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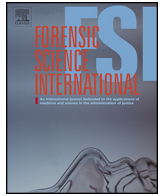
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Amsterdam Research Initiative for Sub-surface Taphonomy and Anthropology (ARISTA) - A taphonomic research facility in the Netherlands for the study of human remains



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ABSTRACT

A taphonomic research facility for the study of human remains was recently realized in Amsterdam, the Netherlands, to systematically investigate the decomposition of the human body under known conditions. Governmental authorization was obtained to make use of the body donation program of the Amsterdam University Medical Centers, location Academic Medical Center, for this specific purpose. In contrast to the small number of comparable initiatives elsewhere, this facility specifically allows for the study of buried bodies e.g. with the use of telemetry and remote sensing. Here, we discuss the concept of body donation in the Netherlands, its role in taphonomic research, and the sequence of events that preceded the realization of this facility, which is the first of its kind in Europe. In addition to offering novel research options to the scientific community, we hope that it will also pave the way for the successful realization of similar initiatives in other locations.

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1. Introduction

Over the past decades, forensic science has evolved from a niche discipline into a global and multidisciplinary scientific field of broad societal impact. This is true both of its role in daily forensic case work as well as in the translation of established and novel scientific methods into forensic practice. Consequently, the needs and challenges encountered in forensic practice have ignited and accelerated new research projects within varied scientific disciplines. For example, questions arising from forensic case work (e.g. the time since death or the identification of discovered human remains) have highlighted the need for detailed research in the field of taphonomy, *i.e.* the study of how decay and deposition alter organic remains. As an auxiliary discipline to paleontology, taphonomy was originally focused on the study of the transition of animal remains from the biosphere to the lithosphere, in order to understand the composition of the fossil record. As a result, the Russian scientist Ivan Efremov defined taphonomy as 'the science of the laws of embedding' [1]. These taphonomic concepts were later integrated within the fields of archaeology and paleoanthropology, specifically for the study of cultural and natural site formation processes (e.g. [2]). Around the turn of the 21st century, forensic anthropologists and archaeologists introduced this knowledge in forensic science where its use serves three primary objectives: (i) to understand how a crime scene may have been altered by taphonomic agents, (ii) to reconstruct the activities that took place at the crime scene and (iii) to estimate the postmortem interval (PMI) in cases of alleged homicide (e.g. [3]).

In order to address these questions reliably, the taphonomic processes involved in the decay of recently deceased humans must be studied systematically. It is therefore insufficient, and in many countries even legally prohibited, to make use of forensic case work for such research purposes. Consequently, there is an urgent need for research facilities enabling the extensive and comprehensive study of the effects of decomposition on recently deceased human bodies under known conditions. This, in turn, renders an instituted body donation program (BDP) an essential prerequisite. Although most countries have legislation that allows the donation of human bodies to science through public or private programs, the purpose of these donations almost exclusively pertains to medical research and training. As a result, forensic scientists usually turn to animal cadavers as an alternative resource of organic remains for taphonomic studies. Thus far, initiatives to raise a taphonomic research facility using donated *human* bodies have been successful only in a small number of countries, including the United States [4,5] and Australia [6,7].² In this paper, we describe the realization of the first, and presently the only, European taphonomic research facility using human remains, located in Amsterdam, the Netherlands (hereafter referred to as human taphonomic research facility (HTRF))³.

2. Studying decomposition: human vs. non-human (animal) bodies

The decomposition of a vertebrate organism, from a fresh corpse to its complete skeletonization, is a complex process. While most of the separate (intrinsic and extrinsic) variables in this process have been identified, their timing and interdependency

generate an almost infinite number of possible taphonomic trajectories (e.g. [8]). Particularly the (reciprocal) response to known and unknown biological, meteorological, pedological, soil hydrological and geographical variables allows for a multitude of distinct interactions and hence case-specific decomposition patterns. Consequently, the systematic study of these patterns requires some standardization of the decomposing remains. As animal subjects can be standardized to a much higher degree than human subjects, the question whether animal bodies are preferable over human bodies for taphonomic studies has been debated extensively [7,9–12] since the creation of the first HTRF in 1981 [13]. Important characteristics which are more easily standardized for animal subjects include age, sex, stature, body weight, body integrity and, especially in contrast to humans, provenance, nurture, diet, medical history, treatments, intoxications as well as the cause and manner of death. All of these characteristics may have a profound influence on the individual's microbiome (reviewed by [14–16]) and thus on the decomposition processes of its corpse (reviewed by [17]). Moreover, animal subjects are more readily available (also in large numbers).

Notwithstanding, several aspects of organic decomposition research necessitate the use of human remains. While animals are frequently used as an alternative for human bodies in a variety of scientific studies, research comparing human and non-human models in taphonomic research has demonstrated that there are significant differences between the two species in this context [7,18–20] including the profile of volatile organic compounds (VOCs) released during decomposition (e.g. [21]). Moreover, as individual conditions, such as medication, intoxications and their post mortem metabolites may be major contributors to distinct decomposition patterns, they should form the topic of specific *human* taphonomic research. An increased understanding of the potential impact of these variables on decomposition rates is vital in improving the determination of the cause and manner of death of human remains in forensic casework. Finally, the results of taphonomic research performed with animals should be validated with human bodies in order to be applicable to forensic case work.

3. Body donation and its legal aspects in the Netherlands

The Dutch Burial and Cremation Act ('Wet op de Lijkbezorging', WLB) describes three possible final destinations of human remains: burial, cremation and donation to science (art. 1 and 67), each of which requires a specific certificate to be issued by the local authorities upon death. For donation to science this corresponds to a certificate for dissection, which requires hand written consent from the concerned individuals prior to their death. This WLB certificate for body donation can also be obtained by proxy (*i.e.* by the spouse, a first or higher degree (blood) relative, or a legal representative) after the death of the concerned individual. However, most medical schools are reluctant to accept such donations unless the intentions of the donor can be verified beyond reasonable doubt (despite the absence of written consent).

Each of the eight Dutch universities that house a medical school have their own body donation program (BDP). The size of these BDPs varies from 2000 to 6000 registrations, which corresponds to 70 to 200 donations annually. Unlike BDPs in other countries [22,23], medical schools in the Netherlands have not experienced any shortage of donations over the last decades, meeting the demands imposed by their (bio)medical research and teaching programs. Indeed, most medical schools use periodical or permanent registration restrictions to keep the number of donations on a par with their demands. The WLB states that with its donation to science, a body arrives at its final destination; accordingly, the concerned bodies cease to be corpses, in the legal sense of the word, as soon as they have reached this destination.

² An exception to the above-mentioned is the use of human remains to train cadaver dogs by law enforcement officials; a practice that is allowed and accepted in several countries, but that is not in itself scientific in nature as it does not aim to elucidate underlying decomposition patterns and mechanisms.

³ Concurring with others (e.g. Black, 2017; Blau, 2017) the authors discourage the use of the term 'body farm' to denote an HTRF, as it is colloquial, distasteful and disrespectful towards body donors and their relatives.

Consequently, the WLB does not stipulate any further actions for such bodies, once they have served the purpose they were donated for. The general procedure among medical schools is to have the remains cremated. As with all costs involved in body donation, this is at the expense of the BDP.

The BDP of the medical school of the University of Amsterdam (UvA), housed in the Amsterdam University Medical Centers- location Academic Medical Center (AMC), is directed by the department of Medical Biology. With 6000 registrations in a 100 km radius around Amsterdam and 200 annual donations, this is one of the larger BDPs in the Netherlands. In this program, the bodies of deceased donors are collected by the mortician within 24 hours after death and delivered at the morgue of the department. While most donated bodies are conventionally embalmed to be used for dissection courses in the bachelor curriculum of the medical school and for demonstration courses in various (bio/para)medical curricula, an increasing number of bodies are not embalmed, but instead stored frozen for surgical trainings and simulation purposes. To enhance their value for research and education, a full body high resolution CT scan is recorded of all donations. In accordance with the policy of the AMC's medical ethical committee, requests concerning bodies, body parts, organs or tissues for specific research and educational purposes are evaluated and assessed regarding their academic and ethical merits by the department's staff prior to granting.

4. Building an HTRF: exploration phase

The possibilities of creating an outdoor HTRF in the Netherlands, using the BDP of the AMC, were first explored in 2010, following the advent of a master's program of forensic science at the UvA and the first initiatives to establish a Dutch forensic research community. The main focus of this exploration was the divergence between the WLB's legal phrasing of the certificate of *dissection* required to donate a body to science and the intended purpose of its use within a HTRF, namely *decomposition*.

Fortunately, in April 2013, the governmental departments involved in enforcing the WLB, being the Ministries of the Interior and Kingdom Relations, of Security and Justice, and of Health, Welfare and Sports argued that 'donation to science' in principal includes all legally and ethically approved scientific purposes which utilize (parts of) deceased human bodies. The WLB was designed in the early 1950s, when decomposition research pertaining to human bodies was non-existing and hence not taken into consideration. It was therefore reasoned that as long as this type of research is carried out within a legal framework, the discrepancy between dissection and decomposition as phrased in the WLB is of purely semantic nature. However, since decomposition (as a topic to be studied) differs profoundly from the conventional purposes for which individuals donate their bodies, it was decided that (potential) donors should be given the opportunity to opt out of any taphonomic studies during the registration procedure. As it turned out, hardly any donors, including those that were previously registered and re-contacted since early 2014, objected to the taphonomic use of their bodies. Given the pragmatic and altruistic motives underlying most of the donations, this did not come as a surprise.

From 2011 onward, efforts were made to find a suitable location for the HTRF, preferably in the direct vicinity of the responsible institute (AMC). This preference served to ensure ease of access to the BDP's morgue, technical assistance and facilities. To this end, a proposal was drafted and presented to the AMC's board of directors, who subsequently expressed support for the project. As a result, around 500 square meters of unused land in the periphery of the hospital's private terrain were allocated for this project (Fig. 1) in collaboration with the local housing department. This land was then included in the assignment and zoning plan of the AMC, which was due for re-evaluation by the Amsterdam city council in 2014, who approved it a year later. As the area surrounding the AMC is densely populated, the board of directors precluded on-surface decomposition studies and agreed exclusively to subterranean decomposition studies to prevent nuisance to nearby residents and offices.



Fig. 1. Map (Google Earth) of the south east of Amsterdam with the location of the plot assigned to the HTRF (yellow circle) on the AMC territory (yellow polygon).

While the authorities involved were requested to treat all information regarding the project as confidential, a passive communication plan was designed in anticipation of potential leakage to the media. In January 2017, this was transformed into an active communication plan and a press release was issued after the final permit for the construction of the HTRF was obtained from the local environmental authority. In the days following the press release, various local and national news outlets, and in the ensuing weeks and months, several international newspapers, magazines and scientific journals [24] reported on the planned HTRF. Without

exception, the plan was received positively by both the general public as well as the scientific community.

5. Building an HTRF: design and realization phase

The AMC is situated in the southeastern part of Amsterdam and built on land which was reclaimed from peaty wetlands, moors and lakes. From the early 1600s onward, this part of the province of North-Holland, near the border with Utrecht (Amstelland), was drained with mills. It was then filled, mainly with sandy and peaty



Fig. 2. A: Detail of the map in Fig. 1, including a magnification (inlay), showing the facility and the location of the data logging hubs (orange squares), the ground water wells (purple dots), the weather station (light blue dot), the first two pits (yellow rectangles), the wires from the pits to the hubs (dark blue dotted lines) and from the hubs to the hardware in the shed (red lines). The shed is in the south west corner. B, C: Pictures of ARISTA during the first inhumation, in the northwest corner of the field. The data logging hub in the foreground carries a weather station. The pipeline along the north and west walls carries the wiring from the hubs to the hardware in the shed.

soil won from the bottom of nearby existing and recreated lakes, in particular the Gaasperplas. As a result, the top layer of the terrain assigned for the HTRF, which is 4 m below sea level, consists of at least 1 m of a homogenous blend of various sand types and some peat, covered with 10–20 cm of humus-rich topsoil. The groundwater table fluctuates around 70 cm and is slightly tilted downward in the northwesterly direction.

The surface of this terrain was levelled for the purpose of inhumations by removing any larger-sized heaps of soil without disturbing the top layers, and stripped from larger-sized vegetation, such as birches and bramble. To retain its original state as much as possible, the remainder of the vegetation was kept *in situ*. A plot of 32 m by 18 m was demarcated on the terrain and enclosed with a fence, extending 3 m above and 1 m in the ground, to avert unauthorized people and larger animals, such as rabbits, hares, foxes and dogs. This plot can accommodate 30–50 graves and control pits, depending on their mutual distance. A data logging system (Sweco Nederland B.V.), which covers the west half of the terrain, was installed for continuous telemetric registration of temperature, humidity and other physical parameters in the graves and control pits. The registration of these data is coupled to that of simultaneous non-taphonomic ambient data retrieved from a weather station and two ground water gauges that measure the water table and temperature. All data can be digitally retrieved through a web-based platform (Sweco Nederland B.V.). Baseline measurements were taken for future reference, which include an inventory of the native vegetation and samples of the soil and groundwater. Subsurface (in)homogeneity was determined using ground penetrating radar (GPR) and ground conductivity and validated with soil profiles retrieved by hand using an auger. A shed, comprising bench space, storage rooms, a refrigerator and a freezer for sample storage, and modest sanitation was placed in the southwest corner of the terrain; this shed also houses the data logging hardware (Fig. 2A, B). Mounted on the shed is a camera from which time lapse videos of the field can be obtained.

6. First inhumation and official opening of ARISTA

The first inhumation took place on the 20th of March, 2018. This inhumation served to test the logistical and operational workflows and as a reference for future inhumations. Two pits were dug in the northwest corner of the terrain (Fig. 2C), which were circa 2 m long, 80 cm wide and 60 cm deep. The first pit was allocated to a recently deceased donor, whose body was stored at 4 °C for several days prior to its burial. The second pit was dug for reference purposes and was kept empty except for the presence of a temperature probe and a humidity probe. Both pits were flat-bottomed and leveled to keep the distribution and dispersion of the decomposition fluids equal throughout the whole pit. The specific location of these two pits on the terrain correlates with the lowest level of the tilted ground water table, thus preventing taphonomic contamination of nearby locations for prospective graves. The body was buried naked in a supine position together with three temperature probes, one placed rectally, the other two below and on top of the body. A humidity probe was placed near the side of the body to register the ambient humidity of the soil at the level of the buried body. Once the data logging system was confirmed to be operational, the pits were closed. Both pits were documented, before, during and after the inhumation, by means of a Faro Focus 3D scanner. The whole procedure, which was completed within 6 hours, was covered by national television. On the 24th of November, 2018, during the anniversary symposium of the Dutch Society for Physical Anthropology, the facility, which was named Amsterdam Research Initiative for Sub-surface Taphonomy and Anthropology (ARISTA), was officially opened.

7. Present and future perspectives: opportunities and limitations

The current setting at ARISTA, in which bodies are buried in shallow graves, resembles the common *modus operandi* of criminals in the Netherlands to conceal their victims' bodies [25] and is therefore useful for forensic training and simulation purposes. ARISTA's strategy is to focus taphonomic research activity on remote and telemetric sensing, minimally invasive sampling and partial or full archaeological excavation. Remote sensing, including the use of GPR, spectral imaging, and the monitoring of on-surface insect activity, preserves the integrity of the taphonomic processes within the graves, since it does not involve direct access of the buried body and its immediate environment. Consequently, use of such methods can be repeated indefinitely. The placement of telemetric devices, such as temperature and humidity sensors, in and around the body could theoretically influence the decomposition processes, for example due to contact between the decomposing body and the wired connection to aboveground data logging systems. Minimally invasive sampling options range from measuring VOCs, either on-surface or in contact with the body, to temporary exposure of body parts for obtaining tissue biopsies. These, however, will inevitably influence the decomposition process, just as any partial or full archaeological excavation.

At present, five graves are in use at ARISTA for various (international) research projects, which involve all of the previously mentioned types of research. The authors would like to stress that this HTRF was established as a facility with the aim of serving the national and international forensic and taphonomic research communities. ARISTA therefore welcomes all requests for accommodating scientific projects, trainings and simulations that involve human belowground decomposition. To optimize the utility and translatability of such proposed taphonomic research for forensic practice, we consider it mandatory for prospective studies to be carried out according to standardized protocols. Importantly, such protocols also enable the replication of these studies at other locations, by identifying and accounting for confounding factors such as local differences in geography, ecology, weather conditions and in the individual characteristics of the donated bodies.

Finally, the experiences gained from the realization of extant HTRFs should be capitalized on in the development of new initiatives worldwide. Reflecting on the process that led to the realization of ARISTA, all involved authorities, both local and national, were cooperative but were faced with requests that they had never been confronted with before, causing delays in reaching decisions. Since these authorities had to be consulted in successive order, these delays accumulated, which resulted in a total duration of more than seven years. However, now that a precedent of realizing an HTRF in the Netherlands has been established, it is to be expected that the processing for subsequent Dutch initiatives will be expedited.

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CRediT authorship contribution statement

Roelof-Jan Oostra: Conceptualization, Funding acquisition, Writing - original draft, Supervision. **Tamara Gelderman:** Writing - original draft. **W.J. Mike Groen:** Conceptualization, Writing - review & editing. **H. Gepke Uiterdijk:** Conceptualization, Project

administration, Funding acquisition, Writing - review & editing. **Erik L.H. Cammeraat:** Methodology, Writing - review & editing. **Tristan Krap:** Methodology, Writing - review & editing. **Leah S. Willk:** Writing - review & editing. **Mark Lüschen:** Methodology, Writing - review & editing. **W. Elly Morriën:** Methodology, Writing - review & editing. **Frans Wobben:** Resources, Writing - review & editing. **Wilma L.J.M. Duijst:** Conceptualization, Writing - review & editing. **Maurice C.G. Aalders:** Conceptualization, Methodology, Writing - review & editing, Supervision.

Declaration of Competing Interest

None.

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