# The Potential for Insect-Driven Sanitation in Haiti

***Abstract:***

Poverty and unsafe sanitation are inextricably linked. Poor sanitation results in the spread of disease, increasing the likelihood of malnutrition and wage or education losses due to an inability to attend work or school. Likewise, the world's poor are overwhelmingly the ones burdened by inadequate sanitation resources, and thus the cycle of poverty continues. This paradigm can be shifted by implementation of sanitation systems that generate income while sustainably treating human wastes. One such system utilizes larvae of the common fly *Hermetia illucens*, or Black Soldier Flies, to reduce waste material volumes, pathogens, and generate a valuable product in the form of the protein-rich larvae. The larvae can be utilized in animal feeds and thus have economic value in addition to their value as a sanitation solution. The goal of this research is to launch a new collaboration with an existing sanitation-focused nonprofit in Haiti to investigate the resources available for implementation of a pilot-scale Black Soldier Fly Larvae (BSFL) treatment system. The availability of low-value growth substrate amendments will be investigated and a suite of growth substrate mixtures will be developed. Growth of larvae on the mixtures will then be assessed to optimize human waste degradation and protein generation. A cost-benefit analysis will also be conducted to summarize recommendations for future operation of a BSFL-driven treatment system in Haiti. The overall goal of this project is to improve sanitation resources using alternative, low-energy treatment methods that generate economically valuable products from waste.

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## 1. Introduction and Background

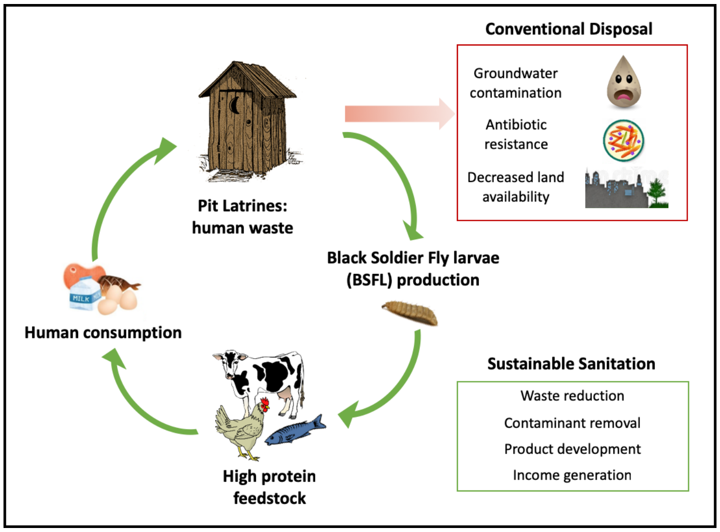


***Figure 1.*** *Commercial production of animal feed from insects grown on human waste can improve sanitation, generate income, and increase food security.*

Almost a quarter of the global population uses pit latrines for sewage disposal [1]. Most pit latrines are unlined, allowing pathogens and other chemical contaminants in fecal matter to enter groundwater and negatively impact human health. Furthermore, when pit latrines become full, space constraints often make digging a new pit impossible. In such cases, the waste is emptied above ground, further exposing people and resources to contaminants. As pit latrines are overwhelmingly used in impoverished areas, the health consequences of exposure to fecal contaminants also place a dis-proportionate burden on the poor [2]. Sanitation systems that sustainably treat fecal sludge while also generating valuable end products represent a new paradigm to simultaneously address health challenges associated with sanitation and poverty. One such sanitation solution showing promise harnesses the power of insects to degrade organic matter (Figure 1) [1, 3]. In this system, the larvae of *Hermetia illucens*, commonly known as Black Soldier Fly Larvae (BSFL), are grown on fecal sludge. The treated waste and larvae themselves also offer potential revenue streams, as the larvae are high in protein and fat, and can be sold as soil amendments, animal feed, or biofuels [4, 5].

BSFL are a particularly good candidate for human waste treatment and commercial production of animal feed because, compared to crickets and mealworms, BSFL consume a wide variety of organic material with high conversion efficiencies, and their nutrient contents remain relatively stable across different diets [6]. BSFL also practice "self-harvesting" by leaving growth substrates prior to pupation, thus eliminating the labor-intensive step of insect harvesting [6]. The flies do not feed past the larval stage and therefore do not act as disease vectors [6]. Companies are beginning to commercially produce animal feed from insects grown on food waste [7-11], but there remains untapped potential to extract value from sanitation systems by commercially producing feed from insects grown on human waste. Recent studies by Dr. Bischel's lab and others document successful growth of BSFL on human waste, during which both pathogen concentrations and waste volumes were reduced [3, 6, 12-14].

The objective of this study is to evaluate the potential for insect-based sanitation to provide value in low-resource communities. Research will be conducted in collaboration with Sustainable Organic Integrated Livelihoods (SOIL), a nonprofit that provides container-based sanitation to over 6,500 households in Haiti [15]. SOIL currently composts collected wastes and sells them as fertilizer, and is interested in expanding its practice to include BSFL-driven waste reduction. Haiti has been battling a nine-year cholera outbreak, and thus expanding methods of safe waste treatment in the area is a valuable tool in the fight against this disease [16]. Studies also suggest that BSFL-driven human waste reduction may be a faster method of fecal waste treatment and result in greater pathogen removal than traditional composting [6, 13, 17]. Adding this treatment technique to SOIL's arsenal may enhance its sanitation capacity.

## 2. Project Goals and Outcomes

This project seeks to collaborate with a sanitation nonprofit to evaluate the potential for insect-driven sanitation in Haiti. Despite the considerable potential of insects for waste treatment and product development, the environmental conditions necessary to optimize BSFL growth and waste reduction are still largely unknown. This study will investigate local materials available and necessary for insect rearing as well as bioprocess engineering steps that can optimize BSFL-driven waste reduction. The specific project goals and expected outcomes associated with each are shown in Table 1. Follow-up work is described in **Section 5**.

| Project Goals | Project Outcomes |
|---|---|
| 1. Evaluate local demand for insect-based animal feeds. | Evaluate if, in addition to providing waste treatment, larvae produced from a BSFL treatment system will be of value to the local community. |
| 2. Characterize BSFL treatment system inputs and availability. | Determine physiochemical characteristics of key substrates to establish an optimal substrate mixture based on carbon, nitrogen, and moisture contents of the inputs. |
| 3. Identify materials available onsite for building a pilot-scale BSFL treatment system. | Provide recommendations for the design of a pilot-scale BSFL system. |
| 4. Identify growth substrate amendments that result in optimal BSFL growth rates. | Determine reproducible, optimal substrate mixtures for BSFL growth. |
| 5. Perform a cost-benefit analysis on inputs and outputs to a BSFL-driven treatment system. | Summarize costs and benefits associated with varying operating parameters of a BSFL-driven treatment system in comparison to SOIL's current composting practices. |

*Table 1. Project goals and expected outcomes.*

## 3. Methodology

The following project goals, with associated project tasks, are set for the proposed field work. A timeline for task completion is shown in Table 2.

***Project Goal 1:*** *Evaluate local demand for insect-based animal feeds.*

*Task 1.1*. Conduct literature research and contact existing insect-production companies to characterize potential buyers of insect-based products.

*Task 1.2*. Interview employees and customers of SOIL and visit local markets to assess the value of insect-based feedstocks in the local area.

***Project Goal 2:*** *Characterize BSFL treatment system inputs and availability.*

*Task 2.1*. Identify low-value organic amendments (e.g. peanut hulls, sugar cane bagasse, biochar, etc.) that may be added to raw wastes to increase carbon availability and thus improve BSFL waste reduction.

*Task 2.2*. Evaluate substrate mixtures that may be used in combination with human waste for insect production in Haiti.

Samples will be collected before and after non-BSFL composting to measure moisture content and carbon to nitrogen ratios. Published research will be consulted to identify ideal ranges for these parameters in BSFL treatment. Methods of adjusting raw human wastes to better meet ideal growth conditions for BSFL will then be identified, such as drying the wastes to decrease moisture content, pre-composting for a reduced period to lower nitrogen concentrations, or amending with organic materials to increase carbon concentrations.

***Project Goal 3:*** *Identify materials available onsite for building a pilot-scale BSFL treatment system and order necessary materials.*

*Task 3.1*. Use the BSFL Biowaste Processing manual published by Eawag [18] to identify materials available onsite for setup of a pilot scale BSFL system.

*Task 3.2*. Utilize findings from *Tasks 1.1* and *2.1* to provide additional recommendations for the development of a pilot-scale BSFL treatment system appropriate for use by SOIL.

Eawag's BSFL Biowaste Processing manual is a comprehensive guide to growing BSFL on human waste in low-resource areas [18]. This, and collaboration with partners at SOIL, will allow design and set up of a BSFL waste treatment system that is tailored to the capacity of SOIL's facilities.

***Project Goal 4:*** *Identify growth substrate amendments that result in optimal BSFL growth rates.*

*Task 4.1*. In Dr. Bischel's lab at UC Davis, BSFL will be grown on biosolids from the campus wastewater treatment plant amended with varying mixtures of different organic materials. BSFL growth rates, waste reduction volumes, and sustainability of different growth mixtures will be assessed.

This task will be performed in Dr. Bischel's lab to ensure safety and repeatability of waste reduction experiments. Biosolids from the campus treatment plant will be used as a proxy for raw human wastes, and will be amended with organic materials identified in *Task 2.1* or with materials that could reasonably act as proxies for Haitian organic wastes—for example, almond hulls are likely similar in characteristics to peanut shells, and thus could be used as a proxy in this test. High lignocellulosic materials, such as corn stover or hay, could be used as proxies for sugarcane bagasse. Performance of this step will allow us to recommend ideal substrate mixtures for BSFL growth and waste reduction to partners at SOIL.

***Project Goal 5:*** *Perform a cost-benefit analysis on inputs and outputs to a BSFL-driven treatment system.*

*Task 5*. This task is detailed in **Section 4, Evaluation Plan**, because it pertains to project data evaluation.

## 4. Evaluation Plan

Throughout *Tasks 1-4*, the costs and benefits associated with operation and maintenance of a

BSFL-driven treatment system will be considered. This means that, in *Task 2*, labor, time, and monetary investments required to obtain low-value substrate amendments will be considered and recorded. Costs of any required pre-processing to these amendments, such as drying or shredding, will also be determined.

In *Task 3*, supply costs and labor related to operating a BSFL-treatment system will be considered. Costs related to replacing disposable materials and energy use will also be determined and recorded. In *Task 4*, costs associated with obtaining and preparing each substrate amendment mixture and the benefits in terms of increased BSFL production and waste reduction will be determined. Lastly, information gathered in *Task 1* will be utilized to estimate the monetary value of BSFL production as based on local demand for insect-based feedstocks.

This data will then be synthesized into a cost-benefit summary table that ranks each system input and output in order to determine the most cost-effective method of system operation for SOIL's use in Haiti. A summary of this form will allow workers at SOIL to quickly estimate costs associated with process adjustments, enhancing the sustainability of this project and adding to the body of knowledge associated with BSFL-driven waste treatment in Haiti and beyond. This data will also inform future experiments conducted at UC Davis, as described in **Section 5**.

## 5. Project Scalability, Sustainability, and Future Work

Funding for this project would allow formation of a partnership between UC Davis and SOIL, enabling future research opportunities on optimization of BSFL-driven waste treatment. We intend to use this partnership to drive scale-up and improvement of the pilot scale BSFL treatment system, as well as ensure the system is sustainable by continuing research on improvements to both the waste reduction process and the final larvae product.

Specifically, we hope to use data and samples collected during the initial visit to SOIL to seed an investigation of pharmaceutical impacts on BSFL waste reduction and treatment. Preliminary data and limited studies have indicated that BSFL can uptake and accumulate pharmaceutical compounds in their tissues; however, it is still unknown if 1) these pharmaceuticals can be transferred to animals consuming BSFL feeds, 2) pharmaceuticals negatively impact BSFL growth and waste reduction efficacy, or 3) BSFL may degrade pharmaceuticals to less harmful metabolites. Therefore, the goal of future work is to investigate these three unknowns in order to better understand the ultimate value of BSFL as a treatment option.

Samples of human waste will be obtained from SOIL and analyzed for pharmaceutical compounds. Commonly occurring pharmaceuticals will be spiked into substrates and used in waste reduction experiments similar to those described in *Task 4.1*. Impacts of these pharmaceuticals on BSFL growth and waste reduction will be assessed, and larval protein and fat will be extracted and analyzed for pharmaceuticals via high performance liquid chromatography-mass spectrometry. Growth substrates will also be analyzed for pharmaceuticals and pharmaceutical metabolites in order to assess degradation of these compounds. We hope to use findings from this study to recommend operating conditions for BSFL-driven treatment at SOIL that will minimize pharmaceutical accumulation in BSFL tissues and maximize degradation of pharmaceuticals to less-harmful products.

## II. 6. Timeline

| | **Week 1** (June 17 - 24) | **Week 2** (June 24 - July 1) | **Week 3** (July 1 - 8) | **Week 4** (July 8 - 15) | **Week 5** (July 15 - 22) | **Week 6** (July 22 - 29) | **Week 7** (July 29 - August 5) | **Week 8** (August 5 - 12) |
|---|---|---|---|---|---|---|---|---|
| Task 1.1 | | | | | | | | |
| Task 1.2 | | | | | | | | |
| Task 2.1 | | | | | | | | |
| Task 2.2 | | | | | | | | |
| Task 3.1 | | | | | | | | |
| Task 3.2 | | | | | | | | |
| Task 4.1 | | | | | | | | |
| Task 5. Evaluation | | | | | | | | |

*Table 2. Project timeline. Tasks are detailed in Section 3 and Evaluation in Section 4. Note that Task 4.1 will occur off-site at UC Davis and therefore is not included in budget calculations.*

## 7. Budget

| **Item** | **Cost** | **Amount requested from PASS** | **Justification** |
|---|---|---|---|
| Roundtrip airfare | $900 | $900 | Travel to Cap-Haitien for one researcher from June 17 - July 12 (source: Google Flights) |
| Room, Board, Food, and Transportation | $75 x 25 days = $1875 | $1875 | Based on a per diem rate of $75/day (less than the maximum federal per diem rate, provided by the US Department of State [19]) |
| Prototyping materials | $1225 | $1225 | This includes nitrile gloves, mesh netting for BSFL containment, containers for BSFL growth on waste, and construction of BSFL nursery equipment. |
| **TOTAL** | | $4000 | |

*Table 3. Estimated project budget.*

## III. Supplemental Information

### 8. IRB Statement

Human subjects research will not be conducted and therefore IRB does not apply to this project.

### 9. References


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