in different pharmaceutical industries. Popularization of these species is also required to generate awareness for their cultivation and conservation as these species are among the important elements of the ecosystem. Besides, there is a need to generate baseline datasets as with *H. edgeworthii* and *H. intermedia* in other species too. The present study has projected a model that could be applied for undertaking research on other threatened Ashtvarga plants towards developing strategies for their conservation and sustainable utilization.

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LALIT GIRI
INDRA D. BHATT*
RANBEER S. RAWAL

G.B. Pant Institute of Himalayan Environment and Development,
Kosi-Katarmal,
Almora 263 643, India
**e-mail: idbhatt@gbpihed.nic.in*

Endosulfan: analyses sans logic

The alleged health problems in Kasaragod district, Kerala, where endosulfan was aerially sprayed for two decades, have gained national and international attention through campaigns organized by NGOs and activists. A slew of court cases, allegations and counter-allegations, large-scale financial aid and its misappropriation, a plethora of social problems and above all, the stealthy replacement of cheap generic pesticides with the costly new-generation proprietary ones in India and elsewhere are some of the outcomes of this well-organized campaign. However, the campaigners carefully avoid a comprehensive health survey of the so-called affected population from their charter of demands, besides making it clear that any proposal for such a study would be staunchly opposed, since the link between the alleged health problems in Kasaragod and the aerial spraying has already been established conclusively. The anti-endosulfan campaign, as is the case with most such movements, has been deriving its momentum from cherry-picked studies and anecdotal evidences. The popular media engaged in the high-voltage campaign using heart-rending images of 'endosulfan victims' has blacked out all voices of reason and dissent. No wonder that a few studies originating from the politically charged institutions of the state government especially in an atmosphere created by a protracted and emotionally charged campaign, also turned out to be biased, erroneous and misleading. Such studies cater to the needs of the campaigners rather than bringing the truth to light. The epidemiological study conducted by a team of researchers at the Calicut Medical College is an illustrious example[1]. The study by Harikumar *et al.*[2] too falls within this genre of research on the endosulfan issue. We would like to place on record the methodological lapses, inaccuracies in the results and the misleading conclusions communicated by Harikumar *et al.*

Methodological lapses

The laboratory at the Centre for Water Resources Development and Management (CWRDM), where Harikumar *et al.*[2] carried out analysis of the water, soil and sediment samples for endosulfan residues is not an accredited one for conducting analysis of pesticide residues. In the absence of accreditation by the National Accreditation Board for Testing and Calibration Laboratories (NABL), the quality of the data generated is questionable as there is no mechanism in place to ascertain the same. The authors have used gas chromatograpy with electron-capture detector (GC-ECD) technique to estimate endosulfan residues. But mass spectroscopy (MS) was not done to confirm the results. The Government of India has made it mandatory to confirm the results with MS under the All-India Coordinated Research Project on pesticide residues. The studies by the Centre for Science and Environment and the Calicut Medical College on endosulfan residues turned out to be grossly erroneous, as they did not confirm the results with MS. Weber *et al.*[3], who reviewed the fate of endosulfan in the environment, underscore the measurement challenges for endosulfan and state that GC-ECD significantly over-estimated actual concentrations. Vidal *et al.*[4] demonstrated the advantages of tandem mass spectroscopy over the ECD in the analysis of serum samples where matrix interferences can be confused with target pesticides.

Harikumar *et al*. have not compared the endosulfan residues in the sprayed areas with those in the unsprayed areas as done by the National Institute of Occupational Health (NIOH)[5]. This is essential as pesticide residues are often found in unsprayed areas too. Had this been done, biases and errors in the analysis would have been evident.

Implausible results and illogical conclusions

The two-decade-long aerial spraying of the pesticide was stopped following public outrage and the last round of aerial spraying was carried out on 26 December 2000 (ref. 5). No endosulfan has ever been applied during the past 13 years in Kasaragod due to the extreme vigil of the people. Harikumar *et al*.[2] have conveniently forgotten the fact that they are analysing residues of a pesticide applied 13 years ago while emphatically stating that 'the combined toxic residues of endosulfan in the sediment and soil samples of selected areas of Kasaragod were found to be persistent for a period of 1.5–2

years...'. Had the date of the last application of endosulfan been stated, being inconsistent with the existing information on the fate of endosulfan in the environment, the study would have readily fallen apart. Harikumar *et al.* have shied away from reviewing the studies on persistence and half-life of endosulfan in the environment, especially in the tropical soils under field conditions. It was also imperative that they discussed their findings in the light of the NIOH study[5] that includes analysis of endosulfan residues in soil, water, sediment and blood serum in the affected and unaffected areas in Kasaragod. The NIOH study recorded mean residues of 0.998 and 0.372 ppb of total endosulfan residues in soil samples collected in September–October 2001 in sprayed and unsprayed areas respectively, 9–10 months after the last spray. Residues of total endosulfan in soil samples collected in June 2002 ranged from 0.3008 ± 0.18 to 0.106 ± 0.085 ppb and 0.162 ± 0.08 to 0.062 ± 0.059 ppb in sprayed and unsprayed areas respectively, 18 months after the last spray. According to the NIOH study, the mean residue of total endosulfan in sprayed areas in September–October 2001 was 0.998 ppb. However, the levels of residues were reduced to 0.3008 ppb in topsoil and 0.106 ppb in subsoil by June 2002. Harikumar *et al.* reported the highest concentration of endosulfan residues of 16.91 ppb (µg/kg) in Pullur Periya during the first phase of sampling (March 2010), which degraded to 1.93 ppb during the second phase of sampling (March 2012). If the NIOH study is taken as the baseline, this is a whopping over-estimation. Several-fold increase in the concentration of endosulfan residues, instead of drastic reduction, over a period of nearly eight years, certainly warrants an explanation from Harikumar *et al.* According to the USEPA[6], 'Half-lives in acidic to neutral soils range from one to two months for α-endosulfan and from three to nine months for β-endosulfan under aerobic conditions. Dissipation rates observed in the field studies, which capture a combination of degradation, transport and uptake, suggest that endosulfan will persist in the surface soil for weeks to months after application. The estimated half-lives for the combined toxic residues (endosulfan plus endosulfan sulfate) ranged from roughly 9 months to 6 years'. However, the rates of dissipation in tropical climates have been much faster. Chowdhury *et al.*[7] observed half-life of 4.4–5.0 days in soil. Jia *et al.*[8] reviewed half-lives of endosulfan in soils at temperatures varying from 20°C to 40°C and pH 5.5–8.5. According to them, half-lives of α-endosulfan and β-endosulfan varied from 12 to 187 days. There is also a report of the half-life of β-endosulfan extending up to 800 days under unspecified temperature. Ntow *et al.*[9] reported 98.7% dissipation of endosulfan residues 112 days after spraying in Ghana. Castro *et al.*[10] estimated the half-lives of α-endosulfan and β-endosulfan in soils in Spain as 21–22 days and 34–73 days respectively. Half-life for α-endosulfan, β-endosulfan and endosulfan sulphate reported by various workers, according to Becker *et al.*[11], ranges from 5 to 115 days, 15 to 376 days and 60 to 240 days respectively.

According to Weber *et al.*[3], degradation rates of endosulfan in the soil under field conditions strongly depend on the water content and ambient temperature. Hence the inordinately long persistence of endosulfan residues over 12 years under tropical conditions of Kasaragod, with a mean annual rainfall of 3462 mm (mean of ten years from 2003 to 2012), mean annual temperature of 27.15°C (mean of ten years from 2003 to 2012) and mean soil temperature of 33.29°C (range 28–38°C; mean of four years from 2009 to 2012)[12], is highly improbable. The average annual rainfall values of 138 and 1213 mm for 2009–10 and 2010–11 respectively, for Kasaragod given by Harikumar *et al.*[2] are wrong. The correct figures as given by the India Meteorological Department are 3077.5 and 4144.4 mm respectively for 2009–10 and 2010–2011 (ref. 13). The rate of use of endosulfan in the plantations too was as low as two sprays of 500 ppm each in a year (1.34 litres of endosulfan 35EC per hectare per year), compared to other crop situations like cotton, rice or tea where 3–20 sprays are carried out in a year or cropping season.

The bias of the authors is evident in their urge to correlate the high persistence of endosulfan in the soil with high organic matter content. Soils in Kasaragod are divided into five series with organic matter content in the topsoil ranging from 0.8% to 6.2% (ref. 14). Maloth series, cited by Harikumar *et al.*[2] as representative of the study area, having organic matter content of 6.2% falls outside the study area, while most of the study area comes under the Thekkila series having organic matter content of 3.96%. Soil organic matter contents reported by Harikumar *et al.* range from 0.55% to 17.36%. Values of soil organic matter content as high as 17.36% are astronomical for agricultural fields, unless the samples are drawn from manure pits.

In short, the study by Harikumar *et al.*[2] does not adhere to the required rigour in methodology or collection and interpretation of data, and raises more questions than answers. The endosulfan issue in Kasaragod needs science, good science alone, to answer many a question. However, the science community and institutions have failed to rise to the occasion, leaving it to other players to hijack science and mislead the society.

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K. M. SREEKUMAR[1,*]
K. D. PRATHAPAN[2]

[1]*Kerala Agricultural University, Padannakkad P. O., Kasaragod 671 328, India*
[2]*Kerala Agricultural University, Vellayani P. O., Thiruvananthapuram 695 522, India.*
**e-mail: sreekumarkmofficial@gmail.com*

Response:

The Government of Kerala directed the Kerala State Council for Science Technology and Environment (KSCSTE) to monitor endosulfan persistence in soil, water and blood samples in selected areas of Kasaragod district and its impacts on human health and environment vide G.O. (MS) No. 1550/20/10/HFW, dated: 09.04.2010. The soil, sediment and water samples were collected from specific sampling points of the affected panchayaths. The sampling points were fixed by taking into account the drainage morphometry, topography and hydrological parameters, and also according to the direction of the Endosulfan Victims and Remediation Cell constituted by the Government of Kerala. A technical cell was constituted by KSCSTE with specific terms of reference. The technical cell entrusted laboratories of the Centre for Water Resources Development and Management (CWRDM), Kozhikode and the Salim Ali Centre for Ornithology and Natural History (SACON), Anakatty, to study the endosulfan residues in various environmental samples of Kasaragod. Standard procedures were adopted in collecting the samples and analyses were done based on a standard protocol developed and approved by the technical cell. Repeated sampling of water/soil/sediments in the area was done to ensure consistency and accuracy. Split sample analysis was done in the laboratories of CWRDM and SACON, which helped minimize any errors. The results of the study were periodically discussed and reviewed by the technical cell.

The gas chromatograph used for the analysis had been calibrated; verification and validation of methods was periodically done to eliminate errors during the analysis. The details are provided in our paper. Repetition/confirmation of results which supplement the analysis of samples were done for quality control. Also, the study employed analysis of water/soil/sediment analysis using gas chromatography (GC) in CWRDM as well as in SACON for validation. The Water Quality Division Laboratory of CWRDM is an NABL accredited laboratory for the analysis of general water quality parameters (T-2846, dated 24.2.2014). We followed standard procedures reported by journals with high impact factors, World Health Organization (WHO) and USEPA for the detection of endosulfan[1–7]. WHO recommends the determination of endosulfan by GC combined with electron capture detection[8]. USEPA also recommends GC with electron capture detector (GC-ECD) for the determination of organochlorine pesticide residues, including endosulfan[9–11]. Canadian Water Quality Guidelines[12] for the protection of aquatic life also recommend detection of endosulfan using GC-ECD.

Though aerial spraying of endosulfan was stopped in 2000, there is no proper evidence about the year in which endosulfan usage was completely discontinued. The values reported in our paper are not just assumptions based on the last date of aerial spraying of endosulfan. Proper analysis and interpretation of data were carried out to find the concentration of endosulfan in the collected samples. Endosulfan in the selected samples was found to be persistent for 1.5–2 years based on our study which began in 2010. The study conducted by NIOH and CWRDM cannot be compared since the sampling locations are entirely different. The sampling locations in our study are predominantly in the depositional environment like the confluence of tributaries, valleys and ponds where organic concentrations are also relatively high. The above sampling stations are quite different from what was followed by earlier workers. The persistence of endosulfan is reported based on the date of start of our study. The results were also further validated and cross-checked with the monitoring done by SACON. It is quite possible that manual application of endosulfan might have continued in the area even after stopping aerial spraying in 2000. There can be a chance of re-application of endosulfan in the areas of the affected panchayats, where endosulfan might have been stored and not completely destroyed. Similarly, the retention of endosulfan residues in the matrix of clay-rich laterite soils which are predominant in the area is also possible. We admit that the average rainfall given in our paper is a typographical error. The correct figure is as pointed out. The high value of organic matter content, 17.36%, was confirmed by repeated analysis. It is clearly mentioned in our paper that there was specific evidence of the presence of decayed vegetation in the sampling area. Several published works have already proven the fact that organochlorine pesticide residues are persistent in the environment and long-term exposure can cause severe health problems[13–16].

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