Original Article

Evaluation of Housefly Infestation Management at Waste Processing and Disposal Centers

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Abstract

Background: More than half of the global population resides in urban areas. Urban waste, landfills and leachate provide abundant food and habitat for houseflies. Various control methods are employed for pest management. This study aimed to evaluate the effectiveness of an integrated pest management approach for controlling houseflies at a large-scale waste-processing and disposal facility.

Methods: This study was conducted from May to October 2022 at Iran's largest waste processing and disposal facility. Sticky traps were used to monitor infestation levels before and after each intervention. Chemical interventions included a cypermethrin-chlorpyrifos combination in processing halls; a cypermethrin-chlorpyrifos-diflubenzuron mixture in the compost area; and Ajita poison bait in office buildings. Physical controls included installing nets and air curtains, using large adhesive banners, and environmental sanitation measures like washing halls and managing compost.

Results: The dominant fly species was *Musca domestica*. For monitoring, sticky traps were the most efficient (49% of captured flies), while pheromone traps were the least efficient (4%). The highest infestation intensity occurred before interventions in April-May, averaging 191 flies per 10 traps. The lowest intensity was observed in September-October, with an average of 6 flies per 10 traps. Significant reductions were observed in fly numbers when comparing the peak infestation period (April-May) with subsequent months, indicating the effectiveness of the interventions.

Conclusion: An integrated pest management approach can significantly reduce the severity of housefly infestations in municipal waste facilities. This strategy is crucial for preventing the development of insecticide resistance and minimizing negative environmental impacts.

Keywords: Housefly; Physical control; Chemical methods; Integrated pest management (IPM); Disposal centers

Introduction

Increased urbanization and the expansion of cities have led to an increase in waste production that is estimated to be double the rate of urbanization itself. More than half of the world's people live in cities and this rate is increasing and expected to increase by 1.5-fold by 2045 (1). Waste generated from urban areas has very deadly and harmful effects on urban ecology, plants, animals and people's health. Urban wastes can serve as a food and reproduction source for many pests, such as rodents and insects, particularly flies of the order Diptera (2). Diptera is a large insect order with over 160,000 species, including filth flies that reproduce in waste and excrement, posing public health risks as mechanical vectors (3).

The housefly, *Musca domestica* (Diptera: Muscidae), is the most common fly species with worldwide distribution. It is considered an important medical insect, capable of carrying and transmitting more than 100 human pathogens, including antibiotic-resistant bacteria (4). Because these flies feed and reproduce on animal excrement, food waste and garbage, they can mechanically transmit diseases such as diarrhea, cholera, food poisoning, dysentery and

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eye infections to humans and domestic animals (5). Flies can also cause myiasis (infestation of the body of a human or animal by dipteran larvae) as a facultative or accidental agent (6). In landfill sites, both the waste and the leachate act as primary sources of nutrition and reproduction of houseflies. Under these situations, fly populations can proliferate rapidly, reaching very high numbers and becoming major nuisance pests in surrounding parks, schools and neighborhoods (7).

Various methods are employed to control houseflies, such as eliminating potential sources of food and odour, screening all windows and doors, using insecticides and so on. Indiscriminate and repeated use of pesticides has led to the development of resistance in pests because of their cheap, convenient, fast and effective action. Insecticide resistance describes the decreased susceptibility of an insect population to an insecticide through natural selection (pre-adaptive). The most resistant specimens survive, mate and produce resistant offspring (8).

Consequently, researchers and pest management professionals continue to seek new strategies to overcome this resistance. One such approach involves the use of insect growth regulators (IGRs). IGRs are primarily applied to pre-mature stages, particularly as larvicides. Juvenile hormone analogues (JHAs) and chitin synthesis inhibitors (CSIs) are among the most common classes of IGRs. Integrated Pest Management (IPM) is a comprehensive approach that integrates both chemical and non-chemical practices, such as physical and environmental controls, to suppress pest populations while minimizing risks to human health and the environment. In recent years, there has been a notable increase in the adoption of IPM strategies for controlling houseflies (9). The combined utilization of biological, physical and chemical control methods not only offers suitable solutions for population control but also minimizes environmental impact and reduces the selection pressure for resistance within the target species. This approach, known as resistance management, helps to prevent and slow the development of resistance (10).

While IPM is recommended, there are few studies documenting its large-scale, long-term application and efficacy in complex municipal waste facilities. This study aims to evaluate such an approach in one of the world's largest landfill sites, providing empirical evidence for its practical implementation and effectiveness.

Materials and Methods

Study area

This study was conducted at the Arad Kouh Waste Processing and Disposal Center, located approximately 25 km south of Tehran City. The complex spans nearly 1400 hectares and processes around 7500 tons of solid waste daily, including household, commercial, clinical and industrial waste from 22 districts of Tehran City and surrounding small towns. This complex operates with six active halls (S10, S9, S500, M1M2, S1S2, S3M3) (11).

Monitoring methodology

To assess the extent of housefly infestation, a preliminary evaluation was conducted in April-May 2022 before any interventions. Four types of traps were deployed in the halls to determine the most effective monitoring method: yellow sticky traps, bottle traps baited with sugar water, traps containing liver and pheromone traps. Ten traps of each type were placed in consistent locations to allow for comparison of their effectiveness. Based on the superior performance of yellow sticky traps in the preliminary assessment, this method was used for monthly monitoring throughout the study. From April-May to September-October 2022, ten yellow sticky traps were placed in each of the six active halls. Traps were installed monthly between 11:00 AM and 1:00 PM, a period of peak fly activity. After one hour, traps were collected and captured flies were counted and identified to species using a valid taxonomic key (12). Infestation intensity was recorded as the number of flies per 10 traps.

To account for potential confounding environmental factors, mean monthly temperature and humidity data were obtained from the nearest meteorological station (Imam Khomeini Airport Meteorological Center).

Control interventions

Following the initial assessment, a multifaceted IPM program was implemented, combining chemical, physical and environmental control methods. The choice of interventions was tailored to the specific conditions of each area within the facility.

Chemical control

Chemical interventions were conducted monthly, with the volume of insecticide applied adjusted for the dimensions of each hall. The selection of insecticides was based on local availability, prior experience, and consideration of existing reports on housefly resistance in the region.

- **Processing halls (S10, S9, S500, M1M2, S1S2, S3M3):** A tank-mix of cypermethrin (10 % EC) and chlorpyrifos (40.8% EC) was applied at a ratio of 1:4 by volume (e.g., 1 liter of cypermethrin and 4 liters of chlorpyrifos per 100 liters of water). This combination was used to target adult flies.
- **Composting area:** Due to the presence of larvae at various developmental stages, pupae, and emerging adults, a different formulation was used. This consisted of the cypermethrin-chlorpyrifos mixture (at the same 1:4 ratio) combined with the IGR diflubenzuron (Dimilin®), a chitin synthesis inhibitor, applied as a wettable powder (WP) at a rate of 5 kg per 100 liters of water. This was intended to reduce adult emergence by targeting immature stages.
- **Office buildings:** To control flies in sensitive areas with less contamination, Ajita poison bait (containing the active ingredient spinosad) was used in granular form (GR) according to the manufacturer's instructions.

Physical and environmental control

A range of non-chemical methods were implemented to reduce fly breeding sites and prevent entry into buildings:

- **Barriers:** Air curtains and automatic doors were installed or repaired at hall entrances. Windows were fitted with appropriate mesh nets.
- **Traps:** Large yellow banners coated with adhesive (mouse glue) were deployed monthly as a supplementary control method. In a combined chemical-physical approach, some large yellow banners were soaked in a mixture of insecticide and an attractant.
- **Sanitation and source reduction:** To eliminate breeding conditions, halls were washed with high-pressure water at the end of each working day. In the composting area, the material was continuously stirred and compacted and a layer of soil was sprinkled on top to create an unfavorable environment for egg-laying and larval development (13).

Statistical analysis

Statistical analyses were performed using SPSS version 25. The normality of the data was first assessed using Q-Q plots. As the data were not normally distributed, the non-parametric Kruskal-Wallis test was used for overall comparisons of fly counts across multiple months. For pairwise comparisons between individual months, the Mann-Whitney U test was employed. A significance level of $p< 0.05$ was considered statistically significant.

Results

Evaluation of monitoring methods

In the preliminary assessment, sticky traps captured the highest proportion of flies (49%), demonstrating the greatest efficiency for monitoring infestation intensity. In contrast, pheromone traps were the least effective, capturing only 4% of the total flies (Fig. 1). Consequently, sticky traps were selected as the sole monitoring tool for the duration of the study.

Infestation intensity and intervention effectiveness

Following the selection of sticky traps for monitoring, infestation intensity was assessed monthly before and after each intervention (Table 1). The peak infestation intensity occurred in April-May, before any interventions, with an average of 191 flies per 10 traps across all halls. A steady decline in fly numbers was observed over the subsequent months. The lowest infestation intensity was recorded in September-October, with an average of just 6 flies per 10 traps after the final round of interventions.

Hall S10, located closest to the main fermentation site, consistently showed the highest cumulative infestation (610 flies over the study period). Hall S1S2, situated furthest from the fermentation site, had the lowest cumulative infestation (290 flies).

Pairwise statistical comparisons using the Mann-Whitney U test confirmed the significance of this decline (Table 2). Significant differences ($p < 0.05$) were found between the peak month (April-May) and several subsequent months (June-July, July-August, August-September, September-October), demonstrating the effectiveness of the interventions.

Environmental factors

Meteorological data for the study period are presented in Table 3. A Kruskal-Wallis test revealed no statistically significant differences in either mean monthly temperature ($p=0.416$) or mean monthly humidity ($p=0.416$) across the study months (Table 4). This suggests that the observed reduction in housefly infestation was not driven by seasonal changes in these environmental factors, but rather by the implemented control interventions.

Table 1. Monthly housefly infestation intensity (number of flies per 10 sticky traps) at the Arad Kouh Waste Processing and Disposal Center, Iran, 2022

Site Code	April-May	June	July	August	September	October	Total
S10	281	187	83	27	21	11	610
S9	201	164	68	24	15	10	482
S500	168	118	40	17	12	8	363
M1M2	180	64	27	16	11	5	303
S1S2	168	92	20	5	3	2	290
S3M3	148	103	21	9	7	4	292
Total	1146	728	259	98	69	40	2340
Average	191	121	43	16	11	6	390
Percentage	48.97	31.23	11.4	4.53	2.84	1.03	100

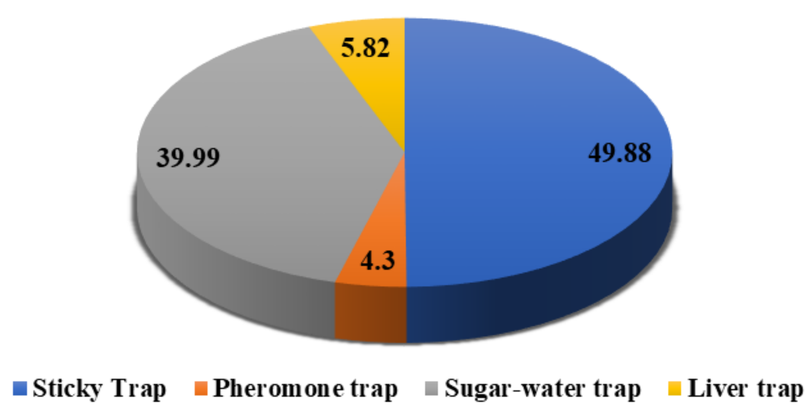

Fig. 1. Percentage of flies captured by different trap types during the preliminary monitoring at the Arad Kouh Waste Processing and Disposal Center, Iran, 2022

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Table 2. Pairwise comparison of housefly catches between different months at the Arad Kouh Waste Processing and Disposal Center, Iran, 2022

Time studied	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig. a
October-September	4.33	6.08	0.71	0.48	1.00
October-August	7.67	6.08	1.26	0.21	1.00
October-July	15.00	6.08	2.47	0.01*	0.21
October-June	22.17	6.08	3.65	0.00*	0.00
October-May	26.83	6.08	4.41	0.00*	0.00
September-August	3.33	6.08	0.55	0.58	1.00
September-July	10.67	6.08	1.75	0.08	1.00
September-June	17.83	6.08	2.93	0.00*	0.05
September-May	22.50	6.08	3.70	0.00*	0.00
August-July	7.33	6.08	1.21	0.23	1.00
August-June	14.50	6.08	2.39	0.02*	0.26
August-May	19.17	6.08	3.15	0.00*	0.02
July-June	7.17	6.08	1.18	0.24	1.00
July-May	11.83	6.08	1.95	0.05*	0.78
June-May	4.67	6.08	0.77	0.44	1.00

*: There is a significant difference in the p< 0.05

Table 3. Mean monthly temperature and humidity from Imam Khomeini Airport Meteorological Station, 2022

Month	Average humidity	Average temperature
April-May	28.29	22.85
May-June	16.14	31.13
June-July	25.05	30.57
July-August	20.48	29.79
August-September	20.53	27.40
September-October	31.53	20.74

Table 4. Kruskal-Wallis test results comparing temperature and humidity across different months of 2022

	Humidity	Temperature
Total N	6	6
Test statistic	5.000[a, b]	5.000[a, b]
Degree of freedom	5	5
Asymptotic Sig. (2-sided test)	.416	.416
Std Dev.	5.6880	4.3386

a. The test statistic is adjusted for ties.
b. Multiple comparisons are not performed because the overall test does not show significant differences across samples

Discussion

Increased urbanization and population density, coupled with sanitation challenges, create favorable conditions for urban pests like houseflies in waste disposal centers (14). In warm, moist and contaminated environments, houseflies achieve high densities and become the predominant species. Beyond causing nuisance to personnel, they serve as mechanical vectors for numerous pathogens, underscoring the public health importance of their control. Therefore, environmental improvement is fundamental for achieving sustainable long-term management of houseflies (15).

This study demonstrates the effectiveness of an IPM approach in a challenging, large-scale setting. A critical first step was identifying an appropriate monitoring tool. Consistent with Gerry's findings (14), yellow sticky traps proved most efficient for assessing adult fly populations, capturing 49% of specimens. In contrast, pheromone traps were largely ineffective (4%), likely due to overwhelming competition from natural olfactory cues (food waste, leachate) present throughout the facility. Bino Sundar et al. (16) further demonstrated that pheromone trap performance varies significantly with dispenser type and environmental conditions, supporting our observation that pheromone-based monitoring is poorly suited to large-scale waste processing facilities with diverse and potent natural attractants (10).

The results demonstrate a progressive and significant decline in housefly populations following IPM implementation. Peak infestation in April-May (191 flies/10 traps) was reduced by over 95% by September-October (6 flies/ 10 traps). Crucially, meteorological analysis confirmed this dramatic reduction was not attributable to seasonal temperature or humidity changes, as these factors did not vary significantly during the study period. This strongly supports that the interventions were the primary driver of population decline.

Spatial distribution patterns provide valuable insights. Hall S10, closest to the main fermentation site, consistently showed the highest infestation levels. This finding corroborates Goulson et al. (17), who demonstrated a direct relationship between proximity to breeding sites and fly abundance in English landfill facilities. This highlights the critical importance of targeting source reduction efforts-such as the composting management strategies employed here-as a cornerstone of any IPM program.

The temporal control pattern merits attention. Despite initial intervention in April-May, a significant reduction was not observed until later months. This lag can be attributed to several factors: the immense initial population size (1146 flies total in April-May), the short housefly life cycle (4-7 days) allowing multiple generations monthly (7) and the presence of pupae protected from initial insecticide applications (8). This underscores the need for persistence and multi-generational approaches in IPM, as immediate results are unlikely in heavily infested areas.

The combination of chemical agents with different modes of action was strategically important. Cypermethrin (pyrethroid) and chlorpyrifos (organophosphate) target adult flies through neurotoxicity, while diflubenzuron (IGR) inhibits chitin synthesis in developing larvae (9). This rotational approach helps manage resistance, aligning with Malik et al. (18), who emphasized that alternating insecticide classes within IPM frameworks delays resistance development. The use of spinosad-based bait (Ajita) in offices provided targeted control in sensitive areas, consistent with Hinkle and Hogsette's recommendations for alternative control agents (10).

Physical controls complemented chemical interventions effectively. Installing nets and air curtains reduced fly entry, while hall washing and compost management eliminated breeding substrates. These environmental modifications address the fundamental principle that source reduction is essential for sustainable control (13). The innovative use of large adhesive banners provided continuous mechanical trapping, supplementing chemical control efforts.

This study had limitations. The facility's scale and hall proximity made establishing a true control location impossible, as withholding treatment from one area risked reinfestation of adjacent halls (11). Additionally, the 6-month study period, while capturing seasonal trends, may not reflect long-term population dynamics or resistance development patterns. Future research should explore longerterm monitoring and molecular characterization of resistance mechanisms, as recommended by Norris et al. (4) and Hubbard and Gerry (19).

Despite these limitations, the findings align with previous research demonstrating IPM efficacy. Abbas et al. (15) emphasized that integrated approaches combining biological, physical and chemical methods offer optimal solutions for fly control while minimizing environmental impact. Similarly, Geden et al. (7) highlighted that sustainable housefly management requires comprehensive strategies addressing all life stages and ecological factors.

This study provides empirical support for IPM implementation in municipal waste facilities-environments often overlooked in pest management research. The demonstrated 95% population reduction validates this approach as both effective and sustainable. Furthermore, by reducing reliance on any single insecticide class, this strategy constitutes active resistance management (8, 19).

Conclusion

This study confirms that integrated pest management, prioritizing environmental sanitation complemented by targeted physical and chemical interventions based on pest biology, is highly effective for controlling houseflies in large-scale waste facilities. This approach achieves significant population suppression while promoting sustainable pest control and resistance management in challenging urban environments.

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Ethical considerations

Ethical approval for this study was obtained from the Deputy of Public Health for Tehran University of Medical Sciences (IR. TUMS.SPH. REC.1401.160).

Conflict of interest statement

The authors declare there is no conflict of interest.

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