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Applying Citizen Science Method for Odor Measurement in Urban Areas

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ABSTRACT

Urban site analysis includes tangible factors such as the physical site features and intangible factors as the sensory site features like odors affect the inhabited area in the site. Environmental and chemical studies have much greater attention and studies to the odor effects in urban areas than urban designers. This paper aims to provide a validated and applicable method for urban designers in odor measurement. The objective of this research is to present the various methods of measuring odors adopted in chemical and environmental studies to achieve an applicable odor measurement method in the urban design field. The odor measurement tools are usually dedicated to measuring odor concentration at the odor source or at the receptor location that are used in chemical and environmental studies. However, in urban design studies the odor measurement could be performed using a method called citizen science considering the FIDOL factor to evaluate the odor nuisance including odor frequency, intensity, duration, offensiveness, location, and hedonic tone. This research conducts a case study in Tripoli city and determines Tripoli landfill as a significant odor source that affects people in their inhabited areas. A questionnaire was distributed in the affected area by the odor source, and the respondents of the inhabitants ensured that the summer season is the most season that they can feel the odor in their places associated with the wind direction. The results ensure that the citizen science method in measuring odors is validated, applicable, and available for urban designers to detect and estimate the affected area by odor source.

Index-words: *Citizen Science, Odor measurement, Weather factors, FIDOL Factors.*

I. INTRODUCTION

One of the urban site analysis factors is the sensory assessment of the location, this includes the noise and odor that negatively affect the site. Although urban designers pay significant attention to noise studies, the consideration of the odor nuisance at the site is at a lower level of urban designers' interest.

The lack of interest of the urban designers concerning the sensory factor of odor assessment in the urban site analysis is the main problem of this research. The odor assessment tools are mainly used by specialists in the chemical and environmental fields, and these tools are dedicated to measuring odor concentration. In contrast, in the urban design field, odor measurement could be done in another method called the Citizen Science method which depends on measuring people's perception according to FIDOL factors which is one of the odor assessment tools.

This paper aims to provide a validated and applicable method for urban designers for odor measurement. The objective of this research is to present the various methods of measuring odors adopted in chemical and environmental studies to achieve an applicable odor measurement method in the urban design field.

The methodology of this research includes the following steps; as first defining the odor and odor categories, second presenting the most significant factor in controlling the odor dispersion which is the weather factor, third providing the odor impact evaluation methods to select an applicable method in this research, and fourth conducting a case study in Tripoli city.

As this method is not widely applicable in urban design studies to evaluate people's annoyance from an odor source, this research conducts a case study in Tripoli city to find out the corresponding results

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between determining the area of odor dispersion by wind direction and the odor perception by people.

II. LITERATURE REVIEW

The word "odor" refers to a smell, frequently an unpleasant one (Cambridge, 2023) (Oxford, 2023). However, several researchers such as (Li & Wang, 2021) (Jo et al., 2020) (Rho et al., 2021) (Poncet et al., 2021) (Hou & Meng, 2021) consider that odor can be characterized as pleasant, unpleasant, or neutral. Odor is a property of a group of compounds that can sufficiently activate the olfactory sense to cause an odor perception. Sensory input is often transferred from the nose cavity to the brain, where it may have either pleasant or unpleasant effects. Odor perception starts in the nasal cavity. Sniffing causes molecules of the odorant present in the air to travel past the turbinate, which are curved bones. In the top nasal tube, where the nerve cells that detect odors are located, the turbinate creates turbulent airflow patterns that deliver the volatile compound mixture there (Capelli et al., 2019).

The odor was categorized in the thesis of (Jingyan, 2021) as follows:
psychological reactions: Scent and odor are the two broad categories into which odor perception can be divided. Even though this method is inaccurate, it is suitable for a wide sample of scents.
Chemical characteristics: Volatile aromatic molecules with a range of molecular weights give off odors. Some of these molecules are inorganic, but the majority are organic.
Odor class: Fruity, aromatic, minty, lemony, chemical flavor, woody, sweet, popcorn, sour, and putrid are the ten main sorts of odors.
Source of odor: This approach is particularly pertinent to the study of odor cities since there are many major categories from which odor sources may be classified, and doing so reveals both formal and spatial distributions.

St. Croix Sensory, a market-leading sensory evaluation laboratory, has begun to offer analytical testing of chemical odorants and built an odor wheel to include a wide range of naturally occurring and artificially produced aromas. Natural Offensive, Marine, Animal, Chemical, Earth, Vegetable, Naturally Pleasant, and Culinary are the eight major odor classifications. The wheel contains trigeminal sensations as the basic tastes occasionally recognized in the mouth because fundamental tastes might occasionally be observed in the mouth while smelling smells. (Sensory, 2020).

The several predicted scents in the urban area are provided by the odor wheel shown in Fig.1

Fig. 1. Odor Wheel (Sensory, 2020)

These eight odor groups further break down into 22 additional layer odor categories, such as the naturally disagreeable category which is further divided into two subgroups (sulfur and decay), and the chemical category which is further divided into four subgroups (petroleum, chemical, plastics, and medical). Vinyl, rubber, and Styrofoam are listed as the types of each specific category in the outer ring for the plastics category (Sensory, 2020).

A. Weather Factor

Weather conditions that have a significant impact on odor occurrence, such as temperature, wind speed, and precipitation, are related to the likelihood of odor (Jia et al., 2021). The main results of (Piringer & Knauder, Odour Impact Assessment in a Changing Climate, 2021) research presented that the developed odor impact might change as a result of climate changes between the present and the future. The geographical qualities and atmospheric conditions will determine how the odorous composites diffuse and change over time and space (Bruce & Antileo, Assessment of odour emissions by the use of a dispersion model in the context of the proposed new law in Chile, 2021).

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The analysis of the study discussed the rural smells and their effects on odor dispersion considering the weather conditions (Caffyn, 2021). Weather conditions including rain and humidity, as well as wind speed and direction, have an impact on how odors are interpreted and identified (Allen, 2021). The variations in climatic circumstances could not support the air dispersion (Hoang et al., 2022). The weather factor affects the smell produced in rainy weather as this smell will be more intense (Febrian, 2021).

To determine the damaging impact distance of odor irritation, (Fang et al., 2022) regarded the climatic data to be a crucial aspect in modeling the dispersion of odorous substances. Calculating odor exposure using air dispersion (Zhang et al., 2021).

Weather conditions, concentration, time, turbulence, and volume, along with wind velocity, temperature changes, relative humidity, and air pressure, have a significant impact on the smell identity and impression (Badach et al., 2018). Nearly 60 percent of the fluctuation in daily odor report totals is accounted for by meteorological conditions and air pollutants (Bhandari et al., 2022).

The focus on the elements of wind and temperature will be provided as follows, by earlier research that demonstrates the critical importance of weather conditions in odor diffusion:

III. Wind Factor Study

Earlier research has noted the significance of the wind element in smelling diverse odors as in (Brancher et al., 2019) study which shows why it is important to consider wind direction when determining how far a given spot is from the source of an odor.-To help prevent odor disruption at two distinct places, (Piringer et al., 2016) offer models of separation distances that are estimated based on wind speed and direction. As well (Eltarkawe & Miller, 2019) provide a research on odor problems in various areas while taking wind studies into account. In the case study of (Allen, 2021), the weather conditions varied significantly during one very windy day, making it difficult to smell anything. The vast amount of water in the chosen area such as the bay, sea, and lake, along with the humid climate, suggested that on calm days, fragrance intensity was strong. For each smell walk, (Allen, 2021) noted the time, day, and weather conditions, taking wind strength and direction into account. (Caffyn, 2021) addressed the weather, focusing on the wind effect and noting that stronger breezes are likely to cause odors to be dissipated in areas on higher ground.

The meteorological information of the research area, such as wind speed and direction, air pressure, temperature, and relative humidity, was used to evaluate the influence of odors from wastewater treatment plants (Zhang et al., 2021). Wind and the Pasquill stability class climate dataset were used in the study of (Kiefer et al., 2022) to evaluate the geographical and temporal variability of cattle odor dispersion potential in Michigan.

Wind speed and direction significantly influence the value of the odor concentration (Bruce & Antileo, Assessment of odour emissions by the use of a dispersion model in the context of the proposed new law in Chile, 2021).

The smell is moved by the wind and dispersed by the wind direction (Conchou et al., 2019). High wind speeds reduce the strength of the smell while dispersing it across a wider region (Song & Wu, 2022). Wind measurements in the context of the wind direction frequency dispersion are the necessary atmospheric data for the application of the Austrian and German experimental calculations (Schauberger et al., 2020). According to a study by (Çeven et al., 2022) based on smell preferences and the dispersion of smells according to climatic and spatial properties, the recommendation to control urban smell makes it clear that smell is possibly directed with the wind direction and impacted by geographical closeness, as locations with high closeness enable higher smell perception and locations with high openness enable low smell perception. (Ma et al., 2022) offer a numerical simulation based on research of wind velocity to investigate the impact of the spread of olfactory pollution. The 'volatiles' of odors disperse from their source due to ambient motion and molecular dispersion. In natural environments, wind is the most potent and unstable agent for odor dispersion. With larger volatile contents and a faster wind speed, the odor plume became a sharper cone and diminished as it got farther away from the source of the odor (Cai et al., 2022) as shown in Fig.2

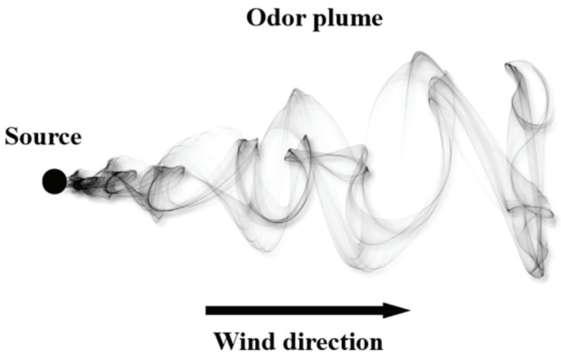

Fig. 2. The odor plume from the source moves downwind (Cai et al., 2022)

IV. Temperature and Humidity Factors Study

Heat-related smells especially, make waste smell unpleasant and breed bacteria and flies (Huang et al., 2021). The main complaints of the nearest residents are unpleasant smells and noise, especially in hot weather (Hoang et al., 2022). The research of (Devonald et al., 2022) stated that the unpleasant smell is made worse by rising temperatures and severe weather. The relationship between odor concentrations and temperature, as well as daytime weightings, was primarily deemed to be upsetting (Zhang et al., 2021). As temperatures increase, vapor pressure rises, raising the amount of odor that is present (DeGreef & Maughan, 2022). Unpleasant odors and noise annoyance are among the major issues, especially in hot weather (Tran, 2020) (Pham et al., 2022). (Jo et al., 2020) demonstrated that stimuli become stronger and more unpleasant at high temperatures, especially when an unpleasant odor is present. Humidity in the air traps odor-causing molecules, allowing them to travel further and linger longer, increasing the smell intensity by 1.29 on average (Billottet, 2020). The study of (Jia et al., 2021) highlighted that odor pollution worsens in hot climates. (Çeven et al., 2022) confirmed that at 27 °C and higher temperatures and 55% humidity, smell intensity rose. Particularly, the intensity was not particularly notable during the cold months of November to May, but it did grow between May and September. Although it was lower in places with short buildings, the perception of scent intensity was higher in regions with narrow streets, tall buildings surrounding them, and high walls. Additionally, smell diffusion increased as the distance between smell sources grew. Depending on the distance, smell strength had an impact on smell dispersal as well. Under the same temperatures, the stench got stronger as the humidity rose. It turns out that the smell strength dropped as wind speed increased, despite the humidity rising as a result. According to the thesis of (ÇEVEN, 2021), the smell intensity varies according to the openness and closedness of the space and changes as a function of temperature and humidity. Wind speed, temperature, humidity, and the study site are the factors that have an impact on the amount of CO in the surrounding air. Because the wind speed in an open, flat lowland is high enough, the atmosphere can diffuse and minimize the pollutants (Brontowiyono et al., 2022).

V. Methodology

A. Odor Impact Evaluation Methods

The research of (Zarra et al., 2021) offered several approaches to assess the effects of odors brought on by an industrial plant situated in a sensitive area:

First Method: The grid method, which involves dividing the study area into cells and assigning teams of trained assessors to each cell to conduct a field assessment. This approach is based on the FIDOL variables, which stand for frequency (F), intensity (I), duration (D), offensiveness (O), and location (L) in the definition of odor nuisance. This method adheres to the regulations for odor nuisance assessment, which vary depending on the country. It also considers the weather conditions, particularly the wind and temperature that change depending on the research. This strategy is thought to be the most practical one for assessing odor nuisance. This method is expensive and time-consuming.

Second Method: This method for describing odor nuisance takes the prevailing wind in the area into account as well as the FIDOL components. The interviewees' emotional investment in the issue can have an impact on this methodology. To produce accurate evaluations, a broad social involvement and significant community participation are afterward formed. The Citizen Science approach is used in this method. Additionally, this method is used in the research of (Lotesoriere et al., 2021) (Eykelbosh et al., 2021) (Cangialosi et al., 2021) (Bokowa et al., 2021) and numerous further researches.

Third Method: In modeling atmospheric dispersion, meteorological elements including wind speed, wind direction, climatic stability, precipitation, temperature, and more are considered. This method

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aids in identifying the minimum separation distances from the odor source and the nearest receptors as well as the necessary protection level. This method of getting the results is claimed to conserve time. The research of (Bruce & Antileo, Assessment of odour emissions by the use of a dispersion model in the context of the proposed new law in Chile, 2021) (Schauberger et al., 2021) (Oettl et al., 2022) and several others applied this method in determining the odor dispersion.

The study of (Jonca et al., 2022) supports the use of earlier methods for odor nuisance evaluation.

The bigger categories of odor effect assessment methodologies, which may include mathematical methods like dispersion models, determine how odors are measured. Four categories can be used to group these techniques:
First: sensorial as using the human nose as the receptor, second: instrumental, third: odor measurements at a specific emission level such as at the odor source might be measured, and fourth: odor measurements at the receptor level, in the neighborhood where the complainants live (Capelli et al., 2019) as shown as Fig. 3.

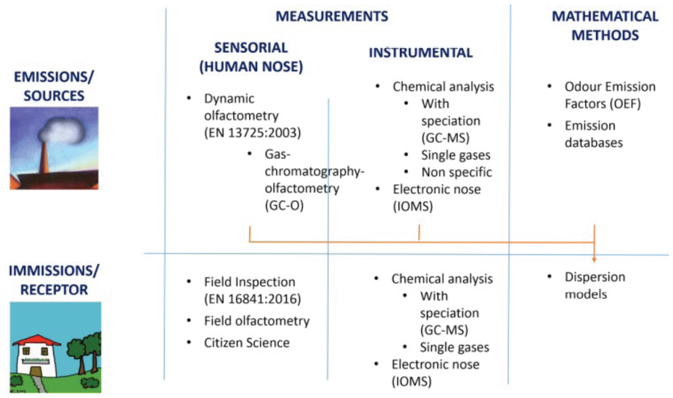

Fig. 3. Overview of odor impact assessment methods (Capelli et al., 2019)

Chemical analysis, Gas Chromatography-Olfactometry (GC-O), Tracer analysis, Instrumental odor monitoring like e-noses, Field inspection, Field olfactometry, and Citizen science are among the important methods for measuring odors (Bax et al., How Can Odors Be Measured? An Overview of Methods and Their Applications, 2020) as shown as Fig. 4.

	Emissions	Immissions
Sensorial	Dynamic olfactometry (EN13725:2003)	Field inspection (EN16481:2016) Field olfactometry Citizen Science Gas chromatograpfy-olfactometry
Instrumental	Chemical analysis • Speciation • Single gases • Non-specific Electronic nose (IOMS)	Chemical analysis • Speciation • Single gases Electronic nose (IOMS)
Mathematical methods	Odor Emission Factors (OEF) Emission databases	Dispersion models

Fig. 4. Schematization of odor impact assessment methods (Bax, Sironi, & Capelli, 2020)

The following part is a summary of the odor effect evaluation techniques:
1. The European Standard EN 13725:2003 regulates the sensory dynamic olfactometry approach. This technique determines the concentration of odors released at the source, confirms compliance with regulatory requirements, and provides information used as input data for dispersion modeling to determine the exposure of residents to scents. However, this approach is regarded as discontinuous; it offers no details regarding the scents distinctive qualities or hedonistic tones, nor does it reveal whether they are present in the surrounding air as shown in Fig. 5.

2. Chemical analysis with speciation method GC-MS is a practical technique that may be used to analyze emissions at the source or ambient air at the receiver. This method provides details on the chemical makeup of the scents and categorizes the chemical compounds that are discovered to aid in determining how they might affect the environment and human health. Due to masking effects between odorants, this method is not always effective, particularly when it comes to classifying compound odors. It also only approximates the relationship between the chemical arrangement and the mixture odor concentration, and it is less sensitive to malodorous compounds with low odor thresholds than the human nose. As shown as Fig. 5.

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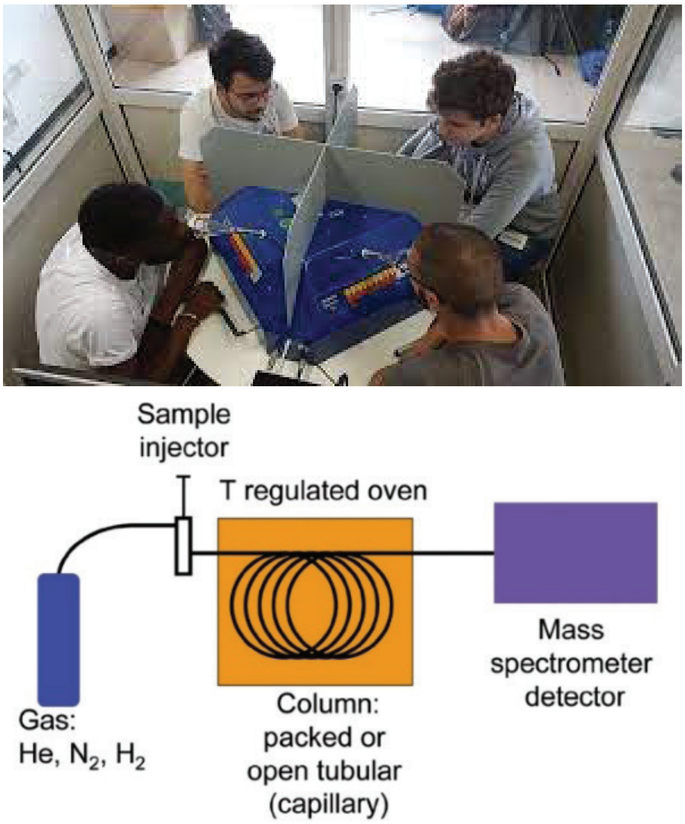

Fig. 5. Dynamic olfactometry session (left). Schematization of a GC-MS (gas chromatography coupled with mass spectrometry) analysis system (right) (Bax, Odor Measurement Methods, 2022)

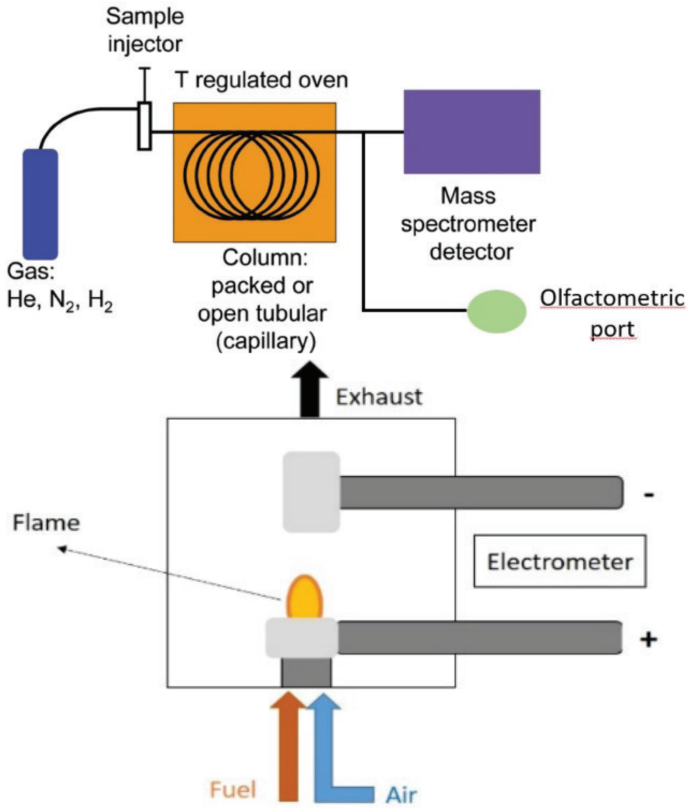

Fig. 6. Gas chromatography analysis with olfactometric detection (GC-O) (left). Flame ionization detector (FID)(right) (Bax, Odor Measurement Methods, 2022)

3. As it combines traditional gas chromatography analysis with human olfaction to distinguish volatile organic molecules eluting from GC separation, gas-chromatography olfactometry GC-O is a mixed method instrumental and sensory. It is applied at the emission level. This technique, which has a high sensitivity since the human nose is more sensitive than an instrument sensor, gathers information on the olfactory character associated with the different particles present in an odor sample. However, because the sample is broken down into its individual components, this method cannot provide information about the odor concentration of the sample, so the olfactory properties of the sample as a whole are not considered. Additionally, because this method is unable to offer information for the odor impact, it is not used as an input for dispersion modeling. As shown in Fig. 6.

4. Chemical analysis—non-specific is a useful technique that might be used at the emission level. This technique enables the detection of gas leaks, which may be associated with diffusing odor emissions. However, this approach provides no information regarding the odor characteristics of the tested gas. As shown in Fig. 6.

5. Chemical analysis—single gases is an instrument method that could be used for ambient air or emissions which is a chemical analysis of single gases. In the rare instances where the odor is directly correlated to tracers and the source can be uniquely identified, this method offers an assessment of the impact of the odor in surrounding air, a calculation of the odor concentration in emissions, and a quantification of the concentration of single gases in emissions or ambient air. It could be supplemented with other ways for a more thorough olfactory description; however, this method is ineffective for complicated odorous combinations because it does not reveal their composition.

6. Instrumental odor monitoring E-noses is an instrumental technique that may be used for ambient air or emissions. With a constrained budget, this method offers continuous and quick results, continuous monitoring of the odor concentration at emissions, a direct assessment of the odor effect at receptors, and identification of the odor source. However, this technique cannot replace dynamic olfactometry because it cannot provide information on odor intensity and hedonic tone. As shown as Fig.7

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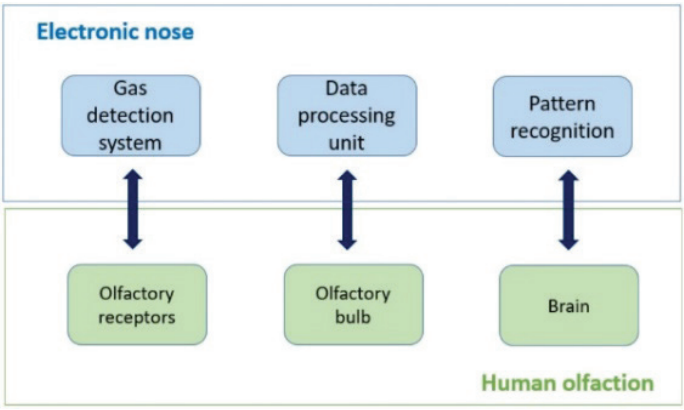

Fig. 7. Electronic nose structure. (Bax, Odor Measurement Methods, 2022)

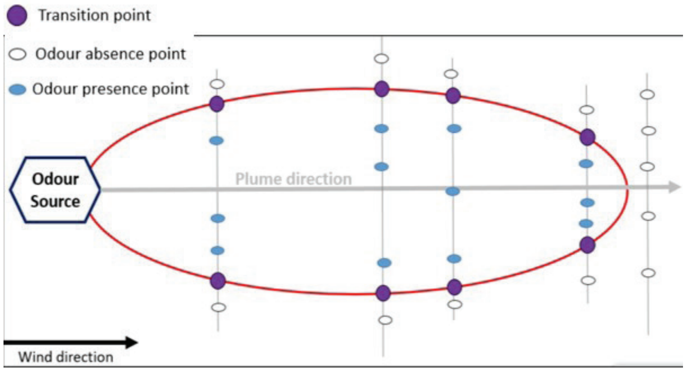

Fig. 8. Example of an assessment area in the surroundings of an odor emission source with assessment squares and measurement points(left). Stationary plume method—field inspection(right). (Bax, Odor Measurement Methods, 2022)

7. A sensory technique that may be used at the immissions receptor level of ambient air is field inspections. This method specifies the extent of the odor plume from a facility under specific climatic circumstances plume method; experienced assessors can provide information about the odor quality; it assesses the degree of irritation concerning odor hours in a designated negatively affected area. However, this procedure is time-consuming and expensive, and it gives no information regarding the odor concentration grid method as shown in Fig. 6.

The grid method is a statistical study technique that can offer a symbolic map of odor detection while also being descriptive of the local meteorological circumstances.

The plume method is used to determine the region that, under specific weather and operational conditions, may be used to identify and detect an odor plume emanating from a specific odor source as shown in Fig. 8.

8. Field olfactometers, which are portable odor detection and measurement instruments, are used in field olfactometry, a sensory technique, to quantify scents in ambient air. This technique shows how many times ambient air must be compressed to become odorless close to an odor source. On the other hand, the dynamic olfactometry method following EN 13725:2003 at the emissions level is the sole way to determine the odor concentration in ouE/m3, which is not provided by this method. Another drawback is the results great unpredictability when considering numerous uncontrollable elements like wind speed and direction, etc. Field olfactometry provides data that can practically never be compared to any other odor characterization techniques. Therefore, for various sensorial approaches, the assessors' measurement is an important aspect of the reproducibility of results.

9. A sensory technique called citizen science may be used at the emissions receptor level of ambient air. This approach involves involving the public in the mapping and management of odor problems and estimates the level of irritability by discussing the impact on the public. However, this method has a significant degree of result unpredictability, and the potential for biased information, and is rarely suitable in contentious circumstances such as legal proceedings.

After presenting the numerous odor evaluation techniques, it is revealed that not all of them could be applicable in this study as the main emphasis is at the receptor level and the measurement techniques that rely on chemical measuring tools will not be used in this research. The first technique, Dynamic Olfactometry, is only effective at the emissions source level and is unable to detect scents in the

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surrounding air. Even though the second approach, Chemical Analysis with Speciation approach GC-MS, is valid at the emissions source or/and ambient air receptor, it is less sensitive than the human nose because, in the situation of mixed scents, this method is regarded as ineffective. The third technique, gas chromatography olfactometry GC-O, is applicable at the emission level and is also regarded as a study of chemical analysis. The fourth technique, non-specific chemical analysis, is valid at the emission level and relies solely on gas measurement, giving no details about the odor qualities. The fifth technique, Chemical analysis of single gases, can be used to analyze emissions or ambient air, but it must be paired with other techniques to provide a more thorough description of the odor. The sixth technique, E-noses, is valid for emissions and/or ambient air, but it is unable to provide data on the study important measurement variables, odor strength, and hedonic tone. The seventh method, although it identifies the many environmental factors that influence odor dispersion, field inspections are only valid at the receptor level ambient air because they need the presence of qualified assessors who are not present in the study region. The measurements of the assessors are a major factor for the repeatability of results in the eighth method, field olfactometry, which is usable in ambient air. The ninth technique, citizen science, is valid at the receptor level of ambient air. Despite the significant variability of outcomes and the possibility of biased information, this method is best for measuring odor annoyance and mapping results based on citizen participation. Additionally, this approach has no need to perform chemical investigations that rely on the molecular characteristics of odors.

B. The Citizen Science Method

The goal of citizen science CS is to increase public participation and collaboration in scientific research (Heigl et al., 2019). The citizen science method is an essential part of place-making, research investigates the way citizen science may promote a closer relationship between individuals and their surroundings, lead to fresh perspectives on those locations, and inspire people to take an active role in protecting those environments. In order to gain a deeper understanding of the connections between citizen science and sense of place in relation to urban waterfronts, researchers assessed the goals and experiences of citizen scientists (Toomey et al., 2020). Place-making can be challenging in cities; it can be experienced by taste, smell, sound, and skin sensation. Many Taipei residents believe that their city lacks a distinct international identity (Freeman et al., 2019). Another researcher has also embedded the collaborative sensory act of place-making as some residents declined the smells (Perkins, 2023). Researchers studying smells say that distinct cities may be distinguished by their smell, as demonstrated by the way one's nose distinguishes between urban and rural areas, according to Porteous (1985) and Henshaw (2014), communities used to be recognizable as pulp mill, colliery, leatherworking, chemical, or smelting towns because they each had a unique scent associated with their respective industries. Early 20th-century rural areas, on the other hand, were distinguished by the natural scents of hay, plants, horses, and cows. Though city design and urban management strategies have diminished the perceived role of odor to one that is limited and viewed as having a typically negative influence on the urban environment, modern urban smellscapes are less odorous (Allen, 2021).

The human nose, one of the most effective odor sensors, is used in the CS method to detect and analyze scents. Populations are actively involved in mapping and managing odor concerns. Citizens are specifically asked to create surveys based on questions on the frequency, severity, length, source of the odor, and type of odors they encounter. A clear description of the odor matter can be built using several personal observations, but because this methodology is relatively new, it is also important to examine prospective solutions. The method drawbacks include the potential for biased data, the difficulty of implementation in contentious contexts like court cases, and the high degree of outcome variability (Bax et al., How Can Odors Be Measured? An Overview of Methods and Their Applications, 2020).

(Seltenrich, 2022) applied a smartphone application to pinpoint the location of the odor on a map, he has used the citizen science technique to characterize different odor sources and create a comprehensive picture of how environmental aromas and air pollution are perceived. The research of (Chen et al., 2022) conducted a poll to determine the preferences of 103 German participants and 96 Chinese participants for 40 different odors. The goal of (Lotesoriere et al., 2021) project is to verify a novel approach to managing odor pollution developed using citizen scientists. Despite

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traditional methods for measuring and analyzing odor intensity, olfactory impact, and hedonic tone, the analysis typically ignores the knowledge of the general public. Additionally, real-time citizen odor observations are employed to evaluate the impact of odor on a community (Schleenstein et al., Advanced psichometrics based on citizen science. A history, a new standard, a European project and a case study in Chile., 2021).

Numerous elements that this method depends on can be listed as follows:
The four main determinants of sensitivity are generally agreed to be experience, expectations, motivation, and the receiver's level of attentiveness. These four criteria also have an impact on the sensitivity of groups, the number of affected people city, town, scattered houses, etc. The land use where the receptors are located is industrial, rural, hospital, school, etc. The housing uses continuous, occasional, fortuitous, etc. Even the type of environmental protection that the impacted area may have affects group sensitivity in the case of people exposed to odor impact (Schleenstein et al., Advanced psichometrics based on citizen science. A history, a new standard, a European project and a case study in Chile., 2021).

In order to quantify and calculate odor emission rates OERs and utilize them as an input for air dispersion models, the odor concentration is the factor that is most frequently used. Human perception or social interaction are crucial tools for odor assessment (Capelli et al., 2013). The analysis regional and temporal scope, the region difficulties, the availability and predictability of weather and emission data, as well as the needed time solution for effect assessment, are the main influences on the odor dispersion method (Onofrio et al., 2020).

Odor concentration fluctuations vary depending on a number of parameters, including the unpredictable nature of emissions, the type of source, the steady air state, and the distance between the source and the receiver (Zanetti et al., 2020).

When compared to a dispersion model, the study of (Schauberger et al., 2020) simplifies the process of confirming the direction-dependent influence of air data on calculated separation distances.

As shown as Figures 9 and 10 in this study, participants were given the opportunity to translate their thoughts through the use of numerical indicators that represent odor intensity as well as hedonic tone. Due to the lack of chemical characteristics of the odors in this study and the lack of odor meters often used in this field, it will not be possible to determine the concentration of odors.

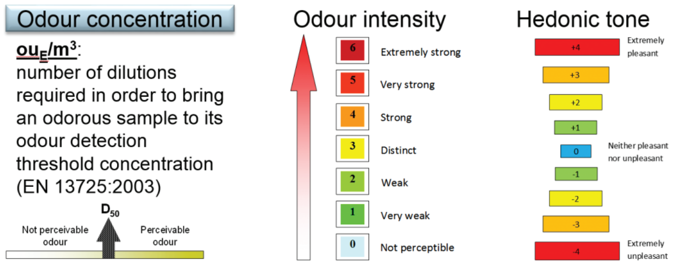

Fig. 9. Odor concentration definition, odor intensity scale and hedonic tone scale (Dynamic Olfactometry- Odour Observatory, 2018)

Hedonic Tone	Verbal Description
−4	extremely unpleasant
−3	moderate unpleasant
−2	unpleasant
−1	slightly unpleasant
0	neutral
1	slightly pleasant
2	pleasant
3	moderate pleasant
4	extremely pleasant

Degrees	Intensity	Properties
0	None	People cannot feel an odorous smell with a normal sense of smell
1	Threshold	People smell something but cannot recognize the type of smell
2	Moderate	People smell something and can recognize the type of smell
3	Strong	People easily smell something strongly like a cresol smell in hospitals
4	Very Strong	People strongly smell something like a conventional rest room
5	Over Strong	People strongly smell something and gag or hold their breath

Fig. 10. The 9-point hedonic scale for odors (left) (Li, Zou, Li, & Yang, 2019), Classification of odor intensity by the human nose (right) (Park, 2020)

Human assessors breathe air to test and record how they perceive odors. Hedonic impression, perception frequency, and odor concentration are the established standard criteria for odor measurement. In order to eventually determine typical measurement values, numerical procedures play a crucial role in the assessment of the unprocessed data gathered from the assessors (Petrich & Delan, 2021). In the study by (Çeven et al., 2022), the human

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assessors identified the types of smells. (Bax, Odor Measurement Methods, 2022), (Bax et al., How Can Odors Be Measured? An Overview of Methods and Their Applications, 2020).

A study team created a particular application (APP) to gather citizen reports. The purpose of the APP is to request that users identify an odorous event and its primary features. Citizens are requested to complete a questionnaire with their observations regarding the odor incident intensity (weak, distinguishable, strong); duration (instant odour, more than 1 hour; and more than 6 hours), offensiveness ("unpleasant" or " unpleasant"), type of odour perceived (listed in wheel precisely designed to analyze all the probable odour sources in the studied area) (Oliva et al., 2024).

An engagement strategy that includes the phases of pilot design and data collecting has been established by a pilot study conducted in Chile. The participants were instructed to record odor episodes as they happened using a pen and paper odour diary or OdourCollect, a smartphone app that enables the collection of real-time odor observations. The software allows users to report odors by asking "what does it smell like?" and to provide details about the intensity, hedonic tone, subtypes of odors, duration of the odor episode, and possible source. The location, time, and date of the odor observations are automatically noted (Schleenstein et al., 2021).

C. Case Study

In the process of planning and designing, site study is a crucial phase. A site geographic, climatic, legal, historical, and infrastructural surroundings are examined as part of site analysis, a pre-design phase in architectural and urban design. The site evaluation contains the following:
Site Location: This comprises the site specifics, such as its roads and landmarks, context, such as nearby buildings, and vehicular and pedestrian access.

Neighborhood context: this category covers both proposed and existing structures, as well as outdoor areas, activities, vernacular settings, architectural elements, and landscaping.
Site-Specific Information: This section covers the site boundaries and measurements, buildable area, building height limitations, access to the site, and safety on the site and in the immediate vicinity.
Natural Features: these include the site geography, vegetation, and elevations. In addition to accessibility and circulation for both automobiles and people.
Utilities: this category comprises the location of all services, including water, power, gas, and sewer.
Sensory: This category covers views of the location from various angles as well as noise, odor, and pollution.

Human and Cultural: This category consists of local cultural, psychological, behavioral, and sociological elements. Along with the population, it considers the density, family size, ethnic tendencies, occupation, and leisure pursuits.
Climate: comprises site orientation, weather parameters such as temperature, rainfall, predominant wind directions, and the movement of the sun during the day and distinct seasons. (Urban Design Site Analysis, 2022)

Fig. 11. Tripoli City map with odor source location (Google Map, 2023)

To examine the efficiency of the citizen science method in measuring odor perception, the measurement of odor intensity and hedonic tone is applied in this part of the study. The selected case study is located in Tripoli city in Lebanon, and as the focus of this study is on the unpleasant odor, the measurement will focus on the unpleasant part of the hedonic tone, in addition to the measurement of the odor frequency, and intensity. As the main focus is on the unpleasant odor, the landfill of Tripoli city is selected as a significant source of unpleasant odor that affects people in their inhabited areas.

It was mentioned previously that the odor dispersion is affected by wind direction, and it is increased in hot and humid weather. For these reasons, the criteria of the selected impacted inhabited area by Tripoli landfill odors depend on:

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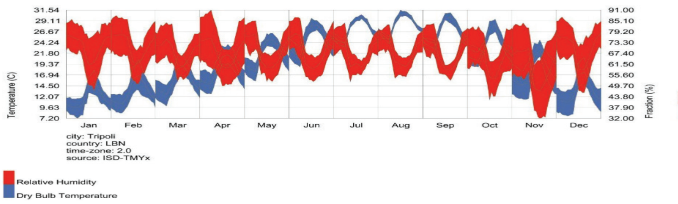


Fig. 12. The relative temperature and humidity in Tripoli city (EPW Map, 2023)

First: the selected season to apply for this study is the summer as this season has the most months of humid and hot days as shown in Fig.12.

Second: the location of the impacted area is selected according to Tripoli city wind rose in the selected season; the summer season. The wind rise of this season shows that the dominant wind direction is from the northwest, so the expected affected inhabited area by odor is located in the southeast of the odor source as shown in Fig.13.

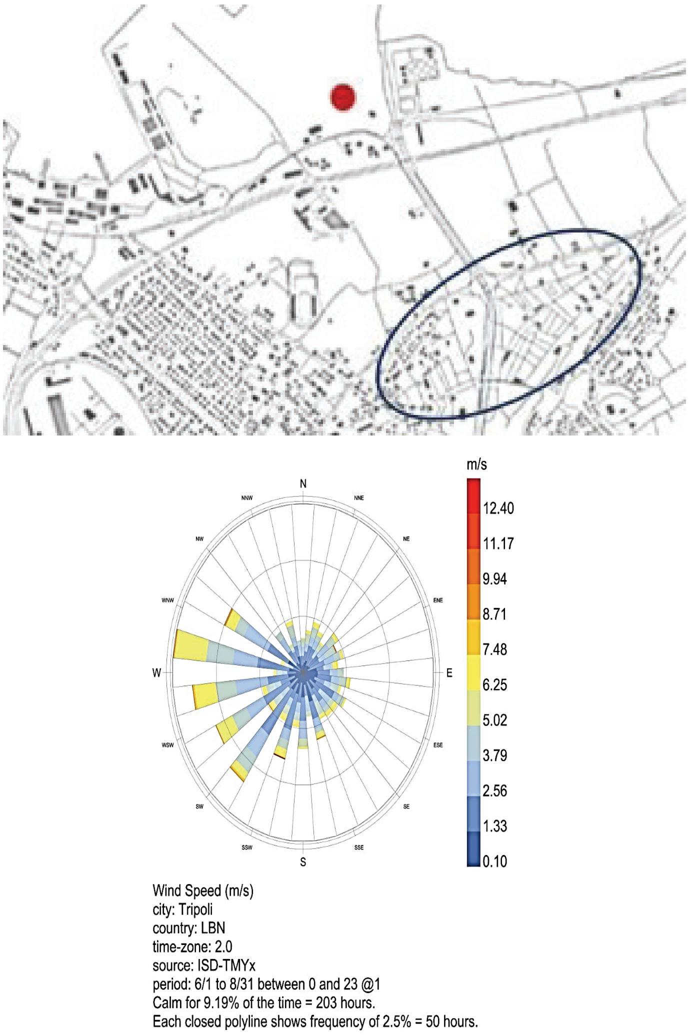
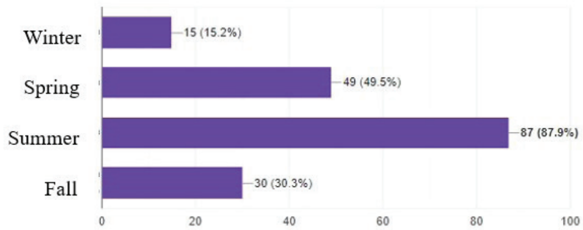


Fig. 13. The selected inhabited area with the odor source location (left), the wind rose of Tripoli city in the summer (right) (EPW Map, 2023)

As this research aims to apply the citizen science method for odor measurement, the questionnaires were distributed to the people in the selected area using Google Forms, and the questions include:
Section One: Socio-Demographic data: Gender, Age group, Employment status, Place of residence, and Duration of residency.

Section Two: includes the odor perceptions of the people living near the landfill site: The landfill odor perception on a scale of -4 extremely unpleasant -3 Moderate unpleasant -2 Unpleasant -1 slightly unpleasant 0 Neutral. The seasons in which people feel the smell or odor become stronger: Winter, spring, summer, and autumn. Time of the day people receive the odor: morning, noon, afternoon, evening, night. Duration of odor: a few hours, a day, more than a day. The odor intensity on a scale of 0 Not perceptible 1 very weak 2 weak 3 distinct 4 strong 5 very strong 6 extremely strong. The odor frequency on a scale of 1 seldom 2 sometimes 3 often 4 very often 5 always. The hedonic tone scale was limited to the nature of the landfill odor as an unpleasant smell, so the scale of this question is from 0 neutral -1 slightly unpleasant -2 unpleasant -3 moderate unpleasant to -4 extremely unpleasant.

The collected answers show that 93 percent of people living in this area are affected negatively by odor sources, and 88 percent of the answers indicate that the summer season is the season that enables people to receive the odors. For the time of the day that people can receive the strongest odors, 57 percent of the answers indicate that noon time is the significant time to receive the odors. The duration of odors according to the answers could last for more than a day according to 44 percent of the answers. For the odor intensity, the answers were equal between Distinct the scale of 3, and Strong the scale of 4 with 30 percent answers for each of these two scales. The odor frequency answers show that 37 percent of people Often receive the odor; on a scale of 3. The hedonic tone question shows that 63 percent of people consider the odor extremely unpleasant; on a scale of -4 as shown as Fig.14.



a. The season.

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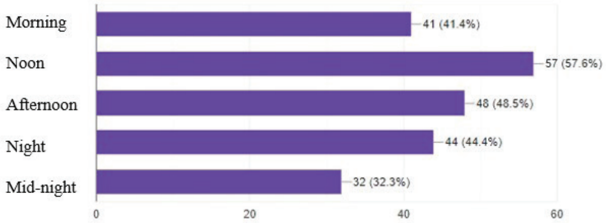
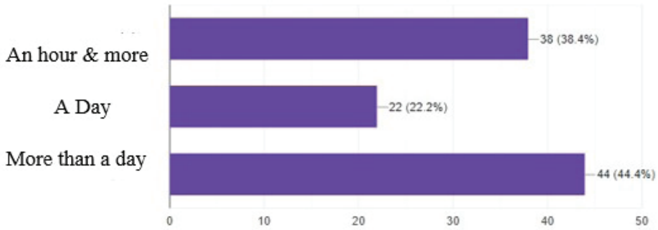
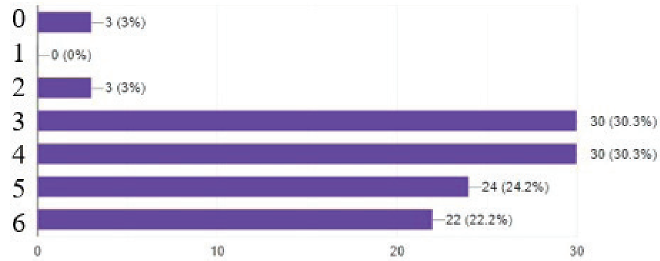


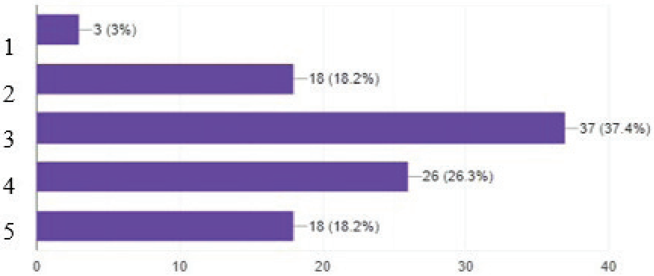
b. Time of the day.



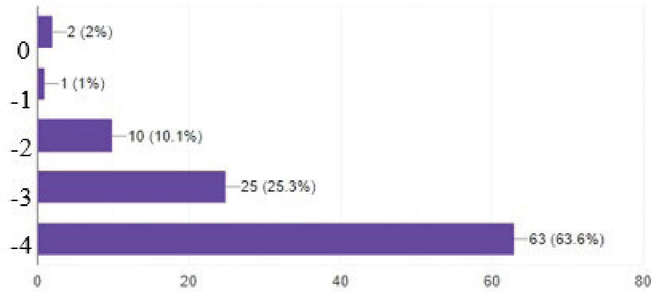
c. Duration of odors.



d. Intensity of odor.



e. Odor frequency.



F. Hedonic tone.

Fig. 14. People's responses to the questionnaire (Author)

The people's answers ensure the expected outcomes as the theoretical part presents the role of wind in carrying odors and the wind direction controls the odor dispersion side. In addition, the high temperature following the high humidity level plays a significant role in increasing odor intensity which causes people to receive a high level of odors.

Citizen science is an applicable measurement tool that could be adopted to measure and estimate the odor intensity and frequency with less requirement to odor measurement tools that might be not available for the urban designers while studying the sensory part of the urban site analysis.

FIDOL factors are significant analyzing factors that help the urban designers to assess the people perception and determine the scale of odor nuisance in the investigated area. Therefore, applying the citizen science method for odor measurement is an effective method to evaluate the odors that affect people.

VI. CONCLUSION

The smell concept has received more attention recently, especially in architectural and urban studies. The consequences of odors in metropolitan settings, however, are a topic that receives much more attention from chemical and environmental studies. This paper aims to provide a validated and applicable method for urban designers in odor measurement. The objective of this research is to present the various methods of measuring odors adopted in chemical and environmental studies to achieve an applicable odor measurement method in the architectural urban field. Chemical and environmental investigations use odor measurement equipment that is typically specialized in measuring odor concentration at the odor source or at the receptor location. However, in urban design studies, a separate technique known as the citizen science approach could be used to assess the odor if the urban designer intended to estimate the odor effects in the examined region. The measurement in this case considers the FIDOL factor to evaluate the odor including odor frequency, intensity, duration, offensiveness, and location, in addition to hedonic tone to estimate the degree of odor nuisance that people can feel. This method aids the urban designer in estimating the odor nuisance that adversely affects the people in their inhabited areas. This study was applied in Tripoli, Lebanon, as a case study to identify Tripoli landfill as a significant source of odor that affects residents there. An odor source circulated a questionnaire to the affected region, and the residents who responded confirmed that summer is the most common time of year for them to notice the odor in their locations to be related to the wind direction. The findings confirm the validity, applicability, and accessibility of the citizen science approach for assessing odors for urban designers.

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