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CASE REPORT

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Forensic entomology in court: analysis of a case of time of death estimation

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ABSTRACT

This study examines the indispensable role of forensic entomology in scientifically estimating the post-mortem interval (PMI) and thus aiding court convictions. This case study estimated the PMI of a female corpse that was found in an advanced stage of decomposition in an apartment in Amman, Jordan (Archives of Qararak database of the Jordanian Bar Association). In contrast to the perpetrator's alleged PMI of 19 days, the analysis of the entomological data suggests a minimum PMI of 10 days. This result does not support a conviction for assault leading to death but intentional homicide. This case study assures the potential of forensic entomology in criminal investigations in Jordan.

Keywords: forensic, entomology, court, Jordan, TESD

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Introduction

Forensic entomology is a subfield of forensic science that involves the study of insects and other arthropods concerning legal investigations [1]. In the context of post-mortem interval determination, forensic entomology is essential for estimating the time of death by analysing the insect colonization of a corpse [2]. This method is particularly useful when other methods of estimating the time of death, such as rigour mortis or lividity, are not possible due to the decomposition of the body [3]. Forensic pathologists encounter challenges when attempting to determine the time since death in investigations involving victims who have been deceased for more than three days [4]. Therefore, by analysing the species and developmental stages of the insects mainly blowflies, a forensic entomologist can estimate the minimum post-mortem interval, which provides critical information for a criminal investigation or other legal proceedings [5–7]. Blowflies are attracted to decaying organic matter and are among the first to arrive after death. Blowflies go through a regular life cycle that includes four stages: egg, larva, pupa, and adult. The duration of each stage is determined by temperature and humidity. Forensic entomologists can determine the time of oviposition and calculate PMI by studying the accumulated degree hours (ADH) of blowfly larvae found on the body.

Accumulated degree hours consider the total thermal energy or heat units required for the growth and development of insect larvae, providing a quantitative means to assess the advancement of insect colonization on a deceased individual [8]. Within the field of forensic entomology, the calculation of accumulated degree hours (ADH) involves summing the degree hours (DH) or heat units acquired during a specified time frame. To determine the degree hour, the base temperature (T_0) is subtracted from the mean daily temperature (T) observed at the location of the deceased [9]. This computation takes into consideration the temperature-dependent nature of insect development, as different species possess distinct thermal thresholds for their growth and maturation. After determining the ADH, it can be juxtaposed with insect developmental data collected through controlled laboratory experiments or observations in the field. These datasets offer valuable insights into the correlation between temperature and the rate of insect development, enabling forensic entomologists to estimate the stage of growth. The precision of ADH-based estimations is contingent upon several assumptions, including a consistent temperature environment and the absence of factors that could hinder

insect development, such as temperature fluctuations, exposure to chemicals, or the presence of pesticides [10, 11]. It is vital to acknowledge these limitations and validate ADH estimations by cross-referencing them with other entomological and environmental indicators to improve the accuracy of PMI estimates.

Entomological evidence is now frequently collected from crime scenes and used in courts around the world, being used to determine temporal, spatial, and causal aspects of a crime or help identify a victim and convict the perpetrator [12]. Unfortunately, the use of insects to determine the post-mortem interval in Jordan, based on decomposed bodies, is not a very dependable method. Consequently, the circumstances of a crime may mislead the court and thus lead to issuing a wrong judicial ruling. The common forensic blowflies that have been reported from Jordan include *Lucilia sericata* [13], *Lucilia cuprina* [14], *Chrysomya albiceps* [15], and *Sarcophaga haemorrhoidalis* [16]. However, field and laboratory experiments on carcasses from Jordan revealed *Lucilia sericata* as the most prevalent and first-arriving carrion insect [17]. *Lucilia sericata* is distributed all over the planet, however, it is best defined as having a Holarctic range. It is easily distinguished by its metallic-green or copper-green colouration, yellow mouth parts, hairy back, a diameter of 8–10 mm, hairless squama near the base of the wings, smooth posterior spiracles of all larval stages with a full peritreme, and larval length in the third instar of 12–18 mm [18]. The life cycle of *Lucilia sericata* has been extensively examined, including the accumulated degree hours in different temperature ranges [19–21].

The case

This case study was selected from 75 criminal cases available in the 'Qararak Database' published by the Jordanian Bar Association. The facts of this case are summarized as follows: On October 9th, 2012, the 38-year-old male quarrelled with his girlfriend in his apartment and hit her in the face and head with his fist. She fell on the ground, where she lost consciousness and eventually passed away, as he claimed. He then carried the body and placed it on the bed, covering it with a sheet. The body remained in bed until October 28th, when the accused's neighbours alerted the police after smelling a foul odour coming from the apartment. The police arrived at midnight and searched the apartment to find the victim's naked body in a state of advanced decomposition with huge masses of blow flies' larvae that were not entomologically identified. The autopsy revealed that the victim had suffered multiple fractures in her facial bones and eye socket, which were consistent with being hit on the head and face.

Based on the perpetrator's confession statements, the post-mortem interval was estimated to be 19 days (9–28 October). The autopsy report did not mention the time elapsed since death but stated that the stage of decomposition was advanced; the internal organs were significantly decomposed, the brain tissue was completely absent due to decomposition, and the knee was covered with a bandage, whereupon removal, the knee tissues were found completely decomposed. The neck tissues were also decomposed, including the cartilage, and thus could not establish a cause of death.

The offender was sentenced to the felony of intentional homicide but later appealed the verdict. Then, after reviewing the merits of the case by the Court of Appeal, the sentence was commuted to assault leading to death. Jurisprudence has settled that for the elements of the felony of beating leading to death, the following conditions must be met: First, the issuance of a material act on the part of the accused, which is the beating or wounding. Second, this beating is with tools that do not lead to death — in other words, tools that are not fatal in nature. Third, that the perpetrator never intended to kill. Fourth, the result (death) is linked to the behaviour by a causal link.

Justification of the court's decision

Delayed time of death for more than 24 hours after the inflicted blow indicates that if the accused intended to take the life of the victim, he would have done so immediately and directly, as there was no obstacle preventing him from doing so. On one hand, applying the four conditions mentioned above to the facts of this case, the court finds that the actions of the accused towards the victim fulfil all those conditions. The criminal behaviour, which is the assault and harm inflicted by the accused on the victim, is established. Additionally, the assault occurred with tools that are not inherently lethal. As mentioned earlier, the intention of the accused was not directed towards murder. Furthermore, the result that occurred, which is the death of the victim and the loss of her life, was a consequence of the behaviour inflicted by the accused, namely the assault and harm to the victim. If it is proven through medical expertise that the injuries and fractures in the facial bones could result in brain concussion and bleeding, and if specialized treatment is not provided, it could lead to death. Thus, the actions of the accused fulfil all the elements and components

Table 1. An example of accumulated degree hours of *Lucilia sericata* at 21°C

From	To	T	T0	T–T0	H	DH	ADH
Egg	1st Instar	21	10	11	23	253	253
1st Instar	2nd Instar	21	10	11	27	297	550
2nd Instar	3rd Instar	21	10	11	22	242	792
3rd Instar	Pupa	21	10	11	130	1430	2222
Pupa	Adult Fly	21	10	11	143	1573	3795

ADH — accumulated degree hours; DH — degree hours; H — number of hours; T — average temperature; T0 — threshold temperature

of the crime of assault leading to death, according to the provisions of Article 330/2 of the Penal Code, considering the gender of the victim. This necessitates amending the charge attributed to the accused from the crime of intentional homicide under Article 328/1 of the Penal Code to the crime of assault leading to death under Article 330/2 of the Penal Code.

This study reviews the entomological evidence to estimate the time elapsed since death, which was not included in the autopsy report to rule out the sentences that were issued against the perpetrator; the intentional homicide that then commuted to assault leading to death. If death occurred on the 9th of October, the crime of assault leading to death would be a proper verdict but unless death occurred after that.

Material and methods

The World Weather Database was used for calculating the average daily temperatures in Amman for October 2012 (maximum + minimum/2). Since the case was found inside an apartment with little if any variation in the daily average temperature, the estimate was then adjusted by 2. The accumulated degree hours (ADH) were calculated using the published life cycle of 15 commonly used blowflies in FOR-BUG_ID software created by Al-Shorman [17]. *Lucilia sericata* is used as an example to show the ADH calculation method for various species [19, 21] (Tab. 1). The ADH method was calculated using the formula:

ADH = Time (hrs) × (average temperature – 10)

Where 10 is the minimum development threshold temperature

Results

The average daily temperature in the city of Amman during October 2012 was 23.4 ± 2.8°C. Since the corpse was discovered inside an apartment, it was assumed that the temperature was 2°C lower (21°C) [22]. The minimum accumulated degree hours for third-instar larvae of various species are listed in Tables 2 and 3. According to Figure 1 below, the minimum date of oviposition was the 19th of October while the maximum date was the 26th (10–16 days). These dates contradict the confession of the perpetrator, which means that the victim did not immediately die on October 9th. Despite losing consciousness on October 9th, the victim probably survived for a minimum of 10 days without adequate medical attention, during which she likely succumbed to the effects of the blunt trauma, or another undetectable cause that autopsy could not reveal. Accordingly, the time of death negates the third condition (*the perpetrator never intended to kill*) of the second sentence, and thus, intentional murder is the most likely verdict.

Discussion

Determining the time of death is a critical aspect of forensic investigations, providing crucial insights into criminal cases. Entomological analysis, which involves studying insect activity on or near a corpse, can provide valuable information regarding the post-mortem interval [23] to obtain information beneficial to a judicial inquiry, particularly in certain suspected criminal cases [24]. Based on the objective of the study, the research results related to time of death estimation in a specific case were examined to challenge the initial claim of premeditated murder based on entomological analysis. However, temperature plays a crucial role in insect development and activity on corpses found indoors, where the relatively non-fluctuating indoor temperatures generally slow down insect growth and thus expand the PMI [25]. Degree days are a measure of accumulated temperature over time, commonly used in forensic entomology to estimate the development stages of insects [26]. Based on this entomological analysis, it

Table 2. The ADH of the various blowflies' species using 10°C as a threshold and the expected time of death, where T is the rearing temperature. Sources of data are the FOR-BUG_ID created by Al-Shorman [17]

No.	Blowflies species	T	ADH	Time of death
1	*Lucilia sericata*	21	2222	20–21
2	*Lucilia cuprina*	25	1419	25–26
3	*Chrysomia albiceps*	25	1350	24–25
4	*Sarcophaga haemorrhiodalis*	15.6	1025	25–26
5	*Calliphora cadevrina*	26.7	1804	22–23
6	*Chrysomia megacephalia*	27	2448	20–21
7	*Cochlioma macellaia*	25	1170	24–25
8	*Chrysomia rufificies*	29.7	1182	25–26
9	*Calliphora terranovea*	26.7	1570	23–24
10	*Calliphora vicina*	26.7	1536	23–24
11	*Phormia regina*	26.7	2488	20–21
12	*Protophormia terranovea*	26.7	1035	25–26
13	*Sarcophaga bullata*	26.7	1637	23–24
14	*Calliphora vomitoria*	26.7	2204	21–22
15	*Lucilia exima*	20.7	2563	19–20

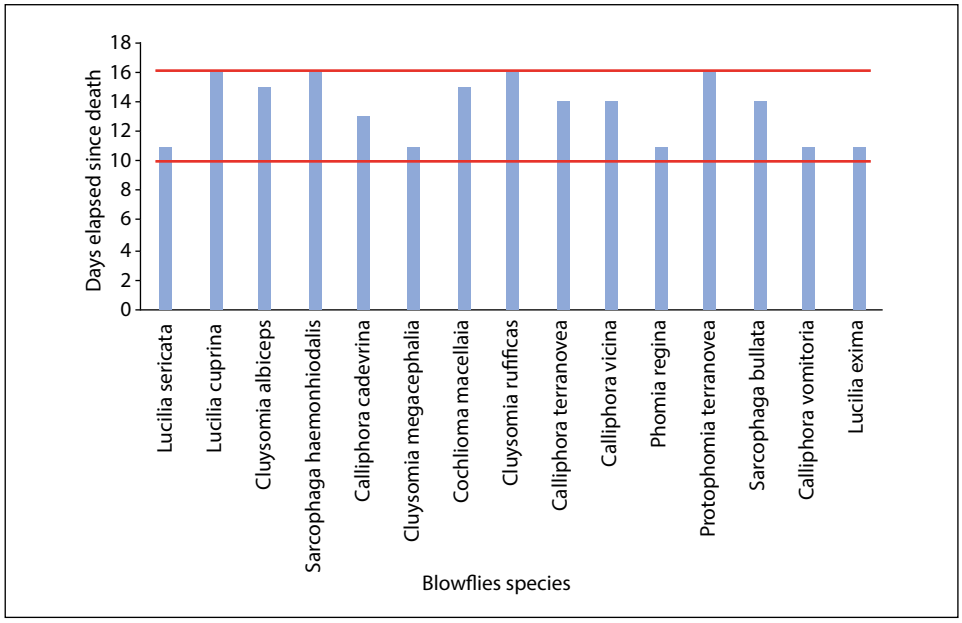

Figure 1. Days elapsed since death for the various species of blowflies; oviposition occurred between 10–16 days

is reasonable to infer that the victim likely died around October 19th, in contrast to the perpetrator's claim of October 9th. Considering the entomological evidence and the discrepancy in the timeline provided by the perpetrator, it is legitimate to question the second verdict of beating leading to death. The entomological analysis suggests a different time of death, which challenges the nature of the crime. The findings indicate that the victim survived for a significant period after losing consciousness, potentially altering the circumstances surrounding her demise.

Given the conflicting information and the significant implications for the case, further investigation is crucial. Collaborative efforts between forensic entomologists, pathologists, and law enforcement professionals should be initiated to reassess the evidence and testimonies, establish a more accurate timeline and uncover the truth behind the victim's death.

Table 3. Accumulated degree hours of blowflies' growth from 9–29/10/2012

Day	T	T0	T-T0	H	DH	ADH
28	27.5	10	17.48	23	402.04	402
27	21	10	11	24	264	666
26	21	10	11	24	264	930
25	21	10	11	24	264	1194
24	21	10	11	24	264	1458
23	21	10	11	24	264	1722
22	21	10	11	24	264	1986
21	21	10	11	24	264	2250
20	21	10	11	24	264	2514
19	21	10	11	24	264	2778
18	21	10	11	24	264	3042
17	21	10	11	24	264	3306
16	21	10	11	24	264	3570
15	21	10	11	24	264	3834
14	21	10	11	24	264	4098
13	21	10	11	24	264	4362
12	21	10	11	24	264	4626
11	21	10	11	24	264	4890
10	21	10	11	24	264	5154
9	21	10	11	24	264	5418

ADH — accumulated degree hours; DH — degree hours; H — hours of the day; T — temperature, T_0 — base temperature

Conclusions

The entomological analysis, combined with the research findings, challenges the claim of assault leading to death in the case under discussion. The discrepancy in the time of death, as revealed by the entomological analysis, calls for a comprehensive reevaluation of the evidence and testimonies. Continued collaboration between experts in the field and thorough investigations are necessary to ascertain the true circumstances surrounding the victim's demise and ensure justice is served.

Article information and declarations

Ethics statement: *This research article upholds rigorous ethical standards throughout its inception, execution, and reporting. Informed consent was obtained from all participants, ensuring their understanding and willingness to take part. Confidentiality, participant well-being, and data integrity were paramount, with steps taken to mitigate potential risks and biases. The study respects diversity, adheres to guidelines, acknowledges contributions, and remains open to feedback. Our commitment to ethical conduct underscores our dedication to responsible and respectful research advancement.*

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Conflict of interest: *The authors declare that there are no conflicts of interest that could influence the objectivity or integrity of the research and its findings. This includes any financial, personal, or professional relationships that might be perceived as potential sources of bias. The research was conducted independently, and the authors have no affiliations or interests that could undermine the credibility of the work presented in this article.*

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