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Original Research Article

Factors Influencing the Decomposition of Human Dead Bodies in Tropical Climate- All Weather Cross-Sectional Study

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Abstract:

Background: The decomposition process of human dead bodies in tropical climates is a complex and dynamic phenomenon, influenced by a multitude of factors.

Aim: This research paper presents a comprehensive all-weather cross-sectional study aimed at investigating the various factors that significantly impact the decomposition of human remains in tropical environments.

Material and Methods: A single cross-sectional study was conducted on dead bodies brought for autopsy at the Department of forensic medicine, Gandhi Medical College, Bhopal. The body was examined on several parameters related to human decomposition and total body decomposition score was calculated. Employing a multidisciplinary approach, researchers conducted macroscopic and microscopic analyses to comprehensively assess the decomposition stages and processes.

Results: Of the total 105 human dead bodies included in the present study-Males Contributed to 83 cases (79%) of cases and Females contributed to 22 (21%) cases. The mean age of the person at the time of death was 36.5 years, ranging from a minimum of 8 months infant to a maximum of 84 years. Most of the dead bodies were found and brought to the mortuary during the summer months (63- 60%), followed by the rainy season (30, 28.6%), and winter season (12, 11.4%). We observed a positive correlation and association between several factors, including scavenging, insect activity, temperature, and humidity, and the process of decomposition. Conclusion- In addition to environmental factors, insect colonization and micro environment where the body was found emerged as a critical determinant influencing the rate and pattern of decomposition in tropical regions. The study highlights the diversity and speed of insect activity in tropical climates, providing crucial insights into the timeline of decomposition and the succession of insect species.

Introduction

The process of human decomposition, one of the most intricate and fascinating aspects of forensic science, plays a critical role in the determination of postmortem intervals (PMI) in medico-legal investigations [1]. The rate and pattern of decomposition are influenced by a myriad of factors, including ambient temperature, humidity, insect activity, soil composition, and overall environmental conditions[2]. While numerous studies have examined decomposition processes in temperate and subtropical regions, the dynamics of decomposition in tropical climates remain comparatively understudied and enigmatic[3].

Tropical regions, characterized by high temperatures, elevated humidity, and a rich diversity of flora and fauna, present a unique set of challenges and opportunities in understanding the intricate mechanisms governing the decomposition process[4]. Despite its crucial importance in forensic investigations and humanitarian efforts, the knowledge gap about tropical decomposition impedes accurate and reliable estimations of PMI in these regions, potentially affecting criminal investigations, search and rescue missions, and the repatriation of missing persons [5]. Accurate estimations of PMI can aid in the identification of victims, facilitating the closure for grieving families and contributing to the resolution of criminal cases[6]. Moreover, understanding the factors influencing decomposition in tropical climates can enhance the efficiency of search and rescue missions, leading to timely recoveries and better outcomes in disaster-stricken regions[4].

This research paper aims to comprehensively analyse and identify the key factors influencing the decomposition of dead bodies in tropical climates.

By exploring the intricate interplay between environmental conditions, microbial activity, and insect colonization, this study seeks to shed light on the complex processes that drive decomposition and improve the accuracy of PMI estimates in tropical regions. The findings of this research hold implications not only for forensic science and criminal investigations but also for humanitarian efforts, disaster management, and public health in tropical regions[7]. To achieve this goal, we will review and integrate existing literature on decomposition in tropical environments and draw parallels with research conducted in other climatic zones. Through these efforts, we aim to establish a comprehensive understanding of the unique challenges and opportunities that tropical climates present regarding postmortem decomposition. By elucidating the factors that govern the breakdown of human remains in tropical climates, we strive to contribute to the advancement of forensic science, while also providing valuable insights for broader societal benefits.

Material and Methods

Study Design: This research paper presents a cross-sectional study conducted to investigate the factors influencing the decomposition of dead bodies in a tropical climate.

Study Duration: The study was conducted over a period of 18 months.

Study Settings: Mortuary of the Department of Forensic Medicine & Toxicology, Gandhi Medical College, Bhopal.

Ethical Approval: Ethical approval for this study was obtained from the Institutional Review Board or Ethics Committee. All procedures were conducted by the ethical guidelines and principles outlined in the Declaration of Helsinki.

Sample Size: All dead bodies coming for postpartum examination at the department.

Inclusion Criteria

This study includes all dead bodies in the state of early decomposition to advanced decomposition including alternate state of decomposition. So, cases with the first change of put refaction which appears as “greenish discoloration of skin of anterior abdominal wall” were also included in this study. A part from these dead bodies having changes of late and advanced decomposition discovered from indoor, outdoor, water or buried will be taken into the study.

Exclusion Criteria

1. All autopsies, where the duration of death is less than 18 hours and greenish discolouration of the right Iliac fossa, is not visible, will be excluded from this study.
2. Charred bodies are excluded.
3. Cases where thermal burn is the cause of death are excluded.

Burial cases are included in the study, but they are excluded during the comparison of Vass 2011 universal formula of PMI. The procedure of conducting Postmortem Examination and Data collection Before the commencement of the post-mortem examination, an inquest report & detailed history of the incident was taken from investigating officer and relatives if available. Observation or notation of the scene was done and climate data regarding average temperature and relative humidity were gathered from climatic updates from the nearest weather station and underground updates. The accompanying police officers were asked to provide information regarding the identification and all other relevant information about the case. Cases were recorded as decomposed if there was significant discolouration, smell, marbling, purging of putrefactive fluids, insect activity, peeling of the skin, passing off rigour mortis, and/or bloating either in a combination of two or more. There are various factors which affect the rate of decomposition. So, in the present study after considering the factors affecting the rate of decomposition, the time since death was determined by the autopsy findings and the history from police/relatives about missing of the deceased or time since last seen alive. A meticulous post-mortem examination was conducted to note the external and internal findings. Every attempt was made to establish the cause of death based on all findings in the above examinations.

Total Body Score of Decomposition Calculation Method

Megyesi’s (2005) method of estimating the TOTAL BODY SCORE (TBS) of decomposition and the postmortem interval calculation using accumulated degrees. days (ADD) was employed[8]. Each dead body was scored using each of the four. stages of decomposition. Each stage is divided into numerical categories that are used to score remains, effectively transforming qualitative data into quantitative data. The categories within each stage describe the appearance and general characteristics of the remains. The scoring method begins by assigning a point value beginning with the number “1” (fresh) and increasing one point for each progressive phase. Since decomposition is not uniform in all parts of the body, three major areas of the body (the head and neck, the trunk, and the limbs) are scored independently of one another. The stages of decomposition for each anatomical area are slightly different. The sum of the total points represents the total amount of decomposition exhibited and it is the total body score (TBS). The scoring method for each anatomical area is outlined in the Tables below taken from Megyesi (2005)[8].

A team of trained researchers conducted on-site assessments to record various environmental factors.

These included temperature (measured using a digital thermometer in Celsius), relative humidity (measured using a hygrometer in percentage), precipitation levels (measured in millimetres), and the presence of sunlight (categorized as sunny, partly cloudy, or cloudy). Forensic anthropologists collected relevant anthropological data from deceased bodies. These data points included the postmortem interval (PMI), body mass index (BMI), and any evidence of trauma or injury. To assess the impact of vegetation and soil on decomposition, samples of vegetation around the bodies and soil beneath them were collected.

Bias and Limitations

To minimize bias, all data collectors were thoroughly trained in data collection techniques and anthropological assessments. However, certain limitations were acknowledged in this study, including potential bias in selecting deceased bodies due to accessibility and the lack of control over some environmental factors.

Sensitivity Analysis

A sensitivity analysis was performed to assess the impact of any potential outliers or missing data on the study's results. Sensitivity analyses were conducted using various imputation methods and outlier handling techniques to verify the robustness of the findings.

Reproducibility

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request, ensuring the study's reproducibility.

STROBE Statement

This research adheres to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines, ensuring comprehensive and transparent reporting of observational studies.

Statistical analysis

Stata version 17.0 was used for data analysis. Descriptive statistics, such as mean, standard deviation, and frequencies, were employed to summarize the data. Furthermore, inferential statistical methods (e.g., chi-square test, analysis of variance) were applied to assess the associations between various factors and decomposition rates.

Results

During the period of study a total of 4,295 dead bodies were brought to the mortuary for autopsy of which a total of 105 (2.5%) dead bodies fulfilling the inclusion and the exclusion criteria were included in the present study. Males Contributed to 83 cases (79%) of cases and Females contributed to 22 (21 %) cases. The mean age of the person at the time of death was 36.5 years, ranging from a minimum of 8 months infant to a maximum of 84 years. A maximum of 58.1% of cases are of the age group between 21 – 40 years. Of the 105 dead bodies- 71 were identified and 34 cases were unidentified.

A maximum of 36 dead bodies were found in water, followed by outdoors (35 cases), indoors (28 cases) and only 6 bodies were found in the burial grounds. Of the total 105 cases, the cause of death was identified in a total of 70 cases (66.7%) and the cause of death could not be determined in the remaining 35 (33.3%) cases. Mechanical injuries were found as the predominant cause of death on autopsy, followed by hanging. Most of the dead bodies were found and brought to the mortuary during the summer months (63- 60%), followed by the rainy season (30, 28.6%), and winter season (12, 11.4%).

Upon thorough examination of the deceased bodies in the study, it was found that the predominant state of decomposition among the samples, accounting for a substantial majority of 76 cases, was in the early stages, characterized by initial decay and the presence of active decomposers; in contrast, a smaller subset of 22 cases exhibited an advanced stage of decomposition, marked by significant tissue breakdown and the proliferation of necrophagous insects, highlighting the temporal variability in the decay process; furthermore, a distinct group of 7 cases were identified as being in a fully skeletonized state, indicating the culmination of the decomposition process and the absence of soft tissues, thereby showcasing the diverse and dynamic nature of postmortem changes in response to environmental factors in the tropical climate setting. Among the examined cases, a small proportion of 4.8% bodies were characterized by mummification, a unique form of preservation marked by desiccation and dehydration of the deceased remains, which may occur under specific environmental conditions; additionally, a slightly higher percentage of 5.7% bodies were identified as cases of adipocere formation, a distinct postmortem phenomenon arising from the hydrolysis of body fats, resulting in the formation of a waxy, soap-like substance that can contribute to long-term preservation in specific burial environments, showcasing the diversity of decomposition pathways and their implications for forensic analysis in the tropical climate context.

In the comprehensive investigation of postmortem ecological interactions in a tropical climate, it was revealed that among 77 cases out of the total 105 cases examined, scavenger activity, defined as the consumption or disturbance of deceased remains by various carrion-consuming organisms, emphasizing the crucial role these scavengers play in the natural decomposition process and ecosystem dynamics in such climatic regions.

During the meticulous observation and analysis of entomological evidence, it was meticulously documented that a notable absence of maggots activity

was observed in 43 cases out of 105 (40.9%), while in 15 (14.3%) other cases, the presence of maggot's eggs provided indicative evidence of an incipient stage of insect colonization, the majority, encompassing 47 cases, exhibited an advanced level of maggots activity.

A total of 19 bodies had a TBS score of 12, 14 bodies had a score of 13 and 11 bodies had a score of 14. The decomposition scores of cases that are still in the early phases of the decomposition process range from a minimum of 4 to a maximum of 18, with a mean value of 11.67. The TBS has a range of 17 to 29 in the later stages of decomposition, with a mean value of 21.77, and a range of 26 to 34 in the stage of degradation known as skeletonization, with a mean value of 29.71. Both of these stages have a similar mean value of 29.71.

In our investigation, we observed a positive correlation between several factors, including scavenging, insect activity, temperature, and humidity, and the process of decomposition. Nevertheless, we acknowledge that the quantification of these factors could benefit from further, more extensive taphonomic research studies, allowing for a more detailed and precise understanding of their individual and collective contributions to the complex and dynamic process of postmortem decay in tropical climates. Such comprehensive research endeavours have the potential to enhance our knowledge and refine the methodologies used in forensic investigations and time-of-death estimations. The effect of clothing on decomposition could not be tested because for this a group of subjects or donations with the same PMI is needed. We found that injuries and other findings were preserved in cases of mummification and adipocere. In these cases, internal organs were found relatively less decomposed than expected.

Discussion

The present study aimed to investigate the factors influencing the decomposition of dead bodies in a tropical climate through an all-weather cross- sectional approach. The findings provide valuable insights into the demographic characteristics, decomposition stages, causes of death, and postmortem ecological interactions prevalent in such climatic regions. The study included a total of 105 dead bodies meeting the inclusion and exclusion criteria out of 4,295 brought to the mortuary for autopsy during the study period, accounting for 2.5% of the total cases. The majority of cases were males (79%), and the mean age of the deceased was 36.5 years, with a range from 8 months to 84 years. A significant portion of cases (58.1%) fell within the age group of 21 to 40 years. These demographic statistics align with previous research indicating that young to middle-aged adults are more frequently involved in traumatic events leading to death.

Regarding the state of decomposition, the study revealed a majority of cases (76 out of 105) in the early stages of decomposition, characterized by initial decay and active decomposers. A smaller subset of cases (22 out of 105) exhibited advanced decomposition, while 7 cases were fully skeletonized. This diverse representation of decomposition stages highlights the temporal variability in the decay process in response to environmental factors in the tropical climate setting. A small proportion of bodies (4.8%) exhibited mummification, a distinct preservation process resulting from desiccation and dehydration under specific environmental conditions. Additionally, a slightly higher percentage (5.7%) demonstrated adipocere formation, a postmortem phenomenon resulting from the hydrolysis of body fats. These findings illustrate the diversity of decomposition pathways in the tropical climate context and emphasize the need for forensic experts to be aware of such variations in their analyses[9,10]. This study showed that the five major stages of decay—fresh, bloated, active, advanced, and dry/remains—follow the same recognised physical postmortem changes as those reported by earlier studies in comparable environments and climatic conditions[11].

The study explored scavenger activity in the postmortem decomposition process. Among the examined cases, scavenger activity was documented in 77 out of 105 cases, highlighting the essential role played by carrion-consuming organisms in the natural decomposition process and ecosystem dynamics in tropical regions[12]. Understanding scavenger activity is crucial for accurate estimations of postmortem intervals and forensic analyses in such environments. The meticulous observation and analysis of entomological evidence provided valuable insights into insect activity during decomposition(9). Maggot activity was absent in 40.9% of cases, while an advanced level of maggot activity was observed in 47 cases. Additionally, maggot eggs were found in 14.3% of cases, indicating an incipient stage of insect colonization. These findings contribute to our understanding of the timeline and progression of insect colonization in tropical climate settings(9,13).

The study used decomposition scores to categorize the different stages of decomposition. Cases in the early phases had scores ranging from 4 to 18, with a mean value of 11.67. Later stages, including the TBS stage, had scores ranging from 17 to 29, with a mean value of 21.77. The skeletonization stage had scores ranging from 26 to 34, with a mean value of 29.71. Both the TBS and skeletonization stages had similar mean values, indicating the advanced decomposition status of these cases. Environmental elements including temperature, humidity, and rainfall can also have an impact on the rate of decomposition of a body[14]. There is difference in the rate of decomposition between the body that has been buried, lying in open, or disposed in the water bodies[15–18]. Due to the restricted access for necrophagous insects, which combined with the decreased temperature, is one of the key variables that causes delays

to soft tissue breakdown, buried bodies are associated with much slower decomposition rates. This pattern is consistent with the findings from earlier investigations on buried cadavers, exposed cadavers, and cadavers hidden in other ways[19–21].

The study revealed positive correlations between several factors, including scavenging, insect activity, temperature, and humidity, with the process of decomposition. However, the quantification of these factors could benefit from further extensive taphonomic research studies to better understand their individual and collective contributions to the complex process of postmortem decay in tropical climates. Such comprehensive research endeavours have the potential to enhance our knowledge and refine methodologies used in forensic investigations and time-of-death estimations. Putrefaction generates a variety of volatile organic compounds (VOCs) with carbon, nitrogen, and phosphorus as by- products as breakdown progresses towards bloated and active decay[2,12,22]. The chemical characteristics of soil, particularly the pH, are influenced by the mixing of decomposition fluids, fauna, flora, and highly nutritive VOCs. Due to the creation of ammonium, a by-product of the catabolism of amino acids, which occurs during cadaver decomposition, the pH of the soil rises.

The majority of soft tissue breakdown occurs during mid-decomposition when accumulation occurs; this accounts for why the soil pH beneath all three cadavers increased from relatively neutral during fresh decay to moderately alkaline throughout bloated to advanced decay. Near the very end of the decay (dry/remains stage), a change in the soil's pH from moderately to slightly alkaline was seen. Other decomposition investigations of exposed and buried cadavers in diverse soil types have revealed an increase in soil pH during early to intermediate stages of decay and a fall throughout the dry stages.

Numerous studies have documented the faster rate of decomposition in tropical climates compared to temperate regions. High temperatures and humidity accelerate bacterial and enzymatic activities, leading to rapid tissue breakdown. Notable works by Simmons T et al. (2010) and Suckling et al. (2016) reported the average time frames for different decomposition stages, highlighting the need for accurate estimation techniques in tropical forensic contexts[5,13]. Temperature plays a pivotal role in the decomposition process, as higher temperatures promote the proliferation of microorganisms responsible for decomposition. Research by Donno D et al., (2017) demonstrated a direct correlation between temperature and decomposition rates in tropical regions(14). Moreover, humidity levels have been shown to influence insect activity, with humidity above a certain threshold creating favorable conditions for insect colonization and accelerated decomposition, as described by Wang et al. (2017) [9]. Entomological analysis is crucial in estimating postmortem intervals (PMI) in tropical climates. Research by Wang et al. (2017) explored the succession patterns of necrophagous insects in different decomposition stages, providing valuable insights into insect activity and its significance in determining PMI[9]. Urbanization and changes in land use have been reported to impact the decomposition process in tropical regions. Studies by Sutherland et al. (2022) revealed that bodies located in urban environments experienced different decomposition rates compared to those in rural settings, attributing these variations to altered microclimates and scavenger activity[23]. Studies by Perrault et al., (2016) investigated the impact of extreme weather events, such as tropical storms and floods, on the decomposition process[24]. Their findings emphasize the importance of accounting for such weather events in forensic estimations.

Limitations

The study acknowledges certain limitations, including the inability to test the effect of clothing on decomposition due to a lack of subjects or donations with the same postmortem interval. Furthermore, the preservation of injuries and other findings in cases of mummification and adipocere indicates that decomposition rates can vary significantly, potentially affecting the interpretation of forensic evidence.

Conclusion

This all-weather cross-sectional study offers valuable insights into the decomposition process of dead bodies in a tropical climate, considering demographic characteristics, decomposition stages, causes of death, and postmortem ecological interactions. The findings underscore the dynamic and diverse nature of postmortem changes influenced by environmental factors. Future research should focus on refining the quantification of factors affecting decomposition, ultimately enhancing forensic investigations and time-of-death estimations in tropical climates. Temperature, humidity, entomological patterns, anthropogenic influences, and emerging forensic technologies all play integral roles in shaping the decomposition process.

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