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Effect of temperature variation on lindane dissipation and microbial activity in soil

Vishal Tripathi [a], P.C. Abhilash [a,*], H.B. Singh [b], Nandita Singh [c], D.D. Patra [d]

[a] Institute of Environment & Sustainable Development, Banaras Hindu University, Varanasi 221005, India
[b] Department of Mycology & Plant pathology, Institute of Agriculture Science, Banaras Hindu University, Varanasi 221005, India
[c] Eco-Auditing Group, CSIR-National Botanical Research Institute, Lucknow 226 001, India
[d] Agronomy & Soil Science Division, CSIR-Central Institute of Medicinal & Aromatic Plants, Lucknow 221005, India

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ABSTRACT

There is a general consensus that temperature variation can significantly affect the fate and behavior of pesticides and microbial activity in soil. Therefore, the present study was aimed to evaluate the effect of temperature variation on dissipation of lindane from soil. The soil samples were spiked with four different concentrations of lindane (5, 10, 15 and 20 mg kg^{-1}) and were incubated at 28, 33, 40 and 48 °C for 45 days. The residual lindane concentrations in soil, 50% dissipation rate of lindane (DT_{50}), microbial biomass carbon (MBC) as well as soil dehydrogenase activities were monitored periodically. Irrespective of the initial lindane concentrations and exposure days, the increase in temperature significantly reduced the residual lindane and increased the dissipation of lindane from soil ($p < 0.001$). Similarly, the temperature increase from 28–48 °C significantly reduced the MBC content ($p < 0.01$) and soil dehydrogenase activity ($p < 0.001$). Most interestingly, the warming climate significantly reduced the DT_{50} days at 99.9% confidence level. This was more prominent at 48 °C ($r^2 = 0.981$). Our study concludes that warming temperature can significantly reduce the microbial activity, soil enzymes as well as the dissipation rate of pesticides from soil. To the best of our knowledge, this is the first experimental report on the dissipation of lindane under warming temperature. However, more studies are required to underpin the detailed physical, chemical and biological process involved in the dissipation and bioremediation of pesticides under warming temperature.

1. Introduction

The global warming due to increasing green house gases emission is considered as one of the most serious environmental problems for the present and future generations (IPCC, 2013). This warming will not only affect the living organisms but also the fate and behavior of xenobiotics and other chemical compounds present in the biosphere (Abhilash et al., 2013a; Abhilash and Dubey, 2014). Warming temperature would also induce various changes in the physico-chemical properties of the toxic pollutants present in soil like their absorption–desorption, mobility, leaching and volatility. Moreover, the increasing global atmospheric temperature can also affect the biotransformation and bioavailability of the pollutants present in the soil due to the altered microbial activity (Noyes et al., 2009; Abhilash et al., 2013a). Organochlorine pesticides (OCPs) constitute a predominant group among the various persistent organic pollutants (POPs) in soil, (Abhilash and Singh 2009; Abhilash et al., 2013b). Although OCPs were completely banned in most of the countries, their residues continues to pose a serious threat to human health (Vijgen et al., 2011; Abhilash et al., 2013a; Köhler and Triebskorn 2013; Dubey et al., 2014; Tripathi et al., 2014a,b).

Lindane is a OCPs candidate recently included in the Stockholm list of POPs for global elimination (Vijgen et al., 2011). However, according to the recent estimates, about 4–7 million tons of lindane and other HCH isomers residues are left over worldwide and these residues pose a serious threat to environment and human health (Weber and Varbelow, 2013). Since lindane is volatile, it has the ability to undergo long range atmospheric transport and leading to the contamination of various pristine ecosystems (Abhilash, 2009; Abhilash and Singh, 2009a,b,c). Moreover, it has been speculated that a warming climate may further accelerate pesticides volatility and long range transport as well as the rate of dissipation and microbial degradation in soil (Abhilash et al., 2013b; Abhilash and Dubey, 2014).

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* Corresponding author. Tel.: +91 9415644280.
E-mail addresses: pca.iesd@bhu.ac.in, pcabhilash@hotmail.com (P.C. Abhilash).

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Table 1
Physico-chemical properties of soil samples.

Variables	Values
pH	6.75 ± 0.29
Conductivity (μS cm^{-1})	325.6 ± 2.93
Organic matter (%)	0.5 ± 0.01
Total nitrogen (%)	0.06 ± 0.02
Phosphorous (mg kg^{-1})	79 ± 3.20
Calcium (mg kg^{-1})	23.14 ± 1.25
Magnesium (mg kg^{-1})	21.10 ± 1.86
Sodium (mg kg^{-1})	24.52 ± 2.50
Potassium (mg kg^{-1})	80.20 ± 3.09

However, apart from the speculations, nothing more is known about the fate and behavior of POPs in soil under warming climatic conditions. Till date, only limited studies have explored the behavior and partition of POPs under warming climate (Eisenreich 2005; Dalla Valle et al., 2007; Jenssen 2006; Macdonald et al., 2005; Lamon et al., 2009; Abhilash et al., 2013a). As a result, there is a paucity of experimental data regarding the fate and behavior of POPs in a warming temperature and also many uncertainties and challenges have to be still explored and answered (Lamon et al., 2009; Abhilash et al., 2013a). Therefore, the present study was aimed to evaluate: (i) the dissipation of lindane at varying temperature (28–48 °C) and (ii) study the effect of elevated temperature on soil microbial and dehydrogenase activity. To the best of our knowledge, this is the first experimental report on the dissipation of lindane under warming temperature.

2. Materials and methods

2.1. Dissipation assays

The top layer garden soils (with no previous insecticidal history) were collected and dried in room temperature and passed through a sieve of mesh size 2-mm. The physico-chemical properties of the soil samples are presented in Table 1. The soil samples were spiked with four different concentrations of lindane such as 5, 10, 15 and 20 mg kg^{-1}. The details of soil preparations and lindane spiking are elaborated in our earlier publications (Abhilash and Singh, 2008a,b). The dissipation assays were conducted as batch experiments. For this, sixteen batches of pots were prepared in triplicate and filled with 600 g garden soil having four different concentrations of lindane, i.e., 5, 10, 15 and 20 mg kg^{-1}. Each batches of pots were incubated at four different temperatures such as 28 °C (room temperature and hence taken as the control), 33 °C and two elevated temperatures viz 40 and 48 °C, respectively. The incubation temperatures were selected according to the mean maximum and minimum temperature experienced in Varanasi, Uttar Pradesh during the last two years (Fig. 1). The residual lindane from all the pots were analyzed at a time interval of 15, 30 and 45 days. Similarly, soil microbial biomass carbon (MBC) and soil dehydrogenase activity was also studied during each sampling. The dissipation of lindane from soil samples were studied using linear regression and the 50% dissipation (DT_{50}) values were calculated as $DT_{50} = M_0 + \ln(1-50/100)$ where M_0 is the initial concentration of pesticide at a particular time 't' (Sarmah and Close, 2009).

2.2. Soil extraction and analysis

Soil analyses were done according to the standard operating procedures described elsewhere. Soil pH and conductivity was measured from saturated soil solution (1:5 soil:water) using pH and conductivity meter (Cyber Scan-500). The soil nitrogen content was estimated by Kjieldal method using Kjeltech Analyzer and the phosphate content of the soil was measured by colorimetrically using UV–vis Spectrophotometer (Thermo variance). The sodium, potassium and magnesium concentrations of the soil sample were measured by flame photometric method (Systronics-128). Microbial biomass carbon (MBC) was estimated by the method of Vances et al. (1987). Soil dehydrogenase activity was measured colorimetrically by monitoring the rate of reduction of 2,3,5-triphenyltetrazolium chloride (TTC) to the red, water insoluble triphenylformazan (TPF) (Fan et al., 2008). The determination of lindane residue in the soil was carried out by Soxhlet extraction followed by gas chromatograph equipped with 63Ni electron capture detection. Sample preparation, purification, calibration and chromatographic conditions are described in our previous publications (Abhilash and Singh, 2008a,b).

2.3. Statistical analysis

The experimental results were subjected to analysis of variance to test the effect of various temperatures on pesticide dissipation

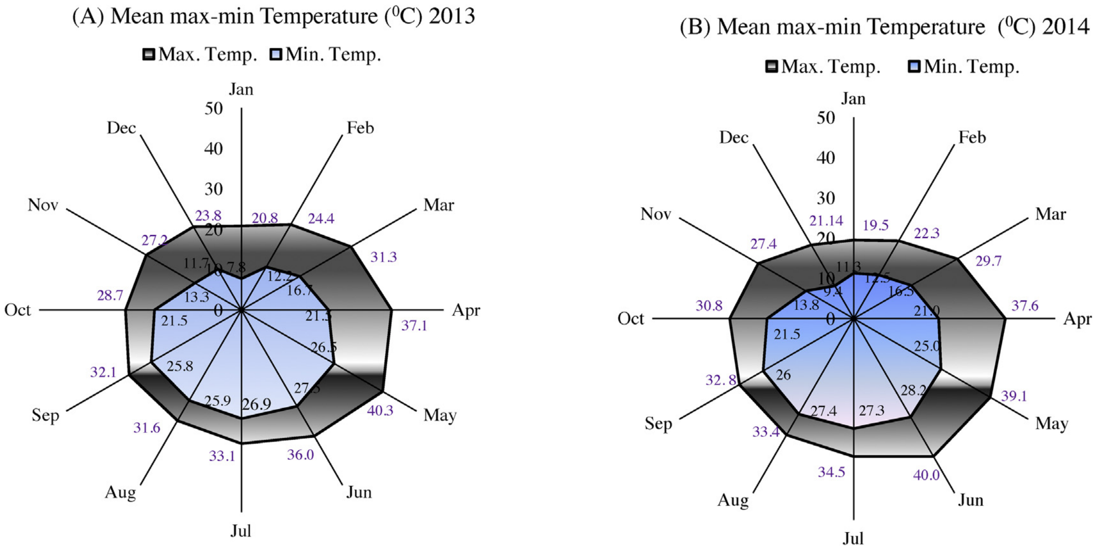

Fig. 1. Mean maximum–minimum temperature of the study area during (A) 2013 and (B) 2014.
Source: IMD weather station, BHU, Varanasi.