Network Project on pesticide residues. The study on endosulfan residues by CSE⁸, turned out to be a blunder³, as they did not confirm the results with MS.

Triangulation: The conclusions of the CMC study are largely based on subjective parameters. The information gathered is mainly based on memory recall by the subjects. No effort was made to cross-check this information with other easily available documented facts. For example, death and birth data are accurately documented in the Panchayath offices, which is a fairly reliable source of information to study any possible change in the demographic pattern. Similarly, local veterinary hospitals record unnatural death in cattle. Banks and insurance companies too have a database of morbidity and mortality in cattle, as they pay compensation. No attempt was made to make use of such readily available information. The study was conducted at the peak of propaganda by the local clubs and the visual media. Hence it is highly probable that the responses of the subjects were biased and hence the inferences of the study are erroneous and misleading.

Sociological confounding issues ignored: The reproductive health events in women above 30 years (whose reproductive period was during the period of aerial spraying) have been compared with those in women aged below 30 years (whose reproductive period started after the cessation of the aerial spraying; Table 1).

This study had been designed to assess plausible improvement in the reproductive health of women following withdrawal of endosulfan application. The study report has specified that data on the reproductive health events in all married women in the study area were collected. However, women are literally

Table 1. Reproductive health events*

Reproductive health events	Area I – Muliyar N = 2986		Area II – Banam N = 1872		OR	95% CI	P value
	No.	%	No.	%			
Treatment for infertility	104	1.7	31	0.8	2.08	1.39–3.31	<0.0001
Abortion	229	7.7	82	4.4	1.81	1.40–2.35	<0.0001
Intrauterine death/stillbirth	64	2.1	18	1.0	2.26	1.33–3.62	<0.0001
Neonatal/infant/child deaths	100	3.3	43	2.3	1.47	1.03–2.12	<0.035

*Reproduced from Prabhakumari *et al.*⁵.

Table 2. Physical disability in population below 20 years*

Age group	Area I – Muliyar		Area II – Banam		OR	95% CI	P value	
	No.	%	No.	%				
<9 years; N = 961	5	0.5	<9 years; N = 517	7	1.4	0.38	0.12–1.21	0.084
10–19 years; N = 1184	13	1.1	10–19 years; N = 606	1	0.2	6.7	0.57–51.5	0.025

*Reproduced from Prabhakumari *et al.*⁵.

transplanted into the family of their husbands following marriage, under the Indian family system, for which Kasaragod is no exception. This means, at least a section of the women studied by the CMC researchers was living outside the study area with their parents during the period of application of the insecticide. Similarly, many housewives in Banam (unsprayed reference area) are likely married into their respective families from the neighbouring sprayed areas. This simple social reality is strong enough to contort the whole data and inferences on reproductive health events in women, as evidently the study is based on a mixture of subjects from both exposed and unexposed areas. Generally, a high proportion of young married men in muslim families in Muliyar work in Gulf countries. As a result of the long spell of separation of couples, chances of conception are less and it is common that such couples seek infertility treatment. This is a strong factor that would distort the results of the study on the reproductive health of women as well as their infertility rates. Moreover, the data on reproductive health problems during the period of pesticide application (1980–2000) was never statistically compared with the same during the decade after cessation of the pesticide application.

Inconsistencies in the results and conclusions of the study

Endosulfan residues in the blood serum of 41 subjects from the affected areas

were tested and all samples contained pesticide residues varying from 2.51 to 170.40 ppb (parts per billion), with an average of 41.65 ppb.

However, the level of endosulfan residues in blood serum nine months after the last spray was only 0–12.77 ppb according to the NIOH study conducted in 2001. This shows more than fourfold increase, on an average, in the endosulfan residues in the blood serum of affected people over 10 years! No endosulfan was ever applied in Kasaragod in the past decade due to the extreme vigil of the people. According to the study conducted by the Centre for Water Resources Development and Management (CWDRM), no detectable endosulfan residues were observed in water in the sprayed area. As there is no endosulfan in the drinking water, it is surprising that such extremely high levels of residues were observed in the blood. Data on pesticide residues in the blood serum of 41 subjects are provided in the published report. We statistically compared the data on pesticide residues in the blood serum of 41 subjects with the health status of each individual, provided in the unpublished report⁵, and found that the health status of an individual is not related to the endosulfan content in his/her body. Thanks to the RTI Act, we could obtain copies of the chromatograms of the endosulfan analysis of blood serum from the Salim Ali Centre for Ornithology and Natural History. However, only values of four samples mentioned in Prabhakumari *et al.*⁵ agree

with the chromatogram readings. This reveals that serious lapses have crept in the analysis of endosulfan residues.

A parameter that was objectively assessed is physical disabilities (Table 2).

The prevalence of physical disabilities in the age group 1–9 years, in Bovikkanam affected by endosulfan spraying is 0.5%, while the same in Banam where no spraying was undertaken is 1.4%. The reason for the increased incidence of physical disabilities in the unsprayed area is not clarified in the study report. The study is silent on the incidence of physical disabilities in the age group 20–29 born after commencement of the pesticide application. None of the parameters studied was compared with the state average or national average. Without comparing the prevalence of every health parameter in the study area with that of the state, how is it possible to establish the epidemiological evidence of the ill-effects of endosulfan application?

The sex ratio in Bovikkanam is 957 (957 females per 1000 men), while the same is 1016 at Banam. The researchers attribute the male-biased sex ratio to the application of endosulfan, as organochlorine insecticides are implicated in change of sex ratio. There is no empirical evidence that endosulfan would tilt the sex ratio towards males. Some studies suggest that organochlorines might reduce the proportion of male births^{9–11}, while on the other hand, the opposite also has been indicated¹². However, many studies in this regard remain inconclusive¹³.

Table 3. Sex hormones*

	Study group N = 98		Comparison group N = 97		P value
	Mean	SD	Mean	SD	
Oestrogen	51.02	68.24	42.22	51.38	0.32
Follicle stimulating hormone	6.45	5.64	13.01	9.26	0.001
Luteinizing hormone	5.08	6.84	6.06	9.77	0.433
Testosterone	1.98	2.94	1.99	2.08	0.989

*Reproduced from Prabhakumari *et al.*⁵.

According to the 2001 census data, out of the 11 Panchayaths affected by endosulfan application, five have a female-biased sex ratio. However, boys outnumber girls in the age group 1–6 years in most of the Panchayaths in the district. The sex ratio of Muliya Panchayath that includes Bovikkanam is 1012. Deriving conclusions without examining available facts and figures clearly indicate the bias of the researchers.

It is stated that the titre of oestrogen in high-school students was lower while follicular stimulating hormone and luteinizing hormone were comparatively higher in Bovikkanam affected by pesticide spraying (Table 3).

This conclusion is wrong as the statistical yardsticks used by the researchers themselves do not suggest a significant difference in these measures. Moreover, the value of standard deviation exceeds that of mean in the case of oestrogen, indicating high variability and poor quality of the data.

The study states that reproductive health events such as abortion, intrauterine death/stillbirth and child deaths were found to be reduced to 50% among the age group 20–29 years indicating a reduction in reproductive health problems after stopping the pesticide application 10 years ago (Table 4).

This inference is not based on any statistical analysis. A comparison of data on abortion and neonatal/infant child deaths of the affected area against that of Banam (unsprayed area) would prove this inference to be totally baseless. For example, the rate of abortion in the unsprayed Banam in the age group 30–39 years is 4.3% and the same in the age group 20–29 years is 2.5%. In the affected Muliya, rate of abortion in the age group 30–39 years is 7.4% and the same in the age group 20–29 years is 4.3%. The percentage rates of fall in both the sprayed

and unsprayed areas are roughly the same (42), which may be due to better access to improved medical facilities.

It is stated⁵ that the ratio of death due to any cancer among those below the age 50 in these areas (sprayed versus unsprayed) was 11 : 1. However, no data is provided to substantiate this statement.

Epidemiological study by Embrandiri *et al.*

The epidemiological study by Embrandiri *et al.*⁶ is amateurish and prima facie unreliable as the methodology followed is totally flawed. The study was neither designed properly nor was any statistical tool adopted for analysis and interpretation of the data. The prevalence of parameters like mental retardation generally varies from two to five per 1000 individuals. However, this study is based on a group of only 1000 individuals, which is further divided into eight categories based on age and gender for comparison. The number of individuals in a category varies from 77 to 319. With the possibility of a huge margin of error, this sample size is too small to derive any meaningful conclusion out of the study. The health problems of the affected population were never compared with that of an unaffected population, which is the normal practice in such cases. The only comparison is between four age groups, viz. 0–14, 15–30, 31–45 and >46 years. Apparently, the rationale of this comparison is that the subjects in the age group 0–14 years were born after cessation of the pesticide application, most in the age group 15–30 years were born during the period of pesticide application and those above 30 years were born before the application of the chemical, so that assessment of the health problems

before, during and after the pesticide application would give a direct measure of the impact of the pesticide on the health of the people in the affected area. However, this notion is totally flawed, as many of the health conditions studied have a strong survival bias or are often directly age-related. For example, the median age of survival of an individual suffering from severe mental retardation is less than 30 years. Similarly, incidence of some of the cancers like leukaemia is more prevalent in children, while some others like prostate cancer affect the elderly. Hence it is totally absurd to make comparisons between various categories of age to find out the impact of endosulfan spraying on the health problems of a population.

It is stated that 'random method of survey was used to select the households'. It is also stated that 'data was also collected from the Primary Health Centres (PHC) and District Medical Officers'. The methodology followed in the 'random' selection of the participants is not clearly stated. However, it appears that the study is strongly biased as the data were directly collected from PHCs. This bias is clearly reflected in the results. The prevalence of mental retardation reported by Prabhakumari *et al.*⁵ is only two per 1000, whereas the same reported by Embrandiri *et al.*⁶ is 5.2–35.8% in various age groups of males and females. According to the 2001 census figures, the prevalence of mental and physical disabilities in Kasaragod district is only 0.24%. Prevalence of any cancer in the affected area as reported by Prabhakumari *et al.*⁵ is two per 1000. However, according to Embrandiri *et al.*⁶, it varies from 1.2% to 15.6%. As in the case of Prabhakumari *et al.*⁵, Embrandiri *et al.*⁶ too have not bothered to compare the prevalence of various health problems with the national average or state average. The data on the consumption of various groups of pesticides such as organochlorine and organophosphorus compounds, provided by Embrandiri *et al.*⁶, are outdated and erroneous. According to them, organochlorines are still the most commonly used pesticides in India. However, it remains a fact that after the use of BHC was banned in India in 1997, the consumption of organochlorines has reduced drastically and the organophosphorus pesticides form the largest group of chemical compounds deployed for pest control in India¹⁴.

Table 4. Age of women and reproductive health events*

Reproductive health events	Area I (Muliyar – sprayed)				Area II (Banam – unsprayed)			
	Age 20–29 years N = 1220		Age 30–39 years N = 986		Age 20–29 years N = 684		Age 30–39 years N = 623	
	No.	%	No.	%	No.	%	No.	%
Treatment for infertility	19	1.6	38	3.9	11	1.6	10	1.6
Abortion	53	4.3	73	7.4	17	2.5	27	4.3
Intrauterine death + stillbirth	5	0.4	14	1.4	2	0.3	5	0.8
Neonatal + infant + child deaths	8	0.7	16	1.6	2	0.3	7	1.1

*Reproduced from Prabhakumari *et al.*⁵.

Table 5. Prevalence of selected diseases*

Disease	Area I – Muliyar (sprayed) N = 6107		Area II – Banam (unsprayed) N = 3742	
	Number	Prevalence per 1000	Number	Prevalence per 1000
Seizure	47	8	39	10
Psychiatric problems	21	4	17	5
Behaviour problems	28	5	4	1
Mental retardation	12	2	7	2
Skin disease	110	18	82	21
Asthma	109	18	113	30
Any cancer	10	2	11	2
Kidney disease	33	5	8	2
History of infertility	44	7	9	2
Liver disease	3	0.5	0	0
Weakness	55	9	27	7
Tremor	9	2	6	2

*Reproduced from Prabhakumari *et al.*⁵.

Propaganda and reality

Data on objective parameters generated by the CMC team, that reflect the reality of health status of the people in Kasaragod (Table 5 on p. 13 of Prabhakumari *et al.*⁵), have not been made public. For example, 10 out of 6107 individuals (0.16%) in the pesticide-sprayed area are cancer patients. However, the number of cancer patients in the unsprayed reference population in Banam is 11 out of 3742 (0.29%). The rate of incidence of mental retardation is equal in both the populations. The prevalence of skin diseases in the unaffected area is 2.19%, while that in the pesticide-affected area is only 1.8%. Asthma, seizure and psychiatric problems too are less in the insecticide-sprayed area. Death due to old age is proportionately higher in the affected Bovikkanam (Table 10; p. 18 of Prabhakumari *et al.*⁵). However, kidney and liver diseases and the history of infertility are more in the affected area.

The proportion of individuals who have undergone various surgeries (Table 11 on p. 19 of Prabhakumari *et al.*⁵) is

more in the unsprayed Banam (5.85%) compared to that in Bovikkanam (4.49%; Table 6).

Surgical rectification of hand or foot anomaly was less in the endosulfan-sprayed area. Endosulfan is known as an endocrine disruptor (the latest toxicological review of the pesticide disputes this argument¹⁵), and is linked to cryptorchidism (undescended testis) in boys. However, according to the unrevealed data, more surgeries were performed in the unsprayed area to correct cryptorchidism.

Sublethal doses of the pesticide are likely to affect the foetus during the first three months of pregnancy. However, according to Table 7 (table 6 on p. 14 of Prabhakumari *et al.*⁵), the rate of congenital organ anomalies and congenital heart diseases is similar in both places.

Opportunistic use of scientific claims

It is clear that the unsprayed and sprayed areas do not differ much in terms of the occurrence of diseases or disabilities.

This vital information has been hidden from public view. The 2001 census data show that Kasaragod does not have an increased rate of any of the mental or physical disabilities compared to other districts in the state. There is no reliable data to prove that there is a higher occurrence of any disease or disability in the sprayed area compared to the unsprayed area.

The propaganda and fear-mongering is taking its toll on the lives of the people in Kasaragod in general and those living in the affected area in particular. They are a stigmatized lot due to fears of genetic defects that would be transmitted across generations resulting in mentally and physically challenged offspring. Prospective brides and grooms from the affected area find it difficult to get suitable marriage alliances. There are people haunted by phobia afflicted by the propaganda that the soil, water and air that sustain their life are poisoned. Following reports of allegedly high rates of cancer, panic-stricken people suspect any and every illness as cancer and approach hospitals for treatment. There are also

Table 6. Reasons for surgery*

Reasons for surgery	Area I – Muliyar N = 6107		Area II – Banam N = 3742	
	N = 274	Per 1000 population	N = 219	Per 1000 population
Uterus-except delivery	41	6.7	45	12.1
Appendicitis	44	7.2	27	7
Hernia	33	5.4	9	2.4
Heart	14	2.3	5	1.3
Genito urinary/kidney	16	2.6	10	2.6
Mouth/throat	15	2.5	19	5.1
Cleft lip	4	0.7	1	0.3
Hand/foot anomaly	4	0.7	3	0.8
Undescended testis	2	0.3	3	0.8
Ovary	2	0.3	4	1.1
Tubal pregnancy	0	0.0	4	1.1
Cancers	22	0.4	16	4.2
Brain/CNS	2	0.3	6	1.6
Bone	10	1.6	10	2.6
Abdomen	5	0.8	9	2.4

*Reproduced from Prabhakumari *et al.*⁵.

Table 7. Congenital anomalies*

Disease	Area I – Muliyar (sprayed) N = 6107		Area II – Banam (unsprayed) N = 3742	
	Number	Prevalence	Number	Prevalence
Any organ anomaly (limbs + organ)	44	7	25	7
Congenital heart disease	23	5	19	5
Cleft lip/palate	6	1	0	0
Undescended testis	3	0.5	2	1
Hernia	25	4	12	3

*Reproduced from Prabhakumari *et al.*⁵.

couples who decide to terminate pregnancies for fear of congenital abnormalities. Even if a few decide to flee from this hell of a propaganda and social stigma, after selling-off all their possessions, the doors are shut as they will have to sell everything at throw-away prices. In short, irresponsible activism and propaganda have made people refugees in their own land. Well-facilitated medical camps were conducted in all the affected Gramapanchayaths during the last two years and 4226 persons affected by a range of about 350 diseases were enlisted as victims of endosulfan spraying. However, no criterion, including clinical or biochemical, was applied for the selection of these victims according to the information obtained by the authors through the provisions of the RTI Act. Also, no guidelines were provided by the Health Department for selection of the so-called endosulfan victims. Almost all types of common diseases

ranging from pulmonary bronchitis, piles, polio, liver problems, skin diseases, Alzheimer’s disease, dementia (which is common among the old people), etc. are included in the list. Persons with congenital malformations who were born before the commencement of the pesticide spray as well as those who were born 10 years after the stoppage of the spray are included in the list of endosulfan victims. Persons residing at the border of the cashew plantations as well as those residing 10–15 km away from the estates have also ensured a berth in the list of endosulfan victims. According to the RTI information, Rs 734 lakhs was distributed to the next of kin who allegedly died due to endosulfan and Rs 66 lakhs is disbursed as financial assistance every month to the alleged endosulfan victims by the state government. People with all sorts of alleged medical problems still through the PHCs in thousands for inclusion in the list of endosulfan

victims to get free medical aid and financial benefits. The people of an entire area have been converted into government-aid-dependent rather than self-reliant. The present studies, flawed on many counts, have only succeeded in adding fuel to fire.

The allegation that there are increased health issues in the endosulfan-sprayed areas in Kasaragod is not proved conclusively by any study till date. It is important that the true picture of this allegation that shook the conscience of the whole world is brought to light. It is inevitable that fears of the local people are dispelled through a comprehensive, multidisciplinary epidemiological study.

Note

1. After submission of the manuscript, the CSE has withdrawn this partial version of the study report and substituted the same with the unabridged version (ref. 5). Selec-

tively abridged version published by the CSE is now available at www.scribd.com/116428426.

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Solar energy for information technology: challenges and possibilities

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Information technology (IT) equipment is already estimated to account for about 2% of the global energy consumption, and this figure is only expected to rise. However, the use of solar power for IT is yet to receive the attention it deserves from researchers, and there is a vast array of important problems to be addressed to enable the use of solar and other alternative energy sources in IT. In this note, we take the view that a broad systems perspective of solar power generation and utilization (rather than looking only at component technologies such as PV, solar-thermal, etc.) is essential, and mention major directions which in our opinion merit attention in this regard.

With the worldwide increase in both solar energy production as well as in the consumption of energy by information technology (IT) systems, especially large data centres and such, it appears inevitable that these two seemingly disparate trends will soon interact in a much more significant way than at present. It is therefore necessary for us to understand the likely manner of such an interaction, and prepare to meet the challenges that come with it. Some obvious points may be noted in this regard:

- IT loads often have stringent availability requirements, coming to ‘five-9s’ (i.e. 99.999% uptime) or more.

- IT equipment and services cannot be easily shut down or restarted, but unlike other systems, IT jobs can sometimes be (re-)located across great geographical distances.
- Solar energy is subject to known variations (hourly, seasonal, latitudinal) that can be taken into account in some cases.

It is thus of interest to consider how solar generation systems (regardless of the specific technologies used) can be tuned to meet the needs of IT systems, and how IT systems in turn can be built to work with solar power. It could be thought that networked systems such as

data centres are not in the proper purview of studies of solar energy consumption, but it should also be noted that with new technologies and concepts such as the ‘Internet of Things’, many systems that were not commonly considered networked are becoming so. Therefore, studies based on concepts involving networked systems can and do apply in the analyses of large systems (even conventional, non-IT systems) that are not usually thought of as being networked.

State of the art

It has been more than 50 years since the first efficient solar cell was developed.