# Odour nuisance and urban residents' quality of life: A case study in Kraków's in Plaszow district[☆]

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A B S T R A C T

This paper aims to assess the level of odour nuisance in the south-eastern part of Kraków (Płaszów) and the related quality of life. It includes two aspects: life comfort and the health aspect. Kraków is one of the largest urban centres in Poland. It is globally perceived as the cultural capital of Poland and is the country's main tourist destination. It is also one of the most polluted cities in Poland. Płaszów, as a district of Kraków, is characterised by the largest increase in urbanised areas and changes in the spatial development of the municipality of Kraków.

The research methodology was divided into the phases comprising of qualitative and quantitative research. Qualitative research included (1) the analysis of the content on Internet forums and social networking sites as regards odour nuisance concerns, (2) in-depth ethnographic interviews with residents of Płaszów's housing estates, which were conducted in the form of strolling groups created specifically for this purpose, combined with the recording of impressions, remarks and associations of their participants and representative residents of the studied area.

A measurement tool, developed according to the VDI 3883 guidelines, based on the latest outcome of research on odour and noise nuisance, was used for assessing odour nuisance. The questionnaire was developed based on German experience. Empirical research was conducted for the area sample of 2000 respondents. The selection of respondents was carried out by a random stroll.

Questions scaled according to two scales of annoyance constituted the key part of the questionnaire. One of them was a 7-point ordinal scale and the other a 10-point interval scale. These scales allowed collecting information from respondents significantly related to the purpose of the study. The research sample consisted of respondents representing households using the water supply and sewage disposal services located in the area of Płaszów. Within that area, according to the data obtained, 21,925 people utilised these services.

The conducted qualitative and quantitative research carried out on a large wide scale in one of Poland's largest cities in Poland ‑- Kraków -‑ undoubtedly constitutes the beginning of the identification and assessment process concerning of the scale of this problem in urban space. The results of this research work indicate unequivocally point to the influence of perceived fragrances smells on the health and the sense of comfort of local residents. The assessment of this phenomenon is common and does is not dependent on the gender or age of respondents. However, it has an impact on everyday life and subjective feelings about concerning the state of health caused by living in an area with unpleasant odours. This research proves that the more intense the and unpleasant the odour is, the less resistant one is to move out of their current home. The longer people live in the area, the less negative their feelings are, which may mean they get used become accustomed to the environment they are living in. According to the respondents, the unpleasant odours have the greatest impact on health factors, which in turn determines the sense of life comfort. The results obtained in this study indicate the need for further, in-depth research in this area.

## 1. Introduction

Air pollution related to the presence of fragrances is referred to as odour nuisance, which is particularly severe for residents of areas directly adjacent to industrial plants (Carrera-Chapela et al., 2014, Gębicki et al., 2014). Although the problematics of odour nuisance generally affects urban areas, which is related to population density (Pedersen, 2015), odour compounds present in the air constitute a significant problem for the whole of society (Carrera-Chapela et al., 2014). Literature on the subject indicates the impact of odours on the quality of life in the context of health problems associated with long-term exposure to odours. The term "quality of life" used in the article is based on the definition of the World Health Organization (WHO). WHO defines Quality of Life in general as an individual's perception of their position in life within the context of the culture and value systems in which they live, and in relation to their goals, expectations, standards and concerns. It is a broad-ranging concept influenced in a complex way by a given person's physical health, psychological state, personal beliefs, social relationships, as well as their relationship to the salient features of their environment. It is the most frequently used and applied term in research and literature. In most cases, the harmful effects of odours are not related to their toxic effects on the body but result from their subjective reception and evaluation, which have an adverse effect on the human psyche in the long run. Stress from this situation can result in headaches, problems with concentration, nausea or insomnia (Byliński et al., 2019).

Growing public awareness of the impact of air quality on health (Nicell, 2009) translates into citizen complaints to public health agencies that suggest odours can not only serve as a warning of potential risk, but that smell alone can give rise to negative health symptoms (Schiffman and Williams, 2005). Exposure of residents to "onerous branches of the industry", such as devices for the removal and treatment of urban wastewater, the use of sewage sludge, breeding of industrial animals and the production, storage and transport of industrial chemicals, have rendered odour measurement in recent decades a very important issue (Schiffman and Williams, 2005; Buettner, 2017; Croy et al., 2014). The research scope includes research in the field of identification of factors influencing the recognition and assessment of odours by humans (Greenberg et al., 2013) as well as the evolution of methods, techniques and views regarding odours as an air component (Gruber et al., 1960; Kerka and Kaiser, 1958). Research is also being conducted increasingly to take into account the social behaviour of residents (Eltarkawe and Miller, 2019), including the ability to change residence. According to Boswall and Lee, 2002, there are many factors and sources causing an abandonment effect, and roads, airports and sewage treatment works, for example, may result in the occurrence of odours. There is a combination of possible effects, such as noise, visual intrusion, unpleasant odours, extending over the active life of a landfill. The decision to abandon home and move elsewhere is inducted after long-term living in an unpleasant environment and when the trade-off costs are lower than investment in the current living space (house or apartment).

Urbanisation means not only creating better living conditions but also several unfavourable phenomena affecting what is referred to as "Quality of Life" (QOL). Quality of life is one of the key issues at the focal point of research integrating researchers from many scientific disciplines and practitioners for several decades (Blomquist et al., 1988; Gehrmann, 1978). So far numerous attempts have been made to create a uniform methodology and quality of life indices (Nissan, 1989), but it was only the methodology proposed by the WHO that set the framework within which researchers and practitioners could develop their research projects (WHOQOL Group, 1993).

Specific factors harmful to quality of life in urban areas include anthropogenic factors like urban congestion, electronic smog (mobile phone transmitter antennas), low heat source smog, traffic-intensive car exhaust fumes, existing industrial plants, urban waste, etc. As a result of these factors, the problem of unpleasant odour nuisance is increasingly often the source of the negative assessment of the quality of life, including life comfort. The human nose can distinguish about ten thousand various types of odour (Zucco et al., 2014). The sense of smell is, for a human being, one of the most important tools for identifying environmental factors, collecting information about them, and consequently analysing and evaluating them from the perspective of their importance for human life. The sense of smell – olfaction – is an integrated system of human activity (Mori and Manabe, 2014) considered to be a separate subsystem of memory (Herz and Engen, 1996; Green et al., 2018; Zucco et al., 2014). Fragrances affect not only sleep (Shanahan and Gottfried, 2014) or consumer decisions (Mitchell et al., 1995) but also everyday life (Cowart, 1989). Fragrances are not only an element of the biological environment but also a cultural factor connected with the creation of specific fragrances by man and their use to build interpersonal relations. Fragrances have become the subject matter of cross-sectional studies, identifying factors affecting their recognition and evaluation by humans (Buettner, 2017; Croy et al., 2014; Zucco et al., 2014; Greenberg et al., 2013), and thus can cause discomfort.

This study aims to assess the level of odour nuisance in the south-eastern part of Kraków (Płaszów) and the related quality of life. It includes two aspects: life comfort and the health aspect. In this article the term "life comfort" is used according to the definition of Aletta and Xiao (Aletta and Xiao, 2018). These authors use the term "comfort" in reference to a state of satisfaction or physical or physiological wellbeing produced by harmony between the individual and his or her environment, i.e. between a person's physiological conditions and environmental conditions. Comfort refers to a short-term state of wellbeing, in parallel to the concept of health, which refers to long-term wellbeing. Urban environmental comfort corresponds to the comfort associated with specific factors shaping the environment as acoustic, thermal, lighting, visual and olfactory factors. Kraków is one of the largest urban centres in Poland. It is globally perceived as the cultural capital of Poland and is the country's main tourist destination. It is also one of the most polluted cities in Poland.

According to the opinion of its inhabitants, odour issues have been and continue to be a serious concern for people living in the area, and this concern has been repeatedly reported to institutions monitoring environmental protection. The essence of the concern is confirmed, for example, by Internet diaries maintained by residents describing odour nuisance in the form of reports, as well as the content published on Internet forums describing complaints concerning odour nuisance. Research has also focused on the relationship

between odour nuisance and health and social consequences. The research objective has been achieved particularly owing to the identification, analysis and assessment of the factors constituting the source of the unpleasant odour, as well as an assessment of the degree of odour nuisance for the residents of the research project area. The main research hypothesis reads as follows: odour nuisance has a considerable impact on the life comfort and health of residents. The following specific hypotheses have been formulated:

**H1.** unpleasant odours harming health factors influence life comfort,

**H2.** unpleasant odours are considered by residents to be the reason for leaving their place of residence, accounting for both dissonance and regret caused by such a decision,

**H3.** the intensity of unpleasant odours does not cause one to leave their home unless this is accompanied by changes in life comfort and health factors.

A measurement tool, developed according to VDI 3883 guidelines, based on the latest outcome of the research on odour and noise nuisance, was used for assessing odour nuisance. The questionnaire was developed based on the German experience (VDI 3883/Part 1, 1997; Cervinka and Neudorfer, 2004; Felscher-Suhr et al., 2000; Fields et al., 2001; Gallmann, 2011). The German researchers propose for example the 7-point scale of odour intensity (Extremely strong – 6; Very strong – 5; Strong – 4; Distinct – 3; Weak – 2; Very weak – 1; No odour – 0) and 11 characterisations of odour qualities (A – No odour; B – Farm odour (difficult to define); C – Slurry; D – Farm odour: breeding pigs; E – Farm odour: breeding cows; F – Agricultural straw, corn odour; G – Bakery odour; H – Exhaust fume odour; I – Coal burning odour; J – Fermentation (rot) odour – to be specified; M – Other: to be specified). The key part of the survey questionnaire used were 7-point and 10-point Likert scales. The survey also included questions about the acceptance of odour nuisance, the frequency of the smell, its type and intensity, and the possible sources of smell origin, as well as socio-demographic questions. Empirical research was conducted for an area sample of 2000 respondents. The selection of respondents was carried out by a random stroll.

## 2. Literature review

In principle, since the 1970s, research on the measurement and assessment of quality of life has been carried out mainly in the USA and Europe. It has addressed urbanisation and population density concerns, the impact of these processes on social phenomena (Carnahan et al., 1974) as well as cross-sectional research over nearly 80 years of the 20th century conducted using a deflator to identify the relationship between the size of cities in the USA and GDP growth (Clark et al., 1988). Quality of life was also studied as concerns expenditure, management and institutional structure in selected urban areas (Wish, 1985), and attempts were made to create a methodology for research on quality of life in the context of the labour and real estate markets in urban areas of the US (Stover and Leven, 1992). The methodology proposed by the WHO served as the basis for comparative research and complemented the issues of quality of life with new psychological aspects, such as cognitive maps of urban areas (Faria et al., 2018). Cross-sectional surveys on quality of life in Europe based on Eurostat and Euro barometer (Petrucci and D'Andrea, 2002), the international comparative analysis of the approach to the assessment of the quality of life in urban areas (Bork-Hueffer, 2014) or possibilities of convergence of quality of life indicators on an international scale according to the concept of beta-convergence (Jordá and Sarabia, 2015) constitute examples of an integrated approach. Empirical research carried out on an increasingly large scale has allowed for the verification of various quality of life predictors in urban areas based on scales proposed by the WHO (Tartaglia, 2013) and indicated the possibilities and limitations of research on quality of life in urban areas (Turksever and Atalik, 2001).

Attempts are also being made to develop universal methods and indices to measure quality of life in the urban environment concerning human health. This is exemplified by the Urban Health Indicator (UHI), which accounts for tools used for measuring and assessing the impact of physical conditions on the health of people in urban areas (Pineo et al., 2018; Ray, 2017; Taype-Rondan et al., 2017; Bradshaw, 1988).

Research on quality of life in urban areas shows the tendency to deepen the research at the level of local problems (Gao and Melser, 2016), to adapt the QOL index to the needs of small towns (McGrath and Glenn, 2018), and to define QOL indices in order to tailor them to local determinants (Royuela et al., 2009). Recent years have highlighted the problem of quality of life in cities for ecology and sustainable development, e.g. the impact and assessment of quality of life in cities due to the existence of green areas (van Leeuwen et al., 2006). The other authors increasingly refer to sustainability and smart city concepts (Sharida et al., 2020).

Quality of life in urban space is increasingly a problem of cooperation among various stakeholders (Roukouni et al., 2018). Therefore, it is extremely important to recognise and shape the expectations and ideas of residents to the extent of quality of life resulting in an acceptance of the place of residence (Cilliers et al., 2015), especially in the context of the development of cities and urban areas (Szafranek, 2016).

Air quality and emission of compounds into the atmosphere are the sources of assessment of the quality of life in large cities, i.e. influenced by pollution, weather, climate change (Blanes-Vidal et al., 2012; Cliffe-Byrnes and O'beirne, 2010; Di Gilio et al., 2018; Gou et al., 2017; Mirabelli et al., 2006; Muižniece-Treija, 2017; Wing and Wolf, 2000; Wolkoff, 2018; Alias et al., 2019) and increasingly flagged smells. The term odour has many meanings dependent on context. The negative feelings of people toward odours are subjective. As concerns quality of life and urban space, odours are mentioned in the context of their negative influence on people as something unpleasant and dangerous to human health. The term "scent/fragrance" is mainly used in the case of positive feelings toward an odour, i.e. perfumes. Although this all depends on the context. The positive influence of odour is used predominantly by aroma marketing, cooking promotion, cosmetics sales or aromatherapy. This study and title pinpoint the key issues relating to odour. In literature on this topic, the term odour is used. The paper mainly uses the term "odour" as a term with an unpleasant meaning

regardless of its source of origin. To better highlight the context of odour nuisance, the term "unpleasant odour" is mostly applied in the article.

Along with the development of knowledge on fragrances, methods of their identification and measurement techniques have been devised. As a result, attempts are being made to create universal norms and criteria for their assessment (van Harreveld et al., 1999). Among the methods of assessing air odour nuisance, two key groups should be distinguished: sensory methods and analytical methods. The specificity of the odour perception process makes the sensory methods used for analysing odour nuisance the basis for assessing odour nuisance. The methods of sensory analysis of odour concentration include static olfactometry, dynamic olfactometry and field olfactometry. The static olfactometry method (Cheng et al., 2019b; Cheng et al., 2019a) consists in the static dilution of the collected air sample and presentation of the previously prepared test samples for analytical purposes. The indirect dynamic olfactometry is the second method used for the sensory analysis of odour concentration purposes (Rincón et al. 2019; Hove et al., 2017; Klarenbeek et al., 2014; Zhang et al., 2002; Giungato et al., 2016). The indirect dynamic olfactometry method, i.e. static olfactometry, consists in taking a sample at the test site and delivering it to the laboratory. Subsequently, using a dynamic olfactometer, the test sample is diluted automatically with purified air (Rincón et al. 2019; Hove et al., 2017; Klarenbeek et al., 2014; Zhang et al., 2002; Giungato et al., 2016). This method was presented in the PN-EN 13725: 2007 standard. Air quality – determination of odour concentration by dynamic olfactometry. The third method is field olfactometry, which allows you to perform odour concentration measurements directly at the site under analysis. This method employs the Scentoid SM100 or Nasal Ranger device, which allows for the dilution of stagnant air with air filtered through integrated carbon filters. The measurement is carried out from the highest dilutions and, at each step, the dilution is reduced until an individual perceptibility threshold for the existing smell is reached. The result is calculated as the geometric mean of the odour concentration corresponding to the lowest dilution at which the odour becomes detectable and dilution by a higher degree. These are methods applied only in the analysis of the intensity of fragrances without any correlation with the residents' assessment in the context of the perception of fragrances as having a potential impact on the quality of life.

The issue of odour nuisance is not regulated in Poland, and there are no standards or procedures, so it is often difficult to determine even such an important issue as who should deal with the topic of odour nuisance, i.e. which state institution is responsible for monitoring the environment on this matter. Furthermore, location policy is also not regulated by law, which means that industrial areas are located next to residential areas. Examples of this are some districts of Kraków. The research was carried out in the southeastern part of Kraków (Płaszów). This area is characterised by the largest increase in urbanised areas and frequent changes in the spatial development of the Kraków commune over the last 50 years. Initially, this area was intended as an agricultural area, then an industrial part was separated and, currently, the area is being developed for residential (multi-family) and office purposes. Płaszów has the largest number of industrial plants, including the largest Sewage Treatment Plant and waste processing plants in the Małopolskie Voivodship. Combining so many functions in one area gives rise to growing problems of local communities related, above all, to odour nuisance. Odour issues constitute a serious problem for the residents of Płaszów, often reported to institutions monitoring environmental protection. The essence of this problem is evidenced, for example, by an Internet diary maintained by residents, describing odour nuisance in the form of residents' submissions and content posted on Internet forums describing complaints about odour nuisance.

Given such deficiencies, an attempt has been made to assess quality of life here following the German experience and good practices.

## 3. Research methodology

The methodology of the research was divided into qualitative and quantitative research stages. The qualitative research stage included (1) the analysis of content on Internet forums and social networking sites in respect of odour nuisance concerns, (2) in-depth ethnographic interviews with 14 residents of Płaszów District housing estates in Kraków, which were conducted in the form of strolling groups created specifically for this purpose, combined with the recording of impressions, remarks and associations of their participants and representative residents of the studied area.

Quantitative studies to the extent of the identification, analysis and assessment of factors constituting the source of the unpleasant odour, as well as the assessment of the degree of their annoyance to residents, were carried out employing the questionnaire method. The questionnaire was devised on the basis of the German research outcome. In order to assess odour nuisance, a measurement tool created following VDI 3883 guidelines was used.

The measuring instrument (questionnaire), developed following the guidelines of the VDI 3883–1 standard took into account both the intensity and hedonic aspects of odours troublesome for rural residents. It consisted of two sections: substantive and classifying. The first of these included information on the respondents' period of residence in the area and attachment to the place, assessment of their health status (both subjectively felt and diseases confirmed by a medical certificate – from the perspective of 12 months) and factors impeding daily functioning, with particular attention to airborne odours. Questions concerning odour nuisance allowed to determine their intensity, type (qualitative characteristics), frequency of occurrence, degree of disturbance of the resident of a given area by the smell/smells and complaints associated with him/her. Furthermore, the sensitivity of the examined person to environmental factors as well as their attitude toward the living environment was also taken into account.

The classification part focuses on the following socio-demographic characteristics: gender, age, education, employment, family and housing conditions, as well as involvement in the life of the local community.

The developed measuring tool employs both simple and complex scales. A temperature scale from 0 (zero intensity – causes no disturbance at all) to 10 (unbearable intensity of disturbance) was used to test noise and odour intensity. It stemmed from the latest

research on nuisances caused by odours and noises. The questions in the questionnaire reflected the research questions related to the research problem. The questionnaire consisted of questions concerning such aspects as the type of unpleasant odour, frequency of odour occurrence, seasonality and possible cause of odour occurrence, subjective feelings about the impact of the odour on health and life comfort. The questions scaled on two scales of annoyance constituted the most important part of the questionnaire. One of them was a 7-point ordinal scale and the other a 10-point interval scale. These scales allowed for collecting information from respondents significantly related to the purposes of the study. Both 5-point and 10-point Likert-type scales are regarded as ordinal scales. However, the violation of the assumption of the equality of intervals and attenuation of correlation coefficients are heavy when the scale consists of fewer than 5 points. So, we formally labelled a 7-point Likert-type scale as ordinal and the 10-point scale as an interval. However, as all of the scales have more than 5 points and attenuation is not overly extensive, we decide to label scales as interval accordingly, to be used in SEM – path models based on a covariance matrix. One of them was a 7-point scale and the other a 10-point scale. Formally, both 7-point and 10-point Likert-type scales are regarded as ordinal scales. However, the violation of the assumption of the equality of intervals and attenuation of correlation coefficients are noticeable when the scale consists of fewer than 5 points. However, as all scales have more than 5 points and attenuation is not overly extensive, we decided to treat these scales as interval accordingly, and employ them in SEM path models based on a covariance matrix. Additionally, as Rex Kline (2011) argues "Likert scales with about 5–10 points may be favourable in terms of people's ability to reasonably discriminate between scale values (anchors). The research sample consisted of respondents representing households using water supply and sewage disposal services located in the area of Płaszów. Within that area, according to the data obtained, 21,925 people used these services.

Based on the pre-research analysis of residents' applications and the review of social media and press releases, the district of Płaszów was divided into 11 zones. These zones were separated based on data obtained in the process of qualitative research, carried out in the form of face-to-face interviews, based on the analysis performed prior to the relevant research, which concerned residents' submissions and a review of social media and press releases. Furthermore, the concentration of residents and the main streets and routes were taken into account. The analysis was also based on ethnographic strolls) with the residents of the study area. This rarely used form of qualitative research is a variation on group interviews conducted in natural surroundings. Walks with selected residents took place in varying weather conditions, at different times of the day and week, and in places most frequently indicated in opinions on discussion groups and social networks. Owing to the actions taken, information on the intensity and types of smells found in various areas of the district was verified and detailed. Subsequently, the collected results were marked on the district map. Eleven fragrance zones were designated based on the street and residential communication system. This constituted the basis for the development of quantitative research and verification of hypotheses regarding the occurrence and types of odours in individual residence zones in the district. Before the quantitative data collection process, actions were taken to determine the area of potential odour occurrence. To this end, one of the methods was used, i.e. a complaint map. The qualitative data collected and ordered, including complaints and comments from residents posted on Facebook, enabled not only the carrying out of the initial assessment of the state of odour nuisance in the studied area, but also the determination of a map of potential odour risk.

German researchers propose, for example, the 7-point scale of odour intensity (Extremely strong – 6; Very strong – 5; Strong – 4; Distinct – 3; Weak – 2; Very weak – 1; No odour – 0) and 11 characterisations of odour qualities (A – No odour; B – Farm odour (difficult to define); C – Slurry; D – Farm odour: breeding pigs; E – Farm odour: breeding cows; F – Agricultural straw, corn odour; G – Bakery odour; H - Exhaust fume odour; I – Coal burning odour; J – Fermentation (rot) odour – to be specified; M – Other: to be specified).

The most important parts of the survey used were the 7-point and 10-point Likert scales. The survey also included questions on the acceptance of odour nuisance, the frequency of the smell, its type and intensity, the possible sources of its origin, as well as socio-demographic questions.

Population density and arteries, as well as traffic routes, were taken into account. Given the limited accessibility of respondents and their unwillingness to participate in the surveys, the sample size ultimately came to 2000 questionnaires. A total of 1992 correctly completed questionnaires was qualified for analysis purposes, which resulted in the estimation error at 2.09%, given the least favourable composition index (50%). This is a satisfactory result and the sample size is kept within the range of typical sample sizes used for social research purposes. The obtained data was evaluated and verified, and followed by the analytical procedure conducted according to:

- the comparison within two groups using the Mann-Whitney *U* test,
- the correlation was analysed using the Spearman's rank correlation coefficient. The statistical power of the correlation was interpreted according to the following scheme (Hinkle and Jurs, 2003 Applied Statistics for the Behavioural Sciences. 5th ed. Boston: Houghton Mifflin; 2003):
  - $|r| \geq 0.9$ – very strong correlation,
  - $0.7 \leq |r| < 0.9$ – strong correlation,
  - $0.5 \leq |r| < 0.7$ – medium correlation,
  - $0.3 \leq |r| < 0.5$ – weak correlation,
  - $|r| < 0.3$ – very weak (negligible) correlation.

The multiple correspondence analysis was used to obtain a bi-plot presenting the correlation among categorical variables. The analysis conducted utilising the R software, version 3.6.1 (R Core Team, 2019) path model based on structural equation modelling with latent variables (SEM) was adopted in order to identify and explain the regression paths between odour intensity and regret of residents resulting from the necessity of leaving their homes. Several mediation effects are analysed and compared. The analysis was

conducted utilising Mplus software, version 8.2. All *p* values below 0.05 were interpreted to prove significant correlations.

## 4. Research outcome

### 4.1. Qualitative research

First of all, the analysis covered comments posted on social media – in private groups on Facebook, in which the residents of the Płaszów District in Kraków express their opinions. These comments were analysed. Out of 716 comments, as the main emission sources of unpleasant odours to the atmosphere, the sewage treatment plant was mentioned 124 times, the composting plant – 59 times, the tannery – 22 times, the waste sorting plant – 6 times, and other industrial plants – 4 times.

The analysis of comments showed that, according to residents, unpleasant odours most frequently occur in the evenings (49 comments), at night (36 comments), in the morning (20 comments), less often in the morning (11 comments) and in the afternoon (4 comments). Residents pointed out that the greatest odour nuisance is observed in the summer, on hot days, before a storm, and that the occurrence of odours is further dependent on the direction of the wind.

In some comments, residents expressed their opinions about the level of odour nuisance present. People who spoke emphasised that the smells are very intense, the following words were used: dramatic, irritable, persistent, incredible, monstrous, terrible, unbearable, indescribable, disastrous, merciless. Two people referred to the scale and the first rating of the intensity of the smell as 3 out of 5, while the second was 5 out of 5. Some residents also signalled that the smells are so bothersome they prevent them from opening windows (9 comments), cause problems with going to sleep or staying asleep (5 comments), as well as pain or dizziness and nausea (1 comment).

The second analysis included comments posted on Polish Internet forums about odour nuisance. A total of 119 comments were analysed in which the subject of problematic odours in the Płaszów area was discussed. The time of day in which "unpleasant smells" were felt was also analysed. Most answers indicated the evening. As a synonym for the term unpleasant smell, "stink" was used (46 indications). Among the comments, the most frequently used term for unpleasant odours was "cesspool" (9). Other terms include: sulphur (2); chemical (1); sewage (1); rot (1); chemical (1); burning (1). In some comments, residents expressed a verbal opinion on the annoyance of unpleasant odours: it is impossible to live, unbearable, tragic, oppressive.

In the process of qualitative research, the in-depth interview was the second research method applied. Data collection in this process, i.e., discussions during meetings and walks with representative residents of housing estates, took place separately, following a previously prepared scenario. The following problems were discussed: places troublesome for the residents, type of problems, ailments caused by odours. The survey respondents from the first housing estate comprised a group of six men aged approx. 30. The second study involved eight residents, i.e., five men and three women approx. 30–70 years of age. In the case of the first housing estate, that type of odour nuisance occurred during the summer seasons from April to October. As far as the time of the day was concerned, respondents also agreed that this did not matter. The unpleasant odours were most disturbing during outdoor activities and relaxing with the family on the terrace.

The men indicated a few terms and sources of odours that were the biggest problem. The following vocabulary was used: irritant, sewage, septic tank, rotten eggs, unpleasant, chemical. Those odours occurred in every possible degree of nuisance. Intensity varied depending on the time of day. Men found that one could get used to the smell but they could not imagine living with such odour nuisance. Respondents generally did not complain about health issues caused by odours but several respondents used such phrases as nausea, irritable nose, headaches.

In the case of the residents of the second housing estate, the issue of health conditions proved to be a troublesome question. They did not associate their health problems with unpleasant odours; however, they stated that the situation with the unpleasant odour was extremely stressful. Some expressed the view that it may have been better not to know what impact this had on human health. The tentative outcome of the qualitative research became the basis for devising a research tool and conducting the appropriate quantitative research.

### 4.2. Quantitative research

As a result, quantitative surveys were carried out on 1992 respondents, 58.56% of whom were women and 41.44% men. Persons ranging in age from 18 to 90 years were included in the study. The average age of respondents was 39 (age distribution was characterised by normal distribution). Over 50% of the respondents declared having a higher education (50.76%), a higher bachelor/engineer education (16.28%) and secondary education (27.24%). Only 5.72% of respondents had a lower secondary education (i.e., primary, lower secondary or vocational), and 78.96% of the respondents were married couples, while only 21.04% of the entire sample declared their marital status as free (single). In the light of the data obtained, it bears noting that the vast majority of respondents did not declare their involvement in the affairs of any local organization or association. Only 2.76% of respondents declared active involvement in the operations of social organisations, while a little over 10.89% of respondents declared passive involvement in such organisations.

The results of the survey also indicate that the area (district) in question is, in most cases, inhabited by people who have settled there over the last 20 years. They account for nearly 75% of the population (upper quartile). Approximately 25% of residents declare to have settled in the last four years (lower quartile), which gives an average of 15 years of residence in the area for all respondents. It should be added that more than half of respondents (55.68%) declare a significant and very strong attachment to their current place of residence.

**Table 1**

Frequency of life difficulties resulting from the presence of unpleasant odours (percentage from the column).

| | | Problem situations | | | |
|---|---|---|---|---|---|
| | | Window opening | Hanging laundry | Relaxing on the balcony/in the garden | Recreation |
| Frequency of appearance | Never | 4.99 | 11.94 | 8.09 | 11.42 |
| | Rarely | 11.81 | 15.13 | 15.44 | 15.01 |
| | Often | 33.41 | 29.83 | 28.13 | 26.94 |
| | Very often | 29.55 | 25.95 | 27.63 | 27.84 |
| | Always | 20.24 | 17.14 | 20.71 | 18.79 |

Unpleasant odours that are smelt outside (in the open air, outside the apartment) are the reason for difficulties in life situations related to daily functioning, such as opening windows, hanging laundry outside, spending time in the garden or on the balcony, or recreational activities (e.g. running). The results obtained in this area are presented in Table 1. Research shows this to be a problem for most residents. About 20% of respondents said it always occurs, 30% of the respondents indicated that unpleasant odours make it difficult to function in their apartment often or very often. The scale of the problem can be seen when analysing the results for people who answered: often, very often or always together. A total of 83.2% of residents who experience unpleasant odours in the area have problems with opening windows because of this, 76.47% with spending time on their balcony, 73.57% with recreation in this area, and 72.92% with hanging laundry outside the apartment/house (Table 1). The graphical distribution is presented in Fig. 1. (See Diagram 1.)

To a slightly lesser extent, the odour problem is associated with unpleasant effects on health-related issues (Table 2). If, as before, the results are analysed together for those who have responded: often, very often or always, it turns out that 64.27% of residents experience unpleasant odours causing bad moods, about 50% associate this nuisance with headaches, irritation of the respiratory tract and a scratchy throat, while 40.69% combine odours with respiratory problems. Bothersome odours are unlikely to cause stomach problems (20.73% of the answers in total, at least often). The graphical distribution is presented in Fig. 2.

The analysis was conducted taking into account two aspects: life comfort, where the effects of unpleasant odours were studied, such as "I did not like returning home", "I could not open the window", "I could not hang out the laundry". Odours disturbed relaxation time in the garden or on the balcony, recreational activities, caused interrupted sleep at night, as well as having a negative influence on the health, detailing the following situations and feelings: irritable nose (eyes), headaches, respiratory problems, stomach problems, choking (scratching sensation in the throat), irritation, bad moods.

In the first stage, it was decided to verify the hypothesis on the correlation between factors influencing the health and factors determining the sense of life comfort (H1). Table 3 presents the correlation coefficients between the analysed factors (significant relationships were marked with asterisks). All health factors correlated significantly and positively with all comfort factors. Thus, the greater the feeling of a given health factor, the stronger the feeling of each quality of life factor (and vice versa). The strongest relationships are between irritation and bad moods, the inability to open a window, disturbed relaxation in the garden and on the balcony, lack of willingness to return home, as well as the relationship between a scratchy throat and night waking. (See Table 4.)

Factors affecting the correlation between the analysed variables were shown on the diagram below. The blue areas denote positive
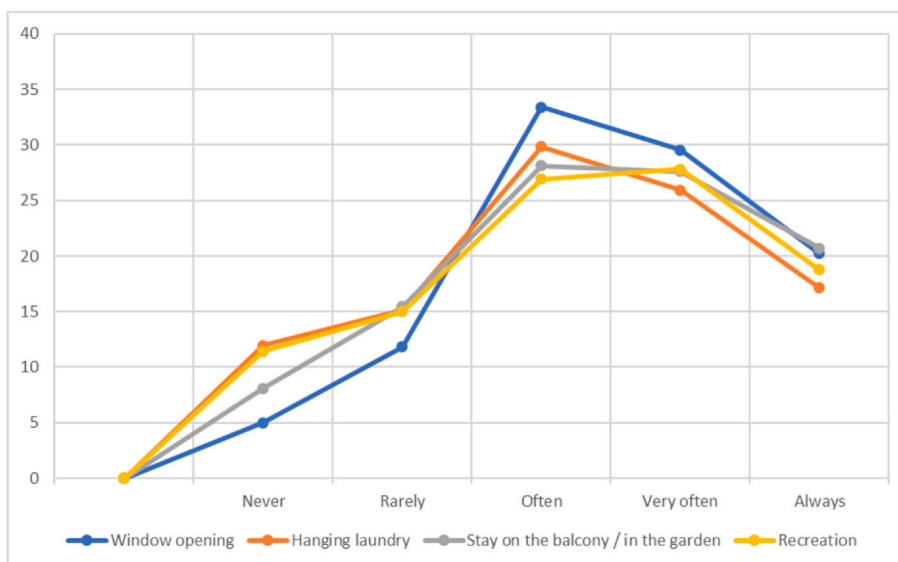


**Fig. 1.** Frequency of life difficulties resulting from the presence of unpleasant odours.
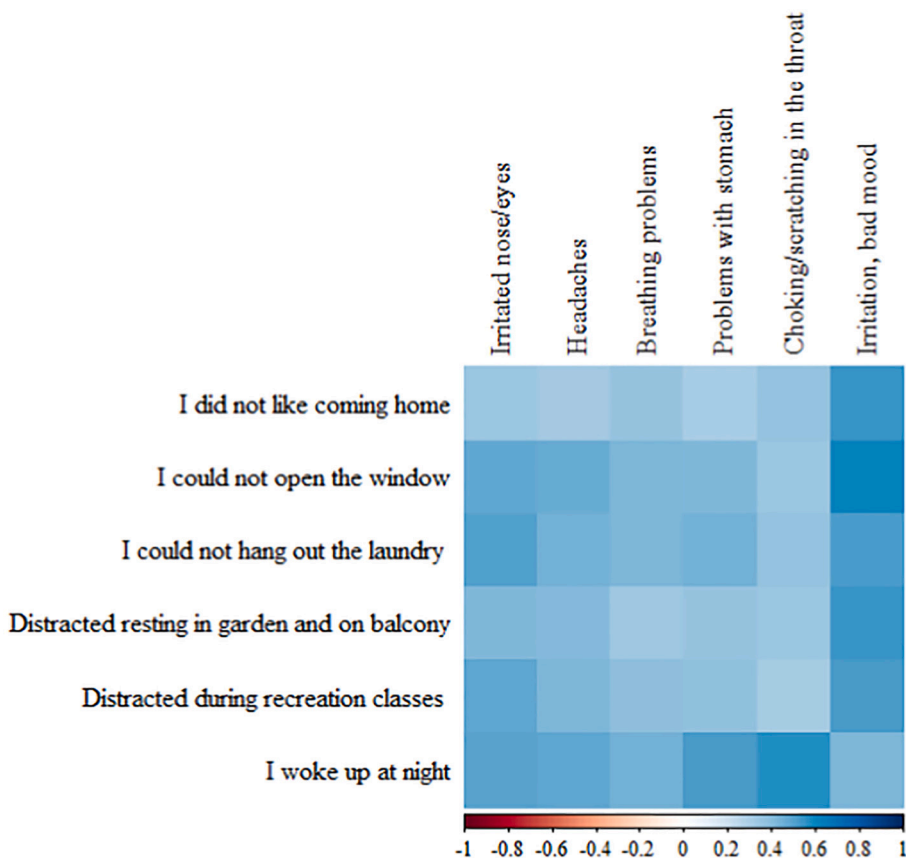
**Diagram 1.** Factors that affect the correlation between analysed variables.

**Table 2**

Frequency of health problems arising from the presence of unpleasant odours (percentage from the column).

| | | Effects | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Bad moods | Respiratory irritation | Headaches | Respiratory problems | Stomach problems | Problems falling asleep | Night waking | Scratchy throat |
| Frequency of Appearance | Never | 12.23 | 21.09 | 19.99 | 26.87 | 46.24 | 34.95 | 39.01 | 26 |
| | Rarely | 23.5 | 27.88 | 27.88 | 32.44 | 31.03 | 26.54 | 25.05 | 26.51 |
| | Often | 37.9 | 26.41 | 28.13 | 22.52 | 14.57 | 19.68 | 18.79 | 25.87 |
| | Very often | 19.24 | 16.92 | 18.14 | 13.05 | 5.09 | 11.59 | 11.22 | 14.41 |
| | Always | 7.13 | 7.69 | 5.86 | 5.12 | 3.07 | 7.25 | 5.94 | 7.21 |

correlations (correlation factor (r) greater than 0), and the red – negative correlations ($r < 0$). The white areas refer to a lack of correlations.

It was subsequently decided to verify the hypothesis concerning the correlation between perceptible odour nuisance and regret resulting from the necessity to leave the place of residence (H2 and H3). The authors intended to answer the question of how the residents, attached to their place of residence, would react in the event of a possible need to leave it due to unpleasant odours. The grief resulting from the necessity of a possible move remains (in a significant relationship) significantly and negatively correlates with headaches, a scratchy throat, irritation, bad moods and the reluctance to return home ($p < 0.05$), hence the greater the intensity of these factors, the less grief from moving out.

It bears noting that the period of living in the current apartment correlates significantly and positively with headaches, respiratory and stomach problems ($p < 0.05$), so the longer it lasts, the greater the problems associated with it. The period of living in the current apartment correlates significantly and negatively with irritation and bad moods, inability to open the window and hang out the laundry, and difficulties in rest and recreation ($p < 0.05$), so the longer it lasts, the less severe these inconveniences are.

The assessment of odour intensity correlates significantly and positively with the perception of all health and comfort factors ($p < 0.05$), so the stronger the odour is, the larger the reported problems. The correlation with the impossibility of opening the window is the strongest. The verification process carried out makes it possible to confirm the thesis that the smell sensation has a
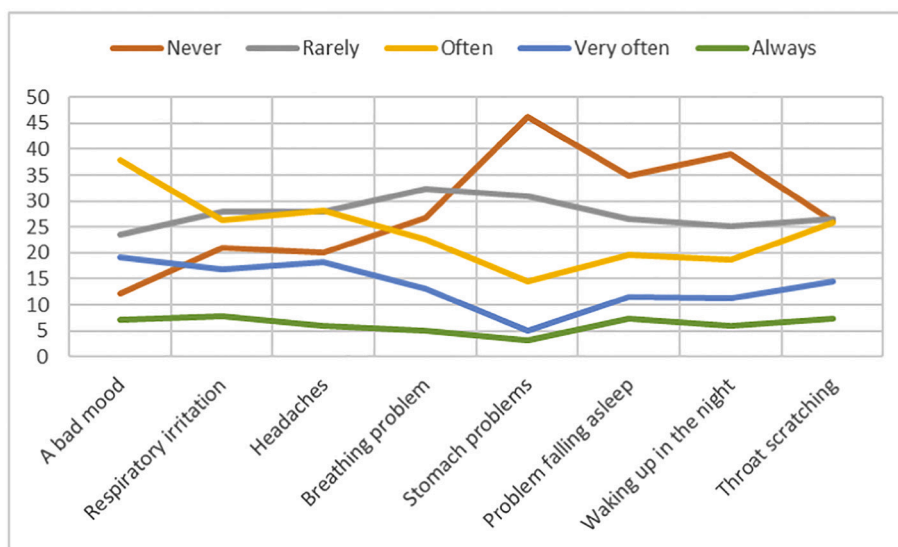
**Fig. 2.** Frequency of health problems arising from the presence of unpleasant odours (percentage from the column).

**Table 3**
Summary of health and comfort factors.

| | Irritable nose/eyes | Headaches | Respiratory problems | Stomach problems | Choking/scratchy throat | Irritation/bad moods |
|---|---|---|---|---|---|---|
| I did not like returning home | r = 0.342 p < 0.001*** | r = 0.325 p < 0.001*** | r = 0.35 p < 0.001*** | r = 0.308 p < 0.001*** | r = 0.362 p < 0.001*** | r = 0.546 p < 0.001*** |
| I could not open the window | r = 0.472 p < 0.001*** | r = 0.463 p < 0.001*** | r = 0.424 p < 0.001*** | r = 0.416 p < 0.001*** | r = 0.34 p < 0.001*** | r = 0.608 p < 0.001*** |
| I could not hang out the laundry | r = 0.506 p < 0.001*** | r = 0.449 p < 0.001*** | r = 0.429 p < 0.001*** | r = 0.446 p < 0.001*** | r = 0.362 p < 0.001*** | r = 0.516 p < 0.001*** |
| Disturbed relaxation in garden/ on balcony | r = 0.413 p < 0.001*** | r = 0.401 p < 0.001*** | r = 0.335 p < 0.001*** | r = 0.35 p < 0.001*** | r = 0.345 p < 0.001*** | r = 0.546 p < 0.001*** |
| Distraction during recreation activities | r = 0.487 p < 0.001*** | r = 0.427 p < 0.001*** | r = 0.383 p < 0.001*** | r = 0.376 p < 0.001*** | r = 0.318 p < 0.001*** | r = 0.523 p < 0.001*** |
| Night waking | r = 0.49 p < 0.001*** | r = 0.485 p < 0.001*** | r = 0.443 p < 0.001*** | r = 0.52 p < 0.001*** | r = 0.567 p < 0.001*** | r = 0.422 p < 0.001*** |

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.
r – Spearman's rank correlation coefficient.

**Table 4**
Evaluation of the relationship between factors influencing health and life comfort and regret resulting from the necessity to leave one's place of residence.

| Factor | Statistical measures and related evaluation | | | |
|---|---|---|---|---|
| | Correlation factor * | P | Direction of correlation | Strength of correlation |
| Irritable nose/eyes | −0.013 | p = 0.63 | – | – |
| Headaches | −0.071 | p = 0.007 | Negative | Very weak |
| Respiratory problems | −0.043 | p = 0.104 | – | – |
| Stomach problems | −0.012 | p = 0.636 | – | – |
| Choking/scratchy throat | −0.074 | p = 0.005 | Negative | Very weak |
| Irritation/bad moods | −0.072 | p = 0.006 | Negative | Very weak |
| I did not like returning home | −0.18 | p < 0.001 | Negative | Very weak |
| I could not open the window | −0.004 | p = 0.866 | – | – |
| I could not hang out the laundry | 0.013 | p = 0.624 | – | – |
| Disturbed relaxation in garden/on balcony | 0.029 | p = 0.266 | – | – |
| Distraction from recreational activities | 0.013 | p = 0.631 | – | – |
| Night waking | −0.002 | p = 0.953 | – | – |
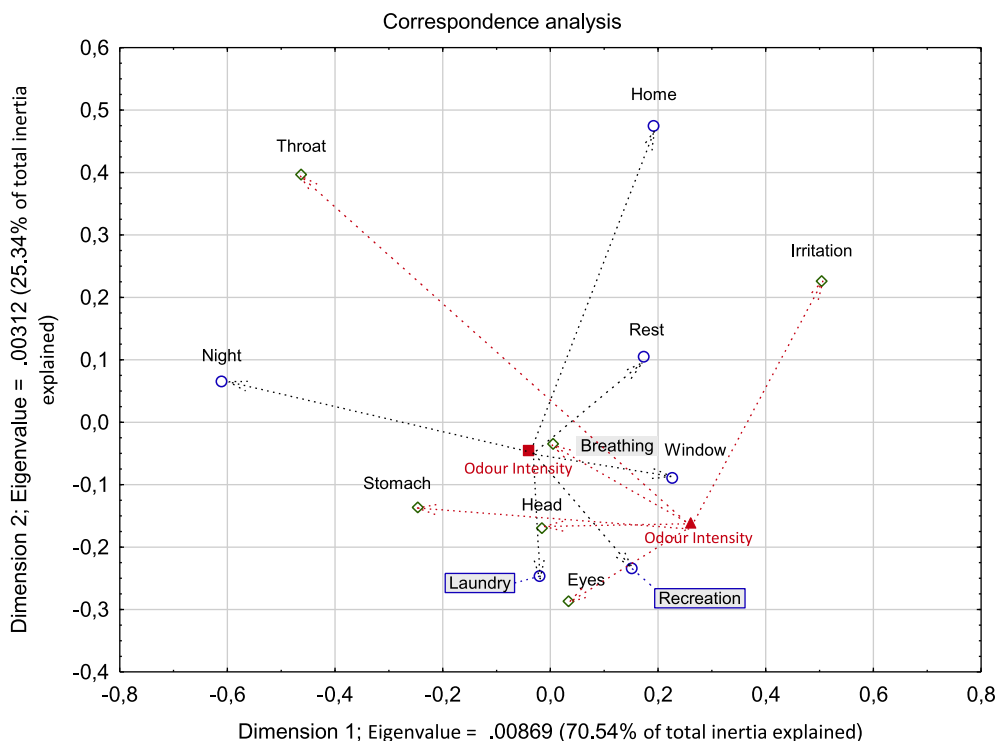
**Diagram 2.** Correlation between health factors, life comfort factors and odour intensity (bi-plot of correspondence analysis).

significant impact on quality of life.

Diagram 2 visualises the correlation between odour nuisance, life comfort and health factors as a result of the correspondence analysis, specialised method of data exploration belonging to the group of multidimensional methods of the co-occurrence analysis.

The above diagram presents the similarity of health factors related to eye (or nose) irritation, headaches, and respiratory and stomach problems. Respective ailments include scratching sensation in the throat and a sense of irritation and bad moods. Psychological factors (irritation) had a stronger impact on the lack of comfort and unwillingness to return home. Physical ailments revealed a stronger connection with the inability to open the window, hang out the laundry and night waking. On the correspondence map, odour intensity is depicted as a passive variable. From life comfort, unpleasant odours have the strongest impact on the inability to open the window, hang out the laundry and constitute an obstacle to recreation and rest. As regards health factors, odour intensity is most strongly correlated with headaches, eye irritation and respiratory difficulties.

As far as measuring the impact of odours on humans is concerned, their physical properties are most important, e.g., receptor sensitivity or biological properties and gender. The study assumes that gender may influence the perception of odours and the assessment of their impact on health and life comfort. Based on qualitative research, it was found that women and men had different approaches to odours. The collected data in the process of the quantitative research made it possible to verify the hypothesis on the

**Table 5**
Breakdown of statistical measures referring to correlations between the duration of residence in the current apartment and factors influencing health conditions and sense of life comfort.

| 5Factor | Correlation with duration of living in the current apartment | | | |
| --- | --- | --- | --- | --- |
| | Correlation factor * | | Direction of correlation | Strength of correlation |
| Irritable nose/eyes | 0.043 | $p = 0.094$ | — | – |
| Headaches | 0.069 | $p = 0.007$ | Positive | Very weak |
| Respiratory problems | 0.087 | $p = 0.001$ | Positive | Very weak |
| Stomach problems | 0.054 | $p = 0.034$ | Positive | Very weak |
| Choking/scratchy throat | 0.016 | $p = 0.538$ | – | – |
| Irritation/bad moods | −0.143 | $p < 0.001$ | Negative | Very weak |
| I did not like returning home | −0.03 | $p = 0.248$ | – | – |
| I could not open the window | −0.093 | $p < 0.001$ | Negative | Very weak |
| I could not hang out the laundry | −0.076 | $p = 0.003$ | Negative | Very weak |
| Disturbed relaxation in garden/on balcony | −0.092 | $p < 0.001$ | Negative | Very weak |
| Distraction from recreational activities | −0.121 | $p < 0.001$ | Negative | Very weak |

**Table 6**

Summary of statistical measures concerning the correlation between odour intensity and health and comfort factors.

| Factor | Correlation with odour intensity | | | |
|---|---|---|---|---|
| | Correlation factor | p * | Direction of correlation | Strength of correlation |
| Irritable nose/eyes | 0.443 | p < 0.001 | Positive | Weak |
| Headaches | 0.43 | p < 0.001 | Positive | Weak |
| Respiratory problems | 0.428 | p < 0.001 | Positive | Weak |
| Stomach problems | 0.411 | p < 0.001 | Positive | Weak |
| Choking/scratchy throat | 0.378 | p < 0.001 | Positive | Weak |
| Irritation/bad moods | 0.508 | p < 0.001 | Positive | Medium |
| I did not like returning home | 0.391 | p < 0.001 | Positive | Weak |
| I could not open the window | 0.598 | p < 0.001 | Positive | Medium |
| I could not hang out the laundry | 0.536 | p < 0.001 | Positive | Medium |
| Disturbed relaxation in garden/on balcony | 0.582 | p < 0.001 | Positive | Medium |
| Distraction from recreational activities | 0.519 | p < 0.001 | Positive | Medium |
| Night waking | 0.497 | p < 0.001 | Positive | Weak |

P = Normal distribution of correlated variables, Pearson's correlation coefficient; NP = Lack of normality of distribution of at least one of the correlated variables, Spearman's correlation coefficient.

existence of the correlation between the gender of respondents and the perception of odours, and to assess their impact on health and life comfort. Table 5 presents a summary of the results of the correlation analyses. (See Tables 6 and 7.)

It should be noted that age correlates significantly and positively with respiratory problems and night waking ($p < 0.05$), so the older one is, the more frequently these problems occur. Age correlates significantly and negatively with irritation and bad moods, the inability to open the window and hang out the laundry, and difficulties in rest and recreation ($p < 0.05$), so the older one is, the less

**Table 7**

Gender concerning health factors and life comfort.

| Factor | | Woman (N = 931) | Man (N = 652) | p[a] |
|---|---|---|---|---|
| Irritable nose/eyes | av ± SD | 1.76 ± 1.22 | 1.4 ± 1.19 | < 0.001 |
| | Median | 2 | 1 | |
| | Quartile | 1–3 | 0–2 | |
| Headaches | av ± SD | 1.8 ± 1.15 | 1.35 ± 1.14 | < 0.001 |
| | Median | 2 | 1 | |
| | Quartile | 1–3 | 0–2 | |
| Respiratory problems | av ± SD | 1.49 ± 1.17 | 1.19 ± 1.12 | < 0.001 |
| | Median | 1 | 1 | |
| | Quartile | 1–2 | 0–2 | |
| Stomach problems | av ± SD | 1.64 ± 1.25 | 1.26 ± 1.14 | < 0.001 |
| | Median | 2 | 1 | |
| | Quartile | 1–2.5 | 0–2 | |
| Choking/scratchy throat | av ± SD | 0.95 ± 1.02 | 0.7 ± 0.95 | < 0.001 |
| | Median | 1 | 0 | |
| | Quartile | 0–1 | 0–1 | |
| Irritation/bad mood | av ± SD | 1.87 ± 1.08 | 1.73 ± 1.11 | 0.017 |
| | Median | 2 | 2 | |
| | Quartile | 1–3 | 1–2 | |
| I did not like returning home | av ± SD | 0.93 ± 1.01 | 0.86 ± 0.95 | 0.217 |
| | Median | 1 | 1 | |
| | Quartile | 0–2 | 0–2 | |
| I could not open the window | av ± SD | 2.6 ± 1.11 | 2.35 ± 1.13 | < 0.001 |
| | Median | 3 | 2 | |
| | Quartile | 2–3 | 2–3 | |
| I could not hang out the laundry | av ± SD | 2.36 ± 1.23 | 1.97 ± 1.27 | < 0.001 |
| | Median | 2 | 2 | |
| | Quartile | 2–3 | 1–3 | |
| Disturbed relaxation in garden/on balcony | av ± SD | 2.39 ± 1.23 | 2.28 ± 1.24 | 0.091 |
| | Median | 2 | 2 | |
| | Quartile | 2–3 | 1–3 | |
| Distraction from recreational activities | av ± SD | 2.26 ± 1.26 | 2.19 ± 1.28 | 0.278 |
| | Median | 2 | 2 | |
| | Quartile | 1–3 | 1–3 | |
| Night waking | av ± SD | 1.28 ± 1.24 | 1.08 ± 1.21 | 0.001 |
| | Median | 1 | 1 | |
| | Quartile | 0–2 | 0–2 | |

[a] The Mann-Whitney's U Test.

**Table 8**

Factors influencing health and life comfort and age of survey participants.

| Factor | Correlation with age | | | |
|---|---|---|---|---|
| | Correlation coefficient [a] | P | Direction of correlation | Strength of correlation |
| Irritable nose/eyes | 0.029 | p = 0.25 | – | – |
| Headaches | 0.003 | p = 0.895 | – | – |
| Respiratory problems | 0.075 | p = 0.003 | Positive | Very weak |
| Stomach problems | 0.034 | p = 0.172 | – | – |
| Choking/scratchy throat | 0.007 | p = 0.794 | – | – |
| Irritation/bad mood | −0.094 | p < 0.001 | Negative | Very weak |
| I did not like returning home | 0.012 | p = 0.64 | – | – |
| I could not open the window | −0.021 | p = 0.395 | – | – |
| I could not hang out the laundry | −0.045 | p = 0.077 | – | – |
| Disturbed relaxation in garden/on balcony | −0.04 | p = 0.111 | – | – |
| Distraction from recreational activities | −0.094 | p < 0.001 | Negative | Very weak |
| Night waking | 0,056 | p = 0,026 | Positive | Very weak |

[a] Spearman's correlation coefficient.

**Table 9**

Mediation effects between the intensity of odour and regret – total effects.

| Total effects from odour intensity to regret | Estimate | Standard error | Est/S.E. | P-value |
|---|---|---|---|---|
| Total | 0.012 | 0.022 | 0.535 | 0.593 |
| Total indirect | −0.044 | 0.024 | −1.832 | 0.067 |

**Table 10**

Mediation effects between the intensity of odour and regret – specific effects.

| Specific indirect effects from odour intensity to regret | Estimate | Standard error | Est/S.E. | P-value |
|---|---|---|---|---|
| Odour intensity to regret via the unwillingness to return home | −0.020 | 0.006 | −3.535 | 0.000 |
| Odour intensity to regret via comfort | 0.049 | 0.016 | 2.958 | 0.003 |
| Odour intensity to regret via the unwillingness to return home and irritation | −0.044 | 0.006 | −6.959 | 0.000 |
| Odour intensity to regret via the unwillingness to return home and health problems | −0.019 | 0.004 | −4.934 | 0.000 |
| Odour intensity to regret via comfort and irritation | 0.022 | 0.008 | 2.931 | 0.003 |
| Odour intensity to regret via comfort and health problems | 0.024 | 0.008 | 2.914 | 0.004 |

severe these inconveniences (Table 8). (See Tables 9 and 10.)

A synthetic picture of the analysed factors constitutes a path model defining the correlation between odour intensity, health factors, life comfort, and regret resulting from the necessity to leave one's home. The model is presented in Fig. 3.

In the model structure, two latent variables identify health factors (Health) and life comfort (Comfort) and four manifest variables denote intensity of odour (v13), irritation (v12), the home (v1) and regret (v14). It is hypothesised that the intensity of odour (as an exogenous variable) influences regret (as a final endogenous variable) through irritation, health factors and subsequently through the home ("I did not like returning home") and life comfort. These paths are subsequently checked for the size and significance of direct, indirect and total effects. In the model structure, there are two hidden variables identifying health factors (Health) and life comfort (Comfort). Construct reliability of Health is acceptable. McDonald's Omega = 0.774 and Fornel-Larcker AVE = 0.408. Construct reliability of Comfort is low. McDonald's Omega = 0.547 and Fornel-Larcker AVE = 0.197 model matching is acceptable. The Chi-squared test of the model fit value is equivalent to 869.859 (df = 62) with p-value = 0.00. RMSEA (Root Mean Square Error of Approximation) = 0.081 and 90%, confidence interval is between 0.076 and 0.086. Probability of close fit (RMSEA ≤ 0.05) = 0.00. Comparative fit index (CFI) = 0.948 and Tucker-Lewis index (TLI) = 0.923. Standardised Root Mean Square Residual (SRMR) = 0.048. All factor loadings are significant. In the model structure, some additional covariances are imposed. First of all, the disturbance of psychological and health factors is correlated with captured psychosomatic negative effects of odour intensity. Secondly, some of the error variances are correlated owing to the inseparable effect of confounders between Eyes (v7) and Throat (v11), Breathing (v9) and Stomach (v10) concerning the Health factor, and between Window (v2) and Night (v6), Window (v2) and Laundry (v3), Rest (v4) and Recreation (v5) concerning the Comfort factor. Odour intensity (v13) has a significant and strong correlation with Irritation (v12), Reluctance to return home (v1), Health Factors and Comfort. Health problems also affect lack of comfort and unwillingness to return home (v1). The strongest direct impact on the lack of regret resulting from the necessity to leave the place of residence (v14) is the reluctance to return home (v1).

Below is a summary of total and indirect effects of the mediation of health, psychological and comfort factors accounting for the correlation between odour intensity and regret resulting from the necessity of leaving one's home.

The total impact of odour intensity on the lack of regret is insignificant. This means that this correlation is fully accounted for by
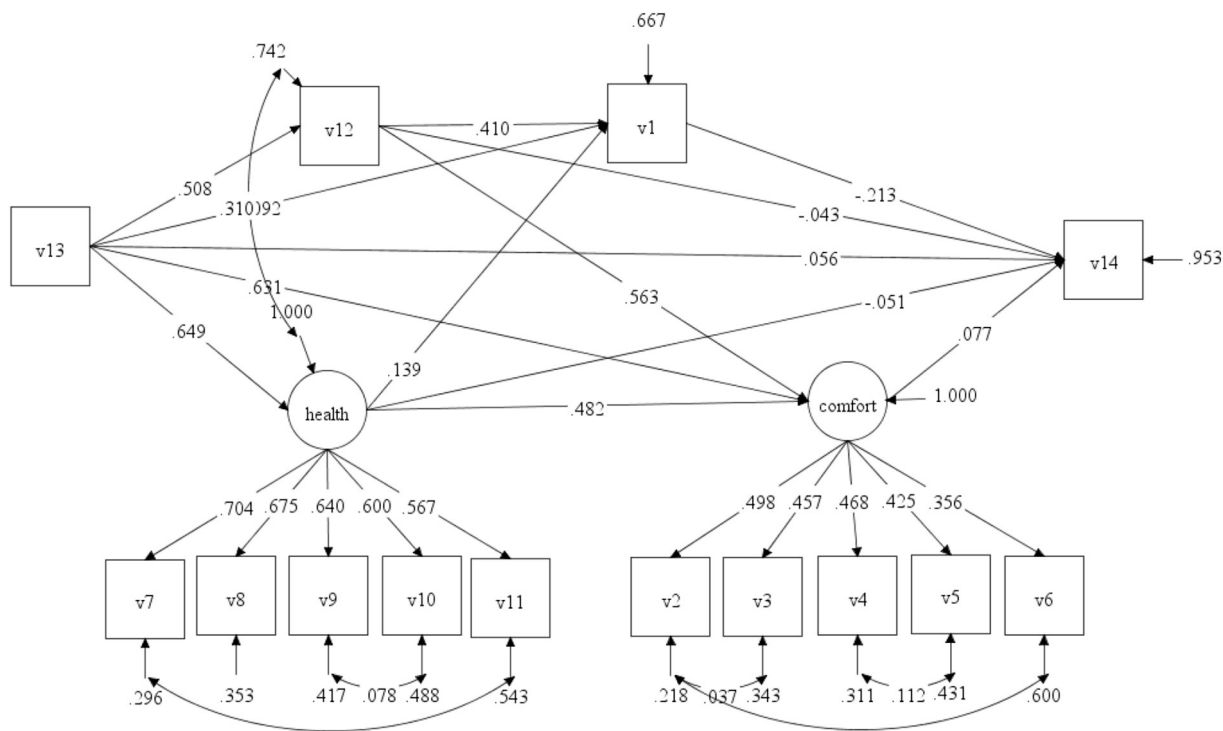
**Fig. 3.** Correlation between odour intensity, health factors, life comfort and regret resulting from the necessity to leave one's home (path model). v1-Home v2-Window v3-Washing v4-Relax v5-Recreation v6-Night v7-Eyes v8-Head v9-Breathing v10-Stomach v11-Throat v12-Irritation v13-Intensity of odour v14-Regret.

mediators applied to the model. Total indirect effect is insignificant at α = 0.05 and significant at α = 0.10. The significant specific indirect effects are provided below:

The reluctance to return home accounts for the correlation between odour intensity and the lack of regret associated with leaving one's home.

The sense of discomfort accounts for the correlation between the odour intensity and the lack of regret associated with leaving one's home.

Irritation and reluctance to return home accounts for the correlation between odour intensity and the lack of regret associated with leaving one's home.

Health factors and reluctance to return home account for the relationship between odour intensity and the lack of regret associated with leaving one's home.

Irritation and discomfort account for the correlation between odour intensity and the lack of regret associated with leaving one's home.

Health factors and discomfort account for the relationship between odour intensity and the lack of regret associated with leaving one's home.

## 5. Conclusions

Outdoor smells, as part of people's living environment, are being increasingly treated as a factor affecting both their health and sense of comfort. The Literature analysis indicates an increase in the importance of this factor in the assessment of the health and wellbeing of residents, especially in developing urban areas. Until recently, the presence of various outdoor smells in Poland had been a "natural" consequence of the existence of emission sources in the environment, such as animal breeding, sewage systems or industrial plants, which are also employers in given areas. In many cases, residents were unaware of the impact of smells on their health and often associated it with the consequences of technological progress, and any discomfort was compensated by localisation benefits, better access to the service-and-commercial infrastructure, or public services.

Environmental awareness and developing living standard demands, including housing and living costs, which must be borne by the residents of not only large cities, cause increasing sensitivity on the part of people to this aspect of life. The difficulty in eliminating unpleasant and harmful odours results from their optical invisibility, their variability in time and space, and their intensity, as well as the impact of other factors such as wind, pressure and the necessary efforts to reduce or eliminate them. The sense of smell often has a subjective aspect. The qualitative and quantitative research carried out on a wide scale in one of Poland's largest cities – Kraków – undoubtedly constitutes the beginning of the identification and assessment process concerning the scale of this problem in

urban space. The results of this research work unequivocally point to the influence of perceived smells on the health and the sense of comfort of local residents. The assessment of this phenomenon is common and is not dependent on the gender or age of respondents. However, it impacts on the everyday life and subjective feelings concerning the state of health caused by living in an area with unpleasant odours. This research proves that the more intense and unpleasant the odour, the less resistant one is to move out of their current home. The longer people live in the area, the less negative their feelings, which may mean they become accustomed to the environment they are living in. According to respondents, unpleasant odours have the greatest impact on health factors, which in turn determines the sense of life comfort. The results obtained in this study indicate the need for further, in-depth research in this area.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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