# Chemical Fingerprinting of Human Body Odor: An Overview of Previous Studies

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**ABSTRACT**: Analysis of human skin emanations has been growing of the past few years, so that it can be utilized more effectively in the cosmetic field, canine training and criminal investigation. The volatile organic compounds (VOC) present in the head space of human body odor, either by presence or by difference in abundance, leads to the uniqueness of each individual. A few theories regarding the production of human scent and its characteristics have also been explored in this paper. Human scent can be categorized into three components namely primary odor, secondary odor and tertiary odor, where primary odor forms the basis of individual identification. Human scent is persistent, chemically stable and has low or moderate vapor pressure. This review highlights the previous studies that have been done in the past years, to sample and to analyze the combination of VOCs present in human odor. Studies have been conducted using variety of sample collection methods like solid phase micro extraction (SPME) of the gauze pad containing scent material and stir bar sorptive extraction and so on. The transfer of the scent material onto a gauze pad also has been done by various means. It has been done by direct contact with the skin or evidence articles, using Scent Transfer Unit (STU), or by swiping the surface containing the scent with the gauze pad. The subsequent analysis of the extracted scent compounds were done mostly using separation technology using the gas chromatography coupled with mass spectrometer. Some studies have also done the study using electronic nose. All the analytical studies indicate that human scent analysis is a viable method that can be used to identify human.

**Keywords:** body odor, individualization, volatile organic compounds

## Introduction

Human identification system is a very important or rather the most crucial part of forensic science. The main purpose of forensic science is to establish the link between the crime, the crime scene, the victim and the perpetrator so that the suspect can be tried in the court of law and convicted successfully to the crime that he has committed [1].

Several types of human identification system have been used through the course of evolution in forensic science. Bertillon system of measuring the human physical attributes, fingerprint analysis and deoxyribonucleic acid (DNA) typing has already been used but each with its own limitations [2].

It is postulated that the human scent is a complex combination of various volatile organic compound (VOC) produced by the human skin which can be collected and measured to produce an individualizing chemical fingerprint. A variety of sampling and analytical combination of method has been tested to separate and quantify the chemical fingerprint of a human. The characteristics and the previous researches done are further elaborated in this paper.

### *Human Integumentary System and the Distribution of Sweat Glands in the Body*

Human skin can be divided into two parts, which is epidermis and dermis. Epidermis is made up of stratified epithelium which becomes flattened as they rise to the surface. The dermis consists of dense connective tissue rich with blood vessels, connective tissues and nerves. The skin has a few appendages like nails, hair follicles, sebaceous glands and sweat glands [3].

Sebaceous glands are simple or compound alveolar glands that produce an oily white substance which is rich lipids. The sebum is secreted onto the skin surface and hair via a duct. A few sebaceous glands open directly onto skin surface in parts such as lips, eyelids

and genitalia. Although the sebaceous glands does not cover the whole body, for example, parts like palms and soles of the feet, the sebum can be found all over the body because of its rapid flow [4].

Sebum is liquid at body temperature, and solid at room temperature. The chemical combination of the sebum is very complex mixture of free and combined fatty acids, wax alcohols, sterols, terpenoids and hydrocarbons with compounds of relatively high weight predominating. The replacement of sebum on the skin occurs very rapidly and it flows over wet skin in about 1.3 inches per second [4].

The subcutaneous layer which lies beneath the dermis consists of loose connective tissues and adipose tissues. It functions to attach dermis to the underlying tissues. This layer also contains two types of glands that are sweat (sudoriferous) glands and ceruminous glands (in the external ear). The secretions of these glands are passed to the skin surface via duct that lie longitudinally along the dermis and epidermis [5].

Sweat or perspiration, is a mixture of water, salts and products of metabolism. Example of products of metabolism is urea, uric acid, amino acids, ammonia and lactic acid. There two types of sweat glands, apocrine and eccrine sweat glands. Apocrine sweat glands are found in the skin of the armpit (axillae), pubic areas and the areolar areas of the breast. It produces viscous secretions that contain fatty acids which serve as the metabolizing substrate by microorganism and thus producing odor [5]. Apocrine sweat also contains pheromones, particularly those that are sexual attractants [6].

The eccrine sweat gland, most common type of gland present in the skin especially in the palm and soles of feet however absent from the margin of lips, the labia minora and the tips of the penis clitoris. The eccrine sweat contains isotonic fluid that is mostly water but contains some salt (mainly sodium chloride) and small amount of ammonia, urea, uric acid and lactic acid. This sweat is reduced copiously to reduce body temperature and as a result of emotional stress [5].
Other glands that are present on the skin are ceruminous glands and the mammary glands. The ceruminous glands are modified eccrine sweat glands located in the ear canal. Ceruman, or ear wax is composed of both ceruminous and sebaceous secretions. The mammary glands, on the other hand are modified apocrine sweat glands located in the breast that functions to produce milk [5].

***Body Odor and its Use in Forensic Investigation***

The human body odor or human scent has been established to be unique to an individual since a very long time ago through the use of canine [7]. However, the use of canine is not a purely scientific method and it relies heavily on the capability of the dog being used. The method is subjective to the different perception of the human scent by the dog. Although canine is widely used for scent trailing, there are a few disadvantages to the method. The disadvantages of canine scent trailing is that it requires immense training and it has been found that the performance of the canine decreases in hot and humid climate. The danger of contaminating the evidence when the dog is allowed to sniff is also present when using this method [8].

Thus the same concept of identifying individuals based on their body scent can be applied but using a scientific instrument as the detector rather than a canine. Before studying how the human scent can be electronically defined, it is important to understand the characteristic of human scent and the underlying mechanism of the scent production.

***Characteristics of human scent***

*Three categories of human scent*

Throughout the last decade, researches have been conducted to determine the chemical composition of body odor. The volatile organic compound from the headspace of the scent collected has been analyzed using various chemical detection instruments. Body odor of an individual can be determined by several factors that are either stable over long period of time or factors which are influenced by environmental, diet and cosmetic applications. There are three groups of body odor types.

The first group is the primary odor [9]. The primary odor is resultant of the genetic makeup of person. Research has been conducted to study the connection between major histocompatibility complex (MHC) genes and an individual's odor signature. It is well established that the MHC gene somehow affect the production of body odor in several vertebrates including humans. A study also

suggests that there could be a difference in odor intensity between MHC heterozygote and homozygote. The homozygote is theorized to smell more intensely especially to MHC dissimilar smellers [10].

The second is the secondary odor which is produced as the result of dietary and environmental influence on an individual [9]. A study conducted by Mebazaa et al, 2011 proved that several odorant compounds were found in sweat as the result of fenugreek ingestion. It has also been said the garlic ingestion could produce distinct body odor [11].

The third group of body odor is the tertiary odor, which is the result cosmetic usage such as perfumes, body shampoo, fragranced soap, facial wash, shampoo conditioner, make-up and many more [9]. Most of these products contains lipid based volatile that is similar to odoristic compound found in natural body odor thus makes up the tertiary odor.

*The Characteristics of Human Scent*

An article published by the Central Intelligence Agency regarding human scent and its detection detailed a few characteristics of human scent based on a few experiments conducted by Lohner, of the Physiological Institute of the University of Graz in 1926. Lohner conducted a series of experiments using trained canines to define characteristics of the human scent [4].

The human scent must be a volatile organic compound but not highly volatile since the presence of scent can persist for a considerable length of time. It must have fairly low or moderate vapor pressure. The scent must also be persistent, chemically stable and relatively dense in comparison to air. Human scent is also not readily soluble in water [4].

The experiments conducted by the Central Intelligence Agency discovered that the scent produced by different parts of the body can be associated with each other and this finding were then corroborated by another research using the Dutch police dogs [4, 12]. Human scent is susceptible to fat solvents and it does not change from day to day [4]. Experiments done using twins supports the theory of the human scent being to some extent influenced by the genetic makeup of a person [13].

*The Theories of Scent Productions*

There are two theories for the production of scent. The Skin Raft Theory by Syrotuck 1972 proposes that the bacterial on the skin and the bodily fluids shed by the Integumentary system contributes to the uniqueness of the raft and thus the scent produced [14, 15].

The second theory implores that the logical source of human scent might be one of the various secretions normal to the human skin [4]. Through the use of elimination mechanism the apocrine sweat glands and the eccrine sweat glands can be ruled out as the possible source of the human scent. Eccrine sweat which is similar in composition to urine could not be the source since urine does not produce the characteristic scent [4, 16]. Similarly the absence of apocrine sweat glands from several parts of the human body where the scent can be detected also eliminates the apocrine sweat gland as a possible source of human scent [4].

The rapid replacement of the scent even after a series of bath makes decomposing skin cells as a less likely origin of the scent since these process occurs slowly [4]. This leaves sebum as the last remaining option for the source of the individualizing scent. Unlike decomposing skin cells, sebum production is very rapid and it covers the whole body even the areas which does not contain sebaceous glands. The components of the sebum are heavy alcohols and hydrocarbons which has properties corresponding to those of human scent. Among the properties are the limited volatility, the persistence and the solubility. However it cannot be concluded that this secretion is the only one that is recognized by the canine and contributes to the uniqueness of human scent [4].

***Previous researches conducted on the human scent***

In 1999, research was conducted using the body odor as sample to determine its effect on female mating choice [17]. In another study, the immediate effect of airborne chemicals on human mind was investigated [18]. These studies show preliminary findings that humans scent is collectable on an adsorbent surface to be investigated further.

Analysis of the headspace of a compress held under the axillae by sensors in electronic nose shows sufficient sensitivity to skin odorant

[19]. 2-nonenal was found to be present in increasing amount in a study conducted by analyzing the headspace of worn t-shirts using TENAX-TA extraction and headspace gas chromatography-mass spectrometry analysis [20].

The Federal Bureau of Investigation found that a scent transfer unit is the most effective way of collecting scent from evidence articles. The scent transfer unit utilizes air flow to move the volatile organic compounds from the evidence to a sterile gauze pad. The resiliency of the scent to high thermal condition, irradiation and chemical treatment was also proved in this research [15]. The previous study has led to another aspect of investigation into the survivability of human scent. This study has proved that the human scent material is also able to withstand extreme thermal and mechanical effects. Human scent picked up by canines from the remaining bomb fragments, were effectively traced back to the right suspect [13].

In 2005, new researches were undertaken to chromatographically define human scent. Scent collected using sterile gauze pads were used for solid phase micro extraction (SPME). The extracted volatile organic compounds were analyzed using gas chromatography-mass selective detector. These studies concluded that human scent is a combination of volatile organic compounds that are able to lead to individualization, by both the presence of unique compounds and the ratio in which they are present [9, 21]. One of this research concluded that the study of the influence of age, sex, and race on the odor profile should be further investigated [21].

Fingerprint characteristics of the emanation of human arm skin were analyze by exposing polydimethylsiloxane-divinylbenzene (PDMS-DVB) for 30 minutes directly to the skin and then desorbing the analyte into GC/MS for chromatographic analysis. The resulting chromatograms were then subtracted for the background signals obtained from the analysis of a blank sample. The chemometric strategies of wavelet transform and polynomial smoothing were used to further purify the chromatograms and the finally principal component analysis (PCA) were done to the data obtained [22].

Stir bar sorptive extraction method with subsequent analysis using automated thermal desorption-gas chromatography mass spectrometry and chemometric analysis indicate that more volatile organic compounds were found in axillary sweat than in saliva or urine, whereby three hundred seventy three markers were consistently present in over ten weeks of sampling period [16]. Volatile organic compounds identified from the emanation of human skin, can be classified into seven groups. The groups are acids, alcohols, aldehydes, hydrocarbons, esters, ketones, and nitrogen containing compounds [21]. A study utilizing much larger group of subjects found that sixty three compounds were identified with high degree of variability of which six of the compounds were present in high frequency [23].

Research done for the purpose of canine training in human remains detection characterized volatile organic compounds emanating from decomposing human remains. This research also acknowledged that further study is warranted in this area, by employing more exhaustive sampling method such as purge and trap method or direct headspace sampling method instead of the SPME method that was used in this experiment [24]. The recent study of detection and classification of human body odor using electronic nose together with humidity correction and principal component analysis, was proved to be able to distinguish two people with similar lifestyles and activities. Although the usage of deodorant reduces the bacterial activity in the axillae, the discrimination between individual can still be accomplished with persons using deodorant [25].

A study done to observe the effect of preservation of scented material by freezing found that there is n significant difference in the rating of the participant whether the samples are fresh or have been long stored [26]. Study by Hudson *et al.* (2009), found that contamination of scent article was the lowest when being stored in glass vials and when gauze pads that are blend of cotton/rayon and polyester are used to collect the scent [27]. Another research also concluded that the type of fiber, weave pattern of the gauze pad and air flow rate of the Scent Transfer Unit effects the retaining and releasing of the analyte from the gauze pad [28].

Analysis of the human male axillary sweat after fenugreek ingestion was studied by Mebazaa *et al.* (2011). The study collected and analyzed the sweat by extracting the headspace of scented gauze pads using headspace SPME method and then using

GC/MS. The result from this study showed that the characteristic odor that is the primary odor profile was still present, but there were also addition of few other compounds that resulted from the ingestion of fenugreek [11].

**Conclusion**

In conclusion, several methods have already been attempted and positive results as to indicate the usefulness of human scent as individualizing biomarkers have been obtained. However, further study into the optimization of the scent collecting material, and analysis that is cost effective should still be investigated. The characterization of human scent compounds can be very useful in the criminal investigation, cosmetic industry, canine training, mosquitoes trapping field and much.

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