Health hazards of mosquito repellents and safe alternatives

V. P. Sharma

Repellents such as vaporizers, diethy toluimide, and herbs are widely used in the country to combat mosquito nuisance and malaria. A multicentric questionnarie-based study revealed that repellents are harmful to human health, and their use should be avoided and discouraged. In this study 11.8% people using various types of repellents complained of ill health effects, and some required medical treatment. Although symptoms disappear shortly after withdrawl, those who do not suffer acute toxicity symptoms and continue to use these repellents for extended periods may suffer neurotoxic and immunotoxic hazards. Safe alternatives are discussed for use by the communities and local bodies.

IN most urban and rural areas of the country, mosquito populations are menacing throughout the year, except for some attenuation during summer and winter. Mosquitoes transmit diseases such as malaria, filariasis and many viral diseases such as the Japanese encephalitis, dengue haemorrhagic fever, yellow fever (in Africa), etc. Mosquito coils containing DDT and other organophosphorus compounds were not effective in repelling mosquitoes. Buzzers and electrocuting devices are also useless, just as mosquito repellents[1–4]. Currently a variety of repellents are marketed in India in the form of mats, coils, lotions and vaporizers. These repellents use allethrin group of compounds, herbs, oils or diethy toluimide (DEET). The protection provided by these repellents generally lasts for 2 to 4 h.

Indian scenario

The current Indian market for various repellents is in the range of Rs 500–600 crores (US $ 12–15 million) with annual growth of 7 to 10%. This increase in growth rate is the result of constant environmental degradation, leading to the creation of mosquito-breeding grounds and also the fact that people's capacity to buy repellents is increasing steadily. Marketing of repellents in India is well organized, so that many brands can be found throughout the country. Introduction of insecticides in the country is subject to registration by the Central Insecticide Board, an autonomous institution under the Ministry of Agriculture, Government of India. Insecticides, for registration, should be safe to human health, wildlife and non-target species. Permission to market a product means that the product has cleared the safety requirements as specified by the Central Insecticides Board. Once the insecticide has been cleared, there is no provision of post-monitoring the adverse health effects of these insecticides, if any.

Health hazards due to mosquito repellents

Researchers are now providing data on the harmful effects of repellents used against mosquitoes. The main site of action of the pyrethroids is the sodium channel, which is kept open for long periods of time, causing prolonged sodium current to flow, leading to hyper-excitation of the nervous system[5]. Synthetic pyrethroids, e.g. allethrin cause subnormal or super-normal excitability by affecting the sodium channel opening time. Cheng *et al.*[6] exposed male ICR mice to mosquito coil smoke with *d*-allethrin and reported histopathological lesions, including the loss of cilia and an increase in vascularity of the alveolar wall. Liu and Sun[7] reported that mosquito coils also contain aromatic and aliphatic hydrocarbons, which are combustion products of wood dust, fillers and dyes in the mats. An exposure of rats to the mosquito coil smoke for 60 days resulted in focal deciliation of the tracheal epithelium, metaplasia of epithelial cells and morphological alterations of the alveolar macrophages. Liu *et al.*[8] analysed mosquito coils from Asia and South America and reported that smoke from heating (or burning) contained sub-micron particles (< 1 micron) coated with considerable amount of heavy metals, allethrin and a wide range of vapours such as phenol O-cresol. Furthermore, allethrin used in the mats increased blood brain barrier (BBB) permeability, suggesting a delayed maturity of BBB and biochemical changes causing health risks, especially at an early age in life[9]. Moya-Quiles *et al.*[10,11] reported aggregation of allethrin in the bilayer core. Eriksson *et al.*[12] and Ahlbom *et al.*[13] reported changes in the density of muscarinic acetylcholine receptors (MAChRs) in cerebral cortex of mice treated neonatally with DDT, who later as

V. P. Sharma is in Malaria Research Centre (ICMR), No. 22, Sham Nath Marg, New Delhi 110 054, India.

adults received bioallethrin, causing the irreversible MAChR changes and behavioural disturbances. Johansson *et al.*[14] found behavioural aberrations in the adult mice treated with bioallethrin. These findings are especially important in view of high DDT deposits in the body of Indian populations. Allethrin has no effect on insect cholinesterase activity, but has stimulating action by releasing acetylcholine (Ach) from the cholingeric ganglion[15]. Diel *et al.*[16] reported the immunotoxic properties of *s*-bioallethrin caused by inhibiting lymphocyte proliferation in a dose-dependent manner. D-transallethrin, through hormonal pathways, may contribute to reproductive dysfunction, development impairment and cancer[17].

Results of questionnaire-based survey

Repellents use Type I synthetic pyrethroids. These insecticides are heat stable and used in the treatment of mats, coils and vaporizers, e.g. allethrin and bioallethrin 4%; *d*-allethrin 0.2 to 0.3% w/w; *d*-transallethrin 0.1 to 0.15% w/w; *s*-bioallethrin 1.9%, etc. On heating or burning of mats and liquids, these compounds vaporize without decomposition at temperatures up to 400°C and produce repellent action on the mosquitoes. To study ill effects on human health, we carried out a questionnaire-based survey to elicit response from (i) users, and (ii) medically qualified doctors. These surveys were carried out in the urban and rural areas in 9 states by the scientific staff of the Malaria Research Centre. Table 1 gives the results of these surveys. Results revealed that 11.8% users comprising all age groups and both sexes complained of a variety of acute toxicity, either soon after or within a few hours of use of repellents. Breathing problems were the most common (4.2%) and frequently this condition was accompanied with headache or eye irritation or both. Eye irritation was the next common complaint (2.8%) and often it was accompanied with bronchial irritation, headache or skin reaction. Cough, cold and running nose was accompanied with fever or sneezing in 1.67% cases. Some people complained of wheezing and asthma and in 2 cases users who did not have asthma became asthmatic, even after discontinuing the use of repellents. There were complaints of pain in the ear and throat. Of those using a DEET-based cream, out of 174 people 20 (11.4%) reported skin reaction, e.g. rash, black spot or in some cases skin turning black or oily and itching, with 3 cases complaining bad suffocating odour and eye irritation. Medical doctors confirmed the reports of questionnaire-based household surveys reporting adverse health effects. Out of the total 286 doctors interviewed from the same locations as the household surveys, 165 (57.7%) reported acute toxicity following the use of repellents. Doctors stated that patients with strong reaction leading to asthma or bronchial irritation, ENT or eye problems required treatment. Menon and Halarnker[18] warned against the use of repellents and stated that: 'Repellents – the Danger Within. There could be danger from mosquito-repelling creams, mats, oils and lotions. The principal class of chemicals they use pyrethrums, could lead to running nose and wheezing, prolonged use could lead to corneal damage, asthma and liver damage, foreign studies warn. Indian ENT surgeons are now reporting similar symptoms in their patients. Not surprising, given our mosquito-ridden cities.' The Industrial Toxicological Research Institute, Lucknow has also recorded serious health consequences of the use of repellents[19].

Table 1. Results of questionnaire-based survey on health risks of commonly used repellents

Complaint	Number of people affected out of 5920 persons interviewed	%
Breathing problem	248	4.20
Eye irritation	165	2.80
Cough, cold and sneezing	99	1.67
Headache	78	1.32
Asthma	28	0.47
Bronchial irritation	27	0.46
Itching	20	0.34
Ear, nose and throat pain	18	0.30
Others*	19	0.32
Total	702	11.80

*Giddiness, vomiting, nausea, allergy, etc.
Note: A variety of repellents were used routinely to protect from mosquito nuisance. Of the total 5920 persons (including 286 medically qualified doctors) interviewed, 5218 (88.20%) did not report any complaint of adverse health impact in the use of repellents.

Alternative measures to combat mosquitos

There are completely safe alternate measures to the use of chemical-based repellents. Use of these requires personal attention, action by the community and the local bodies. They are (i) Source reduction: weekly emptying and drying of all standing water sources, howsoever small they may be, in and around houses and other structures. Water should be stored in containers that can be easily cleaned and the opening should be well protected from the entry of mosquitoes; (ii) Good drainage: proper gradient should be provided to eliminate standing water in drains, low-lying areas, ditches, borrow pits, etc; periodical de-silting of drains, sewers and storm water drains before the onset of monsoon to enable the drains to maintain steady flow; (iii) Minor engineering works: overhead and underground water tanks, wells and sumps should be sealed hermetically and provided with ventilating shafts, made mosquito-proof. Man hole covers should be in place; (iv) Biological control: surface drains, temporary water collections and scraps, etc. should be sprayed with *Bacillus thuringiensis* H-14 at fortnightly intervals; larvivorous fishes should be released in ponds, lakes, rice

fields, drains, etc. (v) Personal protection methods: mosquito nets, preferably treated with synthetic pyrethroid insecticides (treated nets are safe); wire mesh doors, windows and ventilators can be used; and (vi) Neem oil can be extracted from the seeds of *Azadirachta indica* and used as neem cream[20]; neem oil 5 parts and 95 parts edible oil like coconut or mustard oil[21] or mats treated with neem oil[22] or burning neem oil in kerosene[23] would be a cost effective alternative to chemical repellents. Neem oil is safe when used as mosquito repellent[24].

1. Nasci, R. S., Haria, C. W. and Porter, C. K., *Sangyo Eiseigaku Zasshi*, 1995, **37**, 5–8.
2. Belton, P., *Mosq. News*, 1981, **41**, 751.
3. Curtis, C. F. and White, G. B., *New Sci.*, 1982, **93**, 328.
4. Foster, W. W. and Lutes, K. I., *J. Am. Mosq. Control Assoc*., 1985, **1**, 199.
5. Narahashi, T., Frey, J. M., Ginsburg, K. S. and Roy, M. L., *Toxicol. Lett*., 1992, 429–436.
6. Cheng, V., Lee, H. R. and Chen, C. S., *Toxicol. Lett*., 1992, **62,** 163–177.
7. Liu, W. K. and Sun, S. E., *Toxicol. Lett.*, 1998, **41,** 145–157.
8. Liu, W. K., Wong, M. S. and Mui, Y. L., *Toxicol. Lett*., 1987, **39**, 223–230.
9. Gupta, A., Nigam, D., Gupta, A., Shukla, G. S. and Agarwal, A. K., *J. Appl. Toxicol*., 1999, **19,** 67–72.
10. Moya-Quiles, M. R., Munoz-Delgado, E. and Vidal, C. J., *Biochem. Mol. Biol. Int*., 1995, **36**, 1299–1308.
11. Moya-Quiles, M. R., Munoz-Delgado, E. and Vidal, C. J., *Arch. Biochem. Biophys*., 1994, **312,** 95–100.
12. Eriksson, P., Johansson, U., Ahlbom, J. and Fredriksson, A., *Toxicology*, 1993, **77,** 21–30.
13. Ahlbom, J., Fredriksson, A. and Eriksson, P., *Brain Res.*, 1994, **645,** 318–324.
14. Johansson, U., Freriksson, A. and Eriksson, P., *Eur. J. Pharmacol*., 1995, **293,** 159–166.
15. Takeno, K., Tsurukame, T. and Yanagiya, I., *J. Toxicol. Sci.*, 1983, **8,** 269–278.
16. Diel, F., Detscher, M., Schock, B. and Ennis, M., *Allergy*, 1999, **53**, 1052–1059.
17. Garey, J. and Wolff, M. S., *Biochem. Biophys. Res. Commun*., 1998, **251**, 855–859.
18. Menon, S. and Halarnker, S., *India Today*, 25 May 1998, p. 70.
19. Seth, P. K., Industrial Toxicological Research Centre, Lucknow, India, 1998 (pers. commun.).
20. Dua, V. K., Nagpal, B. N. and Sharma, V. P., *Indian J. Malariol.*, 1995, **32,** 47–53.
21. Sharma, V. P., Ansari, M. A. and Razdan, R. K., *J. Am. Mosq. Control. Assoc.*, 1993, **9**, 359–360.
22. Sharma, V. P., Nagpal, B. N. and Srivastava, A., *Trans. R. Soc. Trop. Med. Hyg.*, 1993, **87**, 626.
23. Sharma, V. P. and Ansari, M. A., *J. Med. Entomol*., 1994, **3**, 505–507.
24. Valecha, N., Ansaari, M. A., Prabhu, S. and Razdan, R. K., *Indian J. Malariol*., 1996, **33**, 139–143.

ACKNOWLEDGEMENTS. I thank Dr Sarala K. Subbarao, Director, Malaria Research Centre (MRC), New Delhi and the scientific staff of the MRC field stations for the questionnaire-based surveys carried out in various parts of the country.

Received 9 July 1999; revised accepted 13 November 2000

Facilitating innovation in Indian small and medium enterprises – The role of clusters

V. P. Kharbanda

The present-day knowledge economy demands knowledge-intensive enterprises which only can survive in the ongoing process of globalization and increased international competition. Knowledge as a factor for competitive advantage has replaced traditional factors like labour and capital. As knowledge resides only in the human mind, it can only be harnessed by focusing on increasing human capabilities through the process of increased communication, cooperation and linkages, both within the enterprise as well as across enterprises and knowledge-producing organizations. This paper dwells upon a few case studies, how enterprises in India are facing this challenge, and particularly, how small-scale enterprises are moving towards clusters for international competition.

IN most developing countries, small and medium enterprises (SMEs) constitute the bulk of the industrial base and contribute significantly to their exports as well as to their GDP or GNP. For instance, India has nearly three million SMEs, which account for almost 50 per cent of industrial output and 42 per cent of India's total exports. It is the most important employment-generating sector and is an effective tool for promotion of balanced regional development. These account for 50% of private sector employment and 30–40% of value-addition in manu-

V. P. Kharbanda is in the National Institute of Science Technology and Development Studies, Dr K.S. Krishnan Marg, New Delhi 110 012, India. (e-mail: kharbandavpk@yahoo.com)