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Trends in poisoning associated with the use of insecticides for bed bug infestations: a 20-year retrospective study in France

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Bed bugs are pervasive global pests that have reemerged in the last 20 years as a significant public health concern, especially in densely populated urban areas. Beyond financial losses, expenses, inconvenience, and psychological distress, bed bug infestations often necessitate chemical management, posing poisoning risks to those with an infestation. The French Poison Control Centers recorded 1056 cases of exposure to bed bug insecticide products between 1999 and 2021. This study followed cases over 2007–2021, with a notable surge in reports of adverse reactions from 2016 onwards. Data revealed an increased recurrent misuse of insecticides, including substances banned or not approved for this use. Our findings underscore the growing public reliance on chemical insecticides for home bed bug management. With this is the concern of increased poisoning risks, and potential long-term health consequences from non-professional efforts by the public to manage bed bugs in their homes. This escalating trend emphasizes the need for safer and more sustainable pest management strategies in urban environments.

Keywords Bed bug, Insecticide, Pyrethroids, Poisoning, Pest management

Bed bugs, including the common bed bug, *Cimex lectularius* L. largely in temperate regions and the tropical bed bug, *Cimex hemipterus* F. mainly in tropical areas, are considered significant obligate temporary hematophagous insect pests. Previous studies in France have largely identified *Cimex lectularius* L. as responsible for bed bug infestations [37532686; 34202079]. It is therefore likely that the reported cases of exposure to insecticides used to treat bedbug infestations, in this study conducted in France, mainly involve *Cimex lectularius* L.

Although bed bugs were common in the early twentieth century and before, they became rare in developed countries during the late 1940's into the 1950s with the introduction of dichlorodiphenyltrichloroethane (DDT)[1] and the other organochlorides. However, since the late 1990s, there has been a global resurgence of both bed bug species[2].

Many factors have contributed to this resurgence. One of the most important is probably the development of insecticide resistance[1]. Resistance to DDT was reported as early as the late 1940s, a few years after its widespread use. DDT is currently banned in developed countries. Today, pyrethroids are the most widely used class of insecticides in developed countries, although resistance has been widely reported[3–5]. More recently, bed bugs have proved resistant to new eradication strategies combining pyrethroids and neonicotinoids. Bed bugs are therefore particularly well adapted to resist insecticides, with resistance mechanisms that give them cross-resistance to different classes of insecticide[1]. Other factors have also contributed to the resurgence of bed bugs[1]. Pest control strategies, both chemical and non-chemical, have probably been inadequate. In addition, increased international travel has facilitated the spread of bed bugs, including probably highly resistant strains. Bed bugs can survive long

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periods of starvation. With the increase in human travel around the world, bed bugs present in public transport can easily survive long periods of starvation while being transported over long distances.

While bed bugs are not considered vectors of disease causing pathogens[6], they can still have health-related implications. They feed using piercing sucking mouthparts. The mechanical piercing and introduction of saliva (referred to as the "bite"), typically result in pruritic, maculopapular, and erythematous skin lesions[7], affecting the resident's quality of life due to itching, sometimes complicated by secondary infection due to scratching. More severe allergic reactions, such as bullous eruption or systemic reactions, are rare[8]. Symptoms affect the quality of life of bite victims, who sometimes experience significant mental health distress[9]. Furthermore, bed bug infestations impose financial consequences, including the economic costs associated with management and the potential loss of revenue, particularly for the hospitality industry[10].

Bed bugs can be managed using both non-chemical and chemical and methods as part of an integrated pest management program[1]. Human exposure to insecticides in bed bug management remains a concern since it potentially may lead to poisoning in those applying the products and the occupants of treated areas. Reports of severe acute toxicity cases linked to products used against bed bugs have included desquamative interstitial pneumonia[11], complete heart block[12], and acute tubular necrosis[13]. Between 2003 and 2011, the US Centers for Disease Control (CDC) identified 111 cases of acute illnesses associated with insecticides used to manage bed bugs in seven USA states. Although 90 (81%) were of low severity, one fatality occurred[14]. Among the 91 calls involving exposures to compounds used for bed bug management reported to the Texas Poison Centers between 2006 and 2011, the most common symptoms were coughing or choking (23%), nausea (12%), throat irritation (10%), vomiting (9%), and headache (9%)[15].

Given the increased concerns surrounding the resurgence of bed bugs and the potential health impacts around the use of insecticides for their management, we conducted a study of human toxicity reports as recorded by the French Poison Control Centers (FPCC) over a period of 23 years.

Methods

We conducted a retrospective study including all cases of exposure to a least one insecticidal product used for bed bug management, reported to FPCC between 1999 and 2021.

Data sources

In France, the eight FPCC, supported by the French Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail (ANSES) toxicovigilance program, respond to calls for assistance from the general public, healthcare services, and other professional groups on a 24/7 phoneline regarding any type of xenobiotic exposure. The medical history, age and sex of the patient are recorded, along with the route of exposure, dose of the xenobiotic(s), associated symptoms, and any administered care given. Data is then anonymously recorded in the French National Database of Poisonings (FNDP) administered by the French Ministry of Health. Insecticidal products are coded from the French National Database of Products and Compositions (FNDPC), which contains the brand name and ingredients of all chemical and medicinal products sold in France. Ingredient reporting is mandated by law whether provided by the manufacturer or requested by FPCC.

Selection of cases

First, we identified all cases of exposure to at least one insecticidal product during bed bug treatments that was reported to the FNPD between 1999 and 2021, by searching for the term "punaise" (a French abbreviation "bed bug"), in the medical records. We only retained records explicitly referring to bed bugs; records without specific mention or related to other insects were excluded.

Data collection

For each case, we collected the following data: patient demographics (age, sex), details of the exposure (product, circumstances), and reported symptoms. Exposure was categorized as 'direct' if it occurred while using the product and 'indirect' if it occurred after using the product.

Severity was assessed using the Poisoning Severity Score[16], which categories severity on five levels: PSS0, no symptoms; PSS1, mild severity; PSS2, moderate severity; PSS3, high severity; and PSS4: death.

Ethics

The FNDP is registered and approved by the French Data Protection Authority (FDPA no 2020-131). The consent of patient's personal data and its use for the purpose of research is waived in accordance with French law. All methods were performed in accordance with guidelines and regulations as directed by FDPA.

Results

During the period from 1999 to 2021, FPCC reported 1056 cases involving exposure to products used for the treatment of bed bug infestations, however the first report occurred in 2007. Following this case, there was a slow increase of cases until mid-2016, when reports climbed rapidly peaking by mid-2019 (Fig. 1). Incidents were more frequent during summer months, with 39% of reports occurring between July and September. The reports showed a heterogeneous geographical distribution across France, with a 50% concentration in and around Paris, an area accounting for < 15% of the country's population.

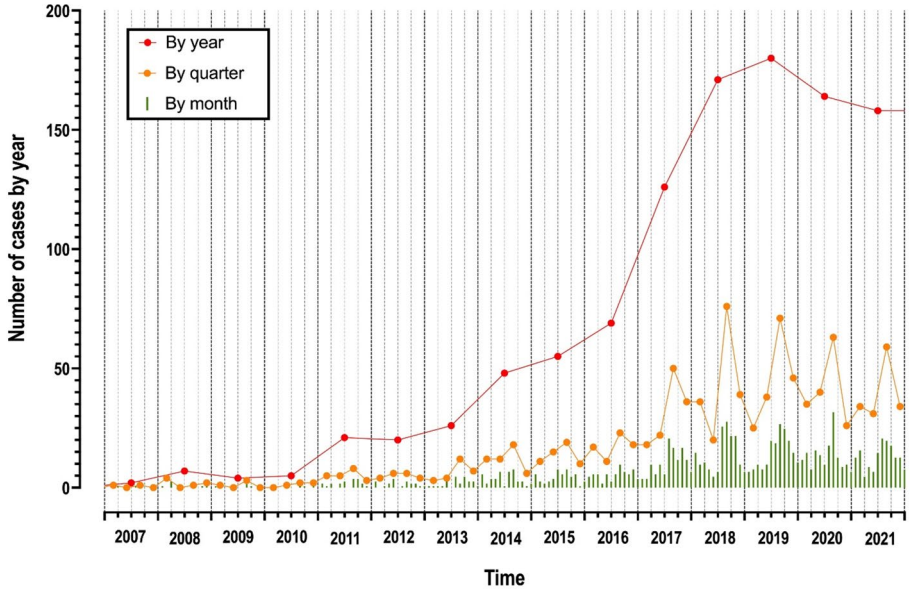

Figure 1. Temporal trends in the number of cases of exposure to insecticides used to treat bed bug infestations reported to French Poison Control Centers (2007–2021): by month (green bars), quarter (orange line), and year (red line).

Characteristics of patients

Sex of patients was known in 95% of cases (n = 1005), with 66% (n = 662) female and 34% (n = 343) male (*sex ratio* 0.5). Age of patients was known for 89% (n = 943). Of these, 16% (n = 151) were under 18, and 10% (n = 94) were under the age of 6. The median age was 35 years (interquartile range 25). The distribution of patients by age and sex is presented in Supplementary Fig. 1. Fifty-eight (n = 58) cases were pregnant or breastfeeding women.

Characteristics of exposures

The mode of exposure was direct in 543 cases (51.4%), indirect in 410 cases (38.8%) and unknown in 103 cases (9.8%). The place of exposure was recorded in 675 cases (63.9%). Of these, 604 (89.5%) were private homes. Exposure occurred at work in 24 cases (2.3%). However, only seven instances (0.7%) involved the exposed individual being the person applying the product, and among these cases, only one was a professional applicator. The type of insecticide(s) used against bed bug infestations was known in 98% (n = 1038) of reports (Table 1). In more than nine out of ten cases, one or more chemical insecticides (primarily pyrethroids) were used. In a quarter of cases, the active insecticide ingredient used was not known. In over half of cases (52%), the pesticide had been applied by a professional who did not tell customers which chemical insecticide was used. Forty-four (n = 44) reports involved a chemical insecticide not authorized for use against bed bugs in the European Union (EU). These were Dichlorvos (n = 36), Malathion (n = 4), Aluminum phosphide (n = 3), and Rotenone (n = 3).

Insecticide type and active ingredient if applicable	N (%)
Chemical insecticides	1047 (95.3%)
Pyrethroids	565 (51.4%)
Cholinesterase inhibitors	87 (7.9%)
Diatomaceous earth	47 (4.3%)
Essential oils	31 (2.8%)
Chlorfenapyr	15 (1.4%)
Rotenone	3 (0.3%)
Aluminum phosphide	3 (0.3%)
Others	11 (1.0%)
Unspecified	285 (25.9%)
Others	34 (3.1%)
Unknown	18 (1.6%)

Table 1. Cases recorded by the French Poison Control Centers (2007–2021), of exposure to insecticides used against bed bugs. In some cases, multiple types of controls were used. This raised the number of data points from 1056 to 1099, an increase of 43 reports. This was adjusted for in the percentages.

Symptoms and severity

Symptoms were reported in 75.5% of patients (n = 797). Exposed pregnant women were less frequently symptomatic (39.1%, n = 18). There were fewer symptomatic cases among children under 18 (66.2%, n = 100) than among adults (81.1%, n = 642). There was no difference in the proportions of symptomatic cases between exposure to pyrethroids (80.9%, n = 442) and exposure to anticholinesterase agents (85.4%, n = 70). The most prevalent symptoms included respiratory distress e.g. dyspnea (n = 164) and coughing (n = 117), followed by headaches (n = 114). Additionally, skin-related symptoms included paresthesia/pruritus (n = 103) and dermal pain/irritation (n = 88). Digestive symptoms included nausea (n = 92) and vomiting (n = 68). The majority of patients presenting with symptoms (98.5%, n = 785) were categorized as PSS1. More severe symptoms (PSS2–3–4) were observed in 1.5% (n = 12) of patients, with one being fatal (Table 2). Notably, four cases involved an insecticide not authorized for use against bedbugs.

Discussion

FPCC documented 1056 cases of exposure to bed bug insecticide products between 2007 and 2021. Although the method of data collection may lead to an underestimation of case incidence, as not all cases were reported to the FPCC, the temporal trend is consistent with observations elsewhere and roughly follows the global resurgence of bed bugs[1], with no cases recorded from 1999 to 2006, whereas the first case was recorded in 2007. Reports then increased slowly until 2016, when reports rose dramatically, with a temporary dip during the COVID-19 pandemic. Reports were more frequent during summer months when ambient temperatures favor bed bug development[17]. More adverse reaction reports originated from Paris and its suburbs, where the population is around 10 million. However, the geographical distribution of the reports suggests high bed bug populations in other French metropolitan areas. These include Lyon, the second most populous urban area with approximately 1.7 million people, and Marseille, the third most populous urban area with approximately 1.6 million.

While the majority of reports were symptomatic, the severity of symptoms remained relatively low, usually manifesting as breathing difficulties, coughing, headache, paresthesia, or nausea. These findings are consistent with the well-established low acute toxicity profile of insecticides approved for use against bedbugs in the European Union, mainly pyrethroids[18]. Nevertheless, greater symptom severity is possible, particularly in vulnerable individuals, such as those with asthma, children, and the elderly.

Not all exposure records were consistently and uniformly collected by FPCC during emergency phone consultations, thus conducting a quantitative analysis of data proved unattainable. Nevertheless, a thorough examination of patient reports provided valuable insights for future preventive strategies. Indirect exposures affecting occupants of treated premises often resulted from premature reentry following treatments, which might be attributed to a number of factors: (i) lack of awareness about product application such as new guest in a hotel room; (ii) unplanned for reentry such as looking for keys or emergency alarms; (iii) insufficient communication by professional applicators regarding safe reentry times; or (iv) among private applicators, a lack of familiarity with insecticide use directions. Furthermore, misuse practices, such as excessive product application, inadequate post-treatment ventilation, application in confined spaces, or the use of insecticide-treated bedding, are known to lead to high direct or indirect exposure. Conversely, the rarity of cases involving professional applicators in our study suggests that workplace safety measures are generally respected. It is also possible that professionals under-report their intoxications to poison control centers.

This study identified 44 cases of exposure to insecticides not authorized for use against bed bugs in the EU. Notably, we reported a collective case of phosphine poisoning resulting in two severe cases of myocarditis, one of

#	Sex, age (y.o.)	Exposure	Insecticide	Severity	Symptoms
1	F, 0–4	Indirect inhalation immediately following spray treatment of a room	Unspecified	PSS2	Convulsive seizure
2	M, 0–4	Direct inhalation during treatment	Pyrethroid	PSS2	Convulsive seizure
3	F, 5–9	Indirect exposure following treatment of a room	Unspecified	PSS2	Convulsive seizure
4	M, 5–9	Phosphine inhalation the night after powdering the insecticide in a room	Banned aluminium phosphide	PSS3	Myocarditis
5	M, 5–9	Phosphine inhalation the night after powdering the insecticide in a room	Banned aluminium phosphide	PSS4	Myocarditis
6	F, 10–14	Indirect inhalation and skin absorption while sleeping on a treated mattress	Banned organophosphate	PSS2	Anticholinesterase syndrome
7	F, 20–24	Phosphine inhalation the night after powdering the insecticide in a room	Banned aluminium phosphide	PSS2	Prolonged vomiting
8	F, 20–24	Direct inhalation during treatment	Pyrethroid spray	PSS2	Dyspnea and prolonged coughing
9	F, 25–29	Indirect exposure of product the night following treatment of a room	Unspecified	PSS2	Prolonged vomiting
10	F, 40–44	Direct inhalation during treatment	Diatomaceous earth	PSS2	Asthma attack
11	F, 45–49	Five days of indirect exposure following treatment of a room including mattresses	Unspecified	PSS2	Prolonged diarrhea, paresthesia, tremors
12	F, 50–54	Direct inhalation	Pyrethroid fogger	PSS3	Respiratory distress

Table 2. Description of cases with moderate severity (PSS2), high severity (PSS3), and fatal outcome (PSS4). *PSS* Poisoning Severity Score[16], *F* female, *M* male.

which died. The use of these insecticides likely underscore the challenges associated with bed bug management and the ineffectiveness of some conventional insecticide treatments, due to pesticide resistance by the insects. Among insecticides not authorized for bed bug management, some are authorized for other uses, while others are totally banned. The latter is the case of dichlorvos, a pesticide banned in the EU in 2013, but still used against bed bugs. These banned products are often acquired during international travel, online purchases or on illicit markets.

Although not documented in reports to FPCC, the mental health impact of bed bug infestations is undoubtedly a significant aspect of the issue. It is well documented in the literature that those who have bed bugs may develop a range of psychological and behavioral symptoms, including sleep disturbance, insomnia, mood changes, nervousness, panic and anxiety, hypervigilance, posttraumatic stress disorder-like symptoms, and socio-occupational dysfunction[9]. This can lead to indiscriminate use of chemical insecticides to eradicate bedbugs. This is illustrated by a US CDC report describing the death of a woman following indiscriminate application, over several days, of dozens of insecticide products in her home[14].

Our study has primarily focused on the acute effects of bed bug treatments. However, it also prompts us to consider the broader issue of pesticide pollution in buildings and the associated potential long-term health risks. Growing evidence suggests an association between exposure to pyrethroids, the most commonly used family of domestic insecticides, and adverse health effects, including neurological, reproductive, and cardiovascular disorders[19–21]. Further studies are needed to determine the contribution of insecticide applications in bed bug management in the exposure of humans to pyrethroids, especially considering that urinary pyrethroid metabolites were recently quantified in 99% of French adults and children[22].

Our findings emphasize the necessity of promoting safer and more sustainable urban pest management practices, prioritizing non-chemical methods for bed bug management and the use of insecticides with lower mammalian toxicity such as the desiccant dusts.

Data availability

The dataset analyzed during the current study is available from the corresponding author upon reasonable request.

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Author contributions

Conceptualization: H.L.C., J.L., M.O.R.; Methodology: H.L.C., D.V., W.C., P.N., J.L., A.O.D.Z., S.B., M.O.R.; Formal analysis: H.L.C., J.L., A.O.D.Z., M.O.R.; Investigation: H.L.C., D.V., W.C., P.N., J.L.; Writing—original draft preparation: H.L.C., D.V., J.L.; Writing—review and editing: H.L.C., D.V., W.C., P.N., J.L., A.O.D.Z., S.B.,

M.O.R.; Supervision: H.L.C. All authors read and approved the final manuscript. French PCC Research Group members collected the data.

Competing interests
The authors declare no competing interests.

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