

Mitigating the Spread of Bedbugs  
In Multi-Unit Dwellings  
for Vulnerable Adults in the City of Toronto

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## Addenda

### Key and Significant Changes Made During the Revision Process Include:

- Further scoping in response to raised issues concerning the difficulty of the initially proposed problem. This RFP only solicits a design for the detection device, and no longer asks for the development of a network / communications system. Associated with this major change is:
  - A new visual (and explanation) added to the 'Scoping - Region of Interest' section
  - Criterion concerning 'scalability' removed (Section 6 - 'Objectives')
  - Criterion concerning 'cost' modified to better suit scope of problem (Section 6 - 'Objectives')
  - Removed Appendix G (Cost Estimation) because the deeper level of scoping rendered it irrelevant.
  - Added a new objective concerning sensor accuracy (Section 6 - 'Objectives')
- 'Stakeholder Section (add number here)' now includes the analysis of three additional stakeholders: Social Workers, Pest Control Companies, and Research Teams. In addition, the stakeholders were separated into two categories: 'primary' and 'secondary' to emphasize their relative importance as it relates to the problem.
  - 'Vulnerable Adults' (Section 5 - 'Stakeholders') modified to include issues concerning substitute decisions, privacy, comfort, and potential legal implications
- Moved 'Appendix F' (reference designs) to the body of the RFP. The contents of this section were also modified to include the analysis of a third detection device.
- Multiple changes (across the entire document) in sentence structure, paragraphing, and word choices to provide a clearer and more coherent reading experience.
- Re-wrote abstract to better expose the gap to the readers.
- Included a list of properly formatted IEEE references (in response to technical difficulties with document mark-up software)

## **Abstract**

This Request for Proposal addresses the growing number of bedbug infestations within the City of Toronto. Toronto Public Health received only 46 bedbug related reports in 2003, but 1500 such reports between March and October of 2008 [1]. This has become a pressing issue for the citizens of Toronto. Bedbug infestations cause much stress and anxiety for those infected, as a typical eradication procedure often requires ongoing financial and physical resources [1].

Early detection is essential in mitigating the spread of bedbugs. Identifying and addressing an infestation before it becomes unmanageable ensures that the eradication process is as effective as possible [2]. This becomes even more important in multi-unit dwellings where spread is made easier due to the proximity of adjacent units [2]. The issue is further complicated when the residents are vulnerable adults. It is often the case that vulnerable adults living in such environments are incapable of identifying and reporting these infestations [3].

Currently, bedbug detection devices fall into one of two categories: active and passive. Active detection devices will immediately notify the tenant of an infestation, but in doing so, require a knowledgeable operator. Passive bedbug detection devices will trap bedbugs in the case of an infestation, but do not notify the tenant of the potential infestation. The onus is on the tenant to check the trap regularly. The problem arises when vulnerable adults are expected to have this level of awareness.

This RFP seeks a design solution that will allow a passive detective device to emit a distinct analogue signal upon detection of a bedbug. When integrated with information collection and distribution networks, this would completely remove the responsibility of the tenant to report the infestation, while at the same time ensuring that proper measures are taken as early as possible. Along with these vulnerable adults, their associated social workers, landlords and Toronto Public Health are major stakeholders in considering this issue. Social workers have a vested interest in the well being of their clients. Landlords have a fiscal interest in keeping their buildings pest free. Toronto Public Health often liaises with landlords and pest control companies to ensure that effective treatment is provided to such vulnerable adults. The objectives developed for this design solution promotes a product that is both fiscally and environmentally sustainable, while at the same time meeting the needs of the aforementioned stakeholders. Key objectives include: detection threshold, time between maintenance, cost of manufacture, and power usage.

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# 1 Introduction

The issue of bedbug infestations has become endemic in the City of Toronto over the past 10 - 12 years [3]. A 2009 research paper written by Habitat Services and WoodGreen Community Services reported that Toronto Public Health received only 46 bedbug related reports in 2003, but 1500 such reports in between the months of March and October in 2008 [1]. The problem is one that is far from being solved, and it will continue to grow rapidly unless a "focused and multi-sector intervention" takes place [1]. The intent of this RFP is not to initiate this scale of intervention, but rather to isolate a small piece of this problem such that our work as 1<sup>st</sup> year Engineering Science students can provide a small, yet meaningful, contribution to the solution.

Mitigating the spread of bedbugs is a multifaceted problem. This RFP focuses on the important role that early detection plays in controlling such infestations. Identifying and addressing an infestation before it becomes unmanageable ensures that the eradication process is as effective as possible [2]. The importance of early detection is all the more relevant when dealing with multi-unit dwellings. In these living spaces, spread is made much easier due to the proximity of adjacent units [2].

This issue is further complicated in that some of these multi-unit dwellings house vulnerable persons who are largely incapable of identifying and reporting these infestations [3]. As a result, infestations can develop unnoticed. Ultimately, this is a problem for the tenants themselves, but also the for the landlords who are responsible for maintaining their units. In such cases where these vulnerable persons develop infestations, intervention on the part of the City (particularly Toronto Public Health) is necessary to ensure an effective eradication procedure.

For a brief history of the development of the bedbug problem in the City of Toronto, the reader is referred to Appendix A (section 6.1). This material is not fully necessary for the purpose of this RFP, yet it is interesting and may help deepen the readers appreciation of the topic.

## 2 Scoping The Problem

This section includes the main definitions that were developed with respect to the problem statement. The first subsection highlights and justifies the choices made in scoping the problem to one of detection. This is followed by a brief explanation of the importance of early detection when it comes to mitigating the spread of bedbugs. Finally, definitions of the key terms 'community' and 'need' (both abstract and concrete) and how they relate to the problem are presented.

### 2.1 Region of Interest

The 2011 Vital Signs Report published by the Toronto Community Foundation highlights the issue of bed bug infestations by briefly describing some of the impacts it has had on home-owners, landlords, and tenants [4]. One can view the issue of bedbug infestations from three main paradigms: Prevention, Detection, and Eradication.

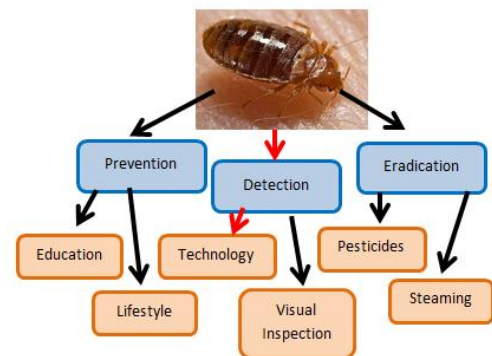


Figure 1: Tree Diagram of Bed Bug Issue

In keeping with our team priorities (see Appendix C), it was decided that the area of bedbug eradication would be too complex to propose as a challenge. Current eradication techniques rely heavily on the use of broad spectrum residual pesticides. It has been the goal of pesticide companies and researchers for the past 10-12 years to create such a pesticide that is completely safe for humans but lethal for bedbugs [2]. It would be unreasonable for a group of 1<sup>st</sup> year Engineering Science students to have to deal with this problem. Prevention was ruled out on the grounds that it did not favour the development / engineering of a material object. The areas of prevention appeared to depend largely on education and awareness of bedbugs, and although this is an extremely important area, is not as easy to frame the problem as an 'engineering design'. In addition, one of our internalities was to promote a problem whose solution could take the form of physical and functional device.

The region of detection can be further broken down into three more sections. There is the actual mechanism by which the bedbugs are detected. Active detection methods, upon successful detection of bedbugs, will immediately notify the home owner of the infestation. Common examples include visual inspection and canine detection. Passive interception methods rely on luring bedbugs into traps. These methods will not directly notify the home owner of an infestation (they are responsible for checking the traps). Common examples include CO<sub>2</sub> detectors and furniture leg traps.

It is also of importance that the scope and extent of infestation is determined as accurately as possible. Particularly for landlords who are responsible for many units, it is of importance that they know **which** units are infected. In addition, another key aspect of detection is how soon the eradication procedure is pursued. Ideally, third parties such as Pest Control Companies are notified as soon as an infestation is detected. An ideal solution to our RFP would cover all three of these bases (physical detection, information collection, and information distribution). Fittingly, the design of a solution would involve sensing packages, networks, graphical user interfaces, and signal processing. This is an unreasonable challenge to ask of 1<sup>st</sup> year Engineering students, and one that we believe would not be solved credibly. We believe that the minimal viable product<sup>1</sup> in this problem is the actual detection mechanism. Aspects such as information collection and distribution can be developed once the most basic model has been implemented, and it has been around long enough to provide enough feedback to the early adopters.

## 2.2 Early Detection

Without a doubt, early detection of bedbugs is absolutely essential in mitigating their spread [6]. A bedbug infestation is a problem that is much easier to fix in the early stages, rather than later. As infestations grow in size, so does the risk of spread and the cost of treatment [7]. In a research report prepared by the Toronto Bed Bug Steering Committee, this was eloquently referred to as the "high cost of doing nothing" [7]. Early detection techniques range from visual inspection, to canine detection, to CO<sub>2</sub> monitors, to passive interception devices. This RFP is based around improving early detection techniques. We learned more about this area in an interview with Reg Ayre. He is the manager for Toronto Public Health's 'Healthy Environments' department. We came to learn that bedbug detection is actually a "very mature field" [2]. It is a developed area, and the products currently on the market

<sup>1</sup>An MVP is the most 'pared down version of a product that can still be released' [5]. It is the simplest idea or model that still captures the essence of the problem.

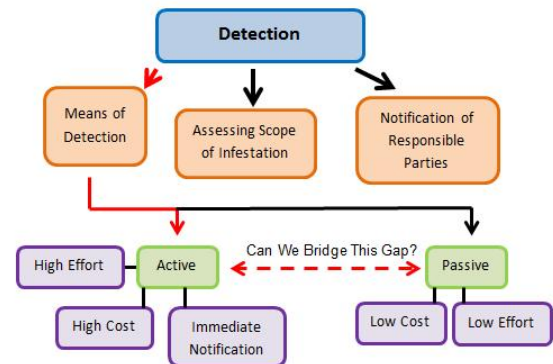


Figure 2: Tree Diagram Expanded

function effectively. The ClimbUp bedbug detector and NightWatch bedbug monitor, are taken as reference designs (See Section 4 - 'Reference Designs'). As mentioned earlier, the goal of this RFP will not be to design a new / better detection apparatus. Rather, it is about bridging the gap between active and passive systems such immediate notification of bedbugs is possible, but without the high costs and efforts generally associated with these methods.

## 2.3 Community of Interest

Our team believe that a community is: "A social unit of beings that are unified by some common identifying characteristic". The specific community dealt with in this RFP is vulnerable adults who live in multi-unit dwellings and are at risk of receiving bed bugs. 'Vulnerable adults' refer to the frail elderly, those living in crushing poverty, with mental health issues, and severe addictions [2]. Normally, residents that are susceptible to receiving bedbug infestations will take cautionary measures to avoid picking them up, and once they find bed bugs in their homes, they will pursue measures to get rid of them [2]<sup>2</sup>. This is not the case for vulnerable adults. Some will not notice an infestation until it is too late, and others will not even care. As a result of this, infestations are not reported quickly enough. This is unfortunate, considering the harm it can bring upon oneself and others. The driving issue within our chosen community is the failure of vulnerable adults to properly manage bedbug infestations.

Compounded with the aforementioned issue is the potential failure of landlords to become involved. Landlords have a legal obligation to maintain their living spaces in habitable conditions (see Appendix D for more details). In fact, they have the right to perform an emergency inspection within just 24 hours of notifying the tenant [2]. Tomislav Svoboda works both as a researcher for St. Michaels Hospital and as a physician. During an interview (See Appendix E for notes), we learned that some landlords will purposefully not attempt to eradicate bedbugs [3]. The reasons are complicated, but some may include fiscal disinterest and loss of hope for the landlords. In this case, especially when dealing with vulnerable adults, it is of utmost importance that a responsible third party (like a social worker) is also notified of the situation.

Bed bug infestations are not limited to any type of dwelling. They can occur in all manners of hotels, university residences, individual houses etc... However, once one unit of a multi-unit dwelling<sup>3</sup> is infected with bed bugs, the infestation can spread to other units much faster than detached housing. The research report "Bed Bugs Are Back: Are We Ready?" mentions that: "a bed bug infestation that is left untreated will spread at a rate of about one room every seven weeks through the walls, electrical wiring, etc... The bugs spread most quickly to units that are adjacent to, across from, and above and below the infested unit" [1]. It is much more difficult for bedbugs to travel between separate housing units because they must completely exit the house to get to the next one. The existence of walls, wood, and wiring as a medium for bedbug travel greatly increases the rate at which they can spread.

## 2.4 Needs of Our Community

Our team defined a need as: 'something, either material or psychological, that a being requires for their well-being'. Our specific community is vulnerable adults living in multi-unit dwellings who are at risk of contracting bedbugs. This community needs sanitary living conditions (a safe and clean environment in which to live). There are many factors that could make these living conditions uninhabitable, but we are only focussing on the effect that

<sup>2</sup>There exist many resources by which people can learn about how to deal with bedbugs and what actions to take. The web page of the City of Toronto alone contains a wealth of informative pamphlets, contact information, documents, and instructions on how to deal with infestations.

<sup>3</sup>Examples include apartments, social housing units, co-operative housing and so on.

bedbugs can have on them. Many of the consequences of bedbugs infestations are described in Appendix A, and it is these effects that are detrimental to one's quality of living. Living with bed bug infestations may even result in psychological trauma and violent behaviours, such as self-harm, and even suicide [1]. It is especially important that these needs are met, given the already difficult positions many of these vulnerable adults may already be in.

Currently, many bedbug detection devices are passive interception ones<sup>4</sup>. These devices capture bedbugs through whatever trapping mechanism they employ, but do not do anything once a bedbug is caught (see Section 4 - 'Reference Designs'). Our community needs systematic techniques and communication devices that will allow for earlier detection of bedbugs, but such that onus is not necessarily on the resident to report the infestation.

### 3 The Challenge

#### 3.1 The Statement

**Design the means by which a bedbug trapping device can send a distinct analog electrical signal to be processed when the presence of bedbugs is detected within the sensors vicinity.**

#### 3.2 Justification

In essence, this RFP strives to have the conceptual design firm develop a "bed bug alarm". Such a product could be installed into the housing units of a multi-unit dwelling. In theory, when a bedbug were to be captured by the trap, the device would send a message to a central location, warning the responsible party that there is a potential infestation developing. Implemented successfully, this system would take the responsibility off of the tenant for reporting the bedbugs.

We decided to focus on the sensing component of the detector for a variety of reasons. Firstly, as this RFP is intended to be solved by first year engineering student, only a small part of the overall design task can be tackled. We found the problem can be divided into three sections: physical detection, information collection, and information distribution. Secondly, the effectiveness of the detector is highly dependent on the effectiveness of the sensor, as it is the first component in the detection chain.

Engineering design is the process through which creative ideas are made real such that they can be implemented to better off society. From the book 'Engineering: An Introduction to A Creative Profession', the process "involves the formulation of problems, the development of ideas, the evaluation through the use of models and analysis, the testing of models, and the description of the design and its function in proposals and reports" [8]. We believe that this process generally starts off with a meaningful problem that in some way or another negatively affects an individual or a group of similarly situated people. Through the aforementioned steps, and most importantly, the application of scientific principles, the idea can be developed into a tangible product (although engineering designs are not limited to physical devices, they usually tend to take the form of some piece of technology).

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<sup>4</sup>An exception would be visual and canine inspection, both of which are not really physical devices)



This RFP identifies a meaningful and relevant problem. In addition, the Conceptual Design Firm is given a basis on which to further develop the problem into a solution. In keeping with our philosophy, our RFP identifies a problem that will require application of scientific principles (the method by which the presence of bedbugs are detected). This is explained further in the 'Objectives' section.

## 4 Reference Designs

This RFP solicits a design that will allow a bedbug trapping device to emit a distinct analogue signal upon detecting the presence of bedbugs in the vicinity of the sensor. It is not the responsibility of the Conceptual Design Firm to create the trapping mechanism. Nevertheless, they might find it useful to use a pre-existing trapping mechanism to work with while designing the detection device.

There are numerous techniques that exist for the trapping of bedbugs. For the purposes of this RFP, we will only mention two major trapping devices that are currently on the market<sup>5</sup>. One type is a simple trap that catches bedbugs as they try to leave or enter a piece of furniture. The other type attracts bedbugs using carbon dioxide and then traps them. Both of these are passive detectors which do not alert users the existence of bedbugs. They rely on visual inspection on the part of the user to notice the infestation. In this section, we will briefly highlight the ClimbUp bedbug detector and the NightWatch detector.

Equally important is the means by which the bedbugs are detected by the sensor. This is, of course, what the Conceptual Design Firm is tasked with doing. We imagine that potential solutions could take advantage of motion, mass, or chemical sensing devices that would in turn be set up to react to the presence of bedbugs. As a reference design for this aspect of the solution, we have included a brief explanation of the 'Electronic Dog Nose' bedbug detector.

### 4.1 ClimbUp Bedbug Detector

The ClimbUp bedbug detector is a passive bedbug detection device. It has a double trough trap structure, with walls covered in talcum powder, which can prevent bedbugs from leaving the trap. The ClimbUp bedbug detector is designed to be placed under the legs of furniture where people sleep. Bedbugs both approaching and leaving the bed will fall into the trap [6]. A package of 12 such detector would cost about \$35.00 depending on the size of the trap.

This detector requires a very low level of maintenance and its relatively low cost might make it possible to install inside each apartment of a building. In addition, CO<sub>2</sub> emitted by the human in the bed would serve as the bait.



Figure 3: ClimbUp Bedbug Detector [6]

<sup>5</sup>Other methods of bedbug detection include visual inspection, while another consists of canine inspection. These do not directly involve physical devices, so we chose to not include them while scoping the RFP

## 4.2 NightWatch Monitor

The design of NightWatch bedbug monitor is based on the fact that bedbugs are attracted to the carbon dioxide and heat produced by humans. The NightWatch bedbug monitor lures and traps bedbugs, as it simulates the heat and carbon dioxide that a human would emit. Bedbugs that are attracted will climb up through the climbing surface and fall into a trap. The device has automatic timer allowing users to set the operating time, and each lure and carbon dioxide bottle can be used for approximately 7 nights without replacement. [9]. Cost of the monitor with 4 lures are about \$450, additional lures are available (\$32.5 for a package of 4), and carbon dioxide can be purchased anywhere for about \$15 per bottle.

The device can effectively covers a room approximately 16 feet x 16 feet in size, even with a light infestation. However, this detector requires users to regularly replace the lure and carbon dioxide. The price of this detector may also be a limiting factor in the consideration of this product.

## 4.3 Electronic Dog Nose

The electronic dog nose is an electronic chemical tracker for bedbugs. It functions by a fan sucking air into the unit through the wand. The air passes through CO<sub>2</sub>, pheromone, and methane sensor [10]. The sensors require to be hydrated every couple hours, and whenever the unit is saturated by pheromones. The data from those sensors are then processed through software, and then displayed to the user. The unit is powered by 4 9V batteries [11]. The first generation units has a detection range of up to a few feet, where the second generation units have a detection range of up to 6 feet. In addition, The first generation version of this unit costs \$200, where the second generation costs \$500 [12].



Figure 4: NightWatch Detector [6]

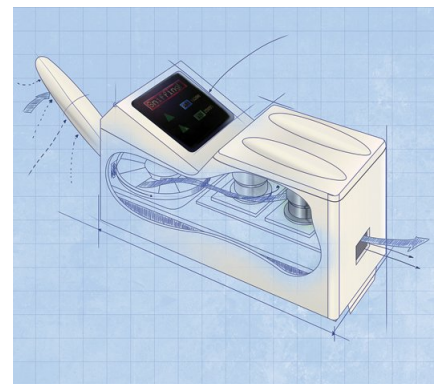


Figure 5: Electronic Dog Nose

## 5 Key Stakeholders

Before developing the constraints and criteria for this RFP, this section provides a brief summary of the stakeholders important to this problem. Appendix B shows a diagram of all the entities that were initially considered before the problem was scoped down. As a result of our research, four key entities were identified: Tenants (specifically vulnerable adults), Social Workers, Landlords, and Toronto Public Health. Two secondary stakeholders are also addressed: Pest Control Companies and Research Teams.

## Primary Stakeholders

### 5.1 Tenants - Vulnerable Adults

Act 45 from the Ontario "Substitute Decisions Act, 1992" states that a vulnerable adult may be defined as a person who is "incapable of personal care if the person is not able to understand information that is relevant to making a decision concerning his or her own health care, nutrition, shelter, clothing, hygiene or safety, or is not able to appreciate the reasonably foreseeable consequences of a decision or lack of a decision" [13].

Vulnerable adults would get direct benefits from implementing an active bedbug detection system. A responsible party (landlord and/or social worker) could be notified as early as possible, and as a consequence, the situation can be controlled sooner. They would more promptly receive the help they need to clean their apartments. Also, bedbugs can be treated before they spread over the building, affecting the daily life of all tenants (See Appendix A - Subsection 2).

In an interview with a Customer Services representative of the Landlord and Tenant Board [14], we came to learn that there are no legal implications associated with this type of support for vulnerable persons. However, concerns with user comfort and privacy might prove to be a barrier in the installation of such a device (See Appendix A - Subsection 3 on Stigma). There is no straight answer to this question, as individual reactions and preferences may vary greatly. The installation of our proposed device would be complicated by these factors, as the rights and wishes of these vulnerable adults still must be considered [15]. This is a problem that we have acknowledged but do not have adequate resources to fully address within this RFP.

### 5.2 Social Workers

Social workers are the ones who assist vulnerable people in order to give them a safe and supportive environment. The Centre for Independent Living in Toronto, a social service organization in Toronto, has the mission statement: "To promote the attainment and maintenance of optimum Independent Living of persons with disabilities in Toronto" [16]. From this perspective, social workers do have the responsibility to help vulnerable people to eradicate bedbugs after bedbugs are detected.

### 5.3 Landlords

Landlords are responsible for providing a clean living environment for their tenants, and they need to maintain it to keep their tenants in order to make profit. Bedbug infestations represent a major threat for the landlords (refer to Appendix A on Stigma). The purpose of the bedbug detection system would be to notify a responsible party (in this case it is the landlord of the multi-unit dwelling) if a potential infestation occurs in their buildings. The system would allow landlords take early measures to stop major bedbug infestations from developing. This would aid them in keeping their building as habitable as possible. In addition, the cost of bedbug treatment would be reduced, as eradication treatment could be localized to the room in which they were detected<sup>6</sup>.

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<sup>6</sup>Due to the stigma associated with bedbugs, we could not directly engage with representative landlords. Instead, we contacted Reg Ayre and Tomislav Svoboda (Interview notes Appendix E) to understand more about the situation of the landlords. For a brief explanation of the issue of stigma, please see Appendix A - Subsection 3

## 5.4 Toronto Public Health (TPL)

Toronto Public Health is currently dealing with this issue, as bedbugs have become a city wide health concern. Currently, many projects and organizations dealing with bedbugs are either under or associated with Toronto Public Health<sup>7</sup>. Inspectors from Toronto Public Health often liaise with landlords, building management and pest control professionals to ensure efficient and professional pest control is provided. Also, in severe infestations, particularly, in cases where vulnerable people are involved, Public Health Inspectors consult and make external agencies to help [17]. In September 2011, City Council approved the 2012 operating budget for all bedbug related initiatives at just over \$1,000,000 [18]. This money would go into the multiple initiatives that the City does to assist vulnerable adults to purchase services for bed bug pesticide treatment. The City has an interest in the well-being of Toronto residents, hence their motivation in promoting intervention.

## Secondary Stakeholders

### 5.5 Pest Control Companies

Pest control companies are often directly responsible for eradicating bedbug infestations. In an interview with Carlos Panacci, owner of Cain's Pest Control, we learned that pest control companies are usually called after a severe infestation as bedbugs cannot be easily detected in the early stage. With a bedbug detection system, pest control companies can be called and apply treatment as soon as a light infestation happens, which would make the treatment process require less time, effort, and chemicals. If the system were to become marketable, our group thinks that pest control companies can be the ones in charge of installing it in multi-unit dwellings.

### 5.6 Research Teams

Research teams study the habits of bedbugs, the effects of infestations, and methods of eradication. Tomislav Svoboda, of St. Michaels Hospital, represents such a research team. He mentioned that their knowledge about bedbugs may help in designing such a detection device (chemical traces and living habits). Tomislav mentioned that the majority of researchers these days are working on eradication techniques (designing a broad spectrum residual pesticide that is lethal to bedbugs but harmless to humans). As the purpose of this RFP largely focusses on bedbug **detection**, the direct role of this party is not entirely relevant. Nevertheless, they play a key role in issue of bedbugs as a whole.

## 6 Objectives

This section is devoted to developing the objectives that shall accompany the development of the proposed bedbug detection device. Associated metrics, constraints and criteria are included where relevant. While developing the criteria for the design solution, fiscal and environmental sustainability were taken into account. The cost of installing the system will ultimately be a limiting factor. In addition, the device should be designed in a way that reduces the use of toxic chemicals.

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<sup>7</sup>One example would be 'Bug and Scrub'. It is a social purpose enterprise that was created within the City of Toronto's Shelter, Support and Housing Administration. It is funded by the City, and it provides assistance in the preparation of tenant households for bedbug treatment [7]. Due to scope limitations, we have not pursued investigation of this particular party.

Before proceeding to the body of this section, it is necessary to emphasize two main points:

**I. You are expected to develop the method by which the presence of bedbugs in an apartment unit can be translated into an analogue electrical signal. This includes determining what patterns the signal processor should look for to determine the presence of bedbugs (i.e. movement, the rising and falling of chemical concentrations).**

**II. You are not expected to design how the electrical signal will be processed to give a binary answer to the presence of bedbugs.**

For example, if you were designing the Electronic Dog Nose, you would be expected to select what chemical sensors will be used, what they would be detecting (rising levels of pheromones in this case), and how the chemicals from bedbugs in an apartment can get to those sensor. You would not design the software and hardware which will translate the signals from those three sensors into a reading to the user, nor the user interface.

It is not **required** that you use a pre-existing trapping device, but it is recommended that you do so (see Section 4 - 'Reference Designs'). If the Conceptual Design Firm chooses to use a bedbug trapping device, it is highly recommended that they use one that is already on the market. The products currently on the market function well, and through our research, we have come to realize that the field of bedbug lures and traps is quite developed [2].

## 6.1 Functional Requirements

- Detection Threshold
  - Objective: To detect the existence of bed bugs in an apartment unit as early as possible.
  - Metric: least population density of the bed bugs that would cause a 50% chance of distinct signal from the sensor.
    - \* Population density defined by the population of bed bugs in the unit divided by the the floor area of the unit (e.g. Bugs per square metre).
    - \* Population defined by the trapping methods in understanding and controlling the German cockroach [19]
    - \* A distinct signal is any signal with a signal to noise ratio of more than 1.
  - Criteria: Should be as low as possible.
  - Justification:

This criterion is the measure of the effectiveness of design. The overall purpose of the bed bug sensor is to mitigate the cost of eradication through early detection. The system should detect the bed bugs when their population is as low as possible. Certain Pest Control Companies charge depending on the scale of the eradication. For example, Home Hardware Pest Control charges between \$350 and \$500 depending on the severity of the infestation [20]. In addition, severe infestations have a much higher rate of return (treatment is less effective). This would in turn incur more costs on the homeowner.

- Time between maintenance
  - Objective: For the system to function the longest period of time without human intervention.
  - Metric: The period between maintenance<sup>8</sup>. Measured in weeks.
  - Criteria: Should be as long as possible.
  - Constraint: Must at least 1 month.
  - Justification:

One of the primary limitations of existing detection system is that they require constant attention to ensure their operation. This would be extremely tedious in a large multi-unit dwelling (15 floor, 11 units per floor), especially if the landlord or superintendent is responsible for the task. We choose monthly inspection cycles are appropriate since smoke alarms, an active alarm in all structures, is inspected monthly.

- Sensor accuracy
  - Objective: Minimize the false alarms generated by the system
  - Metric: The number of false detection events per month in an apartment unit with no bedbugs
  - Criteria: Should be as low as possible.
  - Justification:

To ensure that people will trust the results of the sensor, it need to be accurate. Especially since if a false alarm causes an eradication, that could cost a responsible party a least \$350. [20]

- Power usage
  - Objective: Minimize the electrical power used by the system
  - Metric: The kWh used by the sensor and assisting components (i.e. traps/lures) in an apartment per year.
  - Criteria: Should be as low as possible.
  - Justification:

A critical factor in ecological and economical sustainability is energy usage. The design should use as little energy as possible so to reduce the green house gas emission and cost of energy for the operator.

## 6.2 Non-Functional Requirements

- Cost of manufacture
  - Objective: To have the lowest cost of manufacture of the sensor and assisting components (i.e. traps/lures).
  - Metric: the cost of manufacturing the sensor, plus the cost of either manufacturing assisting components, or purchasing them, in CAD.
  - Criteria: Should be as low as possible.
  - Constraint: Must not be above \$1150

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<sup>8</sup>definition: any human intervention in the physical operation of the lure/trap and sensor

- Justification:

During an interview with Cain pest control[21], the owner said that landlords are hesitant to deal with the issue of bed bugs partially because of the costs of eradication. Given the landlord's focus on cost, the system should cost as little as possible to ensure adoption in multi-unit dwellings. The cost constraint is based on the total cost of purchasing the second generation Electronic Dog Nose and the NightWatch bedbug monitor.

- Regulatory Compliance

- Objective: the system must comply with industry standards.
- Constraints: The sensor and assisting components must comply with the following industry standards:
  - \* FCC part 15 subpart B [22]
  - \* Industry Canada standards ICES-003 [23]
- Justification:

These standards are applied to all electronic systems sold in North America.

- Should not cause adverse health effects

- Objective: Reduce the health and environmental impact of operating such a system.
- Constraint: Any chemicals and materials used in the construction and operation of the sensor and assisting components must not cause ill effect defined by the follow criteria from their Material Safety Data Sheet (MSDS).[24]
  - \* Acute
    - Inhalation
    - Skin Contact
    - Eye Contact
  - \* Chronic
    - Skin Sensitization
    - Heart/Blood Vessels
    - Carcinogenicity:
    - Teratogenicity and Embryo toxicity
    - Reproductive Toxicity
    - Mutagenicity
    - Toxicologically Synergistic Materials
    - Potential for Accumulation
- Justification:

This is to insure the short term and long term safety of the residence in the building where the system is installed. This will also insure the system to be ecologically sustainable as it will insure no toxic compounds are used in the system.

## 7 Appendix A - Introductory Material

### 7.1 A Brief History

Humans have lived with bedbugs since prehistoric times [1]. In fact, the common household bedbug, *Climex Lectularius*, is believed to have evolved from a bat parasite to a human one when we our ancestors were still living in caves [2]. Bedbug infestations were virtually phased out in the mid-20th century, due to the development of very powerful broad spectrum residual pesticides [2]. By 1970, the dangers of these eradication techniques became apparent to most countries around the world, and many of these pesticides were banned from use [2]. Although the world experienced a brief period of respite during the late 1900's, bedbugs have begun to make a resurgence. The exact reasons for this resurgence are not quite known, but many believe that it is due to a combination of: increased resistance to chemical agents, higher living densities, and more international travel [25].

### 7.2 Consequences of Infestation

The question concerning whether or not bedbugs are actually a public health issue is a somewhat contested topic. A 2003 report published by the Centre for Urban and Community Studies (CUCS) mention that bed bugs fulfil all the conditions of efficient carriers of disease [disease vectors], yet this claim was made with reference to a 1979 publication by Harwood and James (its validity is questionable due to its date). A more recent study done in the year 2000 indicated that bedbugs may play a minor role in the transmission of hepatitis B, but not HIV [25]. In an interview<sup>9</sup> with Reg Ayre<sup>10</sup>, he posits that bedbugs do not count as a legitimate health hazard<sup>11</sup>. Ayre stated that bedbugs are not actually known to spread contagious diseases, and that most people do not experience adverse reactions. In fact, the CUCS study mentioned that only approximately 70% of the general public will even notice a bedbug bite [25]. Nevertheless, bedbug bites can cause reddish rashes that last up to 24 hours that can also become infected if scratched too much [2].

On top of this, there are the psychological consequences of having an infestation. First of all, their nocturnal blood-sucking habits can induce "anxiety, worry, stress, and sleeplessness" for those infected [25]. Marsha Lederman, of the Globe and Mail, described her experience dealing with an infestation as "feel[ing] powerless, [and] preyed upon by an unseen terror" [26]. Not to mention, dealing with the issue takes time and costs money. In some cases, there can even be property loss (infested furniture, clothing etc...). The stigma associated with bedbugs is immense. The infected sometimes do not report their infestations to their landlord for fear of eviction and blame [7]. Landlords fear bedbugs because they tarnish their reputation. People feel alienated and stop inviting friends and family to their homes. People become reclusive for fear of being ridiculed. Sometimes ones preoccupation with bedbugs can be so immense that it results in psychological trauma [7]. Ultimately, bedbugs are a factor that can significantly detract from the quality of life of the person infested with them.

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<sup>9</sup>Typed notes of the interview can be found in Appendix E

<sup>10</sup>Manager of Healthy Environments - Toronto Public Health

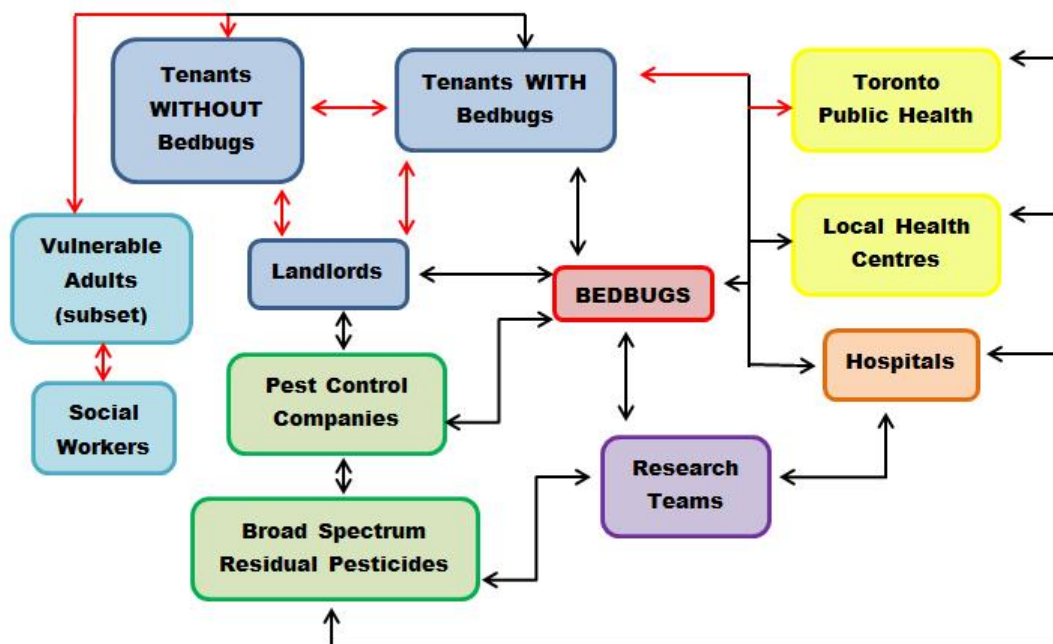
<sup>11</sup>A health hazard is something that "has or is likely to have an adverse effect on the health of ANY person" [2]



### 7.3 Consequences of Stigma

The issue of stigma greatly complicates dealing with the bedbugs. A landlord found through the 'Bed Bug Registry'<sup>12</sup> [27] reacted very negatively when the term 'bedbug' was first used in conversation. He immediately stopped the conversation, interjecting that: "That is the most evil word, and we have never had a single problem with bedbugs here. Our place is clean, and you should call New York and ask them instead". Reg Ayre later confirmed in interview that people dealing with bedbugs tend to be extremely hesitant to speak with members of the public. As unfortunate as it is, the term 'bedbug' carries with it pejorative connotations and images of filth, grime, and unsanitary living conditions. This made it difficult to engage with the community directly, but there existed other sources through which evidence could be gathered. We engaged indirectly with the community through representatives such as Reg Ayre (who works for Toronto Public Health - Healthy Environments) and researchers who regularly deal with bedbugs, such as Tomislav Svoboda. We had attempted to contact a representative from the Toronto Housing Community and the Margaret Frazer Community, but they were unable to correspond in time.

## 8 Appendix B - Mindmap



This mind map was the result of a preliminary brainstorming session. Although it is not made explicit in the image, each double headed arrow represents the relationship that one entity has with the other. For example, 'Research Teams' and 'Broad Spectrum Residual Pesticides' are linked because this is one area of focus of scientists these days (developing such a chemical that is harmless to humans but lethal to bedbugs). The arrows highlighted in red represent our niche as we have defined it in the RFP. Namely, that this RFP focuses on mitigating the spread of bedbugs within multi-unit dwellings for vulnerable adults (who are a subset of tenants).

<sup>12</sup>The registry is a free public database where users across North America can submit reports of bedbug sightings

## 9 Appendix C - Priorities

**FOCI:**

- Choosing an achievable and attainable objective given our circumstances, yet...
- Identify a legitimate 'need' within a community, rather than a 'want'
- Gather a wide range of resources to attain as much objectivity as possible
- Scoping and framing a problem that is unique but still relevant

**INTERNALITIES:**

- Framing the problem as one which involves the engineering of a physical device (we think that a tangible grasp on the problem might make it a little more fun for the conceptual design firm)
- Focus on document layout and professionalism in presentation.
- Obtaining a direct link with the community (why this is not a 'foci' is explained in the section on Stigma (insert number here...))

**EXTERNALITIES:**

- We chose not to deal with the areas of prevention and detection as it relates to the spread of bed bugs, therefore, the associated tools and techniques of these areas were not considered in this RFP

## 10 Appendix D - Landlords

The following excerpt is taken from Residential Tenancies Act, 2006, section on regulation and maintenance standards. It comes from the 'e-laws' site of the Ontario Provincial Government [28]

ONTARIO REGULATION 517/06 MAINTENANCE STANDARDS:

(1) "All interior common areas and exterior common areas shall be kept clean and free of hazards. O. Reg. 517/06, s. 44 (1)."

(2) According to Act 20 (1) from the "Residential Tenancies Act Part III," "the landlord is responsible for providing and maintaining a residential complex, including the rental units in it, in a good state of repair and fit for habitation and for complying with health, safety, housing and maintenance standards. 2006, c. 17, s. 20 (1)."



## 11 Appendix E - Interview Notes

**Reg Ayre**

**Manager Healthy Environments**

**Toronto Public Health**

**February 8<sup>th</sup> 2012 [2]**

This source represents an interview that we held with Reg Ayre on the 8th of February, 2012. Reg works for the Toronto Public Health as Manager of Healthy Environments. His main area of work is in mitigating the spread of bedbugs in Toronto through an Integrated Pest Management system. Reg's advice aided us in pivoting our topic successfully. He helped us scope our community down to one that was legitimate (initially, we did not consider having vulnerable adults as our community). Also, he helped us understand the nature of the bedbug problem in a way that no research paper could have. We do acknowledge that his bias (in his strong belief that the bedbug problem will be solved by awareness and education). At the same time, we must recognize that he is a professional in his field. He knows a lot more than we ever will about bedbugs. Overall, Reg was a very reliable source, who was also happy to have us call back more than once.

**1) A 2009 report published by the Toronto Bed Bug Steering Committee noted that "since the turn of the century, bed bug reports have been increasing significantly". Can you elaborate on some of the reasons for resurgence?**

Bedbugs have been around since cave-man days. In fact, they used to parasitize bats, until they gradually changed to human hosts. It has been this way ever since. In fact, the presence of bedbugs is common in underdeveloped countries. After WWI broad spectrum pesticides (like DDT) were used for eradication purposes, but they were found to be toxic to humans, and thus were phased out. There has been a resurgence in the past 10-12 years, most likely due to increased international travel, less effective pesticides, and higher living densities.

**2) You mentioned that we had a 'brief period of respite from bedbugs around the late 70's'. Did this help us learn more about their habits?**

No, actually it did quite the opposite. In the 1800's, 30% of homes were infested. Bedbugs were a common part of the flora and fauna. Bed bugs were only beaten out because of the harsh and toxic chemicals that were used. 2 or 3 generations of people have completely forgotten what it was like to live with them, and as a result of this, we must redevelop strategies, provide education, and get rid of the stigma associated with bedbugs.

**3) We have provisionally identified 'residents who live in multi-unit dwellings and are at risk of receiving bedbugs' as a community in need. Can you elaborate on the types of people for whom bedbugs are a significant problem?**

You must understand that when we talk about people for whom bedbugs is a significant issue, we are not referring to the 'average Jane or Joe', like you or me. Take a look at the City of Toronto's web-page, and you will see that there exist a wealth of resources for how to deal with bedbugs. If you were to get infested, then you would be able to actively pursue ways to clean your house! It's different when we talk about a community of vulnerable adults. When I say vulnerable adults, I mean those who live in crushing poverty, the frail elderly, those with mental health issues, and those with addictions. Often, it is these types of people that will 'slip through the cracks', pick up an infestation, and bring it back to their units.

Sometimes, these people will not even notice or care that they have an infestation. It is the landlord's responsibility to inspect their units at least once a year, but in many cases this is not done. It is also the tenant's inalienable right to refuse an inspection from Public Health, so in many cases these infestations go unidentified until they have snowballed into a very significant problem.

**4) So if I had an infestation, I would be expected to pursue the process of eradication. How is it done then for these vulnerable adults who can, in some cases, barely take care of themselves?**

This is the difficult part about dealing with bedbugs. How can you access these communities from the outside and deal with their problems? The process is very complicated! It doesn't just involve calling a pest control company and having them just spray the house. Let's look at the social housing sector of Toronto. Jane and Finch has about 30 such buildings. First, we must assess the level of infestation and identify all of the units (which involves individual inspections). There is a whole design protocol with dealing with these situations. The unit must be prepared for spraying, then a company must be chosen. The units must be checked after spraying for resurgence.

All the while, we are trying to educate the maintenance staff in identification techniques (flyers, town hall sessions). We call this Integrated Pest Management (IPM), a process that focusses not only on pure eradication, but methods of prevention, education, awareness etc..

**5) If we wanted to get in touch with people who might represent in some way these vulnerable adults, who (or what organization) would you recommend we pursue contact with? Are there any providers of social housing units that come to mind?**

Actually, one of the largest providers of social housing units in Toronto (and across North America for that matter) is the Toronto Community Housing Corporation (TCHC for short). You'd probably have the best chance at talking with them, but understand that it may be difficult to talk with them. They are generally hesitant to speak with members of the public because of the nature of the issue. I can give you the contact information of someone who works there, and you can follow up with him. His name is Albert Koke. Try sending him an email and explaining your situation.

**Tomislav Svoboda**  
**Researcher and Physician**  
**St. Michael's Hospital**  
**February 15<sup>th</sup> 2012 [3]**

This source represents an interview that we held with Tomislav Svoboda on the 15th of February, 2012. Tomislav Svoboda works as a researcher for St. Michael's Hospital and also as a physician. His particular area of research is bedbugs in the homeless community. Tomislav could not completely identify with the goal of our RFP because his work is mainly in research. He did, however, acknowledge the potential merit that such a detection system could have based on his personal experience as a physician (he regularly deals with patients that have bedbug problems). Tomislav's knowledge in the field of bedbug spread aided us in understanding the risk that bedbugs pose in multi-unit dwellings. He also helped us gain insight into the role of social workers as it relates to bedbugs in particular.

**1) We understand that early detection is key in mitigating the spread of bedbugs. When it comes to populations of vulnerable adults, sometimes infestations can go unnoticed. Do you think that unreported infestations is a problem for landlords?**

In some ways yes, but in others no. There are landlords, that despite knowing that there is an infestation in their building, will purposefully not pursue action. Even with positive identification of bedbugs, one requires a 'progressive landlord' that will be willing to pursue a plan of action. The story is different with certain helpful organizations, whose sole purpose may be to ensure that their tenants are living well. In this case, I think ensuring a means by which bedbugs are detected as soon as possible would be very meaningful.

**2) And why would a landlord, cognizant that he had an infestation, not pursue eradication techniques?**

There are many reasons. Fiscal disinterest, he may feel it is a lost cause, or that spraying may not be helpful. Landlords can sink a lot of money into treating bedbugs, and sometimes the treatment is not effective. I can tell you for sure that I have had at least 3 clients come to me in the past year and tell me that they have bedbugs, and that there landlord firmly stated that they did not want to pursue action. It's unfortunate, but that can be the case sometimes.

**3) So if this hypothetical 'bedbug alarm' were to exist, who would you recommend it notify in the event of a potential infestation (asides from the landlord)?**

Many vulnerable people have what we call case-workers. These are social workers that will typically work with the individuals you speak of, providing them assistance and guidance as necessary. I would recommend that your product also notify these people. They truly have the well-being of the tenants at heart.

**Carlos Panacci**

**Cain's Pest Control**

**February 9<sup>th</sup> 2012 [21]**

**1) When performing a treatment, do you tailor it to the severity of the infestation? If so, do your prices change in these instances?**

We charge \$375.00 flat for a one time treatment with a 1 year warranty.<sup>13</sup> Our philosophy is to hit the bedbugs with the maximum legal dose of chemicals from day 1. You really can't afford to play around with these things...

**2) From start to finish (i.e. from when you receive a call to when you are done with the client), how long does the eradication process take, and what steps are involved?**

It usually takes about 30 days between the call and us being completely finished. After the call, we inform the client that they must prepare the room, and we explain to them how it must be done. All we do is come in with the pesticides and spray. They have to leave for about 4 hours while we do this, but then they can go back into the apartment. We have to stick around and return to the site after a week or two to make sure that the residuals from the pesticide have effectively killed the eggs (the eggs must hatch first).

**3) When a call comes from a multi-unit dwelling, is it more likely to come from a tenant or the landlord?**

Generally it is the landlord that contacts us, and they are usually really pissed off and hesitant to pay for the treatment. It really depends on the situation. The 'Landlord Tenant Act' does require the landlord to provide a safe and clean environment, but the onus can be on the tenant if they are the one to bring in the infestation. Sometimes they can face eviction if this is the case.

<sup>13</sup>Home Hardware Pest Control said that they actually charge \$350 - \$500 depending on the severity of the infestation. It really depends on who you are talking to and their philosophy

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