

Université de Montréal

**« Good Night, Sleep Tight, Don't Let the Bed Bugs Bite »  
Exploring the Mental Health Fallout of Urban Bed Bug  
Infestation in Montréal, Québec**

par

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Université de Montréal  
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Ce mémoire intitulé :

**« Good night, sleep tight, don't let the bed bugs bite »  
Exploring the mental health fallout of urban bed bug infestation  
in Montréal, Québec**

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## Résumé

**Problématique :** La littérature scientifique ne contient actuellement aucune étude épidémiologique portant sur la relation entre l'exposition à une infestation de punaises de lit (*Cimex lectularis*) et la santé mentale. L'objectif de cette étude est d'explorer la relation entre le statut d'exposition aux punaises de lit et des mesures de dépression, anxiété et perturbation du sommeil.

**Méthodes :** Cette recherche est une étude transversale basée sur une analyse secondaire des données provenant de N=91 adultes locataires de logements insalubres qui ont répondu à un questionnaire de santé au moment d'interventions médico-environnementales menées par la direction de santé publique de Montréal entre janvier et juin 2010. Le questionnaire de santé inclut le « Questionnaire de santé du patient (QSP-9) », qui est un outil mesurant les symptômes associés à la dépression, l'outil de dépistage d'anxiété généralisée (GAD-7) et les items 1-18 de l'indice de la qualité du sommeil de Pittsburgh (PSQI). L'association entre une exposition autorapportée à une infestation de punaises de lit et le niveau de perturbation du sommeil selon la sous-échelle correspondante du PSQI, les symptômes dépressifs selon le QSP-9 et les symptômes anxieux selon le GAD-7, a été évaluée en utilisant une analyse de régression linéaire multivariée. Des données descriptives relatives aux troubles de sommeil autodéclarés et à des comportements reliés à un isolement social, dus à une exposition aux punaises de lit, sont aussi présentées. **Résultats :** L'échantillon comprenait 38 hommes et 53 femmes. Parmi les 91 participants, 49 adultes ont signalé une exposition aux punaises de lit et de ce nombre, 53,06% (26/49) ont déclaré des troubles de sommeil et 46,94% (23/49) des comportements d'isolement social, en raison de l'exposition. Les adultes exposés à des punaises de lit ont obtenu des résultats significativement plus élevés sur le QSP-9 ( $p=0,025$ ), le GAD-7 ( $p=0,026$ ) et sur la sous-échelle mesurant la perturbation du sommeil ( $p=0,003$ ) comparativement à ceux qui n'étaient pas exposés. **Conclusions :** Cette première étude exploratoire met en évidence une association significative entre l'état d'exposition aux punaises de lit et des troubles de sommeil, ainsi que des symptômes anxieux et dépressifs, indiquant que ceux qui sont

exposés aux punaises de lit représentent un groupe possiblement à risque de développer des problèmes de santé mentale. Ces résultats viennent en appui aux initiatives des décideurs pour organiser des efforts coordonnés d'éradication au niveau des villes et des provinces.

**Mots-clés** : punaise de lit, santé mentale, anxiété, dépression, perturbation du sommeil

## Abstract

**Background :** The peer-reviewed literature currently contains no epidemiologic study examining the relationship between exposure to bed bug (*Cimex lectularius*) infestation and mental health. The objective of this research study is to explore the relationship between bed bug exposure status and measures of depression, anxiety and sleep disturbance.

**Methods :** This is a cross-sectional study based on a secondary analysis of data from N=91 adult tenants of unfit dwellings who responded to a health questionnaire at the time of medico-environmental interventions led by the Montreal Public Health department between January and June 2010. The health questionnaire included the Brief Patient Health Questionnaire Mood Scale (PHQ-9), the Generalized Anxiety Disorder Screener (GAD-7) and items 1-18 of the Pittsburgh Sleep Quality Index (PSQI). The relationship between self reported bed bug exposure and level of sleep disturbance as per the PSQI's 5<sup>th</sup> subscale, depressive and anxious symptoms according to the PHQ-9 and the GAD-7 respectively, was evaluated using multivariate linear regression analysis. Descriptive data pertaining to self-reported sleep difficulties and social isolation behaviours due to bed bugs in the exposed subset are also presented. **Results :** The study sample included 38 men and 53 women. Out of the 91 participants, 49 adults reported bed bug exposure and of these, 53.06% (26/49) reported sleep difficulties and 46.94% (23/49) social isolation behaviours, due to exposure. Adults exposed to bed bugs scored significantly higher on the PHQ-9 ( $p=0.025$ ), the GAD-7 ( $p=0.026$ ) and on the sleep disturbance subscale, PSQI(5) ( $p=0.003$ ) compared to those unexposed. **Conclusions :** This first exploratory study highlights a significant association between bed bug exposure status and sleep disturbance as well as anxious and depressive symptoms, delineating individuals exposed as a possible group at risk for mental health problems. These findings support policy-makers' initiatives to organize coordinated eradication efforts at the city and state levels.

**Keywords :** bed bug, mental health, anxiety, depression, sleep disturbance

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## Avant-Propos

*“Virtually every urban authority is more or less troubled with this problem.”*

*(Monier-Williams et al, in a report of the ‘Committee on the Eradication of Bed Bugs’, London Ministry of Health, 1934, pp.4).*

Bed bugs are not a new problem, but this may be a surprise to many. At a recent symposium organized by the Entomological Society of America, Michael F Potter, professor and urban entomologist at the University of Kentucky and a leading expert on bed bugs, called the recent resurgence in bed bugs the “most difficult pest management challenge in a generation” (Potter *et al.*, 2008). It has been a long time since anyone has seen a bed bug. A 2006-2007 survey conducted in three UK counties showed that only 10% of the 358 people interviewed were able to correctly identify a bed bug upon being shown an adult specimen (Reinhardt *et al.*, 2008).

The London ministry of Health report published in 1934 from which the quote above was taken was apparently published early “in view of the urgency of the problem” (Monier-Williams et al, 1934, pp. A2). The document may be from another era, yet it speaks to the current experience as we witness the resurgence of the bed bug. The report details the effect that bed bug infestation appeared to be having on the population, while acknowledging the lack of evidence to incriminate the arthropod in the transmission of infectious diseases.

*“...we are convinced that by far the greater number of dwellers in infested houses suffer acutely from the presence of Bed bugs and are genuinely anxious to get rid of them ... there is no evidence that they are active agents in the dissemination of any particular pathogenic organism in the way that fleas carry plague, lice typhus fever, or mosquitoes malaria... It may be that Bed bugs are responsible for actual ill-health from lack of sleep due to skin irritation” (Monier-Williams et al., 1934, pp. 4-5).*

It is apparent that in 1934, the importance of the issue rested in the fact that bed bugs disturbed the lives of the people infested, yet the problem was worrisome enough to

bring about public health mobilization. This mobilization included education campaigns and instructions for cleaning and preparation prior to treatments, the giving of powers to local authorities to clean, disinfect or destroy articles which could be infested, as well as financial compensation to those who had suffered damage to their personal property due to infestation (Monier-Williams et al., 1934, pp. 16-17).

The research which is the subject of this *mémoire* deals with the impact of bed bug infestation on mental health, a subject which up to now has never been examined through the lens of epidemiology. This is an exploratory study, but as bed bugs again become part of the landscape of urban life, research on the impact of this problem will become increasingly pertinent. This *mémoire* is meant as a call to others to join me in dusting off those old documents and papers and get to work, as more studies, both quantitative and qualitative will be needed to guide clinicians, public health practitioners, entomologists and policy makers in the fight to take our cities back from the ever-resourceful bed bug.

# CHAPTER 1 – CONTEXT

## 1.1 Some history on the relationship between bed bugs and humans

It is thought that bed bugs have been associated with humans since the days of cave dwelling, gradually evolving from feeding on bats to humans, adapting to our habitats with the advancement of technology (Usinger, 1966, pp 1-3). Evidence of the presence of *C. lectularius* in ancient Egypt has been confirmed archaeologically, (Panagiotakopulu *et al.*, 1999) and mention of the bug in the folklore and legends of many languages is testament to its association with various groups (Usinger, 1966, pp 1-3). It is believed that bed bugs arrived in North America with the colonists and there is evidence of the arthropod in Canada during the late 18<sup>th</sup> century. Ships would have provided good accommodation, and bed bug infestations reportedly disturbed travellers on Mississippi steamboats in the New World. The wooden beds used by settlers favoured bed bug development (Wheeler, 1982).

In the 18<sup>th</sup> and 19<sup>th</sup> centuries, the bed bug became a common urban pest, not unlike the rat, a situation which became worse with the advent of central heating. Bed bugs became more of an issue in poor neighbourhoods, as wealthy individuals learned they could detect and reduce infestations relatively effectively with ‘vigorous housecleaning’ carried out by hired help (Potter, 2011 citing an 1875 report by the Commissioner of agriculture). One contributing author to the journal *Pest Control Technology* recounts the early 20<sup>th</sup> century saw bed bugs brought home from movie theatres, schools, storage facilities, garage sales, hotels, youth hostels and even upper class hotels. He claims to remember “the stench of roasted bed bugs in the 20’s”. In those years, he says, mattresses were sprayed with “kerosene, cresylic acid and a masking agent” and candles were used to burn bed bugs in the bed springs (Katz, 2000).

During the time of the second world war, bed bugs were so abundant, and army bunks were so infested that the morale of US soldiers was affected. Hundreds of army barracks were subsequently fumigated with hydrogen cyanide (Potter, 2011 citing

Whitford, 2006). The importance of the bed bug epidemic during this period fuelled research in universities and government agencies (Potter, 2011), culminating in 1966 with the publication of Usinger's 'Monograph of Cimicidae' (Usinger, 1966; Reinhardt *et al.*, 2007).

In conjunction with this outpouring of work, public education campaigns and appropriate infestation prevention practices along with the widespread use of chlorinated hydrocarbons such as DDT and other synthetic pesticides during the 40s and 50s, lead to a dramatic decline in bed bug populations in the developed world (Romero *et al.*, 2007; Boase, 2008; McDonald *et al.*, 2009).

## **1.2 Resurgence**

Until the 1990s, what followed in the developed world was a period when bed bugs became an almost virtual unknown. Research interest following this time diminished along with bed bug populations and according to Cooper "research on bed bugs has been virtually non-existent since the sixties" (Cooper, 2006). Urban entomologist Harold J. Harlan claims "infestations were so rare that it was hard to find specimens for college classes" (Harlan, 2007). Unfortunately, along with the bed bug, public knowledge of the pest, its habits, as well as ways to prevent infestation disappeared as well (McDonald *et al.*, 2009). The survey mentioned above by Reinhardt *et al.* showed that older people were more likely to recognize a live specimen than younger people, and highlighted the impact this would likely have on pest control (Reinhardt *et al.*, 2008).

It appears the initial rumblings of a 'bed bug comeback' emerged in the entomological and pest control literature in the early 90s. Bryon Ried of the Department of Entomology of Purdue University claimed in 1990 within the pages of *Pest Control* that bed bugs were on the rise within populations living in "substandard housing and in the street" and deplored the lack of experience of pest control operators in dealing with "this most challenging insect pest" (Ried, 1990). Next, came two publications in the medical



literature, according to Clive Boase of the UK's Pest Management Consultancy who presented an evidence-based analysis of the bed bug resurgence at the Sixth International Conference on Urban Pests in Veszprém, Hungary in 2008 (Boase, 2008). The first of these articles appeared in *BMJ* in 2000, and was written by Drs Paul and Bates, two UK consultant microbiologists who claimed four bed bug specimens were submitted to the Brighton Public Health Laboratory service to be identified between February and October 1999, while only one had been submitted in 1998 and zero had appeared for the three years prior. They claimed the history surrounding all the cases involved the transferring of bed bugs within furnishings or luggage, and highlighted that doctors were unfamiliar with these pests and their bites (Paul et al., 2000).

### **1.3 Dispersal**

A flurry of case reports and series has appeared in the medical literature within the last ten years alerting unsuspecting physicians of the reappearance of the bed bug. If one follows these case reports, it is possible to track the dispersal of the bed bug around the globe. The notorious blood-drinker has reportedly found victims in homeless shelters in Toronto (Hwang *et al.*, 2005), short stay lodges in Sydney (Ryan *et al.*, 2004), emergency departments in New Jersey, New York and Ohio (*ED manag*, 2010) and train sleeping cars in Europe (Anders *et al.*, 2010). Ever the traveller, the bed bug has apparently managed to hitchhike from South America to Israel (Mumcuoglu, 2008), New Jersey to Seoul (Lee *et al.*, 2008) and find its way between the sheets with an unsuspecting military agent in Hyères, France (Bencheton *et al.*, 2010).

#### **1.3.1 Exponential increase**

As might be expected, the increase in bed bug populations appears to be exponential. According to a National Pest Management Association (NPMA) press release on July 26<sup>th</sup> 2010, prior to 2000, “only 25 percent of US survey respondents encountered a bed bug infestation” (NPMA, 2010). However, a 2010 world-wide survey of pest

management companies in 43 countries conducted by the NPMA and the University of Kentucky in collaboration with international pest management companies, showed that of the 521 US respondents (pest control operators), 95% claimed they had encountered a bed bug infestation within the past year. Among the 64 Canadian respondents, the figure was 98%, for Europe's 113 respondents it was 92%, Asia's 26 respondents it was 73%, and for the 10 respondents from Africa and Middle East, it was 90%. In the past year, 80% of respondent companies in Mexico/Central America encountered infestations, as did 59% of respondents in South America (Potter et al., 2010).

### **1.3.2 Where the bugs appeared**

Stephen L. Doggett of the department of Medical Entomology in Westmead, Australia, reported results of a survey conducted among 121 professional pest managers in Australia at the 2008 conference in Hungary and stated in the conference proceedings that “all Australia mainland states had experienced an exponential rise in bed bug infestations since 2001, with an overall national increase of 4.5%”, with 24.7% of infestations found in 1-3 star motels and 21.9% found in backpacker lodges (Doggett et al., 2008). According to the 2010 NPMA-led survey, the most common places in the US where infestations were encountered were apartments and condominiums (89%), single family homes (88%) and hotels and motels (67%). They were also reported in college dormitories, homeless shelters, nursing homes, office buildings, hospitals, schools, on public transportation, in movie theatres, churches, day cares, libraries, summer camps, restaurants, prisons, moving vans, ambulances, doctors' offices and funeral homes, among others (Potter et al., 2010).

## **1.4 The current challenge**

The bed bug problem has become the stuff of popular media and dinner conversations. A trend analysis of US newspapers between 2001 and 2006 revealed a dramatic increase in the number of news articles covering bed bugs (Anderson, 2008). A September 4<sup>th</sup> 2010 TIME magazine article entitled “infestation: Nightmare on Bedbug

Street” described the New York public as “freaked out” and referred to Michael F. Potter as “a University of Kentucky entomologist who spends hours pouring poisons on bedbugs in his lab, seeking the elusive potion that kills them without harming humans or pets (Burleigh, 2010). These descriptions may not be inappropriate. Clive Boase of a UK-based pest management consultancy, describes the bed bug issue as a “classic urban pest management problem” involving multiple stakeholders including the public, the pest-control and pesticide industries, the media, housing organisations, the hospitality industry and government, in addition to health services (Boase C, 2001).

#### **1.4.1 Why we can’t just bring back DDT**

To make matters worse in the context of resurgence, entomologists and pest control workers are now facing a situation where not only is public knowledge of the pest and control practices lacking, DDT is no longer an option and pyrethroid resistance is coming into play. Alvaro Romero et al. in 2007 (then a PhD student of MF Potter), discussed his finding of pyrethroid resistance in bed bug populations collected in Kentucky and Ohio. Alvaro claims that although DDT was banned in the US in 1972, its usage continued in many countries to control mosquitoes. He explains that pyrethroids, which are derived from *Chrysanthemums* and have been in use since the mid-1800s (Potter, 2011), were used in areas where DDT applications persisted, as sprays and as insecticide incorporated in anti-malaria bednets. He suggests this dual ‘selection pressure’ to both DDT and the pyrethroids set off a “doomsday” scenario for accelerating resistance to these products (Alvaro et al., 2007a). Alvaro explains in a 2007 issue of *the Journal of Medical Entomology* that this is of concern because restrictions on chlorinated hydrocarbons, organophosphates and carbamates insecticides have been instituted in many countries, this has left pest control operators with pyrethroids as the “largest remaining insecticide class” (Alvaro et al., 2007b).

In response to the individuals who have stated “if we just had DDT...”, Alvaro Romero presents data which shows that several strains of field-collected pyrethroid-

resistant bed bugs endured very little mortality after 5 days of treatment with DDT (Romero *et al.*, 2007). It has been suggested that a “21<sup>st</sup> century version” of DDT may be necessary to help win the battle against the bed bug this time around (Potter, 2005).

## CHAPTER 2 – LITERATURE REVIEW

This literature review, divided into four sections will provide the reader with an overview of the body of work utilised to support this research endeavour.

The purpose of the **first section** is to acquaint the reader with some elements of the taxonomy, morphology, ecology and behaviour of this insect, guided by the Monograph of Cimicidae by Usinger, as well as recent work. Although the focus of this research is not the biological details of the bed bug, the author considers it important that readers obtain a greater understanding of the ‘enemy’ before they consider its effect on the mental health of humans. It should be noted the Usinger’s monograph includes studies pre-1966, many of which are difficult to find, thus whenever individual studies are referenced, the authors are named but Usinger’s monograph is cited.

The **second section** will treat the current body of literature describing the effects of bed bug infestation on the health of humans with a focus on the dermatologic sequelae. Two studies reviewing the available data on the risks posed by bed bugs in the transmission of infectious disease will be presented as well.

The **third section** will discuss non-quantitative data that is available on the mental health impact of bed bug infestation. This will be complemented by information gleaned from studies examining the impact of other infestations on mental health, as well as literature examining the impact of other pruriginous skin conditions on mental health.

In the **fourth section**, a conceptual framework for this research will be posited, whereby bed bug exposure and subsequent pruritic skin lesions may lead to sleep problems, social isolation and subsequently symptoms of anxiety and depression. The psychological literature on the links between sleep problems, anxious and depressive symptoms will be reviewed and the impact of social isolation on health will be discussed in light of recent work. A proposed mechanistic schema based on this review will be presented, and the section will conclude with a statement of the objectives of this research study.

## 2.1 Introducing the common bed bug *Cimex lectularius*

The following section is divided into three parts. The first deals with taxonomy with the principle goal of describing the classification of the bed bug, as well as differentiating it from others in the cimicidae family. The second discusses morphology and life cycle with a focus on identifying features. The third covers selected aspects of bed bug ecology and behaviour.

### 2.1.1 Taxonomy

Bed bugs are ‘true bugs’ of the order Hemiptera but unlike most other true bugs, they do not feed on plant fluids. Like the reduviidae family (which includes the ‘kissing bugs’ responsible for the transmission of Chagas disease), the Cimicidae family in which bed bugs are included, feed on vertebrates (Boase, 2001). There are 91 described species in the Cimicidae family and most are associated with birds and bats. Only two species, *Cimex lectularius* and *Cimex hemipterus* feed on human blood (Robinson, 2005), although *C. pipistrelli*, also known as the ‘batbug’, will bite humans if they come into contact. An article published in the *Lancet* in 2001 reported a case of batbug bites endured in a house laden with a bat roost. These bites were mistaken for the bites of *C. lectularius* (Whyte et al., 2001). *C. hemipterus*, which feeds on humans in addition to chickens and bats, is common in tropical regions of Africa, Asia and Central America. A survey of fifty-four bed bug infested residences and accommodations in Kuala Lumpur, Malaysia revealed that all sites harboured *C. hemipterus* (How et al., 2009). *C. lectularius*, which can be found in North America, Europe and Russia, favours humans, although it has been found with cave bats in Afghanistan (Robinson, 2005). The official common name ‘bed bug’ was given by the Entomological Society of America to designate the single species, *C. lectularius* (Wheeler, 1982), and this reference is intended throughout this work when mentioning the term ‘bed bug’. Neither *C. hemipterus* nor *C. pipistrelli* will be treated in this master’s thesis, but the interested reader is encouraged to review the relevant literature.

### 2.1.2 Morphology and life cycle

Bed bug adults are 4-6mm long, oval and flattened when unfed and reddish brown after they have eaten. The cuticle is thick and dark brown, but the portion covering the adult abdomen, as well as the cuticle of the nymph, is thinner, thus allowing the observer to note the colour of the blood meal that has been consumed and partially digested inside. The creatures have small wingpads but no wings and are thus incapable of flying (Robinson, 2005). Wheeler, in the 1982 version of the *Mallis Handbook* book of pest control claims the bed bug evolved to lose its flight due to its parasitic lifestyle (Wheeler, 1982). Found on the head of the bed bug are four-segmented antennae as well as ‘beak-like’ mouthparts. The mouthparts are composed of two stylets; these are the structures which pierce the host’s skin (Wheeler, 1982).

There are five nymphal stages and a blood meal is required to pass each stage (Usinger, 1966), however the nymphs can survive for long periods without eating. For example, under specific conditions, the first instar can survive for 114 days, the third for 214 days and the fifth, 161 days without a blood meal (Robinson, 2005). There are structural differences between males and females. The female’s abdomen is more rounded and it contains a cleft on the right side where insemination occurs (Wheeler, 1982). Unlike other insects which evolved within caves, the cimicids possess well-developed eyes (Usinger, 1966).

### 2.1.3 Ecology and Behaviour

Temperature: Like other insects, *C. lectularius* can only develop and live within a certain temperature range (Gullan et al., 2000; Benoit et al., 2009). Usinger, citing Hase (1930) et al., states the “threshold for hatching, nymphal development, and adult activity” in the bed bug is between 13 and 15 degrees celcius with death occurring over 44 and 45 degrees celcius and below -15 celcius (Usinger, 1966). Newer work by Benoit et al. showed the supercooling point of bed bugs (when the body freezes) to be approximately -20 celcius but demonstrated that all bed bugs exposed to -17 Celsius are killed and tolerance is not

improved by cold acclimation (exposure to intermediate temperatures) at 4 degrees for two weeks. Similarly, Benoit et al. showed that all bed bugs are killed at 48 degrees celcius and fewer than 20% can survive a one-hour exposure to 46 degrees, and acclimation for two weeks at 30 degrees does not improve tolerance (Benoit et al., 2009). An article published by Johnson in 1940 in *Parasitology* tells us that “the extreme temperature limits” for eggs laid at 23 degrees to hatch are 13 and 37 degrees celcius, however the longest period necessary for 99.99% mortality below 13 degrees is 79.8 days (Johnson, 1940), indicating a certain resilience (Usinger, 1966).

Humidity: Bed bugs are capable of drinking free water and of absorbing some water vapour from the air, but they do so sparingly and cannot rely on these moisture sources for survival. Bed bugs have a body water content of 69% and replete their moisture stores primarily with blood, although they are capable of long-term quiescence and grouping behaviours which allow them to conserve water when nourishment is scarce (Benoit et al., 2007). In an experiment where female bed bugs were exposed to a range of relative humidities over 100 days (0-100% RH), Benoît et al., showed a significant decline in survival only below 33% RH (Benoit et al., 2009).

Shelter, Aggregation and Dispersal Bed bugs normally occur in aggregations which consist of bugs at all life stages, harboured in cracks and crevices close to the host where fecal matter, exuviae and egg shells accumulate. These aggregations or ‘brood centers’ are thought to be beneficial to the organism (higher resistance to desiccation, higher chances of finding a mate) and their formation is believed to be chemically mediated via the secretion of aggregation pheromones (Usinger, 1966, Pfiester et al., 2009, Olson et al., 2009). After feeding, bed bugs typically return to their harborage site to digest (Usinger, 1966).

The precise reason why bedbugs disperse remain unclear, according to Pfiester et al, but it is thought that sex ratio may be an important factor as females are most often found alone, only virgin females respond to airborne aggregation pheromone, and male bed bugs are more likely to leave when females become scarce. Thus, aggregations can be seen as dynamic groupings, with mated females retreating more often to new locations, leading to



the presence of nymphs away from regular aggregation sites (Pfiester et al., 2009). Dispersal may also represent a by-product of host-finding (bed bugs are attracted to warmth and carbon dioxide), or simply the displacement of humans unaware they are living with bed bugs (Usinger, 1966). When bed bugs disperse, they tend to be surprisingly agile. Wang et al., while analysing bed bug dispersal in a high-rise apartment building in Indianapolis found that bed bugs had the potential to spread into many apartments after introduction, moving through doors, hallways and adjacent walls without being detected (Wang, 2010).

*Feeding/biting:* The bed bug will approach the host and test the surface of its prey with its antennae outstretched. Under normal conditions, the bug will then secure itself to the skin with its claws and insert its beak. Feeding in first-instar nymphs lasts 3 minutes and 10-15 minutes in adults (Usinger, 1966). Bed bugs overcome hemostatic reactions in the host by the injection of a cocktail of molecules which can successfully inhibit vasoconstriction, coagulation and platelet aggregation (Araujo RN et al., 2009). More recent research has shown that distension of the abdomen (simulated with air) is an important factor in determining how long/how much a bug will feed, as excessive feeding may rupture the midgut, killing the insect (Wintle et al., 2008). In a naturally-occurring infestation maintained at 26 degrees celcius, it was shown that females fed every 2.5 days on average (Reinhardt et al., 2010).

*Circadian Rhythm:* The common bed bug usually feeds at night and hides throughout the day, but will feed in daylight if hungry (Usinger, 1966). Bed bugs are more active in the dark (Romero et al., 2010) and peak activity has been observed between 03:00 and 06:00h with this rhythm apparently being endogenous (Barrozo et al., 2004).

*Mating:* Males are more likely to copulate with females shortly after they have fed, a behaviour which is believed to have evolved to take advantage of increased female body size post-feeding (can increase 300%) (Reinhardt et al., 2008). Female bed bugs do not solicit copulations with males, and they sometimes emit a defensive substance when a male attempts to mate (Reinhardt et al., 2008). One may ask why these defences have evolved.

Part of the answer may be due to the increased risk of mortality for a mated female as copulation occurs via ‘obligate traumatic insemination’ where a male will pierce through the female’s abdominal wall (Siva-Jothy, 2006). The spermatheca, a special cleft on the female abdomen where insemination occurs is thought to have evolved to mitigate the costs of wound healing and infection associated with traumatic copulation (Reinhardt, 2003).

Oviposition: Egg-laying in bed bugs is related to nutrition. Larger females who feed more, are capable of producing more eggs. In a typical case, a mated female will feed and then retreat to a harborage site to digest and develop eggs, which she will lay after 5-6 days (oviposition lasting 6 days), producing between six to ten eggs (Usinger, 1966). Bed bug eggs are approximately 1mm in length and are fastened to surfaces with a cement which is extruded by the female when the eggs are laid (Wheeler, 1982).

## **2.2 Effect of the bed bug on human health**

This section briefly reviews the current literature on the health impacts of bed bug bites. As shown below, the medical literature focuses on the dermatologic and potential allergic impact of bites (Goddard *et al.*, 2009). Please consult Appendix 3 for images of a bed bug and a patient afflicted with bed bug associated cutaneous lesions.

### **2.2.1 Cutaneous reactions to bed bug bites**

Doctors have been forced to add bed bug bites to the list of differential diagnoses when examining patients with skin lesions (Paul *et al.*, 2000). As stated by Goddard and de Shazo of the departments of entomology, plant pathology and medicine of Mississippi State University and Medical Center “a decade ago, bed bugs were so rare that they could mostly be ignored as a cause of insect bites” (Goddard *et al.*, 2008). With a clinical appearance resembling urticaria, many individuals presenting with pruriginous bed bug related lesions are initially given topical or systemic corticosteroids and antihistamines, a treatment which may soothe symptoms but which is ultimately ineffective (Scarupa *et al.*, 2006) because the environment has not been treated.

The most common visible cutaneous reaction to a bed bug bite is a 2-5mm pruritic maculopapular erythematous lesion at site where the host was bitten, with a punctum at the center of the bite (one site per insect) (Goddard *et al.*, 2009). Reinhardt et al. demonstrated that 18 out of 19 volunteers showed sensitivity to bed bug bites, with decreasing latency between bites and skin reactions after repeated exposure (from approximately 10 days to a few seconds) (Reinhardt *et al.*, 2009). Reports exist of patients who experienced more complex reactions to bed bug bites, such as local urticaria, and systemic reactions such as generalized urticaria, bullous reactions and anaphylaxis (Goddard *et al.*, 2009; Liebold *et al.*, 2003). Reports of scratching and subsequent infection of bite sites exist as well (Goddard *et al.*, 2009).

## **2.2.2 Evidence concerning other potential health consequences**

*Infectious disease transmission:* To date, no reports of transmission of infectious diseases via bed bugs have been confirmed. Evidence does exist that bed bugs can *carry* some vectorial pathogens, but until now this information has shown to be clinically insignificant (Goddard *et al.*, 2009; Delaunay *et al.*, 2011).

*Anemia:* Reports exist of heavily bitten individuals developing iron-deficiency anemia, particularly in the context of malnutrition (Pritchard *et al.*, 2009).

## **2.3 What is known about the mental health impact of bed bug infestation**

### **2.3.1 Field observations and anecdotes**

Recent field observations made in Montreal (Perron *et al.*, 2010) and Toronto (McDonald *et al.*, 2009) suggest that bed bug infestation is closely linked with sleep difficulty, social isolation and the development of mental health symptoms. One distressed male, middle-income earner in Toronto expressed his feelings particularly well.

*“...To be honest, until you go through it, you have no idea just how horrifying it really is. It is just natural for you to become paranoid; you lose sleep, you end up dreaming and thinking about bed bugs- they just consume every fibre of your being. I had to isolate myself from family and friends; I did not want anyone coming over. I was too afraid that they would bring bed bugs home. This was very difficult for me because you need someone to talk to because it is awful... very awful. There were many days that I did not see an end in sight.” (McDonald et al., 2009).*

Based on results of the 2010 NPMA world-wide survey of pest management companies in 43 countries mentioned above, it is noted that the mental health fallout of infestation can lead to desperate and potentially dangerous attempts at “do it yourself” extermination. In the survey, it was found that 99% of US firms claimed their bed bug infested customers were “upset and concerned” vis à vis the infestation and 77% claimed customers were “very upset and concerned” with similar comments made by managers “around the world” (Potter et al., 2010). Potter claims that 51% of US companies stated that over half of their customers were so distraught by their infestations that they seemed “willing to do anything necessary” to get rid of the bugs. He reports cases of potentially “dangerous measures” being taken by desperate customers involving the use of “ammonia, bleach, fire, smoke, kerosene, wasp spray, bug bombs” as well as the use of “concentrated pesticides bought on the internet” (Potter et al., 2010). Dramatic cases reported in the journal *Environmental Health Perspectives* detail one incident where an infested resident “set off 30 bug bombs at once” and another who “blew the walls out of his apartment after setting off a bug bomb and failing to turn off the pilot light” (Manuel J, 2010).

Interestingly, observations of this kind are not new. As we have previously seen, in 1934 the London Ministry of Health was mobilized based on the idea that the bed bug was “responsible for actual ill-health from lack of sleep due to skin irritation”. (Monier-Williams et al., 1934, pp 5). Ideas have been similar in the US as well. In a CDC report published in 1963 entitled ‘Household and Stored-Food Insects of Public Health

Importance and their Control', it was stated that "bed bugs may cause nervous disorders in sensitive people, and may contribute to the ill health of both children and adults." (Scott HG, 1963, pp XII-9). A recently published joint statement by the CDC (US Centres for Disease Control and Prevention) and the EPA (Environmental Protection Agency) states that "although bed bugs are not known to transmit disease, they are a pest of significant public health importance". The statement specifies that because research has been "very limited over the past several decades" that more inquiry is required to determine the impact of the bed bug on public health (CDC & EPA, 2010).

### **2.3.2 Opinions expressed by medical entomology experts**

Any individual who has encountered a bed bug infestation would tell you that the suffering is definitively not skin-deep. This opinion has been expressed by many well-known figures in the field of medical entomology. As expressed by Dr. Doggett, "often the most serious health aspect for many individuals is the mental trauma of knowing that there is an infestation". He specifies that "some individuals... can experience a great deal of discomfort and loss of sleep from the persistent biting" (Doggett *et al.*, 2004). William Quarles, managing editor of the pest management journal *The IPM Practitioner*, claims that "bed bugs are a dreaded pest because of the anxiety, social stigma, and irritations they cause" (Quarles, 2007). According to Bryon Ried of Purdue University regarding bed bugs "their principal medical importance is associated with the itching associated with their bites. Far more important is the social stigma associated with bed bugs, which arises from the public's perception that bed bug infestations arrive because of poor personal hygiene and bad housekeeping" (Reid, 1990). Indeed, Dr. Doggett, as well as his colleague Richard Russell claim in the pages of *Australian Family Physician*, that the stigma associated with visible bites can "affect an individual's self esteem and possibly interfere with employment performance and prospects" (Doggett *et al.*, 2009). Potter warns that although some people believe that being feasted on by bed bugs is no different than being bitten by other pests such as ticks or mosquitoes, that "this rationale overlooks the fact that in the developed

world, ticks and mosquitoes bite and breed mostly outdoors. Bed bugs, however, dwell in one of the most intimate spaces of the home environment; the bed” (Potter *et al.*, 2010).

### **2.3.3 Epidemiological evidence:**

Despite the intensity of the anecdotal evidence available, there are currently *no* epidemiological studies in the scientific literature which quantitatively document the association between bed bug infestation and mental health. Literature on the mental health fallout of infestation with biting arthropods is scant (Thorburn *et al.*, 2010; Zahner *et al.*, 1985) but some anecdotal evidence is available for pigeon fleas (Haag-Wackernagel *et al.*, 2004) and head lice (Silva *et al.*, 2008).

### **2.3.4 The mental health impact of pruritus: a brief survey of the literature:**

Bed bug bite skin reactions are usually very itchy (Perron *et al.*, 2010). Pruritus (also known as itch) is a complex symptom with both sensory and affective components (Yospovitch *et al.*, 2001) which are associated with numerous cutaneous and systemic disease processes including atopic dermatitis, psoriasis, chronic liver disease and renal failure (Collins, 2003). The pathophysiology underlying most clinical itch conditions is not well understood although it is known that many problems caused by skin disorders are mediated by histamine (via unmyelinated c-fibers) and can thus be treated successfully (albeit temporarily) with appropriate systemic antihistamine drug therapy or corticosteroids. Others can be difficult to control (Ikoma *et al.*, 2006). Interestingly, itch and pain have an antagonistic relationship at the neurological level, such that pain can inhibit itch, hence the urge to scratch (Ikoma *et al.*, 2006).

Itch is not benign. It has been shown that increasing pruritus severity is associated with poor sleep quality, depressive and anxious symptoms as well as non-specific somatic symptoms and impaired quality of life (Zachariae *et al.*, 2008; Zachariae *et al.*, 2011). The dermatological literature shows a consistent link between pruriginous skin disorders such as

atopic dermatitis and psoriasis, with sleep problems (Thorburn *et al.*, 2010; Bender *et al.*, 2003). Hong et al reviewed literature that documented that depression and anxiety are present in 25-43% of dermatological patients, and that sufferers of chronic skin disease experience higher rates of suicidal ideation than general medical patients (Hong *et al.*, 2008).

## **2.4 Hypothesis, Conceptual Framework and statement of objectives**

*Hypothesis:* The present research study is based on the hypothesis that bed bug infestation is associated with cutaneous discomfort, disruption of home life and social isolation which together contribute to sleep problems, and symptoms of anxiety and depression.

*Conceptual framework:* Based on the literature reviewed above, the reader may link the concept of pruritis (itching) with the experience of mental health symptomatology (sleep disturbance, anxious and depressive symptoms). Bed bugs, as described earlier, tend to be most active when humans are usually asleep (03:00-06:00 hrs), with sleepers awaking to the symptoms associated with the night's activities (Barrozo *et al.*, 2004; Poorten et al., 2005). Problematic sleep (as with other pruritic conditions) is thus assumed to be associated with bed bug bites. The psychological literature provides evidence that insomnia and symptoms of depression and anxiety are linked and it has been suggested that this association is reciprocal (Taylor et al. 2005, Jansson-Fröjmark and Lindblom 2008). It is thus assumed that the experience of pruritus linked to bites sets off a cycle of itching, problematic sleep and symptoms of anxiety and depression, with each new problem exacerbating that which came before it.

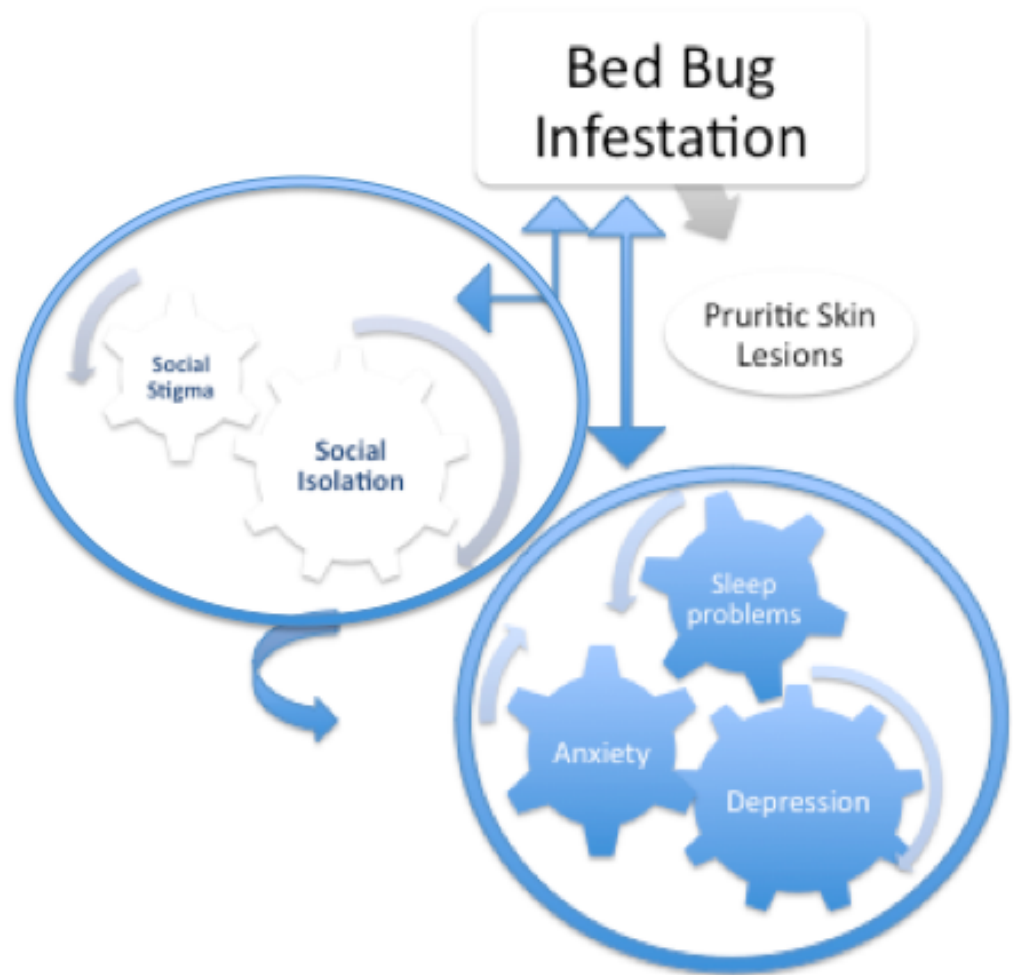
Bed bug infestation is difficult to treat. Individuals must wash their clothing in hot water and store it until extermination is complete. Electronics need to be exposed to cold. Mattresses need to be steamed and covered. Furniture needs to be emptied, inspected and if torn and infested, destroyed. The time and financial investment required can be very

significant, and the process needs to be repeated if there is reinfestation (Perron *et al.*, 2010). Due to the upheaval caused by infestation, those experiencing it tend to isolate themselves from others in order to avoid spreading the problem, and they may also feel stigmatized by it (McDonald *et al.*, 2009). It is presumed that the emotional issues exacerbated by bed bug infestation reinforce one another with infestation-induced social isolation and stigmatization acting as amplifying factors. According to a review by Hawkley and Cacioppo, loneliness (social isolation) is a risk factor for a wide range of physiological disturbances including excessive stress reactivity (Hawkley *et al.*, 2003). Self-reported discrimination is associated with psychological distress (Major and O'Brien 2005). In an essay published in the *Lancet*, Link and Phelan assert that stigma accompanies negative stereotyping and labelling and the experience of chronic stress can ultimately lead to “strained and uncomfortable social interactions, more constricted social networks, a compromised quality of life, low self-esteem, depressive symptoms, unemployment, and loss of income” (Link and Phelan, 2006). These relationships are illustrated in the conceptual framework below (**figure 1**).

*Statement of objectives:* The objective of this research project was to explore the mental health fallout of bed bug infestation in a group of urban dwellers while taking into account individual characteristics, comorbidities as well as recent previous stressful experiences.



Figure 1: Conceptual framework



## **CHAPTER 3 – METHODOLOGY**

The present master's thesis is presented in the form of a 'memoir par article' (a '*thesis by article*'). Chapter 4 of this thesis contains an article entitled '**Exploration of the Mental Health Fallout of Bed Bug (Hemiptera: Cimicidae) Infestation in Montréal, Québec, Canada**'. Complete 'materials and methods' and 'results' sections can be found in this article, but this section will briefly present some details pertaining to study design, the intervention source population, the variables included in the analysis as well as the statistical techniques employed. Full results in table format can be found at the end of Chapter 4.

### **3.1 Study design**

This research project employs a 'cross sectional' study design to analyse data collected during medico-environmental interventions which took place in unfit housing sites during the spring-summer of 2010. These interventions took place in two large housing complexes (at least >350 apartments when combined) which had been signalled to Montreal Public Health by 'Centres de Santé et de Services Sociaux (CSSS)' which are community health and social service centers. Information on the precise number of tenants in these complexes was unavailable at the time of intervention, and a convenience sample of tenants who agreed to have their homes inspected and/or to fill out a health questionnaire was recruited.

Individuals exposed to bed bug infestation are compared to those unexposed in this study in order to discern the association between infestation exposure and a series of mental health measures.

### **3.2. Intervention Source population**

Recruitment for intervention purposes was carried out by community group workers and health and social services professionals who systematically went 'door to door' in the housing complexes which were targeted for investigation based on the suspicion they presented a hazard to human health. Recruited participants agreed to fill out a health

questionnaire which included mental health measures, and to have their dwellings inspected by a professional industrial hygienist associated with the Montreal Public Health Department. Out of the 94 adults interviewed, 91 consented (via an informed consent procedure) to have the information they provided used for later analysis. All children's health questionnaires (up to age 18) were filled out by parents and consent for research purposes was also given by parents. Due to school schedules and other impediments to the scheduling of interviews, not all children in each household were interviewed. Systematic assessment of mental health was not carried out in children and thus is not part of the analysis.

### **3.2.1 Ethical considerations**

All data used in this analysis came from participants who signed a consent waiver indicating that they were informed of possible future use of the data they provided for research purposes. As part of this consent waiver, participants were assured that not signing would in no way preclude any intervention-related activities judged necessary on their behalf. The protocol for this research study was submitted to the Ethics committee of the 'Agence de la Santé et des services sociaux de Montréal' and an approval certificate was granted the 1<sup>st</sup> of September, 2010.

### **3.3 Variables included in the analysis**

All variables included in this research were derived from the health questionnaire administered at the time of intervention. This questionnaire was composed of several parts, and of these, only the sections pertaining to mental health, environmental exposures, past medical history and socio-demographic characteristics were utilized.

#### **3.3.1 Independent exposure variable**

The independent exposure variable in this study was bed bug exposure status (exposed vs unexposed), which was determined via self-report.

### **3.3.2 Dependent variables**

The dependent variables of interest in this study are validated standardized mental health measures. The GAD-7 (a measure of anxiety symptomatology), PHQ-9 (a measure of depressive symptomatology) and the PSQI(5) (the fifth subscale of the Pittsburgh Sleep Quality Index) are described in detail in the methods section of the article presented in chapter 4. These measures had been included in the intervention health questionnaire due to the suspicion that housing conditions could be affecting the mental health of tenants.

### **3.3.3 Other variables**

Variables other than the independent and dependent variables are identified here.

#### **3.3.3.1 Sociodemographic variables**

The sociodemographic variables included were sex, age, employment status, civil status (choice of married/common law, single) and perceived socioeconomic status. Answer choices for the latter variable were adapted from the ‘waiting room questionnaire’ used in investigations of primary care services (Project Dialogue).

#### **3.3.3.2 Comorbidities and previous negative experience**

In the health questionnaire, participants were asked whether they had any chronic physical or psychiatric/psychological problems (>6mos in duration) from a list which was taken from the ‘waiting room questionnaire’ (Project Dialogue). Many of the tenants in the apartment complexes were recent immigrants and refugees, and although this information was not collected in the health questionnaire, participants were asked whether they had experienced a stressful event within the last year as this is a determinant of mental health according to a published conceptual framework elaborated in the context of an ‘enquête Santé Québec’ (Perrault, 1989).

### **3.3.3.3 Environmental exposures**

The questionnaire evaluating environmental exposures was adapted from a pre-existing questionnaire developed by Dr Louis Jacques, one of the co-authors of the article, and a Public Health and Preventive Medicine specialist at the Montreal Public Health Department. Dr Louis Jacques has had extensive experience with similar interventions in unfit housing complexes. Of interest during the intervention was the presence of mould or humidity in the apartments. Most, if not all the buildings visited, were found to be damaged by moisture although hygienist data characterising the extent of this damage was unavailable for many of the locations visited. This variable (mould contamination) was therefore not included in the analysis.

### **3.3.3.4 Self-reported sleep difficulties and social isolation behaviours due to bed bug infestation**

Sleep delay and disruption were measured using a 5-point scale adapted from the 5D-itch questionnaire (Elman *et al.*,2010). Exposed participants were asked whether bed bugs sometimes delayed sleep, often delayed sleep, delayed sleep and sometimes woke them up at night, delayed sleep and often woke them up at night, or none of the above.

In order to verify social isolation tendencies, exposed adults were asked whether they avoided leaving their dwelling, inviting friends into their home or whether they missed days of work, due to bed bugs.

## **3.3.4 Statistical analysis**

Details of the statistical analyses carried out on the data are described in detail in the ‘materials and methods’ section of the article in chapter 4.

### **3.3.4.1 Descriptive and bivariate analyses**

Descriptive analyses characterizing the population based on sociodemographic characteristics, the presence of comorbidities and environmental exposures were carried out.

Groups exposed and unexposed to bed bugs were compared using the Pearson Chi-square statistic and t-test. These analyses are presented in Table 1.

The group exposed to bed bugs was characterized by the number of individuals who reported social isolation behaviours and sleep problems. These analyses are presented in Table 2. The distribution of GAD-7, PHQ-9 and PSQI(5) results according to bed bug exposures status is presented in Table 3. These results were evaluated via computation of ‘linear by linear’ association.

#### **3.3.4.2 Bivariate and multivariate analyses**

Linear regression models were created to evaluate the impact of bed bug exposure status on the dependent variables, while taking into account sex, age, civil status, employment status, medical comorbidities and experience of a stressful event within the last year.

Decisions to include potential confounders in the final models were taken according to guidelines set out by Harrell (Harrel, 2001). The first elimination removed factors which were not theorized to be confounders in the relationship between psychological symptom development and bed bug infestation exposure, based on available literature and field experience. The second elimination removed those with insufficient variability, the third those with many missing values. Included potential confounders did not show collinearity. The variables ‘self-reported cockroach infestation’ as well as ‘number of individuals in the household’ were not included as they did not have sufficient impact on the models. Goodness of fit for the models was adequate, and assumptions when using linear regression models were verified. All analyses were conducted using SPSS for windows (1989-2003).

#### **3.3.4.3 Diagnostic tests**

Several additional analyses were carried out in order to (i) identify the impact of the 9 individuals with a psychiatric history on the models, (ii) identify the impact of outliers with standardized residuals  $>2.76$  and (iii) whether the models differed when the dependent variables were introduced in continuous format.

*Psychiatric history* : Prior psychiatric history is an important determinant of mental health (Perrault, 1989) but the data showed that only 9 individuals reported prior mental health diagnoses (disorders) in our sample (table 1). Sensitivity analyses were conducted in order to discern the impact of these 9 individuals on the models and it was found that results did not change significantly when these individuals were withdrawn. The 9 individuals were therefore retained in the analyses, and the variable ‘presence of psychiatric disorder’ was not included in the final models.

*Outliers* : All outliers with standardized residuals of  $>2.576$  were removed from the models and further sensitivity analyses were conducted. These analyses showed only minimal changes in the models, thus none of the outliers were excluded from the final analyses.

*Dependent variable format* : Final models for the dependent variables in this study are given in ordinal format due to greater ease of interpretation. Models were also created for the psychological measures in continuous format, and conclusions drawn were similar to those for the measures in ordinal format, except for the GAD-7 where the relationship was rendered non-significant at a threshold of 0.05.

## CHAPTER 4 – ARTICLE

### **Exploration of the Mental Health Fallout of Bed Bug (Hemiptera: Cimicidae) Infestation in Montréal, Québec, Canada\***

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\*Please see co-author contributions in Appendix 2. Another article based on the same data set but employing slightly different methodology (logistic regression instead of linear regression as in the paper presented here), is referred to in Appendix 4. The paper was received by BMJ Open on the 6<sup>th</sup> of January 2012 and accepted for publication on the 17<sup>th</sup> of April 2012.



1 **Abstract**

2 Bed bugs (*Cimex lectularius Linnaeus*) are currently re-infesting human-occupied spaces at  
3 a brisk pace. Within the last century, presumed mental health fallout alone propelled  
4 municipal authorities to control bed bugs, yet the scientific literature currently contains no  
5 epidemiologic studies of these phenomena. We explored the relationship between bed bug  
6 exposure status and measures of mental health symptoms by analysing data from ninety-  
7 one tenants who responded to a health questionnaire during medico-environmental  
8 interventions led by the Montreal Public Health Department. Multiple linear regression  
9 models were used to compare individuals exposed and unexposed to bed bugs by scores on  
10 the PHQ-9 (depression), the GAD-7(anxiety) and the PSQI's 5<sup>th</sup> subscale (sleep  
11 disturbance). We found that adults exposed to bed bugs scored significantly higher on these  
12 instruments than those unexposed, and that a considerable proportion of those living with  
13 bed bugs subjectively reported sleep disturbance and social isolation-related behaviours as  
14 a result of infestation. Results of this study suggest that individuals exposed to bed bugs  
15 represent a group at risk for mental health problems, and support the recognition of bed bug  
16 infestation as a veritable risk to public health. These findings support policy-makers'  
17 initiatives to organize coordinated bed bug control efforts at the city and state levels,  
18 continued inquiry into best practices and greater collaboration between medical  
19 entomologists, public health experts and community stakeholders.

20 **Key words:** Bed bugs, mental health, public health

21

## 1 **Résumé**

2 Nous assistons à une recrudescence du nombre d'infestations de punaises de lit (*Cimex*  
3 *lectularius Linnaeus*). Durant le siècle dernier, les municipalités ont piloté des interventions  
4 visant à exterminer les punaises de lit à cause des impacts présumés de celles-ci sur la santé  
5 mentale des personnes infestées. Par contre, la littérature scientifique ne recèle aucune  
6 étude épidémiologique qui porte sur ce lien présumé. Dans cette étude nous analysons les  
7 associations entre le statut d'exposition aux punaises de lit et les impacts sur la santé  
8 mentale. Les données proviennent de quatre-vingt-onze locataires qui ont répondu à un  
9 questionnaire de santé lors d'interventions médico-environnementales menées par la  
10 Direction de la santé publique de Montréal. Des modèles de régression linéaire multiple ont  
11 été utilisés pour comparer les personnes exposées et non exposées aux punaises de lit en  
12 fonction de leurs scores sur le PHQ-9 (la dépression), le GAD-7 (anxiété) et la cinquième  
13 sous échelle du PSQI (perturbations du sommeil). Nous avons aussi analysé l'impact  
14 spécifique des punaises de lit sur le sommeil et l'isolement social. Nous avons constaté que  
15 les adultes exposés aux punaises de lit avaient plus de symptômes d'anxiété, de dépression  
16 et avaient un sommeil plus perturbé que les adultes non exposés. Par ailleurs, les personnes  
17 infestées font état de difficultés de sommeil et des comportements menant à un isolement  
18 social. Les résultats de cette étude suggèrent que les punaises de lit peuvent affecter le  
19 sommeil et la santé mentale des individus. Ces données suggèrent que les infestations de  
20 punaises de lit peuvent avoir des impacts importants sur la santé publique. Ces résultats  
21 cautionnent les initiatives de contrôle des punaises de lit par les autorités municipales et  
22 provinciales. Ces résultats soutiennent les initiatives visant la recherche et la promotion des  
23 meilleures pratiques d'extermination ainsi qu'une collaboration plus importante entre les  
24 entomologistes, les experts de santé publique et les membres de la communauté.

# 1 **Introduction**

2           The City of Montréal, Québec is currently experiencing growth in the number of  
3 dwellings infested with bed bugs (*Cimex lectularius L.*),(Perron et al. 2010) a situation  
4 which is becoming more common across North America and abroad (How and Lee 2010,  
5 Dogget and Russell 2009, Hwang et al. 2005). Based on a 2009 survey conducted in New  
6 York, it was estimated that 6.7% of adult New Yorkers suffered from a bed bug problem  
7 that required the services of an exterminator (CHS 2009). A recent world-wide survey of  
8 pest managers in 43 countries shows that bed bugs have become a global phenomenon  
9 (Potter et al. 2010).

10           The common bed bug is an insect measuring 4-7mm in length that typically bites  
11 sleeping humans at night and hides within the bedding, walls, and belongings of victims  
12 during the day (Kolb et al. 2009). The stings are typically erythematous, pruriginous  
13 papules, with central hemorrhagic pucta. Lesions tend to concentrate on body parts exposed  
14 during sleep and are at times found in clustered or linear configurations (Perron et al. 2010,  
15 Kolb et al. 2009). There is still no evidence that the bed bug is capable of transmitting any  
16 infectious diseases and the medical literature stipulates that primary effects on health are  
17 dermatologic in origin (Goddard and deShazo 2009, Delaunay 2011).

18           Based on anecdotal information and field observation (Perron et al. 2010, Potter et  
19 al. 2010, McDonald and Zavys 2009), there is reason to believe that stresses which could be  
20 associated with bed bug infestation, including social stigmatisation and sleep difficulties,  
21 may exacerbate or predispose exposed individuals to develop mental health problems. The  
22 idea of a link between bed bug exposure and psychological malaise is not new. In a report  
23 published by the London Ministry of Health in 1934 on the subject of bed bugs, at a time  
24 when “virtually every urban authority” had to contend with the problem, it was stated that  
25 although; “there is no evidence that they are active agents in the dissemination of any  
26 particular pathogenic organism in the way that fleas carry plague, lice typhus fever, or  
27 mosquitoes malaria... It may be that Bed bugs are responsible for actual ill-health from  
28 lack of sleep due to skin irritation” (Monier-Williams et al. 1934 pp. 4-5). In the same vein,  
29 a report published by the Center for Disease Control in Atlanta in 1963 entitled ‘Household  
30 and Stored-Food Insects of Public Health Importance and their Control’, stated “bed bugs

31 may cause nervous disorders in sensitive people, and may contribute to the ill health of both  
32 children and adults.” (Scott 1963 pp. XII-9).

33         The literature presents a strong association between insomnia and symptoms of  
34 depression and anxiety and it has been suggested that this association is reciprocal (Taylor  
35 et al. 2005, Jansson-Fröjmark and Lindblom 2008). A review of the dermatologic literature  
36 reveals that other pruritic skin conditions such as psoriasis and atopic dermatitis are  
37 associated with consequences for sleep (Thorburn and Riha 2010, Kelsay et al. 2010) and  
38 mental health (Kelsay et al. 2010, Dalgard et al. 2007). Data examining the links between  
39 infestations and mental health consequences are sparse, consisting primarily of case reports  
40 (Thorburn and Riha 2010, Zahner et al. 1985). The peer reviewed literature currently  
41 contains no studies examining these phenomena in relation to bed bug infestation.

42         The purpose of this research was to explore the relationship between exposure to  
43 bed bugs and mental health symptoms. To this end, data from a community intervention  
44 sample was analysed. It was hypothesized that those exposed to bed bugs would report  
45 symptoms related to sleep difficulty and social isolation due to infestation, and when  
46 compared to those unexposed, they would tend to have higher scores on standardized  
47 mental health instruments.

# 1 **Materials and Methods**

## 2 **Participants**

3           The present study consists of an analysis of medico-environmental data provided by  
4 a sample of tenants living in two apartment complexes in Montreal. Interventions were  
5 carried out between January and June 2010 by the Montréal Public Health Department in  
6 partnership with the Centres de Santé et de Services Sociaux (CSSS) which are community  
7 health and social service centers, the City of Montréal and various community groups.  
8 These two apartment complexes were signalled by the CSSS as possible risks for human  
9 health due to the presence of poor housing conditions. A convenience sample of tenants  
10 who agreed to have their homes inspected and/or to fill out a health questionnaire was  
11 recruited.

## 12 **Data collection**

13           Consenting adult participants filled out an environmental exposures questionnaire as  
14 well as a health questionnaire which included, among many other components, three  
15 standardized psychological measures; the Brief Patient Health Questionnaire Mood Scale  
16 (PHQ-9) (Kroenke et al. 2001), the Generalized Anxiety Disorder Screener (GAD-7)  
17 (Spitzer et al. 2006) and questions 1 through 8 of the Pittsburgh Sleep Quality Index (PSQI)  
18 (Buysse et al. 1989), in addition to questions pertaining to sleep loss and social isolation.  
19 All interviews were conducted by specially briefed doctors and nurses and the complete  
20 questionnaire (including validated standardized measures) was available in French, English  
21 and Spanish. In addition, Bengali and Hindi translators as well as two Spanish-speaking  
22 nurses participated in the data collection. Signed consent was required for secondary  
23 analysis for research purposes and 91 out of 94 adults interviewed consented. Ethical  
24 approval was provided by the research ethics committee of the Agence de la santé et des  
25 services sociaux de Montréal, which is the Montréal agency for health and social services.

## 26 **Study Measures**

27           The present paper is a cross sectional analysis where the results of the three  
28 psychological measures are compared for individuals with and without bed bugs.

29            *Bed bug exposure status:* Self-reported bed bug exposure within the last month  
30 (defined as a dichotomous yes/no variable) constitutes the primary independent variable in  
31 the cross sectional analysis.

32            *Dependent variables:* The 9-item Patient Health Questionnaire (**PHQ-9**) is a  
33 widely-used short depression screener incorporating the DSM-IV-TR criteria for  
34 depression, which was validated in the primary care setting (Kroenke et al. 2001) as well as  
35 in the general population (Martin et al. 2006). PHQ-9 scores range from 0 to 27,  
36 representing the sum of each item's scores which range from 0 (not at all) to 3 (nearly  
37 every day). Usual clinical cut points of 5, 10, 15 and 20 represent mild, moderate,  
38 moderately severe and severe levels of depressive symptoms, respectively (Kroenke et al.  
39 2001, 2010). The instrument has been shown to have a sensitivity and specificity of 88%  
40 for major depression at a cut-off of 10 against standard psychiatric interviews (Kroenke et  
41 al. 2001, 2010). The Cronbach's  $\alpha$  value for the PHQ-9 was 0.83 in this study.

42            The **GAD-7** is a brief anxiety-screening tool developed within the primary care  
43 setting (Spitzer et al. 2006) and later validated in the general population (Löwe et al. 2008).  
44 The 7-item instrument is scored on a 21 point scale representing the sum of the scores of  
45 each item which range from 0 (not at all) to 3 (nearly every day). The scale score is  
46 classified by clinical cut points of 5, 10, 15, representing mild, moderate and severe levels  
47 of anxiety symptoms, respectively (Spitzer et al. 2006). In a large sample of primary care  
48 patients (N=2740), the GAD-7 was shown to have high internal consistency, good construct  
49 validity, sensitivity of 89% and specificity of 82% for generalized anxiety disorder at a cut-  
50 off of 10 upon comparison with a criterion standardized psychiatric interview (Spitzer et al.  
51 2006, Swinson 2006). A French-for-Canada version was not initially available, thus an in-  
52 house translation was utilised for the intervention. This translation was later deemed  
53 semantically equivalent to that released by the authors (Spitzer et al. 2011) by two experts,  
54 one a bilingual psychiatrist and the other a professional translator. The Cronbach's  $\alpha$  for the  
55 GAD-7 was 0.86 in this study.

56            The Pittsburgh Sleep Quality index (**PSQI**) was published by Buysse in 1989 in  
57 order to distinguish groups with sleeping disorders (Buysse et al. 1989). The instrument is  
58 composed of 19 items which upon analysis are divided and examined as a function of 7

59 subscales, each representing a separate factor (ex: sleep efficiency, sleep latency, etc). Each  
 60 subscale is allotted a score between 0 and 3 (with 3 representing the highest level of  
 61 symptomatology), to allow a total possible score of 21 (Buysse et al. 1989). Item 19 was  
 62 not included in the intervention questionnaire due to redundancy. The present analysis  
 63 utilises the score of the 5<sup>th</sup> subscale, ‘sleep disturbance’ which is based on items 5-15. This  
 64 sub score represents the sum of responses to questions about specific disturbances to sleep  
 65 (ex: noise, pain), each having a score between 0 (not during the past month) and 3 (three or  
 66 more times per week) for a total possible sum of 27, which is then divided by cut points of  
 67 0, 1, 10 and 19 to create levels of increasing sleep disturbance severity (Buysse et al. 1989).  
 68 The PSQI(5) has been shown to have high short-interval test-retest reliability in patients  
 69 with primary insomnia (Buckhaus et al. 2002), and moderate-high internal consistency in  
 70 four medical populations (total N=472) (Carpenter and Andrykowski 2006). Cronbach’s  $\alpha$   
 71 value for the PSQI(5) sleep disturbance subscale was 0.69 in this study.

72 Other measures: Other elements from the health questionnaire utilised for this  
 73 analysis include demographic features (sex, age, civil status, education level, perceived  
 74 socioeconomic status, number of individuals in the dwelling), chronic medical and  
 75 psychiatric conditions (>6 months in duration) including mood and anxiety disorders,  
 76 experience of a particularly stressful event within the last year (dichotomous yes/no  
 77 variable) as well as environmental exposure information other than that pertaining to bed  
 78 bugs (self-reported exposure to cockroaches or rodents in the dwelling).

79 Answers to questions pertaining to self-reported sleep disturbance and social  
 80 isolation behaviours due to bed bugs (posed only with exposed individuals) were also  
 81 utilised. Subjective sleep disruption was measured on a 5-point scale adapted from the 5D-  
 82 itch questionnaire (participants asked whether sleep was delayed or disrupted due to bed  
 83 bugs) (Elman et al. 2010). Questions pertaining to missed work days, avoidance of leaving  
 84 the dwelling and of inviting guests assessed social isolation behaviours.

## 85 **Statistical Analyses**

86 Standard descriptive summary statistics were used to characterize the population  
 87 under study in terms of sociodemographic variables as well as environmental exposures.

88 Subgroup analyses using the Pearson's Chi-Square and t-test were conducted in order to  
89 discern any differences between nonresponders (individuals who had not filled out 1 or  
90 more psychological tests) and the rest of the sample, as well as between individuals  
91 exposed and unexposed to bed bugs. Criteria for disqualifying an individual's questionnaire  
92 data based on missing information are described below. Additional, more in depth  
93 descriptive analyses were conducted on the subgroup exposed to bed bugs in relation to  
94 their subjective experience of sleep difficulties and social isolation behaviours due to  
95 infestation.

96 Score distributions for the ordinal scales (defined by clinical cut points in the  
97 literature) were compared for those with and without bed bugs using the Pearson's Chi-  
98 Square and linear-by-linear association. Multiple linear regression models were created to  
99 evaluate the relationship between bed bug infestation status and depression (as per the  
100 PHQ-9), anxiety (as per the GAD-7) and sleep disturbance (as per the PSQI(5)). Models  
101 were created for the continuous as well as ordinal scales. Due to greater ease of  
102 interpretation, we show only those models which were created with the dependent variables  
103 in ordinal format. This decision was justified by the assumption that the categories in  
104 question are equally-spaced and increase in a linear fashion for each of the dependent  
105 variables. Only the PSQI(5) differs slightly, as the first category is 0 (no elements related to  
106 sleep disturbance reported) and the next category up from this is 1-9. Only N=3 individuals  
107 were in this '0' category, and analyses were undertaken as described. The other  
108 assumptions necessary when conducting multiple linear regression were otherwise satisfied  
109 adequately.

110 Decisions to include potential confounders in the final models were taken according  
111 to guidelines set out by Harrell, 2001 (Harrel 2001). Included potential confounders did not  
112 show collinearity. All analyses were conducted with SPSS 12.0.2 for Windows (SPSS  
113 1989-2003).



## 1 **Results**

2           The adult study sample consisted of 38 men and 53 women, many of whom had  
3 recently immigrated and belonged to diverse ethnic groups. Characteristics of the study  
4 population are presented in Table 1. Of note, 54.9% of respondents claimed to be currently  
5 out of work and over half placed their perceived socioeconomic status at ‘poor’ (42.9%) or  
6 ‘very poor’ (9.9%). Out of the total population, 40.7% reported living in a household of 4  
7 or more individuals and 44% reported having no chronic past medical diagnoses. A total of  
8 9 individuals reported prior mental health diagnoses.

9           Based on self-report information, 53.8% of adults (49/91) were found to be exposed  
10 to bed bugs. Other types of infestations were also noted; 79.1% (72/91) reported infestation  
11 with cockroaches whereas fewer reported the presence of rodents; 28.6% (26/90). Of the 91  
12 adults interviewed, 4 did not complete the GAD-7, 4 did not complete the PHQ-9 and 9 did  
13 not complete the PSQI. Out of these individuals, 8 left two out of the three measures  
14 incomplete. The non-responders did not differ significantly from responders in terms of the  
15 characteristics examined in Table 1 upon subgroup comparison. Individuals exposed to bed  
16 bug infestation did not differ significantly from those unexposed on the characteristics  
17 shown in Table 1 except for ‘number of individuals living in the dwelling’ and self-  
18 reported cockroach exposure’.

19           Descriptive analyses pertaining to self-reported sleep disruption and social isolation  
20 among those exposed (N=49) are presented in Table 2. Out of N=49 adults exposed, 53.1%  
21 (26/49) reported sleep difficulties, and 46.9% (23/49) reported some form of social  
22 isolation behaviour associated with infestation. Score distributions for the three  
23 psychological measures in individuals with and without bed bugs are presented in Table 3.  
24 Pearson Chi-Square scores for the univariate associations between infestation status and the  
25 dependent variables were not significant at  $p < 0.05$  but linear by-linear associations for the  
26 PHQ-9 and PSQI(5) were significant at  $p < 0.05$  and that for the GAD-7 was borderline  
27 significant at  $p = 0.051$ .

28           Results of the adjusted regression models are displayed in Table 4. Represented are  
29 multiple linear regression models of predictors by each of the three psychological measures  
30 in ordinal format. In both reduced (1) and fully adjusted (2) models, associations between  
31 all psychological measures and bed bug infestation status are statistically significant ( $p \leq$

32 0.026). Positive bed bug exposure status thus results in an increase of approximately 39.0%  
33 of a symptomological category for the GAD-7, 39.0% of a category for the PHQ-9 and  
34 35.0% of a category for the PSQI(5). Although it is thought to influence the relationships of  
35 interest, psychiatric morbidity was not adjusted for as, upon sensitivity analysis, data from  
36 the 9 individuals reporting prior diagnoses were not shown to have a significant impact on  
37 the models. Models remained significant with the addition of 'self reported cockroach  
38 infestation' as well as 'number of individuals in the dwelling'. Models employing the  
39 psychological measures in continuous format were created as well, and conclusions were  
40 consistent with those above except for the GAD-7 for which the relationship was rendered  
41 nonsignificant at a threshold of 0.05. The goodness of fit of the models is comparable to  
42 others within the field of mental health. Outliers with standardized residuals of  $>2.576$  were  
43 removed from all models and further sensitivity analyses were conducted but these resulted  
44 in minimal change, thus said outliers were left within the sample.

## 1 **Discussion**

2           Our team has revealed statistically significant relationships between scores on three  
3 psychological measures and exposure to bed bugs in an urban setting. Adults exposed to  
4 bed bugs scored significantly higher on the PHQ-9, the GAD-7 and on the sleep  
5 disturbance subscale, PSQI(5), than those unexposed. To our knowledge, these analyses  
6 represent the first to use quantitative data to explore the relationship between bed bug  
7 exposure and consequences to sleep and mental health. Approximately half of the adults in  
8 our sample reported subjective sleep disruption and social isolation behaviours due to bed  
9 bugs.

10           There were limits to this study which could have led to non-differential  
11 misclassification bias towards the null. These include non-uniformity at the level of  
12 questionnaire administration; on several occasions the English and French questionnaires  
13 were translated into other languages at the time of intervention by translators and cultural  
14 brokers. Still, the Cronbach  $\alpha$  values calculated from the totality of our data showed  
15 remarkable consistency with literature values for the original instruments. Alpha values in  
16 our study for the GAD-7, PHQ-9 and PSQI(5) were 0.86, 0.83 and 0.69, respectively with  
17 corresponding literature values of 0.92 (Spitzer et al. 2006), 0.86-0.89 (Kroenke et al.  
18 2001), and 0.70-0.78 (Carpenter and Andrykowski 1998), respectively. In addition,  
19 questions pertaining to bed bug exposure and sleep disturbance as per the PSQI(5) were  
20 based on recall over the past month, whereas those inquiring about anxiety and depressive  
21 symptoms (GAD-7 and PHQ-9) were based on recall over the past two weeks. This might  
22 have lead to a non-differential misclassification bias as well.

23           The convenience sample presents a risk for selection bias. It could be argued that  
24 those with greater mental health problems developed more severe infestations, and were  
25 more likely to consent to interview. It has been reported that individuals with mental health  
26 problems are at an increased likelihood to be burdened by severe bed bug infestation  
27 (McKeown 2008). However, causality in this direction is unlikely given the low prevalence  
28 of prior mental health diagnoses in this population and the fact that most infestations were  
29 recent or ongoing. In addition, the relative homogeneity of the exposed and unexposed

30 groups on all factors except for exposure status further mitigates this risk of bias, as well as  
31 that of potential bias due to confounding.

32         There may be a question regarding external validity. Our sample population was  
33 multiethnic and most individuals were recent immigrants to Montréal. There is evidence to  
34 support that immigrants experience stress due to factors related to migration and  
35 resettlement (Kirmayer et al. 2010). Upon comparison our unexposed population did not  
36 differ noticeably from published general population data in terms of values for the GAD-7  
37 (Löwe et al. 2008), PHQ-9 (Wang et al. 2010), and PSQI(5) (Ramsawh et al. 2009).

38         The results, although compelling, are cross sectional in nature and follow-up studies  
39 are required. A ‘before and after’ case-crossover approach may be appropriate in this  
40 situation as there is an ethical imperative to treat exposed individuals. Further work is also  
41 required to improve methods of quantifying and monitoring infestations and skin reactions  
42 over time. It would also be interesting to explore the subtleties of the relationship further  
43 with qualitative data, particularly in order to describe the influence of social stigma.

44         An August 2010 NYT article (McNeil 2010), citing Goddard and deShazo 2009  
45 (Goddard 2009), indicated that although bed bugs are a nuisance, they are “clean” because  
46 effects are primarily allergic in nature and there is no evidence for infectious disease  
47 transmission. Results from our analyses suggest that bed bug infestation is associated with  
48 mental health outcomes, indicating that consequences are likely far from skin-deep. Self-  
49 reported discrimination has been associated with psychological distress (Major and O’Brien  
50 2005). Insomnia is not only associated with the development of anxiety and depression  
51 (Taylor et al. 2005, Jansson-Fröjmark and Lindblom 2008, Morin et al. 2006), short sleep  
52 duration is associated with an increased risk for the development of hypertension  
53 (Gangwisch et al. 2006).

54         Rapid implementation of policies to control the resurgence based on evidence-based  
55 removal and prevention practices will be required to manage the situation and its potential  
56 societal impacts. This is a considerable order, and one could envision success based on a  
57 multidisciplinary approach with greater collaboration between municipal authorities, health  
58 professionals, entomologists and community stakeholders.

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2 **Competing interests.**

3 The authors declare that they have no competing interests.

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## References cited

- Buckhaus J., K. Junghanns, A. Broocks, D. Riemann, F. Hohagen. 2002.** Test-retest reliability and validity of the Pittsburgh Sleep Quality Index in primary insomnia. *J Psychosom Res.* 53:737-740.
- Buysse D. J., C. F. Reynolds, T. H. Monk, S. R. Berman, and D. J. Kupfer. 1989.** The Pittsburgh Sleep Quality Index- A New Instrument for Psychiatric Practice and Research. *Psychiatry Res.* 28:193-213.
- Carpenter J. S., and M. A. Andrykowski. 1998.** Psychometric Evaluation of the Pittsburgh Sleep Quality Index. *J Psychosom Res.* 45:5-13.
- Dalgard F., L. Lien, and I. Dalen. 2007.** Itch in the Community: associations with psychosocial factors among adults. *J Eur Acad Dermatol Venereol.* 21:1215-1219.
- Delaunay P., V. Blanc, P. Del Giudice, A. Levy-Bencheton, O. Chosidow, P. Marty, et al. 2011.** Bedbugs and infectious diseases. *Clin Infect Dis.* 52(2):200-10.
- Doggett S.L., and R. Russell. 2009.** Bed bugs: What the GP needs to know. *Australian Family Physician.* 38(11): 880-884.
- Elman S., L. S. Hynan, V. Gabriel, and M. J. Mayo. 2010.** The 5-D itch scale: a new measure of pruritus. *Br J Dermatol.* 162:587-593.
- Environmental public health and sustainability tracking portal. 2009.** Adults Reporting Bed Bugs in their Home Citywide NYC Community Health Survey (CHS). Available: <http://nyc.gov/health/tracking>. (Accessed Jan 10 2011).
- Gangwisch J. E., S. B. Heymsfield, B. Boden-Albala, R. M. Buijs, F. Kreier, T. G. Pickering, et al. 2006.** Short Sleep Duration as a Risk Factor for Hypertension: Analyses of the First National Health and Nutrition Examination Survey. *Hypertension.* 47:833-839
- Goddard J., and R. deShazo. 2009.** Bed bugs (*Cimex lectularius*) and Clinical Consequences of Their Bites. *JAMA.* 301:1358-1366.
- Harrell F. E. 2001.** Multivariable Modeling Strategies, pp.66. In *Regression Modeling Strategies: with applications to linear models, logistic regression, and survival analysis.* New York, Springer-Verlag. p. 66.
- How Y. F., and C. Y. Lee. 2010.** Survey of bed bugs in infested premises in Malaysia and Singapore. *J Vector Ecol.* 35:89-94.

- Hwang S. W., T. J. Svoboda, L. J. De Jong, K. J. Kabasele, and E. Gogosis. 2005.** Bed bug infestations in an urban environment. *Emerg Infect Dis.* 11:533-538.
- Jansson-Fröjmark M., and K. Lindblom. 2008.** A bidirectional relationship between anxiety and depression and insomnia? A prospective study in the general population. *J Psychosom Res.* 64:443-449.
- Kelsay K., M. Klinnert, and B. Bender. 2010.** Addressing Psychosocial Aspects of Atopic Dermatitis. *Immunol Allergy Clin North Am.* 30:385-396.
- Kirmayer L. J., L. Narasiah, M. Munoz, M. Rashid, A. G. Ryder, J. Guzder J, et al. 2010.** Common mental health problems in immigrants and refugees: general approach in primary care. *CMAJ.* DOI:10.1503/cmaj.090292
- Kolb A., G. R. Needham, K. M. Neyman, and W. A. High. 2009.** Bedbugs. *Dermatol Ther.* 22:347-352.
- Kroenke K., R. L. Spitzer, and J. B. W. Williams. 2001.** The PHQ-9 - Validity of a Brief Depression Severity Measure. *J Gen Intern Med.* 16:606-613.
- Kroenke K., R. L. Spitzer, J. B. W. Williams, and B. Löwe. 2010.** The Patient Health Questionnaire Somatic, Anxiety, and Depressive Symptom Scales: a systematic review. *Gen Hosp Psychiatry.* 32(4):345-359.
- Löwe B., O. Decker, S. Müller, E. Braehler, D. Schellberg, W. Herzog, et al. 2008.** Validation and standardization of the Generalized Anxiety Disorder screener (GAD-7) in the General Population. *Med Care.* 46:266-274.
- Major B., and L. T. O'Brien. 2005.** The Social Psychology of Stigma. *Ann Rev Psychol.* 56:393-421.
- Martin A., W. Rief, A. Klaiberg, and E. Braehler. 2006.** Validity of the brief patient health questionnaire mood scale (PHQ-9) in the general population. *Gen Hosp Psychiatry.* 28:71-77.
- McDonald L., and R. Zavys. 2009.** Bed Bugs are Back Are We Ready? Habitat and Woodgreen Community Services, Toronto, Available: <http://www.woodgreen.org/LinkClick.aspx?fileticket=6WSSiMTtpGY%3D&tabid=115> (Accessed Feb 22 2011).

- McKeown D. 2008.** Bed Bug Issues in Toronto: Staff Report Action Required Medical Officer of Health Report to Toronto Board of Health.  
<http://www.torontoca/legdocs/mmis/2008/hl/bgrd/backgroundfile-11155pdf>.  
 (Accessed Dec 10, 2010).
- McNeil D. G. 2010.** They Crawl, They Bite, They Baffle Scientists. The New York Times.  
[http://www.nytimes.com/2010/08/31/science/31bedbug.html?\\_r=1&pagewanted=print](http://www.nytimes.com/2010/08/31/science/31bedbug.html?_r=1&pagewanted=print). (Accessed Jan 22 2011).
- Monier-Williams G. W., P.H. Henderson, C. R. Kerwood, et al. 1934.** Report on the Bed-Bug: Report of Committee on the Eradication of the Bed-Bug, Reports on Public Health and Medical Subject No. 72. Ministry of Health, London. Available:  
[http://lrs.afpmb.org/BD5Q6M6Y95P9MHE9UAVV62Y7/arc/al\\_06\\_tit\\_fetch/30/1021](http://lrs.afpmb.org/BD5Q6M6Y95P9MHE9UAVV62Y7/arc/al_06_tit_fetch/30/1021) (Accessed March 15 2011).
- Morin C. M., L. Bélanger, E. Fortier-Brochu. 2006.** Sommeil, insomnie et psychopathologie. *Can Psychol.* 47:245-262.
- Perron S., N. King, L. Lajoie, and L. Jacques. 2010.** Les punaises de lit, retour vers le futur. *Bulletin d'information en santé environnementale*.
- Potter M. F., B. Rosenberg, and M. Henriksen. 2010.** Bugs without Borders-Executive Summary, Fairfax VA: National Pest Management Association, Inc. Available:  
<http://www.npmapestworld.org/documents/bbsurveyexecsummaryjuly26.pdf>.  
 (Accessed March 9 2011).
- Ramsawh H. J., M. B. Stein, S. L. Belik, F. Jacobi, and J. Sareen. 2009.** Relationship of anxiety disorders, sleep quality, and functional impairment in a community sample. *J Psychiatr Res.* 43:926-933.
- Scott H. G. 1963.** Household and Stored-Food Insects of Public Health Importance and their Control, Training Guide- Insect Control Series. US Dept of health, Education, and Welfare, Public Health Service. Communicable Disease Centre, Atlanta, Georgia. Available:  
[http://lrs.afpmb.org/Q9QUHQ14VEM29BPEQFZ47SY/arc/al\\_06\\_tit\\_fetch/133/1292](http://lrs.afpmb.org/Q9QUHQ14VEM29BPEQFZ47SY/arc/al_06_tit_fetch/133/1292) (Accessed March 15, 2011).



- Spitzer R. L., K. Kroenke, J. B. W. Williams, and B. Löwe. 2006.** A brief Measure for Assessing Generalized Anxiety Disorder - The GAD-7. *Arch Intern Med.* 166:1092-1097.
- Spitzer R. L., J. B. W. Williams, and K. Kroenke. 2011.** GAD-7 French for Canada. [http://www.phqscreeners.com/pdfs/03\\_GAD-7/GAD7\\_French%20for%20Canada.pdf](http://www.phqscreeners.com/pdfs/03_GAD-7/GAD7_French%20for%20Canada.pdf). (Accessed Jan 22 2011).
- SPSS for windows RCSI. 1989-2003.** Copyright SPSS Inc.
- Swinson R. P. 2006.** The GAD-7 scale was accurate for diagnosing Generalised Anxiety Disorder. *Evid Based Med.* 11:184.
- Taylor D. J., K. L. Lichstein, H. H. Durrence, B. W. Reidel, and A.J. Bush. 2005.** Epidemiology of Insomnia, Depression and Anxiety. *SLEEP.* 28:1457-1464.
- Thorburn P. T., and R. L. Riha. 2010.** Skin disorders and sleep in adults: Where is the evidence? *Sleep Med Rev.* 14:351-358.
- Wang J. L., N. Schmitz, E. Smailes, J. Sareen, and S. Patten. 2010.** Workplace Characteristics, Depression, and Health-Related Presenteeism in a General Population Sample. *JOEM.* 52:836-842.
- Zahner G. E. P., S. V. Kasl, M. White, and J. C. Will. 1985.** Psychological Consequences of Infestation of the Dwelling Unit. *Am J Public Health.* 75:1303-1307

**Table 1. Characteristics of the study sample by infestation status**

	Participants exposed to bed bugs (n=49) <sup>a</sup> N (%)	Participants not exposed to bed bugs (n=42) <sup>a</sup> N (%)	Total Participants (n=91) N (%)	Exposed vs unexposed		
				Chi-2 or t	df	p- value
Sex				1.17	1	0.28
Men	23 (46.9)	15 (35.7)	38 (41.8)			
Women	26 (53.1)	27 (64.3)	53 (58.2)			
Age Group, y				1.77	1	0.18
< or = 37	29 (59.2)	19 (45.2)	48 (52.7)			
> or = 38	20 (40.8)	23 (54.8)	43 (47.3)			
Mean age, y	37.08	39.43	38.16	-0.87	89	-2.35
Civil Status				0.001	1	0.97
Married /common law	27 (55.1)	23 (54.8)	50 (54.9)			
Single	22 (44.9)	19 (45.2)	41 (45.1)			
Employment Status				0.36	1	0.55
Employed	18 (36.7)	18 (42.9)	36 (39.6)			
Unemployed	31 (63.3)	24 (57.1)	55 (60.4)			

	Participants exposed to	Participants not	Total Participants (n=91)	Exposed vs unexposed		
	bed bugs (n=49) <sup>a</sup>	exposed to bed bugs (n=42) <sup>a</sup>		Chi-2 or t	df	p- value
	N (%)	N (%)	N (%)			
Level of Education				2.41	5	0.80
None / some Primary	4 (8.2)	1 (2.4)	5 (5.5)			
Primary Studies	5 (10.2)	7 (16.7)	12 (13.2)			
Secondary Studies	16 (32.7)	17 (40.5)	33 (36.3)			
Trade School	1 (2.0)	1 (2.4)	2 (2.2)			
College (Cégep)	5 (10.2)	4 (9.5)	9 (9.9)			
University	9 (18.4)	7 (16.7)	16 (17.6)			
Unknown <sup>b</sup>	9 (18.4)	5 (11.9)	14 (15.4)			
Perceived Socioeconomic Status				1.44	3	0.70
Financially at Ease	1 (2.0)	2 (4.8)	3 (3.3)			
Sufficient Revenue	21 (42.9)	15 (35.7)	36 (39.6)			
Poor	20 (40.8)	19 (45.2)	39 (42.9)			
Very Poor	6 (12.2)	3 (7.1)	9 (9.9)			
Unknown <sup>b</sup>	1 (2.0)	3 (7.1)	4 (4.4)			

	Participants exposed to	Participants not	Total Participants (n=91)	Exposed vs unexposed		
	bed bugs (n=49) <sup>a</sup>	exposed to bed bugs (n=42) <sup>a</sup>		Chi-2 or t	df	p- value
	N (%)	N (%)	N (%)			
Presence of Chronic Medical Illness				2.51	3	0.47
None	25 (51.0)	15 (35.7)	40 (44.0)			
1	7 (14.3)	9 (21.4)	16 (17.6)			
2	9 (18.4)	8 (19.0)	17 (18.7)			
3+	8 (16.3)	10 (23.80)	18 (19.8)			
Presence of Psychiatric Disorder				0.64	1	0.42
None	40 (81.6)	36 (85.7)	76 (83.5)			
At least one present	6 (12.2)	3 (7.1)	9 (9.9)			
Unknown <sup>b</sup>	3 (6.1)	3 (7.1)	6 (6.6)			
Experience of a stressful event in last year				0.29	1	0.59
Yes	30 (61.2)	28 (66.7)	58 (63.7)			
No	19 (38.8)	14 (33.3)	33 (36.3)			
Number of Individuals in the Household <sup>*</sup>				13.37	6	0.04
1	2 (4.1)	3 (7.1)	5 (5.5)			

	Participants exposed to	Participants not	Total Participants (n=91)	Exposed vs unexposed		
	bed bugs (n=49) <sup>a</sup>	exposed to bed bugs (n=42) <sup>a</sup>		Chi-2 or t	df	p- value
	N (%)	N (%)	N (%)			
2	6 (12.2)	14 (33.3)	20 (22.0)			
3	17 (34.7)	11 (26.2)	28 (30.8)			
4+	24 (48.9)	13 (30.9)	37 (40.7)			
Unknown <sup>b</sup>	0 (0.0)	1 (2.4)	1 (1.1)			
Self-reported Cockroach Infestation Status <sup>*</sup>				13.99	1	0.00
Yes	46 (93.9)	26 (61.9)	72 (79.1)			
No	3 (6.1)	16 (38.1)	19 (20.9)			
Self-reported Rodent Infestation Status (mice and/or rats) <sup>c</sup>				0.74	1	0.39
Yes	16 (32.7)	10 (23.4)	26 (28.6)			
No	33 (67.3)	31 (73.8)	64 (70.3)			
Unknown <sup>b</sup>	0 (0.0)	1 (2.4)	1 (1.1)			

<sup>a</sup> Bed bug infestation status (yes/no) was determined via self-report.

<sup>b</sup> Refers to individuals who completed the health questionnaire but who did not provide the indicated information.

<sup>c</sup> Only three (3) cases of rats were reported

<sup>\*</sup> An asterisk indicates significant Pearson chi-square statistic for these variable against bed bug infestation status at p<0.05, 2-sided test.

**Table 2. Additional descriptive analyses pertaining to sleep difficulties and social isolation behaviours, due to bed bugs, in those exposed (N=49)**

Self-reported symptoms endured during the last month due to bed bug exposure			
	N	% <sup>a</sup>	
<b>Sleep</b>	Sometimes delayed sleep	4	8.2
	Often delayed sleep	2	4.1
	Delayed sleep and sometimes woke you at night	8	16.3
	Delayed sleep and often woke you at night	12	24.5
	At least one of the Above	26/49	53.1
<b>Social Isolation</b>	Avoided leaving your apartment	4	10.8
	Avoided inviting friends or family members over	19	38.8
	Missed work	0 (0/36)	0 <sup>b</sup>
	At least one of the Above	23/49	46.9

<sup>a</sup> Percentage of all those infested. Adults: N=49

<sup>b</sup> Number of adults in the sample who were employed, N=36

**Table 3. GAD-7, PHQ-9 and PSQI(5) scores by infestation status**

Variable	No. (%) of Participants exposed to bed bugs (n=49)	No. (%) of Participants not exposed to bed bugs (n=42)	No. (%) of Total Participants (n=91)	Linear-by-linear Association		
	N (%)	N (%)	N (%)	Value	df	p-value
<b>GAD-7</b>				3.80	1	0.051
minimal	26 (53.1)	30 (71.4)	56 (61.5)			
Mild	10 (20.4)	9 (21.4)	19 (20.9)			
Moderate	5 (10.2)	3 (7.1)	8 (8.8)			
Severe	4 (8.2)	0 (0)	4 (4.4)			
Missing <sup>a</sup>	4 (8.2)	0 (0)	4 (4.4)			

Variable	No. (%) of Participants exposed to bed bugs (n=49)	No. (%) of Participants not exposed to bed bugs (n=42)	No. (%) of Total Participants (n=91)	Linear-by-linear Association		
	N (%)	N (%)	N (%)	Value	df	p-value
<b>PHQ-9</b>				4.40	1	0.036
minimal	28 (57.1)	32 (76.2)	60 (65.9)			
Mild	10 (20.4)	7 (16.7)	17 (18.7)			
moderate	6 (12.2)	2 (4.8)	8 (8.8)			
Moderately- severe	1 (2.0)	0 (0)	1 (1.1)			
severe	1 (2.0)	0 (0)	1 (1.1)			
Missing <sup>a</sup>	3 (6.1)	1 (2.4)	4 (4.4)			



Variable	No. (%) of Participants exposed to bed bugs (n=49)	No. (%) of Participants not exposed to bed bugs (n=42)	No. (%) of Total Participants (n=91)	Linear-by-linear Association		
	N (%)	N (%)	N (%)	Value	df	p-value
<b>PSQI(5)</b>				6.42	1	0.011
0	0 (0)	3 (7.1)	3 (3.3)			
1-9	35 (71.4)	30 (71.4)	65 (71.4)			
10-18	8 (16.3)	3 (7.1)	11 (21.1)			
19-27	3 (6.1)	0 (0)	3 (3.3)			
Missing <sup>b</sup>	3 (6.1)	6 (14.3)	9 (9.9)			

<sup>a</sup> For any given participant, data from the GAD-7 or PHQ-9 were disregarded if  $\geq 3$  items were left blank. Missing values for these scales were imputed if the number of missing responses was  $< 3$ .

<sup>b</sup> Missing values for any of the items on the PSQI(5) nullified a given participant's results.

**Table 4. Linear regression models showing effects of bed bug infestation status on psychological measures**

Measure	Model 1 <sup>a</sup>				Model 2 <sup>b</sup>			
	B(SE (95%CI)	R <sup>2</sup>	RMSE	p- value	B(SE (95%CI)	R <sup>2</sup>	RMSE	p- value
<b>GAD-7</b>	0.41 (0.18) (0.06 to 0.76)	0.11	0.081	0.022	0.39 (0.17) (0.05 to 0.74)	0.21	0.79	0.026
<b>PHQ-9</b>	0.39 (0.17) (0.05 to 0.73)	0.10	0.78	0.024	0.39 (0.17) (0.05 to 0.72)	0.16	0.77	0.025
<b>PSQI(5)</b> <sup>c</sup>	0.34 (0.12) (0.11 to 0.58)	0.11	0.52	0.005	0.35 (0.11) (0.12 to 0.58)	0.23	0.50	0.003

<sup>a</sup> Adjusted for sex, age

<sup>b</sup> Adjusted for sex, age, civil status, employment status, presence of medical comorbidity, and experience of a stressful event within the last year.

<sup>c</sup> Represents component 5 of the PSQI “Sleep Disturbance”.

## **CHAPTER 5– DISCUSSION**

In this section, principal results of the study will be discussed alongside the strengths and limitations of this research as well as ideas for future work.

### **5.1 Review of principal results**

Our team has uncovered statistically significant relationships between scores on three psychological measures and exposure to bed bugs in an urban setting. Adults exposed to bed bugs scored significantly higher on the PHQ-9, the GAD-7 and on the sleep disturbance subscale of the Pittsburgh sleep quality index [PSQI(5)], than those unexposed. Among those exposed to bed bug infestation, an impressive proportion reported sleep problems and social isolation due to infestation. Our findings echo qualitative data which were gathered during informant interviews in Toronto and reported in a document compiled by McDonald and Zavys of Habitat and Woodgreen Community Services (McDonald et al., 2009). Statements regarding the mental health impact of bed bugs on individuals from this report include:

*“Sufferers talk of feeling ashamed, fearful, and totally overwhelmed once they determined they had bed bugs, which was usually after extensive and fruitless efforts to determine the cause of their welts....Virtually all respondents noted that people living with bed bugs face sometimes extreme levels of isolation”* (McDonald et al., 2009, pp. 33).

### **5.2 Strengths and limitations of the study**

This research study addresses a pressing need to further investigate the impact of bed bug infestation. As readers can tell from the results and testimonies presented above, bed bugs are not benign, and our data represent the only quantitative evidence available to support this statement to date. The study was conducted among tenants, many of whom have had a difficult time with infestation and it might be argued that conducting research close to the communities who need it is a logical and sound way to investigate a public health issue. This analysis also boasts a high degree of internal validity. Aside from bed bug infestation, exposed and unexposed groups were relatively similar in terms of the

characteristics shown in table 1, and data from unexposed individuals resembled published data from general population samples in terms of average values on the GAD-7 (Löwe *et al.*, 2008), PHQ-9 (Wang *et al.*, 2010) and the PSQI(5) (Ramsawh *et al.*, 2009). These factors result in a reduced risk for residual confounding and little risk of selection bias, although it should be noted that external generalisation of our results may be limited by the fact that our sample population had relatively little control over their environments.

Although some questionnaires were translated on-the-spot, Cronbach alpha scores calculated for the mental health instruments used within the health questionnaire were comparable to literature values (please refer to appendix 1). The risk of misclassification bias was further reduced due to the intervention context in which data were collected. Individuals were interviewed within their homes and the majority of infestations were confirmed by the presence of characteristic lesions or by visual inspection of the premises.

Though the study design was cross-sectional nature, one could create an argument for causality based on these results using the Hill criteria (Rothman *et al.*, 2005). It could be argued that exposure very likely precedes effect as very few participants reported prior mental health problems, and most infestations were recent or ongoing. Further, the argument that bed bug infestation is capable of causing sleep disturbance, anxious and depressive symptoms is biologically plausible, as shown by the qualitative evidence and work done in dermatology presented in the literature review accompanying this mémoire.

### **5.3 Ideas for future research:**

This study utilized intervention data for analysis, but it would be interesting to plan a study solely for research purposes as this would allow for a clear and strategic sampling strategy. The production of city-wide portraits could be a result of such a strategy and this may not only help target public health interventions, it would also help gauge the degree of impact the bed bug has had.

To characterise the nature of the relationship with time, it would be interesting to conduct before and after analyses in an intervention trial in which individuals are provided with extermination treatments. Not only could such a project evaluate potentially new and

improved methods for treating bed bugs, it would allow the scientific community to confirm the short-term mental health impacts of infestation on larger samples and with relatively irrefutable evidence. If individuals were followed, researchers could also evaluate whether treatment resulted in a lasting decrease in mental health symptomatology, or whether possible persistence might belie symptoms of post-traumatic stress as has been documented following extermination for pigeon fleas (Haag-Wackernagel *et al.*, 2004). In this same vein, research on bed bugs could help inform the body of literature on the mental health impacts of other types of infestations such as those associated with scabies and head lice.

The confirmation of a significant presence of stigma among individuals suffering from bed bug infestation was an important result of this analysis. Stigma may result in discrimination, excessive stress and have an impact on the distribution of life chances (Link *et al.*, 2006). It behoves the research community to characterise the nature of the stigma suffered by individuals burdened with bed bug infestation with appropriate methodology.

## CHAPTER 6 – CONCLUSIONS

### 6.1 Potential Public Health Impact of the Bed Bug

As we have seen, although bed bugs do not transmit infectious diseases, they represent a hazard to the public's health, and in the past (such as in the England of 1934), this knowledge was sufficient to mobilize public health resources (Monier-Williams *et al.*, 1934). Last summer, the mass media indicated that although bed bugs are a nuisance, they are “clean”, according to an August, 2010 NYT article (McNeil, 2010) citing Goddard and deShazo (Goddard, 2009), because effects are primarily allergic in nature and there is no evidence for infectious disease transmission. Results from this analysis, however, suggest that bed bug infestation is associated with mental health outcomes, indicating that consequences are likely far from skin deep and far from negligible.

Given the potential for mental health fallout, the prospective public health impact stemming from widespread bed bug infestation could be profound. Increased experience of sleep disturbance, anxious and depressive symptomatology may be harbingers of later clinical diagnoses. As mentioned previously, insomnia is associated with the development of anxiety and depression (Taylor *et al.* 2005, Jansson-Fröjmark *et al.*, 2008, Morin *et al.* 2006) but the literature is rich with examples of other pathologies related to poor sleep. It has been suggested that short sleep duration is associated with an increased risk for the development of hypertension (Gangwisch *et al.*, 2006). Sleepiness while driving has been shown to be a strong predictor for the incidence of road traffic accidents (Nabi *et al.*, 2006) and sleep difficulties have been shown to be a predictor of accidental death in the workplace (Akerstedt *et al.*, 2002). More recently, Ferrie *et al.* reviewed literature which suggests sleep may be linked to hormone release processes in the body, citing evidence that sleep restriction and poor sleep quality may be associated with glucose dysregulation. This information indicates that poor sleepers may also be at higher risk of developing diabetes (Ferrie *et al.*, 2011).

Research has shown that clinical anxiety and depression are associated with significant disability in terms of reduction in social and occupational functioning (Stein *et al.*, 2005, Ormel *et al.*, 1999), a finding which appears to be consistent across many

geographic regions and cultures (Ormel *et al.*, 1994). According to WHO statistics on the global burden of disease, neuropsychiatric conditions such as depression are responsible for one third of years spent in a state of less than full health (years of life spent disabled or YLD) (WHO, 2008). It has been shown that depression is responsible for a significantly greater decrement in overall health than angina, arthritis, asthma or diabetes (Moussavi *et al.*, 2007). Presence of an anxiety disorder represents a risk for subsequent suicidal ideation and attempts (Sareen *et al.*, 2005) and affective disorders such as depression represent a real risk of death by suicide compared to the general population (8.6-2.2% vs 0.5%) according to a meta-analysis by Bostwick and Pankratz (Bostwick *et al.*, 2000).

Bed bugs travel within social networks, and as shown by our analyses, individuals dealing with infestation appear to be less likely to visit with social contacts *because of* infestation. Research has shown however, that sustained social isolation can result in impairments to overall health. A review published by Hawley and Cacioppo of the University of Chicago's Institute for Mind and Biology provides evidence to support that perceived social isolation is implicated in a decrease in health-promoting behaviours, excessive stress-induced catabolic reaction, deficient physiological restorative (repair and maintenance) anabolic processes as well as the prediction of morbidity and mortality from cardiovascular disease and cancer (Hawley *et al.*, 2003).

## **6.2 Implications for clinical and public health practice**

Based on our findings it is clear that the ideal public health solution to the issue of bed bugs is to avoid contact by eliminating the pests from dwellings. In the meantime, it might be recommended that clinicians have a low threshold for screening individuals exposed to bed bugs (particularly those with known mental health problems) as they may represent a group at risk for psychiatric complications. The GAD-7 and PHQ-9 have both been recommended for use in primary care settings (Roy-Byrne *et al.*, 2009, Andrews *et al.*, 2008). Health care professionals might also familiarize themselves with local guidelines for bed bug prevention and management, as this information may help empower individuals who are burdened with bed bugs as well help to prevent additional cases. It might also be

recommended that appropriate services such as those of a social worker, psychologist or physician be offered to individuals living in these circumstances, and that appropriate follow up be obtainable. Specific guidelines for health care workers who may have contact with individuals living with infestation are currently being prepared.

In terms of public health actions against bed bugs, an April 2010 statement from the EPA recommends an integrated pest management approach. Broadly, at the community level they recommend action via several routes, including working toward passing legislation which will clarify landlords' and tenants' responsibilities, creating extensive education programs aimed at helping the population to identify the bed bug as well as available resources. At the federal level, they emphasize the importance of working with pest control experts, creating electronic web-based tools focused on integrated pest management, raising funds and creating interagency taskforces (Rossi L and Jennings S, 2010). It should be noted that a 'one size fits all' approach to this problem would be inappropriate. A document presented by McDonald and Zavys of Toronto's Habitat and Woodgreen Community Services highlights the need for special attention to significantly vulnerable people such as those with physical or cognitive impairments or financial constraints in prevention and control plans, as these individuals may be incapable of fulfilling recommendations (McDonald *et al.*, 2009).

### **6.3 Final Thoughts**

*« Sleep tight, don't let the bed bugs bite »*-Unknown

Given current growth rates, it appears we may return to the situation described in the London 1934 report if we do not act quickly. The mental health impact could be important, and given that health and financial burdens tend to cluster within the lower social strata, the issue could serve to widen already existent social inequalities in health. Interestingly, this view is becoming more widely held than previously thought. A recent article reporting a survey of attendees at various conferences including the 2009 National Environmental Health Association Annual Education conference, the 2009 Central Ohio



Bed Bug summit and the 2010 Hamilton County council on Aging Annual Conference, revealed that 90% of respondents felt that bed bugs were a public health concern, and 73% claimed they thought bed bugs represented a concern for environmental justice (Eddy *et al.*, 2011).

It is the hope of the author that this work will lead to two outcomes. First, that it will help to stimulate further inquiry and the development of new tools to further investigate this problem as well as plausible solutions. Second, it is hoped that this effort will help stimulate the formation of partnerships between entomologists, clinicians, public health specialists, government agencies, community groups and other stakeholders and that these collaborations will help tenants and communities (particularly those with limited means) suffering from the presence of this disruptive arthropod, to regain control over their environments. We need to wake up and realize that bed bugs are no longer the stuff of lullabies.

## Bibliographie

- Akerstdt T, Fredlund P, Gillberg M, Jansson B (2002). A prospective study of fatal occupational accidents- Relationship to sleeping difficulties and occupational factors. *J Sleep Res* **11** :69-71.
- Anders D, Brocker E-B, Hamm H (2010). Cimex lectularius - an unwelcome train attendant. *Eur J Dermatol* **20**(2): 239-240.
- Andrews G, Anderson TM, Slade T, Sunderland M. (2008). Classification of Anxiety and depressive Disorders: Problems and Solutions. *Depress Anxiety* **25**(4):274-81.
- Anderson AL, Leffler K (2008) Bedbug Infestations in the News: A Picture of an Emerging Public Health Problem in the United States. *Journal of Environmental Health* **70**(9): 24-27.
- Araujo RN, Costa FS, Gontijo NF, Gonçalves TCM, Pereira MH (2009) The feeding process of *Cimex lectularius* (Linnaeus 1758) and *Cimex hemipterus* (Fabricius 1803) on different bloodmeal sources *Journal of Insect Physiology* **55**:1151-57
- Baron RA, Kenny DA (1986) The Moderator-Mediator Variable Distinction in Social Psychological Research: Conceptual, Strategic, and Statistical Considerations. *Journal of Personality and Social Psychology* **51**(6):1173-1182.
- Barrozo RB, Schilman PE, Minoli SA, Lazzari CR (2004) Daily-Rhythms in Disease-Vector Insects *Biological Rhythms Research* **35**: 79-92.
- Benac N (2010). Bedbug bites becoming bigger battle. *CMAJ* **182**(15): 1606.
- Bender BG, Leung SB, Leung DYM.(2003) Actigraphy assessment of sleep disturbance in patients with atopic dermatitis: an objective life quality measure. *J. Allergy Clin. Immunol* **111**(3):598-602
- Benoit JB, Del Grosso NA, Yoder JA, Denlinger DL (2007). Resistance to dehydration between bouts of blood feeding in the bed bug, *Cimex Lectularius*, is enhanced by water conservation, agrégation, and quiescence. *Am J. Trop. Med. Hyg.*, **76**(5) :987-993.
- Benoit JB, Lopez-Martinez G, Teets NM, Phillips SA, Denlinger DL (2009). Responses of the bed bug, *Cimex lectularius*, to température extrêmes and dehydration : levels of tolérance, rapid cold hardening and expression of heat shock proteins. *Medical and Veterinary Entomology* **23** :418-425.

- Bencheton AL, Pagès F, Berenger J-M, Lightburne E, Morand J-J (2010). Dermite aux punaises de lit (*Cimex lectularis*). *Ann Dermatol Venereol* **137**:5 3-59.
- Boase C. (2001). Bedbugs-back from the brink. *Pesticide Outlook* **12**(4):159-162.
- Boase C (2008). Bed Bugs (Hemiptera : Cimicidae) : An Evidence-Based Analysis of the Current Situation. *Proceedings of the Sixth International Conference on Urban Pests*. Robinson WH and Bajomi D (ed). OOK-Press Kft., Veszprém, Hungary. Available: <http://www.icup.org.uk/reports%5CICUP911.pdf> (Accessed March 29 2011).
- Bostwick JM, Pankratz VS (2000) Affective Disorders and Suicide Risk: A Reexamination. *Am J Psychiatry* **157**(12):1925-32.
- Burleigh N (2010) Infestation: Nightmare on Bedbug Street. *TIME* 04/09/10 Available: <http://www.time.com/time/magazine/article/0,9171,2011937,00.html> (Accessed April 1 2011)
- Busvine JR (1957). Recent progress in the eradication of bed bugs. *Sanitarian* **65**:365-369.
- Carpenter J. S., and M. A. Andrykowski (1998). Psychometric Evaluation of the Pittsburgh Sleep Quality Index. *J Psychosom Res.* **45**:5-13.
- Centers for Disease Control and Prevention and U.S. Environmental Protection Agency. Joint statement on bed bug control in the United States from the U.S. Centers for Disease Control and Prevention (CDC) and the U.S. Environmental Protection Agency (EPA). Atlanta: U.S. Department of Health and Human Services; 2010. (Accessed March 10 2011).
- Chalupka S (2010). Preventing Bedbug Infestation. *AAOHN J* **58**(11): 500.
- Collins RD (2003). *Differential Diagnosis in Primary Care*, 3<sup>rd</sup> edition. Lippincott Williams & Wilkins, New York, 585p.
- Cooper R (2006). Bed bugs- Still more Questions than Answers: A Need for Research and public Awareness. *American Entomologist* **52**(2):111-112.
- Delaunay P, Blanc V, Del Giudice P, Levy-Bencheton A, Chosidow O, Marty P, Brouqui P (2011). Bedbugs and Infectious Diseases. *Clinical Infectious Diseases* **52**(2): 200-10
- Doggett SL, Geary MJ, Russell RC (2004). The Resurgence of Bed Bugs in Australia: With Notes on Their Ecology and Control. *Environ Health* **4**(2): 30-38.

- Doggett SL and Russell RC (2008). The resurgence of bed bugs, *Cimex* spp. (Hemiptera: Cimicidae) in Australia, in W H Robinson and D Bajomi (eds) Proceedings of the 6th International Conference on Urban Pests, OOK-Press Kft., Hungary, 407-25.
- Doggett SL, Russell R (2009). Bed bugs: What the GP needs to know. *Australian Family Physician* **38**(11): 880-884.
- Eddy C, Jones SC (2011). Bed bugs, public health, and social justice: Part 2, an opinion survey. *J Environ Health*, **73**(8): 8-17.
- Elman S, Hyman L, Gabriel V, Mayo M (2010). The 5-D itch scale: a new measure of pruritus. *British Journal of Dermatology* **162**(3): 587-593.
- ED management (2010) EDs trying not to let the bed bugs bite: Decontamination is a common procedure. *ED Manag* **22**(9): 100-101
- Ferrie JE, Kumari M, Salo P, Singh-Manoux A, Kivimaki M (2011). Sleep Epidemiology-a rapidly growing field. *International Journal of Epidemiology* **40**:1431-1437.
- Gangloff-Kaufmann, Hollingsworth C, Hahn J, Hansen L, Kard B, Waldvogel M (2006). Bed Bugs in America: A Pest Management Industry Survey. *American Entomologist* **52**(2):105-106.
- Gangwisch JE, Heymsfield SB, Boden-Albala B, Buijs RM, Kreier F, Pickering TG, et al.(2006) Short Sleep Duration as a Risk Factor for Hypertension: Analyses of the First National Health and Nutrition Examination Survey. *Hypertension* **47**:833-9.
- Gbakima AA, Terry BC, Kanja F, Kortequee S, Dukuley I, Sahr F (2002). High prevalence of bedbugs *Cimex hemipterus* and *Cimex lectularis* in camps for internally displaced persons in Freetown, Sierra Leone: a pilot humanitarian investigation. *West Afr J Med* **21**(4): 268-71.
- Goddard J, de Shazo R (2008) Rapid Rise in Bed Bug Populations: the Need to Include them in the Differential Diagnosis of Mysterious Skin Rashes. *South Med J* **101**(8): 854-855.
- Goddard J, de Shazo R (2009). Bed Bugs (*Cimex lectularius*) and Clinical Consequences of their Bites. *JAMA* **301**(13):1358-1366.
- Gullan PJ, Cranston PS (2000) The Insects: An Outline of Entomology, 2<sup>nd</sup> ed. Blackwell Publishing, Cornwall, UK, 470 p.

- Haag-Wackernagel D, Spiewak R.(2004). Human infestation by pigeon fleas (*Ceratophyllus columbae*) from feral pigeons. *Ann Agric Environ Med.* **11**(2):343-6.
- Harlan HJ (2007). Bed Bug Control: Challenging and still Evolving. *Outlooks on Pest Management* April 2007, pp.57-61. DOI:10.1564/18apr04
- Harlan HJ, Faulde MK, Bauman GJ. (2008) Bedbugs. In : Bonnefoy X, Kampen H, Sweeney K, editors. Public health significant of urban pests. Copenhagen : World Health Organization; 2008. P. 131-153.
- Harrell FE (2001). Multivariable Modeling Strategies, In Regression Modeling Strategies: with applications to linear models, logistic regression, and survival analysis. New York, Springer-Verlag. p. 66.
- Hawkley LC and Cacioppo JT (2003) Loneliness and pathways to disease. *Brain, Behaviour and Immunity.* **17**:S98-S105
- Hong J, Koo B, Koo J (2008) The Psychosocial and Occupational Impact of Chronic Skin Disease. *Dermatologic Therapy* **21**:54-59.
- How YF, Lee CY (2009). Survey of bed bugs in infested premises in Malaysia and Singapore. *J Vector Ecol* **35**(1): 89-94.
- How YF, Lee CY (2010) Effects of Temperature and Humidity on the Survival and Water Loss of *Cimex hemipterus* (Hemiptera: Cimicidae). *J Med Entomol* **47**(6):987-995.
- Hwang SW, Svoboda TJ, De Jong IJ, Kabasele KJ, Gogosis E (2005). Bed Bug Infestations in an Urban Environment. *Emerging Infectious Diseases* **11**(4): 533-538.
- Ikoma A, Steinhoff M, Stander S, Yosipovitch G, Schmelz M. *Nature Reviews Neuroscience* **7**:535-547.
- Jansson-Fröjmark M., and K. Lindblom. (2008). A bidirectional relationship between anxiety and depression and insomnia? A prospective study in the general population. *J Psychosom Res* **64**:443-449.
- Johnson CG (1940). Development, hatching and mortality of the eggs of *Cimex lectularius* L. (Hemiptera) in relation to climate, with observations on the effects of preconditioning to temperature. *Parasitology* **32**:127-173.
- Katz H (2000). Bed Bugs Make a Comeback. *Pest Control Technology* Feb 2000: 79-82.

- Kirmayer LJ et al. (2010) Common mental health problems in immigrants and refugees: general approach in primary care. *Canadian Medical Association Journal*.
- Kramer RD (2004) Closing in on Bed Bugs: Some history and treatment techniques for the industry's 'comeback kids'. *Pest Control Technology* Nov 2004, pp 62-68.
- Kroenke K., R. L. Spitzer, and J. B. W. Williams. (2001). The PHQ-9 - Validity of a Brief Depression Severity Measure. *J Gen Intern Med* **16**:606-613.
- Lee I-Y, Ree H-I, An S-J, Linton J-A, Yong T-S (2008) Reemergence of the bedbug *Cimex lectularius* in Seoul, Korea. *Korean J Parasitol* **46**(4): 269-271.
- Liebold K, Schliemann-Willers S, Wollina U (2003). Disseminated bullous eruption with systemic reaction caused by *Cimex lectularius*. *JEADV* **17**: 461-463.
- Link BG, Phelan JC (2006) Stigma and its public health implications. *Lancet* **367**:528-29.
- Lowe B, Decker O, Muller S, Brahler E, Schellberg D, Herzog W, et al. (2008). Validation and standardization of the generalized anxiety disorder screener (GAD-7) in the general population. *Medical Care* **46**(3):266-74.
- Major B, O'Brien LT (2005) The Social Psychology of Stigma. *Annual Review of Psychology* **56**(1):393-421.
- Manuel J (2010). Invasion of the Bedbugs. *Environ Health Perspect* **118**(10): A429
- McDonald L, Zavys R (2009) Bed Bugs are Back Are We Ready? Habitat and Woodgreen Community Services, Toronto. Available : <http://www.woodgreen.org/LinkClick.aspx?fileticket=6WSSiMTtpGY%3D&tabid=115> (Accessed Jan 22 2011).
- McNeil DG. They Crawl, They Bite, They Baffle Scientists. The New York Times. Aug 30 2010; Available: <http://www.nytimes.com/2010/08/31/science/31bedbug.html> (Accessed March 10 2011).
- Monier-Williams GW, Henderson PH, Kerwood CR, et al. (1934) Report on the Bed-Bug: Report of Committee on the Eradication of the Bed-Bug, *Reports on Public Health and Medical Subject* No. 72. Ministry of Health, London. Available: [http://lrs.afpmb.org/BD5Q6M6Y95P9MHE9UAVV62Y7/arc/al\\_06\\_tit\\_fetch/30/1021](http://lrs.afpmb.org/BD5Q6M6Y95P9MHE9UAVV62Y7/arc/al_06_tit_fetch/30/1021) (Accessed March 15 2011).
- Morin C. M., L. Bélanger, E. Fortier-Brochu. (2006). Sommeil, insomnie et psychopathologie. *Can Psychol* **47**:245-262.

- Moussavi S, Chatterji S, Verdes E, Tandon A, Patel V, Ustun B (2007). Depression, Chronic Diseases, and Decrements in Health: Results from the World Health Surveys. *The Lancet*. **370**:851-8.
- Mumcuoglu KY (2008). A Case of Imported Bedbug (*Cimex lectularius*) Infestation in Israel. *IMAJ* **10**: 388-389.
- Murray CJL, Lopez AD, Jamison DT. (1994) The global burden of disease in 1990: summary results, sensitivity analysis and future directions. *Bulletin of the world health organization*. **72**(3):495-509.
- Nabi H, Guéguen A, Chiron M, Lafont S, Zins M, Lagarde E. (2006) Awareness of driving while sleepy and road traffic accidents: prospective study in GAZEL cohort. *BMJ*. doi:10.1136/bmj.38863.638194.AE (published 23 June 2006)
- NPMA (2010). NPMA Releases First-Ever Comprehensive Global Bed Bug Study to Determine Extent of Resurgence (press release). 26 July 2010. Fairfax, VA: National Pest Management Association. Available: <http://www.pestworld.org/bedbug> (Accessed April 1 2011).
- NYC Community Health Survey (CHS). Adults Reporting Bed Bugs in their Home Citywide, 2009. Environmental public health and sustainability tracking portal. Available : <http://nyc.gov/health/tracking>. (Accessed Jan 10 2011).
- Olson JF, Moon RD, Kells SA (2009) Off-host aggregation behavior and sensory basis of arrestment by *Cimex lectularius* (Heteroptera: Cimicidae) *Journal of Insect Physiology* **55**:580-7.
- Ormel J, VonKorff M, Ustun B, Pini S, Korten A, Oldehinkel T. (1994) Common Mental Disorders and Disability Across Cultures. *JAMA* **272**(22):1741-8.
- Ormel J, Vonkoff M, Oldehinkel AJ, Simon G, Tiemens BG, Üstün TB (1999). Onset of Disability in Depressed and Non-Depressed Primary Care Patients. *Psychological medicine*. **29**:847-53.
- Panagiotakopulu E, Buckland PC (1999). *Cimex lectularius* L., the common bed bug from Pharaonic Egypt. *Antiquity* **73**:908-111.
- Paul J, Bates J (2000). Is infestation with the common bed bug increasing? *BMJ* **320** :1141.
- Perrault C (1989) L'enquête Santé Québec et la santé mentale des québécois : cadre conceptuel et méthodologie. *Érudition* **14**(1) :132-143.

Available : <http://id.erudit.org/iderudit/031494ar> (Accessed June 3 2011).

- Pfiester M, Koehler PG, Pereira RM (2009) Effect of Population Structure and Size on Aggregation Behavior of *Cimex lectularius* (Hemiptera : Cimicidae) *Journal of Medical Entomology* **46**(5) :1015-20.
- Perron S, King N, Lajoie L, Jacques L (2010) Les Punaises de Lit, Retour vers le Futur. Bulletin d'information en santé Environnementale. Institut national de santé public de Québec. Available: <http://www.inspq.qc.ca/bise/post/Les-punaises-de-lit-retour-vers-le-futur.aspx> (Accessed March 10 2011).
- Poorten MCT, Prose NS (2005). The return of the common bedbug. *Pediatric Dermatology* **22**(3):183-7.
- Potter MF (2005) A bed bug state of mind: emerging issues in bed bug management. *Pest Control Technology* **33**:82-85, 88,90,92-93,96-97.
- Potter MF (2008) The History of Bed Bug Management, Bed bug supplement 'Lessons from the Past'. *Pest Control Technology* August, 2008.
- Potter MF, Romero A, Haynes KF (2008) Battling Bed Bugs in the USA. *Proceedings of the Sixth International Conference on Urban Pests*. Robinson WH and Bajomi D (ed). OOK-Press Kft., Veszprém, Hungary. Available: <http://www.icup.org.uk/reports%5CICUP859.pdf> (Accessed March 16 2011).
- Potter MF (2010) Bed Bug Symposia to Address Public health Concerns at Entomology 2010 (list of presentation topics), September 8, 2010. Available <http://entsoc.blogspot.com/2010/09/bed-bug-symposia-to-address-public.html> (accessed March 29 2011).
- Potter MF, Rosenberg B, Henriksen M (2010). Bugs without Borders-Executive Summary, Fairfax VA: National Pest Management Association, Inc. (Available: <http://www.npmapestworld.org/documents/bbsurveyexecsummaryjuly26.pdf>. (Accessed March 9 2011).
- Potter MF (2011) The History of Bed Bug Management- With Lessons from the Past. *American Entomologist* **57**(1):14-25
- Pritchard MJ, Hwang SW (2009). Severe anemia from bedbugs. *CMAJ* **181**(5):297-8.
- Project DIALOGUE 'salle d'attente' questionnaire, INSPQ. <http://www.qualaxia.org/ms/dialogue/projet/methodologie.php?lg=fr> (Accessed May 24th 2011).



- Quarles W (2007). Bed Bugs Bounce Back. *The IPM Practitioner* **XXIX**(3/4):1-7.
- Ramsawh HJ et al. (2009). Relationship of anxiety disorders, sleep quality, and functional impairment in a community sample. *Journal of Psychiatric Research* **43**:926-33.
- Reid B (1990) Don't Let the Bed Bugs Bite. *Pest Control*, June 1990, pp. 48-50.
- Reinhardt K, Naylor R, Siva-Jothy MT (2003) Reducing a cost of traumatic insemination: female bed bugs evolve a unique organ *Proc R Soc Lond B* **270**: 2371-5
- Reinhardt K and Siva-Jothy MT (2007). Biology of the Bed Bugs (Cimicidae). *Annu Rev Entomology* **52**:351-374.
- Reinhardt K, Harder A, Holland S, Hooper, Leake-Lyall C (2008). Who Knows the Bed Bug? Knowledge of Adult Bed Bug Appearance Increases with People's Age in Three Counties of Great Britain. *J Med Entomol* **45**(5): 956-958.
- Reinhardt K, Naylor RA, Siva-Jothy MT (2008) Situation exploitation: higher male mating success when female resistance is reduced by feeding *Evolution* **63**:29-39.
- Reinhardt K, Kempe D, Naylor RA, Siva-Jothy MT (2009). Sensitivity to bites by the bedbug, *Cimex lectularius*. *Medical and Veterinary Entomology* **23**:123-66.
- Reinhardt K, Isaac D, Naylor R (2010) Estimating the feeding rate of the bedbug *Cimex lectularius* in an infested room: an inexpensive method and a case study *Medical and Veterinary Entomology* **24**:46-54.
- Robinson WH (2005) 'Cimitids', from *Urban Insects and Arachnids: A handbook of Urban Entomology*. Cambridge University Press, New York, ch. 8, pp. 204-207.  
Available: <http://www.bio-nica.info/biblioteca/Robinson2005UrbanInsects.pdf>  
(Accessed March 15, 2011).
- Romero A, Potter MF, Haynes KF (2007) Insecticide-Resistant Bed-Bugs: Implications for the industry. *Pest Control Technology*. July 2007: 42,44,46,48,50.
- Romero A, Potter MF, Potter DA, Haynes KH (2007) insecticide resistance in the Bed Bug: A factor in the Pest's Sudden Resurgence? *J Med Entomol* **44**(2):175-178
- Romero A, Potter MF, Haynes KF (2010) Circadian rhythm of spontaneous locomotor activity in the bed bug *Cimex lectularius* L. *Journal of Insect Physiology* **56**: 1516-1522.

- Rossi L, Jennings S (2010) Bed bugs : A public health problem in need of a collaborative solution. *Journal of Environmental health* **72**(8) :34-35.
- Rothman KJ, Greenland S (2005). Causation and causal inference in epidemiology *Am J Public Health* **95**(S1): S144-S150.
- Roy-Byrne P, Veitengruber JP, Bystritsky A, Edlund MJ, Sullivan G, Craske MG, et al. (2009). Brief Intervention for Anxiety in Primary Care Patients. *J Am Board Fam Med* **22**:175-86.
- Ryan N, Peters P, Miller P (2004). A survey of bed bugs in short stay lodges. *NSW Public Health Bull* **15**(11-12): 215-217.
- Sareen J, Cox BJ, Afifi TO, de Graaf R, Asmundson GJG, ten Have M, et al. (2005). Anxiety Disorders and Risk for Suicidal Ideation and Suicide Attempts. *Arch Gen Psychiatry*. **62**:1249-57.
- Scarupa MD, Economides A (2006). Bedbug bites masquerading as urticaria. *J Allergy Clin Immunol* **117**(6): 1508-1509
- Scott HG (1963) Household and Stored-Food Insects of Public Health Importance and their Control, Training Guide- *Insect Control Series*. US Dept of health, Education, and Welfare, Public Health Service. Communicable Disease Centre, Atlanta Georgia. Available:  
[http://lrs.afpmb.org/Q9QUHQ14VEM29BPEQFZ47SY/arc/al\\_06\\_tit\\_fetch/133/31292](http://lrs.afpmb.org/Q9QUHQ14VEM29BPEQFZ47SY/arc/al_06_tit_fetch/133/31292) (Accessed March 15, 2011).
- Shenassa ED, Daskalakis C, Liebhaber A, Braubach M, Brown MJ (2007). Dampness and Mold in the Home and Depression: An examination of Mold-Related Illness and Perceived Control of One's Home as Possible Depression Pathways *Am J Public Health* **97**:1893-1899.
- Silva L, Alencar R de A, Madeira NG. Survey assessment of parental perceptions regarding head lice. *International Journal of Dermatology*. 2008;**47**(3):249-255.
- Siva-Jothy MT (2006) Trauma, disease and collateral damage: conflict in cimicids *Phil Trans R Soc B* **361**: 269-275.
- Spitzer R. L., K. Kroenke, J. B. W. Williams, and B. Löwe. (2006). A brief Measure for Assessing Generalized Anxiety Disorder - The GAD-7. *Arch Intern Med*. **166**:1092-1097.
- SPSS for windows RCSI. 1989-2003. Copyright SPSS Inc.

- Steen CJ, Carbonaro PA, Schwartz RA (2004). Arthropods in Dermatology. *J Am Acad Dermatol* **50**(6): 819-842.
- Stein MB, Roy-Byrne P, Craske MG, Bystritsky A, Sullivan G, Pyne JM, et al. (2005). Functional Impact and Health Utility of Anxiety Disorders in Primary Care Outpatients. *Medical Care* **43**(12):1164-70.
- Taylor DJ, Lichstein KL, Durrence HH, Reidel BW, and Bush AJ (2005) Epidemiology of Insomnia, Depression and Anxiety *SLEEP* **28**:1457-1464.
- Thorburn PT, Riha RL (2010). Skin disorders and sleep in adults : Where is the evidence? *Sleep Medicine Reviews* **14**: 351-358.
- Usinger R (1966) Monograph of Cimicidae (Hemiptera, Heteroptera). College park, MD, Entomol. Soc. Am., 585 p.
- Wang C, Salzman K, Chin E, Bennett GW and Gibb T (2010). Characteristics of *Cimex lectularius* (Hemiptera: Cimicidae), Infestation and Dispersal in High-Rise Apartment Building *Journal of Economic Entomology* **103**(1):172-77.
- Wang J, Schmitz N, Smailes E, Sareen J, Patten S. (2010). Workplace Characteristics, Depression, and Health-Related Presenteeism in a General Population Sample. *JOEM* **52**(8):836-42.
- Wheeler AG Jr, ed (1982) 'Bed Bugs, Other True Bugs and their Relatives', ch 11 of the Mallis Handbook, 6th ed, Harrisberg dept of Agriculture. Excerpt printed in : 'Sombodys been sleeping in my bed!' *Pest Control Technology* **10**(2) : 38, 40, 42, 44.
- Wintle K, Reinhardt K (2008) Temporary feeding inhibition caused by artificial abdominal distension in the bedbug, *Cimex lectularius*. *Journal of insect physiology* **54**:1200-04
- WHO (2008) The Global burden of disease: 2004 update, World Health Organization, Switzerland. Available : [http://www.who.int/healthinfo/global\\_burden\\_disease/2004\\_report\\_update/en/index.html](http://www.who.int/healthinfo/global_burden_disease/2004_report_update/en/index.html)
- Whyte AS, Garnett PA, Whittington AE (2001). Bats in the belfry, bugs in the bed? *Lancet* **24** :**357**(9256):604.

- Yosipovitch G, Goon A, Wee J, Chan YH, GOH CL (2000). The prevalence and clinical characteristics of pruritus among patients with extensive psoriasis. *Br J Derm* **143**:969-973.
- Yosipovitch G, Zucker I, Boner G, Shapira Y, David M (2001). A Questionnaire for the assessment of pruritus: validation in uremic patients. *Acta Derm Venerol* **81**:108-11
- Zachariae R, Lie U, Haedersdal M, Zachariae C (2011). Itch severity and quality of life in patients with pruritus: preliminary validity of a Danish adaptation of the itch severity scale. *Acta Derm Venereol* ;doi:2340/00015555-1221
- Zachariae R, Zachariae COC, Lei U, Pedersen AF (2008). Affective and sensory dimensions of pruritus severity: associations with psychological symptoms and quality of life psoriasis patients. *Acta Derm Venerol* **88**:121-127.
- Zahner GEP, Kasl SV, White M, Will JC (1985). Psychological consequences of infestation in the dwelling unit *AJPH* **75**(11):1303-7.

## Appendix 1

Table 1A: Cronbach alpha values from our data compared with literature values

Measure	Literature value	Value using our data
GAD-7	0.92 <sup>1</sup>	0.857
PHQ-9	0.86-0.89 <sup>2</sup>	0.829
PSQI(5)	0.70-0.78 <sup>3</sup>	0.691

<sup>1</sup> (Spitzer et al., 2006), <sup>2</sup> (Kroenke et al., 2001), <sup>3</sup> (Carpenter et al., 1998)

## Appendix 2

### Co-author contributions to the article found in Chapter 4

**Stephanie R Susser**, resident in Public Health and Preventive Medicine and candidate for the M.Sc. in Community Medicine at the Université de Montréal. Under the supervision of her colleagues, conceptualised and designed the study, participated in the field interventions which gave rise to the data used in this mémoire, cleaned, analysed and interpreted the data, wrote and revised the manuscript.

**Stéphane Perron**, Specialist in Public Health and Preventive Medicine at the Direction de santé publique de l'agence de Montréal, residency program director, and professor in the department of Médecine Sociale et Préventive at the Université de Montréal, was the primary master's supervisor and as such participated in and reviewed the totality of the work conducted by Stephanie R Susser.

**Michel Fournier**, Research agent and statistician at the Direction de santé publique de l'agence de Montréal participated in the conceptualisation and design of the study, oversaw data cleaning and analysis, revised and commented on the manuscript.

**Louis Jacques**, Specialist in Public Health and Preventive Medicine at the Direction de santé publique de l'agence de Montréal and professor in the department of Médecine Sociale et Préventive at the Université de Montréal, participated in the conceptualization and design of the study, oversaw the in data analysis and reviewed and commented on the manuscript.

**Geoffroy Denis**, then resident in Public Health and Preventive Medicine, now Specialist in Occupational Health at the Direction de santé publique de l'agence de Montréal, participated in the conceptualization and design of the study, participated in the field interventions which gave rise to the data used in this mémoire, oversaw data analysis and reviewed and commented on the manuscript.

**François Tessier**, Research agent and informatics consultant at the Direction de santé publique de l'agence de Montréal, participated in data cleaning and analysis, review of the manuscript.

**Pasquale Roberge**, Professor in the department of Médecine de famille at Université de Sherbrooke, researcher affiliated with the Institut National de Santé Publique (INSPQ) and the Centre du Recherche du CHUM (CRCHUM), and previously professor in the department of Médecine Sociale et Préventive at the Université de Montréal was co-supervisor of Stephanie R Susser's work toward her master's degree and as such oversaw, with Dr Stéphane Perron, all work conducted on the article.

## Appendix 3

### Photograph of a bed bug and a patient with bed bug associated lesions



**Figure 1: bed bug**

**Source:** CDC/ Harvard University, Dr. Gary Alpert; Dr. Harold Harlan; Richard Pollack. Photo Credit: Piotr Naskrecki; Available: <http://phil.cdc.gov/phil> and [http://en.wikipedia.org/wiki/File:Bed\\_bug,\\_Cimex\\_lectularius.jpg](http://en.wikipedia.org/wiki/File:Bed_bug,_Cimex_lectularius.jpg)



**Figure 2: Patient with bed bug associated cutaneous lesions (bites)**

**Source:** Wikimedia commons, Dr James Heilman MD; Available: <http://en.wikipedia.org/wiki/File:Bedbug2.JPG>

## Appendix 4

### Notice of publication:

**Susser SR et al. (2012)** Mental health effects from urban bed bug infestation (*Cimex lectularius L.*): a cross-sectional study. *BMJ Open* 2012; **2**:e00838. Doi:10.1136/bmjopen-2012-00838

The article referred to above was published after the writing of this ‘mémoire de maîtrise’. The same data set as that utilized for the article found in chapter 4 was exploited, but logistic regression, instead of linear regression was used in order to simplify comprehension of the results. The reader is directed to the methodology section of the published paper for more information. The reader will also find the conclusions to be in line with those presented in chapter 4, in spite of the methodological differences.

The paper was received by BMJ Open on the 6<sup>th</sup> of January 2012 and accepted for publication on the 17<sup>th</sup> of April 2012.



# Mental health effects from urban bed bug infestation (*Cimex lectularius* L.): a cross-sectional study

Stephanie Rebecca Susser,<sup>1,2</sup> Stéphane Perron,<sup>1,2,3</sup> Michel Fournier,<sup>2</sup> Louis Jacques,<sup>1,2</sup> Geoffroy Denis,<sup>2</sup> François Tessier,<sup>2</sup> Pasquale Roberge<sup>4</sup>

## ABSTRACT

**Objective:** To assess whether bed bug infestation was linked to sleep disturbances and symptoms of anxiety and depression.

**Design:** Exploratory cross-sectional study.

**Setting:** Convenience sample of tenants recruited in apartment complexes from Montreal, Canada.

**Participants:** 39 bed bug-exposed tenants were compared with 52 unexposed tenants.

**Main outcome measures:** The effect of bed bug-exposed tenants on sleep disturbances, anxiety and depression symptoms measured using the Pittsburgh Sleep Quality Index, 5th subscale, Generalised Anxiety Disorder 7-item scale and Patient Health Questionnaire, 9-item, respectively.

**Results:** In adjusted models, bed bug infestation was strongly associated with measured anxiety symptoms (OR (95% CI)=4.8 (1.5 to 14.7)) and sleep disturbance (OR (95% CI)=5.0 (1.3–18.8)). There was a trend to report more symptoms of depression in the bed bug-infested group, although this finding was not statistically significant ((OR (95% CI)=2.5(0.8 to 7.3)).

**Conclusions:** These results suggest that individuals exposed to bed bug infestations are at risk of experiencing sleep disturbance and of developing symptoms of anxiety and possibly depression. Greater clinical awareness of this problem is needed in order for patients to receive appropriate mental healthcare. These findings highlight the need for undertaking of deeper inquiry, as well as greater collaboration between medical professionals, public health and community stakeholders.

## INTRODUCTION

Adult bed bugs are 4–6 mm long, oval and flattened insects that feed on human blood. Feeding sessions typically last 15 min and are followed by the departure of the bug towards its harbourage site. Once fed, bed bugs do not remain attached to their prey.<sup>1</sup> Bed bug bites, like mosquito bites are associated with local cutaneous allergic reactions.<sup>2</sup> To date, there have been no reports of infectious disease transmission via bed bug bites.<sup>2,3</sup> Bed bugs can

## ARTICLE SUMMARY

### Article focus

- Infestations with the common bed bug (*Cimex lectularius* L.) have become problematic in many cities.
- No epidemiological studies currently exist on the mental health impacts of bed bug infestations.
- In this exploratory cross-sectional analysis, we assessed whether bed bug infestations were linked to sleep disturbances and symptoms of anxiety and depression among tenants in Montreal, Quebec.

### Key messages

- This study suggests that individuals exposed to bed bugs may be at risk of experiencing sleep disturbance and of developing anxious and possibly depressive symptoms.
- Appropriate control of bed bug is required to manage the situation and its potential health impacts.

### Strengths and limitations of this study

- The convenience sample presents a risk for selection bias.
- There is a possibility of misclassification biases due to self-report even though the Cronbach  $\alpha$  values calculated from our data showed remarkable consistency with literature values for the original instruments.
- These results are cross-sectional in nature and follow-up studies are required.

be exterminated rapidly but extermination techniques are complex. In some settings bed bug infestation may become chronic.<sup>4</sup>

Anecdotal and historical evidence suggests that infestation by the common bed bug (*Cimex lectularius* L.) may be a stressor that has an emotional and psychological effect.<sup>3</sup> Field workers and pest control managers in Montreal,<sup>5</sup> Toronto<sup>4</sup> and in 43 countries around the globe surveyed by the National Pest Management Association have observed psychological distress among individuals living with infestation.<sup>6</sup> There are reports of

people resorting to dangerous methods in order to rid their dwellings of bed bugs.<sup>7</sup> Recently, Goddard and de Shazo<sup>8</sup> noted that comments posted on bed bug-related websites revealed symptoms of post-traumatic stress disorder. None of these studies, however, were performed in a clinical setting and there are currently no original published epidemiological data available on the mental health impact of bed bug infestation. The objective of this study was to conduct an exploratory cross-sectional analysis comparing individuals living with and without bed bug infestations using three standardised clinical mental health measures.

**METHODS**

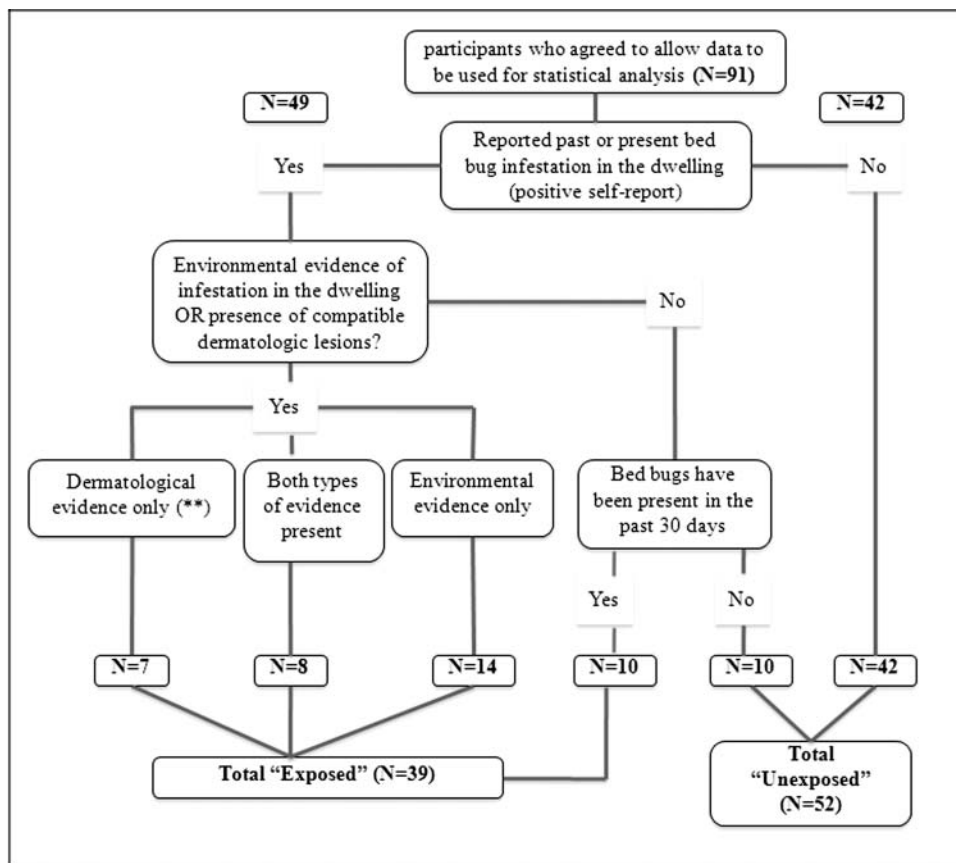
**Data collection and measures**

Unfit housing conditions due to water infiltration, mould and vermin infestation are frequently reported to the Montreal Public Health Department (MPH). Decision to intervene in such situations is taken by the environmental health team that includes physicians and an experienced hygienist. The aim of field intervention, when mandated, is to produce recommendations for remediation of the buildings involved and to ensure healthcare for tenants who may require attention. However, relocation of tenants to

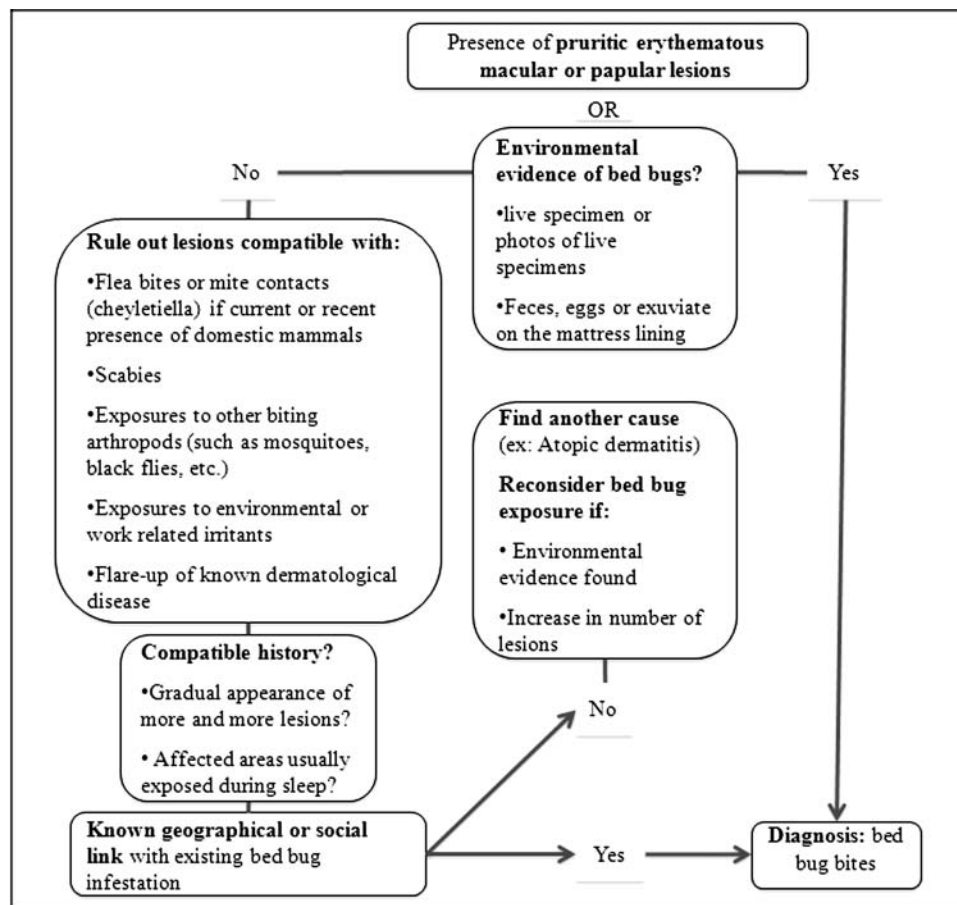
other housing complexes is only recommended in cases where tenants experience a significant negative health impact due to water infiltration. Participants were recruited from the two Montreal apartment complexes who were subject to public health interventions targeting unfit housing conditions led by the MPH Department and their community partners between January and June 2010. This cross-sectional study is based on data provided by a convenience sample of 91 tenants recruited. All participants agreed to allow the data they provided to be used for research purposes.

Physicians and nurses familiar with unfit housing conditions and infestations collected all data. Culturally and linguistically competent translators were available and all questionnaire material was available in English, French and Spanish. Ethical approval was provided by the research ethics committee of the Montreal Agency for Health and Social Services. The research has conformed to the principles embodied in the Declaration of Helsinki.

Data were obtained from an intervention health questionnaire. Symptoms of depression and anxiety were evaluated using the Brief Patient Health Questionnaire Mood Scale (PHQ-9)<sup>9</sup> and the Generalised Anxiety Disorder Screener (GAD-7)<sup>10</sup> which are based on criteria from the Diagnostic and Statistical Manual of Mental Disorders



**Figure 1** Algorithm for attribution of a diagnosis of bed bug infestation based on the presence of characteristic lesions and environmental evidence.



**Figure 2** Participant flowchart.

(DSM)-IV and DSM-IV-TR, respectively. Sleep disturbances were measured using questions 1–8 (5th subscale) of the Pittsburgh Sleep Quality Index.<sup>11</sup> Bed bug exposure status was initially determined by self-report; participants were asked to point to the culprit insect on an identification tool containing pictures of bed bugs and other commonly found insects in Montreal apartment buildings. Details related to infestation (onset, corrective measures taken) were recorded. This subjective evidence was supported by objective dermatological and/or environmental evidence of infestation when available (figure 1). Individuals with past bed bug exposure—but who reported that bed bugs had not been seen in the dwelling for >30 days—were classified as unexposed (figure 2). Other variables from the health questionnaire include demographic features, history of chronic medical and psychiatric conditions (>6 months in duration), experience of a particularly stressful event within the last year (yes/no variable) as well as environmental exposure information other than that pertaining to bed bugs (number of inhabitants, exposure to cockroaches).

### Statistical analysis

The  $\chi^2$  analyses were used to distinguish characteristics particular to the bed bug-exposed group as compared with

the unexposed group. Scores for the three instruments were dichotomised into 'present/absent'. Scores corresponding to symptoms 'present' were: 10 and over on the PHQ-9 of 27, (moderate symptoms of depression or worse), 5 and over on the GAD-7 of 21 (mild symptoms of anxiety or worse) and 10 and over 27 on the PSQI 5th subscale. For any given participant, data from the GAD-7 or PHQ-9 were disregarded if three or more items were left blank. Missing values for these scales were replaced with the mean scores of the other subjects' items response if the number of missing responses was less than 3.

Multivariable logistic regression was used to calculate OR and 95% CI for an association between bed bug infestation exposure and anxiety, depressive symptoms and sleep disturbance. Models were initially run for exposure status alone, then adjusted for sex and age. The PHQ-9 and GAD-7 models were adjusted as well for psychiatric diagnosis and number of inhabitants. The GAD-7 model was additionally adjusted for cockroaches in the dwelling. Adjusted model parameters did not change by more than 10% with the addition of employment status, perceived sufficient means, civil status, medical diagnoses or experience of a stressful event within the last year. Final models were rerun without 10 individuals for whom there were no objective evidence to support or refute their

(previous) self-report. Cronbach  $\alpha$  values were calculated to measure the internal consistency of the psychometric tools (GAD-7, PHQ-9 and PSQI(5)). Analyses were performed using SPSS V.12.0.2 for Windows (SPSS 1989–2003).

## RESULTS

There were 39 individuals exposed to bed bugs and 52 unexposed individuals (figure 2). Exposed and unexposed individuals were found in both housing complexes. Individuals exposed to bed bug infestation did not differ significantly from those unexposed on the characteristics shown in table 1 except for 'number of individuals living in the dwelling' and 'self-reported cockroach exposure'. Pearson  $\chi^2$  scores for the univariate associations between bed bug infestation status and the dependent variables were significant at  $p < 0.05$  for the GAD-7 and PSQI(5), but not for the PHQ-9.

Results of the logistic regression models are displayed in table 2. In both unadjusted and adjusted models, the association between anxiety symptoms and bed bug infestation status was statistically significant (OR (95% CI) adjusted model=4.8 (1.5 to 14.7)). A statistically significant association was also found for sleep disturbance (OR (95% CI) adjusted model=5.0 (1.3 to 18.8)). There was a statistically non-significant association observed between depressive symptoms and bed bug infestation (OR (95% CI) adjusted model=2.5 (0.8 to 7.3)). Sensitivity analysis as outlined above did not alter results.

The Cronbach  $\alpha$  values calculated from the data for the GAD-7, PHQ-9 and PSQI(5) were found to be 0.86, 0.83 and 0.69, respectively.

## DISCUSSION

Our study showed that anxiety symptoms and sleep disturbances were significantly more likely to occur among individuals exposed to bed bug infestation. The association between exposure and depressive symptoms occurred in the expected direction, but was non-significant at the level of  $p < 0.05$ .

To our knowledge, this study is the first to quantitatively explore the anxiety symptoms, depressive symptoms and sleep disturbance associated with bed bug infestations. Literature on anxiety and depressive symptoms and sleep disturbance associated with infestation with biting arthropods is scant, but some anecdotal evidence exists that infestation with pigeon fleas<sup>12</sup> and head lice can have a negative effect on sleep.<sup>13</sup> The dermatologic literature details other pruritic skin conditions such as psoriasis and atopic dermatitis and their consequences on sleep<sup>14</sup> and mental health.<sup>15</sup>

This study has several limitations. The convenience sample presents a risk for selection bias, the magnitude of which is attenuated by the fact that both exposed and non-exposed subjects lived in the same apartment complexes. There is a possibility of misclassification due to self-report in the intervention context. However, the

**Table 1** Characteristics and instrument scores of participants according to bed bug infestation exposure status

Characteristics	Exposed to bed bug infestation (%)	N*
Sex		
Male	50	38
Female	38	53
Age (years)		
$\leq 36$	48	48
$\geq 37$	37	43
Education		
Less than high school	41	17
High school or more	38	60
Employment status		
Employed	42	36
Unemployed	44	55
Legally married		
Yes	42	50
No	44	41
Perceived sufficient means		
Yes	46	39
No	42	48
Stressful event in last year		
Yes	43	58
No	42	33
Psychiatric diagnosis		
None	43	76
1+	44	9
Medical diagnosis		
None	53	40
1+	35	51
Number of inhabitants†		
1–2	20	25
3+	52	65
Cockroaches in dwelling†		
Present	50	72
Absent	16	19
Anxiety symptoms (GAD-7)†		
Present	55	31
Absent	32	56
Depressive symptoms (PHQ-9)		
Present	52	27
Absent	37	60
Sleep disturbance (PSQI(5))†		
Present	71	14
Absent	40	68
Total		91

\*May not total due to missing data.

†These variables differed significantly for the exposure groups on Pearson  $\chi^2$  analysis  $p < 0.05$ , two-sided test.

GAD-7, Generalised Anxiety Disorder 7-item scale; PHQ-9, Pittsburgh Sleep Quality Index, 5th subscale; PSQI(5), Patient Health Questionnaire, 9-item.

Cronbach  $\alpha$  values calculated from the totality of our data showed remarkable consistency with literature values for the original instruments. Cronbach  $\alpha$  values in

**Table 2** ORs and 95% CIs for the associations between bed bug infestation exposure and mental health symptoms

	Unadjusted OR (95% CI)	Fully adjusted OR (95% CI)*
PSQI(5)	3.80 (1.10 to 13.35)	5.00 (1.30 to 18.80)
GAD-7	2.56 (1.04 to 6.32)	4.75 (1.54 to 14.70)
PHQ-9	1.86 (0.74 to 4.67)	2.48 (0.84 to 7.30)

\*All models were adjusted for sex and age. Generalised Anxiety Disorder 7-item scale (GAD-7) and Pittsburgh Sleep Quality Index, 5th subscale (PHQ-9) were further adjusted for psychiatric diagnosis and number of inhabitants. GAD-7 was additionally adjusted for cockroaches in dwelling. PSQI(5), Patient Health Questionnaire, 9-item.

our study for the GAD-7, PHQ-9 and PSQI(5) were 0.86, 0.83 and 0.69, respectively, with corresponding literature values of 0.92,<sup>10</sup> 0.86–0.89<sup>9</sup> and 0.70–0.78,<sup>16</sup> respectively.

These results are cross-sectional in nature and follow-up studies are required. A 'prepost' intervention approach would be appropriate in this situation as there is an ethical imperative to treat the dwellings of patients in addition to their symptoms. Such an approach would allow us to evaluate changes in reported symptoms after the bed bugs have been eradicated in the dwelling and the stressor thus removed.

Clinicians should be aware of the impacts bed bug infestations can have on patients, particularly those from vulnerable populations. Rapid implementation of policies to control the infestation based on evidence-based removal and prevention practices will be required to manage the situation and its potential societal impacts. This is a considerable task, and one could envision success if a multi-disciplinary approach is used with collaboration between municipal authorities, medical professionals, public health, entomologists and community stakeholders.

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submission. The study was conceptualised and designed by SRS, SP, MF, LJ, GD and PR. The data were acquired by SRS, SP, LJ and GD. Statistical analysis was performed by SRS, SP and MF. The data were analysed and interpreted by all authors. The manuscript was drafted by SRS and revised by all authors.

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## REFERENCES

1. Usinger R. Monograph of Cimicidae. Thomas Say Foundation, volume 7, 1966, College Park, MD: Entomological Society of America.
2. Goddard J, de Shazo R. Bed bugs (*Cimex lectularius*) and clinical consequences of their bites. *JAMA* 2009;301:1358–66.
3. Delaunay P, Blanc V, Del Giudice P, et al. Bedbugs and infectious diseases. *Clin Infect Dis* 2011;52:200–10.
4. McDonald L, Zavys R. Bed bugs are back Are we ready? 2009. <http://www.woodgreen.org> (accessed 21 Dec 2011).
5. Perron S, King N, Lajoie L, Jacques L. Les punaises de lit, retour vers le futur. *Bulletin d'information en santé environnementale*. <http://www.inspq.qc.ca/bise/post/Les-punaises-de-lit-retour-vers-le-futur.aspx> (accessed 25 Jan 2010).
6. Potter M, Rosenberg B, Henriksen M. Bugs without borders-executive summary: defining the global bed bug resurgence. <http://www.pestworld.com> (accessed 21 Dec 2011).
7. Manuel J. Invasion of the bedbugs. *Environ Health Perspect* 2010;118:A429.
8. Goddard J, de Shazo R. Psychological effects of bedbug attacks (*Cimex lectularius* L.). *Am J Med* 2012;125:101–3.
9. Kroenke K, Spitzer RL, Williams JBW. The PHQ-9. *J Gen Intern Med* 2001;16:606–13.
10. Spitzer RL, Kroenke K, Williams JBW, et al. A brief measure for assessing generalized anxiety disorder: the GAD-7. *Arch Intern Med* 2006;166:1092–7.
11. Buysse DJ, Reynolds CF 3rd, Monk TH, et al. The Pittsburgh sleep quality index: a new instrument for psychiatric practice and research. *Psychiatry Res* 1989;28:193–213.
12. Haag-Wackernagel D, Spiewak R. Human infestation by pigeon fleas (*Ceratophyllus columbae*) from feral pigeons. *Ann Agric Environ Med* 2004;11:343–6.
13. Silva L, Alencar R de A, Madeira NG. Survey assessment of parental perceptions regarding head lice. *Int J Dermatol* 2008;47:249–55.
14. Bender BG, Leung SB, Leung DYM. Actigraphy assessment of sleep disturbance in patients with atopic dermatitis: an objective life quality measure. *J Allergy Clin Immunol* 2003;111:598–602.
15. Hong J, Koo B, Koo J. The psychosocial and occupational impact of chronic skin disease. *Dermatol Ther* 2008;21:54–9.
16. Carpenter JS, Andrykowski MA. Psychometric evaluation of the Pittsburgh sleep quality index. *J Psychosom Res* 1998;45:5–13.