EFFECTS OF HOUSEHOLD CHEMICAL POLLUTION ON CARCASS DECOMPOSITION AND NECROPHAGOUS INSECT DYNAMICS IN NORTHERN EGYPT

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Abstract. This study evaluated how household chemical contamination affects carcass decomposition and necrophagous insect activity under natural conditions in Kafrelsheikh, a major agricultural region in northern Egypt. Three common chemicals—sodium hypochlorite (Clorox), hydrochloric acid, and formalin—were applied to guinea pig carcasses either by surface dipping or deep tissue injection. Key ecological metrics, including odor emission, decomposition rate, insect succession, larval development, and species diversity were assessed. Statistical analysis was conducted using Kaplan–Meier survival curves, Cox proportional hazards models, generalized linear models (GLMs), and two-way ANOVA. Formalin injection nearly halted both decomposition and insect colonization, while hydrochloric acid caused moderate delays. In contrast, sodium hypochlorite had minimal impact on decomposition or insect diversity. Insect emergence was significantly delayed in injected carcasses, and species richness was reduced, with Shannon diversity index values as low as 0.33 ± 0.67 in the formalin-injected group compared to 1.51 ± 0.83 in controls. Larvae from chemically treated carcasses were also significantly smaller, with formalin-injected specimens averaging 0.04 ± 0.01 g in weight and 0.6 ± 0.1 cm in length, compared to 0.12 ± 0.02 g and 1.5 ± 0.3 cm in the control group ($p < 0.001$). These findings highlight the disruptive impact of common household pollutants—particularly when injected—on natural decomposition and insect-mediated ecological processes. The results have direct implications for forensic investigations, environmental risk assessment, and region-specific decomposition models in chemically contaminated settings.
Keywords: *environmental toxicology, volatile organic compounds, insect-mediated biodegradation, entomofauna, postmortem interval*

Introduction

Necrophagous insects are central to the ecological recycling of organic matter, particularly animal remains, through their active role in carcass decomposition. This biological process contributes to the turnover of essential nutrients such as nitrogen and carbon, facilitating energy transfer across trophic levels and maintaining ecosystem balance (Matuszewski et al., 2016; Wani and Shah, 2024). Insects that feed on decaying tissues serve as primary decomposers and form a critical link between carcass breakdown and soil enrichment (Sharif et al., 2024).

However, this natural process may be substantially disrupted by chemical pollutants, especially in environments exposed to synthetic household products. Detergents, disinfectants, and industrial cleaners can alter the chemical and microbial composition of decomposing remains, suppressing microbial growth and interfering with the cues that attract detritivores (Ermakov, 2013). Globally, over 2500 million tons of synthetic

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chemicals are produced annually, and household cleaning products represent a growing fraction of this burden (Naidu et al., 2021). Improper or excessive use of these substances, whether intentional or accidental, is increasingly linked to environmental contamination, ecological imbalance, and even forensic challenges (Khalil et al., 2022).

In the wake of the COVID-19 pandemic, the global use of disinfectants—particularly sodium hypochlorite, hydrochloric acid, and formalin—increased substantially in households, hospitals, and public spaces (Chung et al., 2022; Oladosu et al., 2022; Vuppu et al., 2023). Such chemicals, when released into the environment, can penetrate biological tissues, disrupt microbial activity, alter volatile emission profiles, and ultimately interfere with insect attraction and colonization (Hashemi et al., 2023; Martin et al., 2019).

In Egypt, several studies have explored insect succession patterns and decomposition dynamics in diverse climatic regions, including Alexandria and Upper Egypt (Tantawi et al., 1996; Aly et al., 2017; Zeariya et al., 2018; Mashaly and Ibrahim, 2022). These studies have enriched our understanding of local necrophagous insect communities and their forensic applications. However, no similar research has yet addressed the Kafrelsheikh region—a major agricultural district in the Nile Delta with unique environmental conditions.

This study addresses a key knowledge gap by evaluating how carcass decomposition and associated insect activity are influenced by exposure to three household chemical agents: sodium hypochlorite (Clorox), hydrochloric acid, and formalin. By applying these substances through both surface dipping and deep-tissue injection, the study simulates realistic contamination scenarios encountered in domestic or forensic settings.

Accordingly, the present work aims to assess the effects of these chemicals and their application methods on decomposition rate, odor emission, insect succession, larval development, and species diversity. The findings are expected to elucidate how such pollutants disrupt natural biodegradation processes and insect-mediated ecological functions, with implications for environmental monitoring and forensic science.

Materials and methods

Study area

The study was conducted from September to mid-October 2023 in Kafrelsheikh City, located in the northern Nile Delta of Egypt (31°05′54″N, 30°57′00″E). The experimental site was situated in an agricultural field with citrus trees at the Faculty of Agriculture, Kafrelsheikh University (31°05′48″N, 30°57′16″E). This region experiences a Mediterranean climate, characterized by hot summers and mild winters.

Environmental data

Temperature and relative humidity were recorded daily using data obtained from the Sakha Research Station meteorological unit during the experimental period.

Chemicals used

Three widely used household chemical products were selected to simulate contamination scenarios:

- Sodium hypochlorite (5%), sold commercially as Clorox bleach.
- Hydrochloric acid (10%), found in toilet cleaning products.

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- Formalin (40%), commonly used as a disinfectant and floor cleaner in households and clinics in Egypt. Although formalin is traditionally used as a tissue preservative, it is often commercially available in this concentration and misused without dilution. The chosen concentration reflects typical overuse scenarios observed during recent public health crises, such as the COVID-19 pandemic (Hashemi et al., 2023; Oladosu et al., 2022). All chemicals were used as purchased, without dilution.

Experimental animals and design

Twenty-one adult guinea pigs, *Cavia porcellus*, weighing 400–600 g, were obtained from a local farm. Animals were anesthetized using 25,000 ppm chloroform for 5 min, in accordance with ethical guidelines (National Research Council, 2013). The carcasses were then randomly assigned to three treatment groups:

(a) Dipping treatment

Nine carcasses (three per chemical) were immersed in 2 L of each chemical for full-body surface exposure.

(b) Injection treatment

A total of nine carcasses—three for each chemical—were injected with 30 mL of the chemical solution. This volume was evenly distributed across six anatomical locations: the thoracic cavity, abdominal cavity, neck, thigh muscle, liver, and rectum, in order to replicate deep tissue contamination.

(c) Control group

Three carcasses were euthanized by chloroform exposure but received no chemical treatment. Each treatment was replicated three times. A total of 21 carcasses were used in the experiment.

Caging and field setup

Each carcass was placed in an individual wire mesh cage (80 × 60 × 50 cm) to prevent access by vertebrate scavengers while allowing insect colonization (*Fig. 1*). Cages were arranged in the field with 10-meter spacing to prevent cross-attraction or contamination among treatments (Velásquez, 2008).

Monitoring of decomposition

Decomposition was recorded daily following the five-stage model described by Goff and Lord (1994): fresh, bloated, active decay, advanced decay, and remains. Observations focused on four main aspects:

(1) Physical changes, including carcass bloating, discoloration, and tissue degradation, were recorded through daily visual inspection; (2) Odor emission was assessed by human observers using a standardized scale (0 = no odor, 1 = mild, 2 = moderate, 3 = strong), and the time to first noticeable odor was recorded for each carcass; (3) Tissue condition was evaluated both visually and by touch, based on texture, presence of desiccation, and fluid leakage; (4) Insect activity was quantified by counting insects observed during sampling sessions using sweep nets, aspirators, and daily yellow sticky trap collections.

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These observations followed standard forensic entomology practices as described in Byrd and Tomberlin (2020).

Figure 1. *Experimental setup used for studying decomposition and insect succession. (A) Field site showing decomposition cages placed in a natural habitat. (B) Researcher placing a guinea pig carcass inside a wire-mesh cage designed to allow insect access while preventing scavenger disturbance*

Insect sampling and identification

Adult insects were collected using sweep nets, aspirators, hand collection, and yellow sticky traps (9 × 7 cm), which were placed next to each carcass from day 2 to day 15 and replaced daily. While yellow traps can attract non-target species, all captured specimens were taxonomically identified, and only confirmed necrophagous species were included in insect succession analysis, diversity assessments, and statistical comparisons. The percentage of necrophagous insects relative to the total number of collected species has been calculated.

Collected specimens were counted, preserved in 70% ethanol, and identified using entomological keys (Ren et al., 2018; Byrd and Tomberlin, 2020; Abu El-Hassan et al., 2021), with expert support from Ain Shams University's Entomology Department.

Insect succession and diversity

Species emergence and succession patterns were tracked daily. Community diversity was assessed using the Shannon Diversity Index (*Eq. 1*) and the Evenness Index (*Eq. 2*), standard metrics in ecological studies (Magurran, 2004; Begon et al., 2006):

Shannon Diversity Index (H′):

$$H' = -\sum_{i=1}^{s} p_i \ln(p_i) \quad \text{(Eq.1)}$$

Evenness Index (E):

$$E = \frac{H'}{\ln(S)} \quad \text{(Eq.2)}$$

where p_i is the proportion of individuals of species i, and S is total species richness.

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Larval measurements

Five larvae per carcass were randomly selected during the second and third instar stages. These larvae primarily belonged to the dominant Dipteran species observed in the study—*Calliphora vicina* —based on their respiratory spiracles and confirmed identification using morphological keys. Larvae were killed in hot water (~80°C) to preserve morphology (Adams and Hall, 2003), then weighed and measured under a Nikon SMZ745T stereomicroscope with a Dino-Lite® camera and DinoCapture 2.0® software.

Statistical analysis

Statistical analyses were performed using Python (Lifelines and Statsmodels) (Davidson-Pilon, 2021), R (MASS) (R Core Team, 2023), and Minitab 18. The following models were applied:

- Negative Binomial GLM: to analyze insect count data with overdispersion.
- Kaplan–Meier Survival Curves: for time-to-odor and time-to-insect-emergence analyses.
- Cox Proportional Hazards Model: to estimate hazard ratios between treatments.
- Two-way ANOVA: to assess the effects of chemical type, application method, and larval age on diversity indices and larval metrics.
- Tukey HSD Test: for post-hoc pairwise comparisons. Statistical significance was considered at $p < 0.05$.

Ethical considerations

All procedures involving animals were approved by the Institutional Animal Care and Use Committee of Kafrelsheikh University (Approval No. KFS-IACUC/148/2023) and followed the ethical and experimental guidelines of the National Research Council (2013). Although OECD and EPA protocols were not explicitly applied, the study was designed in accordance with internationally accepted standards.

Results

Environmental conditions

As shown in *Figure 2,* ambient temperatures during the experimental period ranged from 25 °C to 32 °C, while relative humidity varied between 65% and 80%.

Decomposition progress and duration

Carcasses progressed through five decomposition stages: fresh, bloated, active decay, advanced decay, and remains. The overall decomposition period averaged 15 days. The fresh stage occurred on day 0 across all treatments, followed by the bloated stage within 2 to 4 days, depending on treatment. Active and advanced decay stages were significantly delayed in chemically treated carcasses, particularly those injected with formalin. In these cases, tissue hardening and visible mummification were observed, with some carcasses bypassing bloating and active decay altogether. *Table 1* summarizes the duration of each decomposition stage across treatments.

Kaplan–Meier analysis showed that formalin injection completely suppressed odour emission throughout the observation period ($p < 0.005$). Formalin caused the

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most substantial delay in decomposition onset, with a hazard ratio (HR) of 0.409, indicating a 77.3% reduction in decomposition risk compared to the control group (HR = 1.799). Hydrochloric acid injection further suppressed decomposition with an HR of 0.151, equating to a 91.6% reduction relative to the control. These values show that hydrochloric acid exerted a strong inhibitory effect, although still less than formalin. In contrast, Clorox-treated carcasses did not differ significantly from the control group.

Table 1. *Duration of carcass decomposition stages for different chemical treatments*

Decay stage	Chemical	Treatment	Mean days	Grouping	Significance
Fresh	Control		0.9	A/a/x	–
	Clorox	Dipping	1	A/a/x	–
	Clorox	Injection	1.1	A/a/y	–
	HCl	Dipping	1.1	A/a/x	–
	HCl	Injection	1.2	A/a/y	–
	Formalin	Dipping	1.4	B/b/x	*
	Formalin	Injection	1.3	B/b/y	*
Bloated	Control		2.4	C/c/x	–
	Clorox	Dipping	2.4	C/c/x	–
	Clorox	Injection	2.3	C/c/y	*
	HCl	Dipping	2.5	C/c/x	–
	HCl	Injection	2.1	C/c/y	*
	Formalin	Dipping	3.8	D/d/x	**
	Formalin	Injection	4.1	D/d/y	**
Active decay	Control		4.2	E/e/x	–
	Clorox	Dipping	4.5	E/e/x	–
	Clorox	Injection	4.6	E/e/y	*
	HCl	Dipping	5.2	F/f/x	*
	HCl	Injection	5	F/f/y	*
	Formalin	Dipping	6.8	G/g/x	**
	Formalin	Injection	7.2	F/f/y	**
Advanced decay	Control		7.1	H/h/x	*
	Clorox	Dipping	7	G/g/x	*
	Clorox	Injection	7.3	G/g/y	*
	HCl	Dipping	7.5	G/g/x	*
	HCl	Injection	7.3	H/h/y	*
	Formalin	Dipping	9.7	H/h/x	**
	Formalin	Injection	9.5	I/i/y	**
Remains	Control		11.2	J/j/x	–
	Clorox	Dipping	12.1	I/i/x	–
	Clorox	Injection	12	J/j/y	*
	HCl	Dipping	11.8	I/i/x	–
	HCl	Injection	11.5	I/i/y	*
	Formalin	Dipping	16.3	J/j/x	**
	Formalin	Injection	15.8	K/k/y	***

Statistical groupings are indicated by a triple-letter code (e.g., A/a/x):
Capital letters (A–K): Compare decay stages vertically (↑); different letters = significant differences ($p < 0.05$)
Lowercase letters (a–k): Compare chemicals within the same stage horizontally (→)
x/y: Indicate treatment type — x = dipping, y = injection
*, **, ***: Significant delay or extension vs. Control or others ($p < 0.05$, < 0.01, < 0.001 respectively).
"–": No statistically significant difference observed
All tests were conducted using two-way ANOVA followed by Tukey's HSD ($\alpha = 0.05$)

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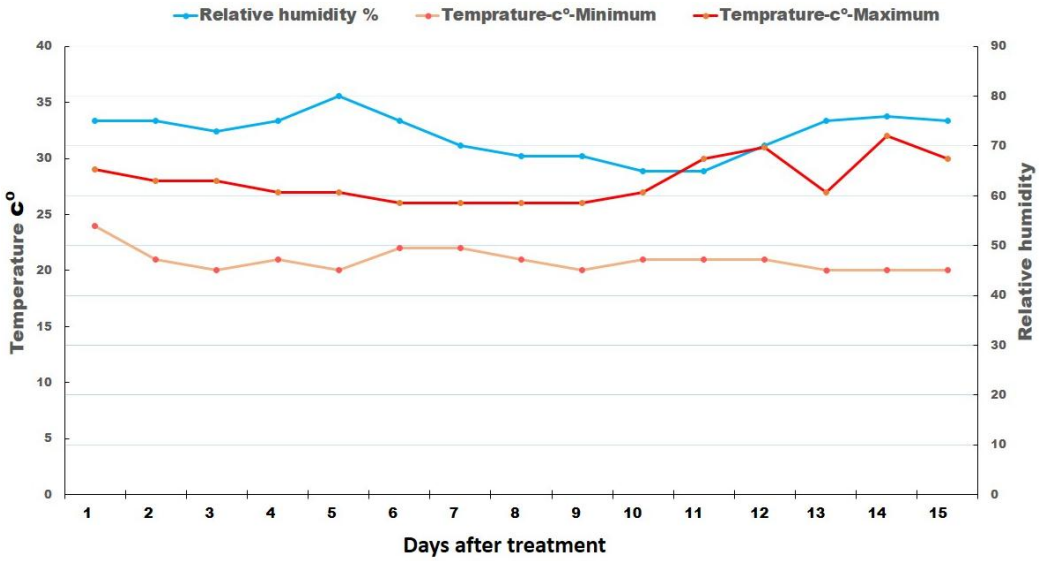

Figure 2. *Temperature and relative humidity variation during October 1–15, 2023, in Sakha, Kafrelsheikh governorate*

Insect succession

Among the insect species attracted to the carcasses, 25 species were identified, accounting for 76% of all recorded taxa. These were confirmed as necrophagous and thus included in the statistical analysis. All other non-necrophagous or incidental species were excluded and not considered in the ecological assessments (*Table 2*).

Species succession varied distinctly by treatment. Control and Clorox-dipped carcasses attracted the highest number and diversity of necrophagous species, including early colonizers such as *Calliphora vicina*, *Lucilia sericata*, and *Musca domestica*. In contrast, formalin-injected carcasses showed significant suppression of insect arrival, with first emergence delayed to an average of 6.8 days postmortem and a limited diversity of only 8 species. Hydrochloric acid also delayed insect colonization; early colonizers arrived later and in lower abundance compared to control and Clorox treatments, but earlier than in formalin-injected carcasses.

Kaplan–Meier analysis of insect emergence confirmed significant differences among treatments ($p < 0.001$). Cox hazard ratios showed that insect emergence was 59.1% less likely in formalin-treated carcasses (HR = 0.409), while the injection method itself reduced emergence probability by 27.5% compared to dipping (HR = 0.725). Control carcasses exhibited the highest emergence probability (HR = 1.799). Succession patterns across decomposition stages and treatments are detailed in *Tables 3* and *4*.

Insect density

A total of 20,669 adult insects were collected throughout the experiment. Two-way ANOVA revealed statistically significant effects for chemical type ($p < 0.001$) (*Tables 5* and *6*), application method ($p = 0.0001$), and their interaction ($p = 0.015$). Generalized linear model (GLM) results indicated that formalin injection produced the greatest reduction in insect density (coefficient = –415.8, $p < 0.001$), followed by hydrochloric acid injection (coefficient = –312.4, $p = 0.003$). In contrast, Clorox-dipped carcasses recorded the highest insect counts, particularly on day 4 (*Fig. 3*).

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Table 2. *Insect species attracted to chemically treated and control carcasses*

Order	Family	Species
Diptera	*Calliphoridae*	*Calliphora vicina* *Chrysomya megaecephala* *Chrysomya albiceps* *Lucilia sericata* *Lucilia cuprina*
	Sarcophagidae	*Ravinia pernix* *Sarcophaga argyrostoma* *Sarcophaga pernix* *Wohlfahrtia magnifica*
	Muscidae	*Musca domestica* *Musca sorbens* *Antherigona theodori* *Atherigona orientalis* *Morellia simplex* *Phaonia incana*
	Piophilidae	*Piophila casei*
	Chloropidae	*Liohippelates sp*
	Ulidiidae	*Physiphora alceae* *Physiphora allomma*
	Phoridae	*Dohrniphora cornuta* *Megaselia scalaris*
Coleoptera	*Dermestidae*	*Dermestes maculatus* *Dermestes haemorrhoidalis*
	Staphylinidae	*Creophilus maxillosus*
	Cleridae	*Necrobia* rufipes

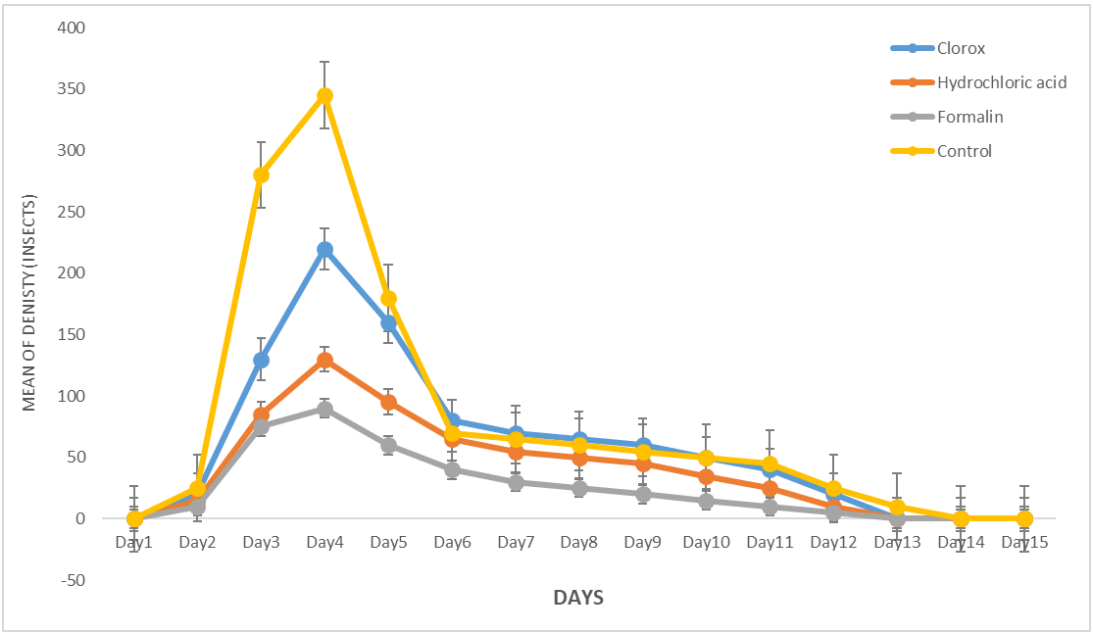

Figure 3. *Interaction plot for insect density during the experimental period of dipping treatment Error bars represent standard deviation (SD)*

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Table 3. *Insect succession patterns in dipping treatments*

Species \ Decay stages	Fresh (0-1) day				Bloated (2-5) day				Decay (6-11)				Remains (12-17)			
	CL	Hcl	F	Control	CL	Hcl	F	Control	CL	Hcl	F	Control	CL	Hcl	F	Control
Calliphora vicina				✓	✓	✓	✓	✓				✓				
Chrysomya megaecephala					✓	✓	✓	✓								
Chrysomya albiceps					✓	✓	✓	✓			✓	✓				
Lucilia sericata					✓	✓	✓	✓								
Lucilia cuprina					✓	✓	✓	✓								
Ravinia pernix					✓	✓	✓	✓								
Sarcophaga argyrostoma					✓	✓	✓	✓		✓		✓				
Sarcophaga pernix					✓	✓	✓	✓								
Wohlfahrtia magnifica					✓	✓	✓	✓								
Musca domestica					✓	✓	✓	✓	✓	✓	✓	✓				
Musca sorbens					✓	✓	✓	✓	✓	✓	✓	✓				
Anthrigona theodori					✓	✓	✓	✓				✓				
Atherigona orientalis					✓	✓	✓	✓				✓				
Morellia simplex					✓	✓	✓	✓								
Phaonia incana					✓	✓	✓	✓								
Physiphora alceae						✓	✓	✓								
Physiphora allomma						✓	✓	✓								
Piophila casei					✓	✓	✓	✓	✓	✓	✓	✓				
Liohippelates sp					✓	✓	✓	✓	✓	✓	✓	✓				
Dohrniphora cornuta					✓	✓	✓	✓	✓	✓	✓					
Megaselia scalaris					✓	✓	✓	✓	✓	✓	✓					
Dermestes maculatus					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Dermestes haemorrhoidalis					✓		✓	✓	✓	✓	✓	✓				✓
Creophilus maxillosus					✓	✓	✓	✓	✓	✓	✓	✓				
Necrobia rufipes					✓			✓	✓			✓				

✓ = Presence of species during the stage and treatment
Clear cell = Absence
CL = Clorox, HCL = Hydrochloric Acid, F = Formalin, Ctrl = Control

As illustrated in *Figure 4,* injection treatments led to earlier and steeper declines in insect density compared to dipping. Survival analysis revealed that the mean duration of insect activity was shortest in formalin-injected carcasses (2.3 days), compared to 13.6 days in control carcasses. According to the Cox model, the likelihood of complete insect cessation was 4.91 times higher in formalin-injected carcasses than in controls (HR = 4.91).

GLM modelling confirmed that formalin significantly reduced diversity ($\beta = -0.68$, $p < 0.001$), followed by hydrochloric acid ($\beta = -0.42$, $p < 0.001$). Dipping preserved diversity better than injection ($\beta = -0.25$, $p = 0.002$). Diversity also declined progressively over time across all treatments ($\beta = -0.12$ per day, $p < 0.001$). *Figure 5* illustrates this temporal decline under each treatment condition.

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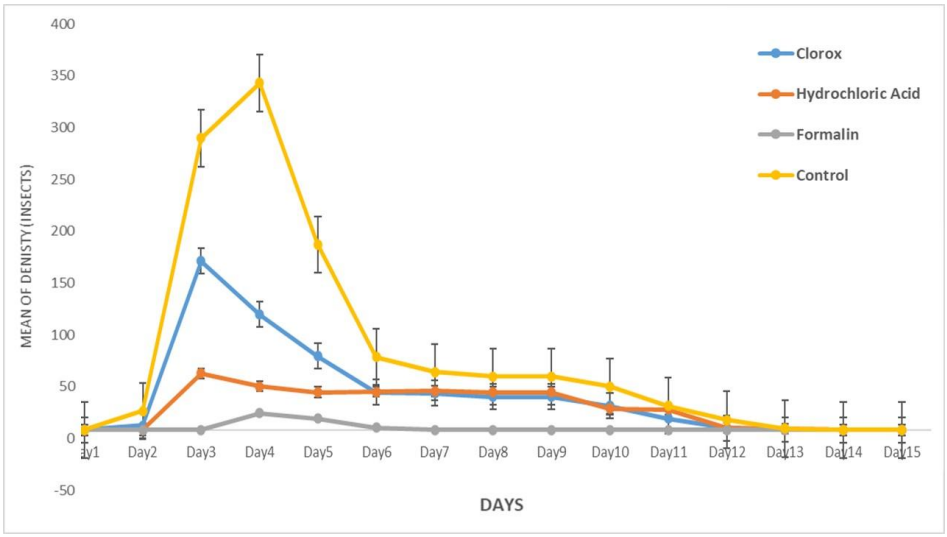

Figure 4. *Interaction plot for insect density during the experimental period of injection treatment. Error bars represent standard deviation (SD)*

Table 4. *Insect succession patterns in injection treatments*

Species \ Decay stages	Fresh (0-1) day				Bloated (2-5) day				Decay (6-11)				Remains (12-17)			
	CL	Hcl	F	Control	CL	Hcl	F	Control	CL	Hcl	F	Control	CL	Hcl	F	Control
Calliphora vicina	✓			✓	✓			✓				✓				
Chrysomya megaecephala					✓			✓								
Chrysomya albiceps					✓			✓				✓				
Lucilia sericata					✓			✓								
Lucilia cuprina					✓			✓								
Ravinia pernix					✓	✓	✓	✓								
Sarcophaga argyrostoma					✓	✓	✓	✓				✓				
Sarcophaga pernix					✓	✓	✓	✓								
Wohlfahrtia magnifica					✓			✓								
Musca domestica					✓	✓	✓	✓		✓		✓				
Musca sorbens					✓	✓	✓	✓		✓		✓				
Antherigona theodori					✓	✓	✓	✓		✓		✓				
Atherigona orientalis					✓	✓	✓	✓	✓			✓				
Morellia simplex					✓	✓	✓	✓								
Phaonia incana					✓	✓		✓								
Physiphora alceae								✓								
Physiphora allomma					✓	✓		✓	✓							
Piophila casei					✓	✓	✓	✓	✓	✓						
Liohippelates sp					✓	✓	✓	✓	✓	✓						
Dohrniphora cornuta					✓	✓	✓	✓	✓	✓						
Megaselia scalaris					✓	✓	✓	✓	✓							
Dermestes maculatus					✓	✓		✓	✓	✓		✓	✓	✓		✓
Dermestes haemorrhoidalis								✓	✓	✓		✓				✓
Creophilus maxillosus					✓	✓		✓	✓	✓		✓				
Necrobia rufipes					✓			✓	✓			✓				

✓ = Presence of species during the stage and treatment
Clear cell = Absence
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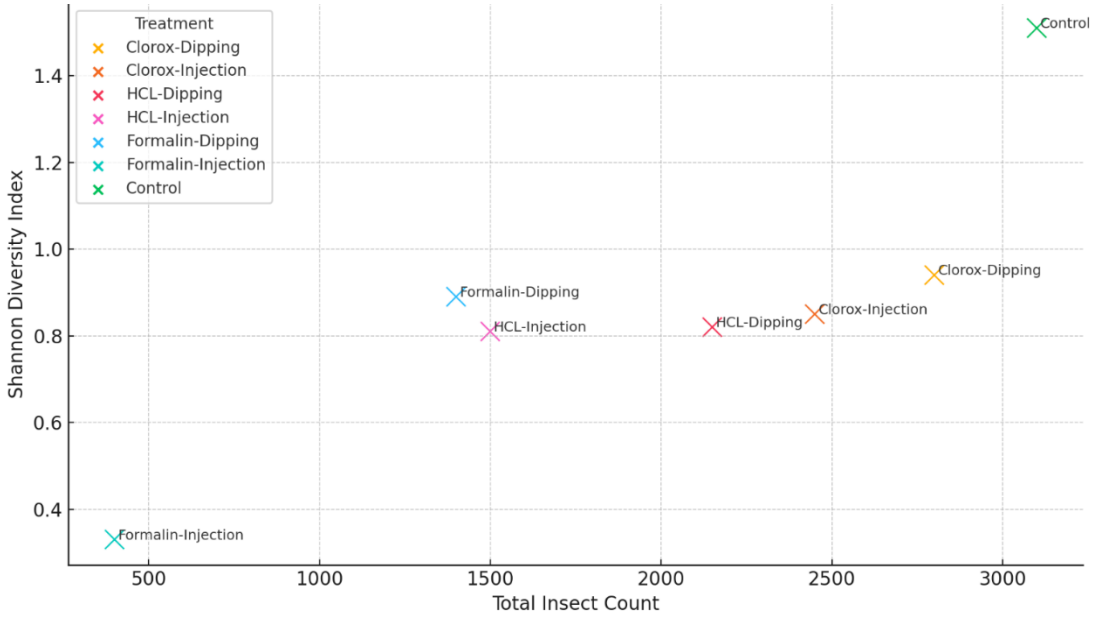

Figure 5. *Interaction between total insect count and Shannon diversity index across treatments during decomposition*

Table 5. *Two-way ANOVA summary table (average number of insects - dipping method)*

Source	DF	Adj SS	Adj MS	F-Value	P-Value	Significance
Decomposition stage	4	46,043	11,510.60	23.23	<0.001	***
Chemicals	4	14,722	3680.40	7.43	<0.001	***
Species	24	123,844	5160.20	10.41	<0.001	***
Error	467	231,392	495.5			

*** $p < 0.001$ (highly significant)

Table 6. *Two-way ANOVA summary table (average number of insects - injection method)*

Source	DF	Adj SS	Adj MS	F-Value	P-Value	Significance
Decomposition stage	4	27,208	6,802.10	17.28	<0.001	***
Chemicals	4	25,157	6289.20	15.98	<0.001	***
Species	24	55,998	2333.30	5.93	<0.001	***
Error	467	183,846	393.7			

*** $p < 0.001$ (highly significant)

Larval growth (weight and length)

Larvae from control carcasses had the highest average weight (0.12 ± 0.02 g) and length (1.5 ± 0.3 cm). In contrast, formalin-injected carcasses yielded the smallest larvae, with an average weight of 0.04 ± 0.01 g and length of 0.6 ± 0.1 cm, representing 66.7% and 60% reductions, respectively. ANOVA showed significant effects of chemical

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treatment ($F = 28.45$, $p < 0.001$), application method ($F = 12.67$, $p = 0.001$), and larval age ($F = 8.23$, $p = 0.006$).

Tukey's HSD post hoc test revealed significant weight reductions in the formalin group ($\Delta = 0.08$, $p < 0.001$) and Clorox group ($\Delta = 0.04$, $p = 0.002$) compared to controls.

Larval length showed similar patterns: ANOVA confirmed highly significant effects of chemical type ($F = 32.18$, $p < 0.001$), application method ($F = 18.34$, $p < 0.001$), and larval age ($F = 10.12$, $p = 0.003$). Injection treatments were more suppressive than dipping for both weight and length. Notably, in some chemical treatments, third instar larvae were smaller than second instars, suggesting chemical-induced developmental arrest or stress (*Fig. 6*).

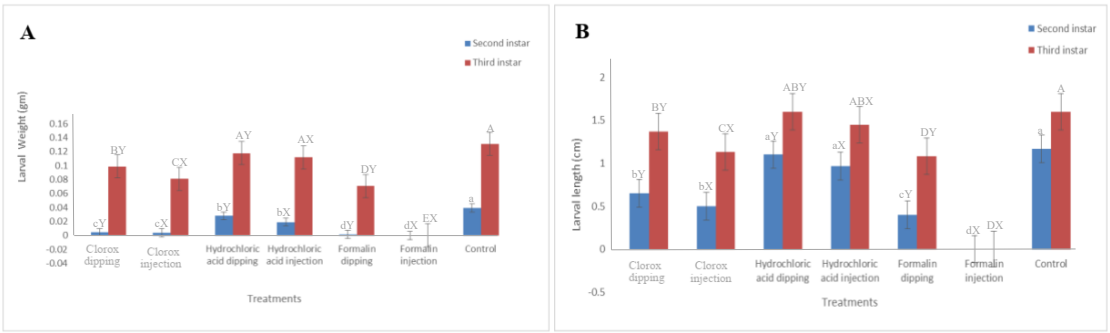

Figure 6. *Average measurements of larvae treated with different Chemicals by dipping and injection, Larval Weight (A), Larval Length (B). Error bars represent standard deviation (SD). Different letters indicate statistically significant differences (Tukey's HSD, $p < 0.05$). Uppercase letters compare chemical effects within the third instar, Lowercase letters compare chemical effects within the second instar, Subscript differences (e.g., AY vs AX) indicate significant differences between application methods (dipping vs injection) within the same chemical and instar*

Discussion

This study demonstrates that household chemical contamination—especially through injection—can significantly suppress carcass decomposition, alter insect succession, and reduce insect density and biodiversity. These findings have both ecological and forensic implications, particularly in environments where chemical exposure is likely.

Formalin exhibited the strongest inhibitory effects across all parameters. Its injection into carcasses almost completely suppressed decomposition, blocked odor emission, and prevented early colonization by necrophagous insects. These results align with previous findings (Keaton, 2012; Onyejike et al., 2022; Heshan and Karunaratne, 2024), which showed that formalin creates an internal environment unfavorable to microbial growth and insect activity. The formation of a dry, mummified shell likely impeded the release of volatile organic compounds (VOCs), essential cues for insect attraction (Hashemi et al., 2023). The strong inhibitory effects of formalin on decomposition and insect colonization observed in this study align with its known preservative properties (Keaton, 2012; Heshan and Karunaratne, 2024). Formalin was included not only due to its biological impact but also because of its widespread availability in domestic and clinical environments in Egypt, where it is sometimes misused as a high-concentration disinfectant. The 40% concentration used here reflects commercially available formulations and was intended to simulate potential real-world contamination events in forensic or environmental scenarios.

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Hydrochloric acid also delayed decomposition and insect succession, though less dramatically than formalin. Its low pH may have interfered with microbial processes essential for tissue breakdown. In contrast, sodium hypochlorite had minimal effects when applied externally, likely due to its volatility and surface-level action. These findings are consistent with those of Mashaly and Ibrahim (2022), who reported limited disruption from sodium hypochlorite under outdoor conditions.

In untreated and Clorox-treated carcasses, succession patterns followed expected trajectories, with early colonizers such as *Calliphora vicina* and *Lucilia sericata* dominating the fresh and bloated stages (Tantawi et al., 1996; Byrd and Tomberlin, 2019). The absence or delay of these species in formalin- and acid-injected carcasses underscores their sensitivity to chemical interference. Reduced larval size and weight further support the idea that chemical exposure disrupts insect development, potentially through toxicity, nutritional stress, or altered microbial communities (Sharif et al., 2024; Martin et al., 2019).

The observed reduction in species diversity, particularly under injection treatments, is ecologically significant. From a forensic standpoint, such suppression may distort postmortem interval (PMI) estimations by eliminating key indicator species or delaying larval development (Adams and Hall, 2003; Wani and Shah, 2024). These effects are especially relevant in urban or medically treated contexts where chemical exposure is common.

In addition to these biological impacts, this study also contributes novel data for the Kafrelsheikh region. The regular occurrence of indicator species such as *Musca domestica* and *Dermestes maculatus* supports local succession baselines, while the effects of chemical exposure suggest the need for adjusted forensic models in contaminated scenarios.

While the experimental design captured major ecological responses, certain limitations should be noted. Laboratory-sourced guinea pigs may differ from naturally deceased animals in their initial microbial profiles. Moreover, standardized chemical dosages may not reflect real-world variability. Future research should examine a broader array of chemical agents, decomposition substrates (e.g., human analogues), and environmental contexts.

Conclusion

This study confirms that household chemical contamination—particularly via injection—can delay decomposition, suppress insect colonization, and reduce biodiversity under natural conditions in Northern Egypt. Formalin produced the most pronounced effects, while hydrochloric acid and sodium hypochlorite had moderate to minimal impact. These disruptions have significant implications for forensic entomology and ecological modelling. Future research should investigate more diverse contamination scenarios to enhance the reliability of postmortem and ecological assessments.

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