Techniques for Human Odor Analysis: A Review

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Abstract- The research and development of new electronic-nose applications in the biomedical field has accelerated at a phenomenal rate over the past years. Many innovative e-nose technologies have provided solutions and applications to a wide variety of complex biomedical and healthcare problems. This review presents a comprehensive analysis of past and recent biomedical research findings and developments of electronic-nose sensor technologies, and to identify current and future potential e-nose applications that will continue to advance the effectiveness and efficiency in biomedical treatments and for many years. As current knowledge does not allow the replacement of the human nose, constructors tend to compensate by integrating several sensor technologies into one instrument. However, one single instrument to be used in every possible application would be over-complicated due to the large number of sensors and time consuming statistical analysis. The trend is to create a system for one specific application. This means that a compact and portable instrument would be desirable. This review describes the current state-of-the-art of this sensor technology, placing special emphasis on GC with E-nose odor analysis applications. The design, technology and sensing mechanism of each type of sensor are analyzed.

Keywords – Human odor, Analysis Techniques, GC-E nose, Olfactometry, Fingerprinting.

I. INTRODUCTION

The idea of distinguishing people by their odor is not a new concept. Trained dogs are routinely deployed by security and law enforcement agencies for forensic investigations and identification of a person committing crime. Odor is being used by animals to recognize each other. People can distinguish the scent of different individuals, especially if they are unrelated or have different diets, and can recognize their own and their mate's scent [1-5]. Mothers can recognize their newborn infants by their smell after a few hours of contact, and infants quickly learn to recognize their mother's scent. When offered human scent, canines can also discriminate individuals, though identical twins are more difficult, and they can recognize individuals with varying degrees of accuracy.

"Odor" is elicited by chemicals in a gas phase which are detected via olfaction producing recognizable smells (cinnamon, lemon) and/or chemesthesis which mediate pungent sensations (tingling, burning, etc) in response to substances such as ammonia. Responses transmitted by the olfactory nerve elicit aroma. Many compounds are pungent at high concentrations. Many compounds detected by chemesthesis via trigeminal nerve stimulation are strong nasal, ocular and throat irritants [6-7]. There are a number of factors which affect odor including the volatile compounds themselves, the number of olfactory receptors available to bind them, the degree to which the compounds become solvated for receptor binding, temperature, humidity, and the matrix in which the odor-producing chemicals are embedded. In addition, individual chemicals may interact (chemically). Odors vary in threshold, intensity and hedonic tone. Measuring odor intensity alone is insufficient to assess human perception of odor [8]. The measurement of airborne volatile organic compounds (VOCs) within and surrounding livestock production facilities has been the subject of extensive research in the past decade [9-14]. Of particular importance has been the characterization and measurement of key potent odorants responsible for the unpleasant odor associated with these facilities and their waste steams, including air emissions. Short-chain volatile fatty acids (VFAs), phenols, amines, indoles and sulfur-containing compounds are the predominant classes of VOCs associated with swine production facilities [9,11,12,15-17]. Accurate measurement of these compounds and their odor impact have been challenging because VOCs possess widely varying physical and chemical properties and are present at concentrations ranging from high parts-per-million (ppb) to low parts-per-billion (ppb). Furthermore, each odorant

has a unique odor and odor detection threshold which means that compounds, even if present at the same concentration, may have markedly different odor impacts. Monitoring odors can be accomplished in several ways: chemical analyses, electronic methods and dynamic dilution olfactometry which takes advantage of the human sensory response. With the current state of technology, the best way to measure odors from livestock facilities is through use of human panels and gas chromatography/mass spectrometry [18].
This paper discusses the use of various instrumental and objective sensory-based techniques for the measurement of VOCs and odors associated with human body. The Heading II discusses about dynamic Dilution Olfactory, a technique for measurement of odor by a panel of judges indicating the overall strength of the odor in terms of how much must be present to detect it. The heading III discusses the use of E- Noses (An array of sensors) to detect VOC present in odor analysis. Heading IV gives an overview of the Gas Chromatographic Techniques for odor quantization. Table 1 shows the different techniques being used for odor analysis and Table 2 discusses about the limitations and advantages to different techniques discussed. The conclusion for using a particular technique and its advantages is discussed in section V.

II. DYNAMIC DILUTION OLFACTOMETRY

Dynamic Dilution Olfactometry (DDO) is based on "dilution to threshold" of a gas sample containing multiple components. Odor threshold is a commonly used term. In general, it is the minimum concentration detectable or the minimum detectable difference between two concentrations (ASTM, 1997a). Because of additive / subtractive effects (of individual chemicals) in mixed systems, the threshold for a particular compound may not be useful. Thresholds for different substances can be several orders of magnitude different, and thresholds for different people can be several odors of magnitude different. An odor threshold (minimum detectable amount) can be measured in "known" samples (standards) and expressed as "X ppm of compound Y" (in air). To conduct a dilution-to threshold test, the gas containing the volatile chemical is collected in a bag, then a known volume is injected through a flow-splitter where air is used to dilute it to selected ratios. The dilutions are usually factors of 2 or 3. The more the gas must be diluted with pure air to lower it to the Detection Threshold, the stronger the odor of the gas. For a pure compound, the dilution corresponds to the concentration:

$$1 \text{ ppm} = 1/1{,}000{,}000 = 10^{-6} \text{ dilution} = \text{dilution factor "6"}$$

In this case, odor intensity is a function of concentration. "Stevens Power Law" (Stevens, 1957) states that the apparent magnitude of intensity grows as a power function of the stimulus magnitude which implies that equal ratio changes in sensation magnitude correspond to equal changes in the stimulus magnitude:

$$I = k\,(C)^{n}$$

Where C is the odorant concentration, and k and n are constants that differ for each odor. Therefore, for a pure compound, if we know the power function and the concentration, we can determine the intensity. A derivative of this relationship is the log function of the concentration of the odorant.
Determining Detection Thresholds of "unknown" complex mixtures (barn air) is much more difficult because (1) we don't know what compounds are present, and (2) we don't know their concentrations. No instrument is available to quickly measure the concentration of odors consisting of many compounds. One way around this problem is to express the odor strength as "odor units". The odor unit is a calculated value based on the Threshold Dilution ratio and the concentration:

$$Z = C / Cs$$

Where Z is the Threshold Dilution ratio measured by an olfactometer (as with a pure compound), C is the odor concentration and Cs is the theoretical minimum concentration of the odor for detection in 50% of the population. To calculate odor units, "Z" must be determined for the unknown sample while C and Cs are determined using a pure substance (standard; n-butanol). The "strength" of the odor is expressed in dimensionless "odor units" which are calculated as the -log of the dilution at which the odor can be detected which may be adjusted for the concentration and the detection threshold of a known substance. For example, if odor is detected at a dilution of 1 part barn air to 27 parts purified air:

$$\text{Dilution Threshold (ratio)} = \text{Volume of pure air} / \text{Volume of odorous air}$$

$$\text{Dilution Threshold ratio} = 27/1$$

DDO requires a panel of 3-10 people who determine how much a sample of air must be diluted before they can no longer smell it. An air sample, most often 10 L, is collected in a bag made of relatively inert material (Tedlar). The odor mixture is diluted with purified air then presented to pre-selected sensory panelists at several dilutions. For each dilution, the panelist is presented with three samples two of which are the same. The panelist then makes a "forced choice" among three alternatives selecting the sample which is different Very dilute samples are presented at the beginning of the test, increasing in concentration after every set of three. At some point in the series of concentrations, each panelist will become able to detect the odor.

Figure 1: Sensory Panelists analyzing the BET by olfactrometry technique.

The Best Estimate Threshold (BET), the halfway point between the dilution where odor can be detected and that where it can't be detected, is calculated as the square root of the product of those two dilution factors m=(ASTM 1990, 1997b). If the odor is detected at the 27/1 dilution but not at the 81/1 dilution, then:

$$\mathbf{BET = \sqrt{(27 \times 81)} = 46.77}$$

The BET value for each panelist is determined. The log of each value is calculated. The logs of the individual BETs are averaged to produce a "geometric mean". This geometric mean is similar to the log of the dilution factor for a pure compound (such as n-butanol). The antilog of the BET geometric mean is the average "concentration" (or average Dilution Threshold ratio for mixed samples) at which the group can "detect" the odor.
The panel response to the mixed sample may be expressed in Odor Units (OU) which are simply the Dilution Threshold Ratio, the Dilution Threshold Ratio adjusted for the concentration at the Detection Threshold for a known amount of a pure standard, or the amount of odorant in one cubic meter (OU/cm3). The European Odor Unit (OUE) is defined in terms of N-butanol (AWME EE-6, 2002)

To calculate the European Odor Units:

1. Determine concentration of n-butanol at its Odor Detection Threshold (ODTb). This is the Odor Detection Concentration for n-butanol (ODCb).
2. Determine the Odor Units for the "mixed sample": this is the Odor Detection Threshold of the unknown sample adjusted to the Odor Detection Concentration for n-butanol

   $OUE = (ODT \times ODC_b) / 40$ ppb
   OUE = European Odor Units
   ODT = Odor detection threshold (ratio) of the sample
   ODCb = Odor concentration of n-butanol at its detection threshold
   40 ppb= the "definition" of 1 OUE in terms of n-butanol

European standards require that ODCb be between 20 and 80 ppb for each panelist, so panelists are screened prior to their participation in an olfactometry panel. One "European Odor Unit" is 123 mg n-butanol (40ppb) by definition so, if we determine the ODCb to be other than 40, we must adjust our ODT accordingly. If we determined that our actual Odor Detection Threshold for n-butanol is 50ppb, we must adjust the Odor Detection Threshold of our unknown:

$$OUE = (ODT) \times ODC_b / 40$$
$$OUE = (25.7) \times 50 / 40$$

OUE = 32.13

Dilution olfactometry will give an indication of the overall strength of the odor in terms of how much must be present to detect it, and it will give "numbers" for comparison (across time, intervention methods, etc.), however it gives no indication of odor strength at suprathreshold amounts. Dilution olfactometry will not identify individual odors, it will not give an idea of which compounds contribute most to a complex odor, and it will not give "hedonic" information (good / bad smell). Unless the DDO data are correlated with a sensory "intensity" reference scale (1 = very weak, 5 = very intense) using reference odorant concentrations, DDO data alone do not give an indication of how intense the odor is.

The primary advantage of DDO is that the human nose is the actual detector—it is the most sensitive detector for many compounds. The disadvantage is that is cumbersome for use outside a laboratory environment. It depends on using panelists who have (1) been selected for their sensitivity in a specific range, and (2) have been "standardized" to a specific concentration of aspecific concentration of a specific compound (usually n-butanol). DDO determines odor threshold, not "odor quality" (smells like lemon, cinnamon, etc.).

The "odor unit" seems to be the most common index for odor emission control. A number of states in the US have a source emission standard. However, there are problems with using the odor unit as a standard: (1) because of the variability of people, who serve as the detectors for generation of the odor unit, data vary from laboratory-to-laboratory, and (2) the odor unit includes *no measure of the importance of the odor*.

III. ELECTRONIC NOSES

The electronic nose is an instrument that consists of an array of electronic chemical receptor which detect volatile chemicals or categories of chemicals and then uses the information to predict sensory-like properties. Electronic noses contain an array of sensors (sintered metal oxides, catalytic metals, conducting polymers, lipid layers, phtholocyanins, organic semi-conductors, and surface acoustic wave or combinations) which respond to a wide variety of chemical classes [23]. The sensors are based on conducting composites that change resistance on exposure to a vapor [24]. The change in resistance (ΔR) of individual sensors from baseline resistance (R) produces a pattern of resistance changes ($\Delta R/R$) across the array [25]. The measured response is then converted to a signal using a computer processor.

To identify the type, quantity, and quality of the odor the computer uses changes in the pattern generated in the entire sensory array. Metal oxide arrays require very high temperatures to operate, and the polymer sensors don't detect small amines and thiols responsible for fishy, skunky and rotten-egg odors (really smelly substances). New sensors using inks based on organometallic compounds change color when bound by vapor molecules (like hemeiron in hemoglobin which becomes bright red when it reversibly binds oxygen [26]. All of these sensors (and their combinations) vary in the magnitude of response to any one compound giving them the discriminatory ability required to analyze odors. The volatile sample is injected, in combination with filtered air, such that it can flow over and interact with the sensors. An output signal is generated as a result of the change in resistance at the sensory surface as a result of its interaction with compounds in the gas phase. The binding and resistance change are rapid and temporary. Response data are exported to a computer which has been trained to use chemometric and "artificial neural network" computer software as a way to recognize the pattern of a mixture of compounds as a specific odorand to discriminate slight differences. Because very large amounts of data are generated, processingit into useful information requires statistical analysis software which can conduct principal component analysis and discriminant factor analysis.

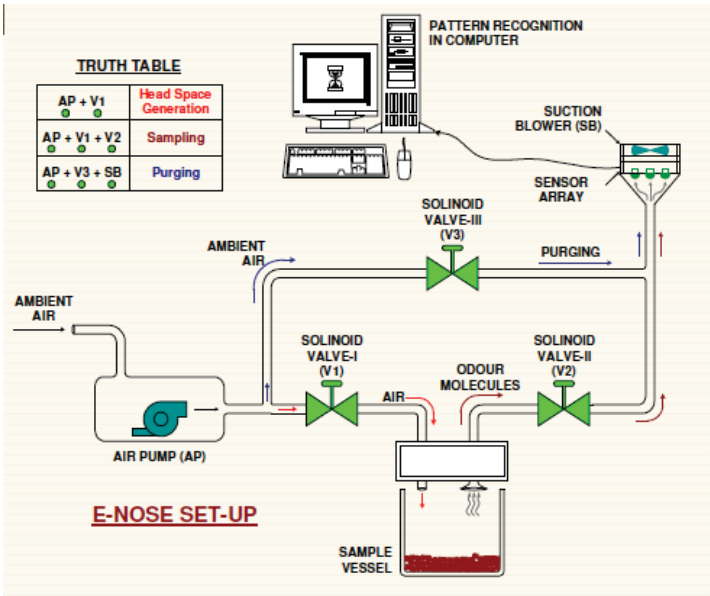

Figure 2 : A Schematic representation of E Nose Setup

Use of arrays of non-specific sensors allows for detection of many thousands of chemical species due to the broad selectivity of the sensory surfaces. The electronic nose can measure a complex group of substances (like the human olfactory system) very rapidly (10-120 seconds), and it can be trained to discriminate “good” from “bad” aromas. However, the electronic nose must be trained for each important component (grassy, smoky) for each application, it must be standardized by both chemical and olfactometric methods, and the “sensor array” is restricted. One of the biggest challenges for electronic noses is detecting complex odors against an intricate background matrix. While the above instrumental methods do offer the potential for the accurate estimation of VOC levels in waste streams and air emissions associated with swine production facilities, they do not, however, allow for the direct measurement of odor intensity nor odor quality. For this purpose, researchers have relied on the use of subjective and objective sensory analysis using human panelists. Foremost among these techniques is dynamic dilution olfactometry.

IV. GAS CHROMATOGRAPHIC TECHNIQUES

4.1 Gas chromatography with Mass Spectroscopy

Instrumental methods have relied mainly on the application of gas chromatography (GC), including gas chromatography-mass spectrometry (GC-MS), since this mature separation technology is capable of the efficient separation required for analysis of complex mixtures of VOCs. In gas chromatography a mixture of volatile substances is injected into a column which separates the compounds based on their relative vapor pressures and polarities. The compounds are then detected as peaks which have specific retention times and peak areas which can be used for qualitative and quantitative determinations, respectively. The main problem or consideration associated with use of gas chromatography has been the requirement of an extraction or preconcentration step. VOCs are most often isolated by taking advantage of their volatility and nonpolar nature. For analysis of airborne VOCs this generally means the use of an adsorbent trap, which allows for the selective enrichment (trapping) of the VOCs away from the bulk of the atmospheric gases and water vapor. The VOCs contained in the adsorbent trap are then transferred via thermal desorption, which releases the compounds from the trap and sends them to the gas chromatograph for analysis.

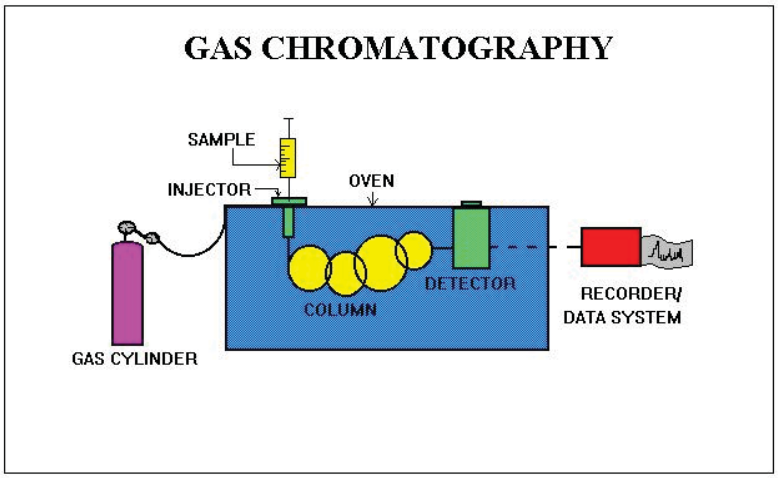

Figure 3: Illustration of Gas Chromatographic technique for sample detection.

Over the past four years we have employed trapping techniques for analysis of air-borne VOCs emitted from swine finishing buildings. For in-the-field studies we have utilized portable air sampling devices in which the air is drawn through an adsorbent tube using vacuum pump at a fixed flow rate (e.g. 20 mL/min). In the literature various trapping agents, e.g. Tenax™ and graphitized carbons, have been shown to be effective for the isolation of airborne VOCs [14, 27-30]. Based on our experience, mixed-bed graphitized carbon traps are an excellent choice, since they allow for isolation of VOCs having widely varying volatilities and polarities, while at the same time, these traps minimize water vapor absorption which can perturb the thermal desorption step by causing blockage (ice) of the cryogenic trap of the gas chromatograph. However, occasionally even these traps can have moisture problems, such as when field sampling is done under very humid or extremely cold conditions. To overcome this problem we now use Tedlar™ bags for the primary field sampling. The bag sample is then brought back to the laboratory where the airborne VOCs are transferred from the bag onto an adsorbent trap using a vacuum pump under controlled conditions which minimize moisture sorption on the trap. This approach had been previously reported by Zhang *et al.* [30]. The above method offers an additional advantage since the same bag samples can be used for dynamic dilution olfactometry.

Gas chromatography-mass spectrometry is applied during the early stages of method development to aid in compound (peak) identification. The use of duel detectors for routine monitoring allows for the simultaneous analysis of key swine odor components found in relatively high concentrations (e.g. volatile short-chain fatty acids and phenols by flame ionization detection) and those found at trace levels (e.g. sulfur-containing compounds by flame photometric detection). The trace level sulfur-containing compounds are of particular importance because they often have very low odor detection thresholds and possess noxious odor properties.

4.2 Solid Phase Microextraction (SPME) with GC

A recent and very successful new approach to sample preparation is solid-phase microextraction (SPME). It was invented by Pawliszyn and co-workers [31,32] in an attempt to redress limitations inherent in SPE and LLE. SPME integrates sampling, extraction, concentration and sample introduction into a single solvent-free step. Analytes in the sample are directly extracted and concentrated to the extraction fibre. The method saves preparation time and disposal costs and can improve detection limits [33]. It has been routinely used in combination with gas chromatography (GC) and GC/mass spectrometry (GC/MS) and successfully applied to a wide variety of compounds, especially for the extraction of volatile and semi-volatile organic compounds from environmental, biological and food samples. SPME was also introduced for direct coupling with high-performance liquid chromatography (HPLC) and HPLC-MS in order to analyse weakly volatile or thermally labile compounds not amenable to GC or GC/MS. The SPME/HPLC interface equipped with a special desorption chamber is utilized for solvent desorption prior to liquid chromatographic separation instead of thermal desorption in the injection port of the GC system. A new SPME/HPLC system known as in-tube SPMS was recently developed using an open-tubular fused-silica capillary column as the SPMS device instead of the SPME fibreforusein HPLC. In-tube SPME is suitable for automation, which not only shortens analysis times but often provides accuracy and precision relative to

manual techniques. The main advantage of SPME is good analytical performance combined with simplicity and low cost. SPME produces relatively clean and concentrated extracts, and is
ideal for MS applications

4.3 Automatic Thermal Desorption (ATD) with GC-MS

ATD-GC-MS is a hyphenated technique which separates mixtures of organic compounds and determines the identity and concentration of each component. The mixture is typically introduced onto adsorbent media contained inside a glass or metal tube. The tube is heated to vaporize the mixture and the vapor is injected onto a capillary gas chromatographic column. The column separates the mixture into individual components which then enter a quadruple mass spectrometer. The mass spectrum of each component is recorded and compared to a database of known compounds for positive identification. The mass spectrum intensity may be used for quantification. This technique is capable of detecting picogram quantities of material. ATD-GC-MS is a powerful tool for identifying organic contaminants. These may be present as an adsorbed film on silicon wafers, as airborne vapors in the manufacturing environment, as dissolved components in ultrapure water or process chemicals, or as vapors which outgas from plastics, coatings, garments, o-rings and similar materials.
The many investigators have carried out their research employing above methods for characterization and identification of odors from different sources. These techniques are being widely used to identify and quantify hundreds of VOCs present in human, animals, plants and many material specimens that have environmental and forensic importance. Some investigations pointed out in literature is comprised in Table 1.

Study	Technique Employed	Findings	Investigator/s
Volatile organic compounds (VOCs) human from hand odor, oral fluid, breath, blood, and urine	SPME-GC-MS	Comparison of odor profile of 31 individuals	Kusano *et al. [34]* , 2012
Key odorants in Sauvignon blanc wines	Aroma Extract Dilution Analysis (AEDA)	methoxypyrazines , 3-mercaptohexanol and 3-mercaptohexyl acetate	Benkwitz *et al.*[35], 2012
Volatiles generated in the meat of grilled beef loin muscle	SPME-GC and Gas Chromatographic-Olfactometric (GC-O)	1-octen-3-one, (E)-2-octenal, methional, and hexanal.	Resconi *et al.[36]* ., 2012
Aromatic compounds in Jiashi melon juice	Gas chromatography-mass spectrometry-olfactometry (GC-MS-O)	Twelve compounds, namely, (2E,6Z)-nona-2,6-dienal, (3Z,6Z)-nona-3,6-dien-1-ol, ethyl butanoate, ethyl 2-methylbutyrate, ethyl 2-methylpropanoate, (Z)-non-6-enal, (E)-2-nonenal, heptanal, methyl 2-methylbutyrate, nonanal, hexanal, and 2-methylpropyl acetate	Pang *et al.* [37], 2012
Aroma compounds in Riesling and Vidal blanc (syn. Vidal) table wines and icewines	GC and olfactometry-mass spectrometry (MS-O)	β-damascenone, decanal, 1-hexanol, 1-octen-3-ol, 4-vinylguaiacol, ethyl hexanoate, and ethyl 3-methylbutyrate	Bowen and Reynolds [38] , 2012
Breath analysis from smokers and non-smokers	Electronic nose and SPME-GC-MS	Found significant different profiles in smokers and non smoker indivisuals	Witt *et al*. [39], 2011
Odor analysis of	GC-olfactometry and GC-	2,5-dimethyl-4-methoxy-3(2H)-furanone (DMMF), 2,5-dimethyl-4-	Du *et al*. [40],

Strawberry from subtropical regions	MS	hydroxy-3(2H)-furanone (DMHF), methyl butanoate, γ-decalactone, unknown (grassy, LRI 1362, wax), (E)-2-hexenal, linalool, (E,Z)-2,6-nonadienal, geraniol, butanoic acid, methyl 2-methylbutanoate, and ethyl hexanoate	2011
Swine odor analysis	Dynamic Dilution Olfactometry (DDO) and GC-O	indoles, phenols, NH_3, and several VFAs (butanoic, 3-methylbutanoic, and pentanoic acids).	Trabue *et al*. [41], 2011
Odor-active compounds of various cherry wines	GC-MS and GC-O	ethyl 2-methyl propionate, 2,3-butanedione, ethyl butyrate, ethyl pentanoate, 3-methyl-1-butanol, ethyl hexanoate, 3-hydroxy-2-butanone, ethyl lactate, 1-hexanol, (Z)-3-hexen-1-ol, ethyl hydroxyacetate, acetic acid, furfural, 2-ethyl-1-hexanol, benzaldehyde, propanoic acid, butanoic acid, guaiacol, beta-citronellol, hexanoic acid, 2-methoxy-4-methylphenol, 2-ethyl-3-hydroxy-4H-pyran-4-one, ethyl cinnamate, 2-methoxy-4-vinylphenol	Niu *et al*. [42], 2011
Analysis of human remains volatiles	SPME-GC/MS	cyclic and straight-chain hydrocarbons, organic acids, sulfides, aldehydes, ketones, and alcohols	DeGreeff and Furton [43], 2011
Volatile organic compounds present in human biological specimens (blood, breath, buccal cells, and urine)	SPME-GC/MS	---	Kusano *et al*.[44], 2011
Odor contribution of pineapple flesh	SPME-GC/MS	methyl and ethyl 2-methyl butanoate and 2,5-dimethyl 4-methoxy 3(2H)-furanone (mesifuran)	Montero-Calderón *et al*.[45], 2010
Aroma profiles of wines elaborated from sound and sour rot-infected grapes	GC-O and GC-MS	Ethyl phenylacetate (EPhA) and phenylacetic acid (PAA), γ-nonalactone and γ-decalactone	Barata *et al*.[46], 2011
Odorous compounds in reclaimed water in water treatment plant (RWTP)	GC-MS	dimethyl disulfide, dimethyl trisulfide, indole and skatole	Yan *et al.* [47], 2011
Analysis of body odor	HS-SPME-GC-MS	Acetic, butyric, isobutyric and isovaleric acids	Caroprese *et al*. [48], 2009
Origin of odor episodes in indoor environments	Automatic Thermal Desorption (ATD) coupled with GC/MS	ethanol, acetone, isopropanol, 1-butanol, acetic acid, acetonitrile and 1-methoxy-2-propanol	Gallego *et al*.[49], 2009
Volatile compounds emitted by two raspberry varieties	SPME/GC-MS) and proton-transfer reaction-mass spectrometry (PTR-MS)	hexanal and hexanol	Aprea *et al*. [50], 2009
Breath odor compounds in liver diseased patients	GC-MS	Dimethyl sulfide, acetone, 2-butanone and 2-pentanone were increased in breath of liver patients	Van den Velde *et al*. [51], 2008
Volatile organic	SPMR and solvent	Nearly 100 compounds were identified, some of which varied with	Gallagher *et*

compounds from human skin.	extraction. GC-MS flame photometric detection.	age	*al*.[52], 2008
Comparison of metal oxide-based electronic nose and mass spectrometry-based electronic nose	GC-MS-O	MS-Enose was better and capable than MOS-Enose device	Berna *et al*. [53], 2008
Volatile flavor compounds of sardine	SPME-GC, GCMS	2,3-pentanedione, hexanal, and 1-penten-3-ol ,(1-penten-3-one), 2,3-pentanedione, hexanal, (Z)-4-heptenal, octanal, 1-octen-3-one, methional, (E,Z)-2,6-nonadienal	Ganeko *et al*. [54], 2008
Analysis of flavour compounds from fish muscle	SPME -GC, MSGC-O	53 compounds responsible for the aroma were identified	Zhao *et al*. [55], 2007
Individual and gender fingerprints in human body odor	Automatic Thermal Desorption (ATD) coupled with GC/MS	Different VOC profiles based on gender	Penn *et al*.[56], 2007
Odor fingerprint acquisition	GC/mass spectrometry (GC/MS) and GC x GC/MS analyses	Developed fingerprints for different perfumes	d'Acampora Zellner *et al*.[57], 2007
Odor of cigar smoker's breath.	SPMR-GC	2,3,5-trimethyl pyridine, 2,5-dimethyl pyrazine, and 2-ethyl-3,5-dimethyl pyridine. Pyridines and pyrazines	Bazemore *et al*.[58], 2006
Body odor of schizophrenic patients	Gas Chromatography-Mass Spectrometry (GC-MS)	specific profile for schizophrenic patient	Di Natale *et al*.[59], 2005
Active odor signature chemicals from drugs, explosives, and humans.	(SPME- GC with electron capture detector (GC/ECD) and Mass spectrometry (GC/MS)	----	Lorenzo *et al*.[60], 2003
Odorous compounds from a landfill	GC-MS	Hundreds of compounds were identified	Davoli *et al*.[61], 2003
Measurement of environmental odors from sewage treatment, landfill and agricultural practise	GC-MS	H_2S and NH_3 measurements	Stuetz and Nicolas [62], 2001

Table 1: Recent investigations on odor analysis using various techniques

The choice of efficient and accurate method is very important for developing the profiles or fingerprints of odors from different sample origins. A comparative aspect of commonly methods used for odor analysis is illustrated in Table 2.

Odor Analysis Techniques	Advantages	Disadvantages
Dynamic Dilution Olfactometry	Simpler than other methods.	Requires a panel of at least 6 members. Complex procedures. Reduced accuracy.

Electronic nose	Can evaluate odor category. Can identify odors and determine the intensity. Permits on-site measurements. Widely used for odor analysis in environmental and forensic areas.	More expensive than olfactometry. Accuracy is less than GC
Gas chromatography	Quantify VOCs form complex mixtures accurately. It can be coupled with E-nose and olfactometry for many more applications. Less time required.	Requires accurate sample preparation.
GC MS	Separate and Identify complex VOCs mixtures accurately More accurate than other methods	Expensive, Requires proper sample preparation, Time consuming method
Electronic nose with GC	Simple and wide variety of odor sample can be analyzed. Requires short time and economical as compared to GC MS. Efficient and accurate than Dynamic dilution olfactometry	Limited to quantitative odor analysis

Table 2: Comparison of various techniques used for human odor analysis.

V. CONCLUSION

The increasing attention of the population to olfactory nuisances and the need to provide a reliable qualification and quantification of odors has led to the development of different odor measurement techniques. In particular, GC-MS, instrumental sensory methods and chemical sensors have been described for these purposes. GC-MS coupled with dynamic olfactometry represents the standardized objective method for the determination of odor concentration. First of all dynamic olfactometry provides point odor concentration data, however, it is not sufficient to evaluate completely a case of olfactory nuisance because it does not allow one to perform continuous and field measurements, useful for monitoring the industrial processes causing odor emissions. Moreover, dynamic olfactometry considers the whole odor mixture and do not discriminate the single chemical compounds and their contribution to the odor concentrations. Odor samples are difficult to store, because of their instability, and, therefore, require rapid time of analysis. Finally, as it is well-known, olfactometry with GC-MS is too time-consuming and quite expensive and moreover frequency and duration of analysis are limited. On the other hand, GC coupled with olfactometry and electronic noses present lower analysis costs and quick results and they allow one to carry out continuous monitoring in the field nearby sources and receptors. *As per as quantification of VOCs in human body is concerned the GC alone or GC coupled with E-Nose is preferred as it is efficient, time saving and economical technique.* After a training step, GC and electronic noses are able to preview the class of an unknown sample and then to associate environmental or body odors to a specific source. Since many techniques satisfy only a part of the problems of odor monitoring, *many authors have focused their attention within GC alone or GC coupled with E-Nose results.* These applications show the opportunity of using more than one approach for describing and understanding olfactory nuisance cases as completely as possible.

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