EXPERIMENTAL RESEARCH ON THE INFLUENCE OF AIR QUALITY ON HAIRS

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The purpose of this research was to analyze hair from participants in two different age categories: 20-30 years old and 40-50 years old. In this experimental research, several key characteristics were followed, including structure, average hair size and, in particular, degree of surface damage (characteristics assessed by SEM analysis). Also, the composition of the elements in the studied hair (aspects assessed by EDS analysis) was a significant indicator of the degree of air pollution.

Keywords: pollution, hair, heavy metals

1. Introduction

Air pollution has become a serious challenge in both developed and developing countries, with multiple emission sources continually adding particulate and gaseous pollutants to the environment [1, 2]. In addition to primary pollutants (such as soot particles, carbon monoxide (CO), sulfur oxides (SO_X), and nitrogen dioxide (NO_2)), air emissions include several other harmful substances, including secondary photochemical pollutants such as ozone (O_3), as well as smaller amounts of toxic chemical gases, heavy metals, organic compounds, and radioactive isotopes [3, 4]. Studies show that pollutants enter the skin through direct accumulation on the skin surface, absorption through hair follicles, inhalation, ingestion, and circulation of pollutants in the plasma, which diffuse into deeper dermal tissues [5, 6].

Hair is an important part of the human body image [7]. Modern people's aesthetic desires for beauty, along with the continuous growth and diversification of hair and the continuous development of hair shape, color, and texture, allow people to use their own personality to change their image to follow changing trends [8]. Hair is composed of 1-8% external hydrophobic lipid epidermis, 80-90% α-helix or β-conformation of parallel polypeptide chains to form water-insoluble keratin, less than 3% melanin pigment, and 0.6-1.0% trace elements, 10-15% moisture, etc. [9, 10]. The normal cuticle has a smooth appearance, reflecting light and limiting friction between hairs. It is responsible for the shine and texture of the hair. The keratin layer of the hair becomes brittle and cracked under the

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influence of the external environment, temperature, humidity, along with chemical and physical treatments, thus affecting the quality of the hair [11, 12]. Although most people's hair is prone to various damage problems because the hair is inconvenient to observe, it is impossible to conduct a detailed analysis, and there are few studies related to hair damage.

In this work, hair samples were investigated from different participants divided into two distinct age categories: 20-30 years and 40-50 years. In this experimental research, special attention was paid to key characteristics such as the structure and average size of the hairs and the degree of surface damage (characteristics assessed by SEM analysis). In addition, the component elements of the studied hairs (characteristics determined by EDS analysis) provided valuable information on the level of air pollution, and the data were compared with the current situation in Bucharest.

2. Materials and Methods

Participants

Hair samples were taken from different participants. The participants whose samples were analyzed were divided into 2 age categories, namely 20-30 years and 40-50 years respectively. It should be noted that the hair of the participants in the 20-30 age category is undyed and as little as possible heat-styled (use of hair straightener, curling iron, etc.). In the second age category, the hair of the participants is frequently colored, involving chemical coloring, bleaching, etc. It is also frequently heat-styled (use of hair straightener, curling iron, etc.) and undergoes constant treatments for regrowth, growth, and other purposes.

Preparation of hair samples

Hair samples were examined, categorized, and trimmed. The hair sections to be analyzed were attached to a conductive tape coated with carbon on both sides and fixed on aluminum metal rods. For the hair samples to have high conductivity, a metallic gold target was used over the aforementioned carbon tape in a 5 nm layer. The equipment used for the sputter coating process was Quorum Q150RES. It performed the sputter coating under high vacuum, the working parameters set being a speed of 3 mm/min at 20 mA.

3. Results and Discussion

Age category 20-30 years

SEM analysis

Fig. 1a shows the most representative image generated by the scanning electron microscope (SEM) from the participants of the 20-30 years category. It can be seen that at x 2000 size in this subject the hair thickness is 65.26 µm. The structure of the hair is relatively homogeneous (except for a certain area), a structure characteristic of the main component of the hair, which is represented by keratin (in general this constitutes about 65-95% of the weight of the hair). A slightly exfoliated area is found on the surface of the hair analyzed, which can be interpreted as the result of the use of a hair dryer. It is well known that regular blow-drying damages the hair due to the heat produced.

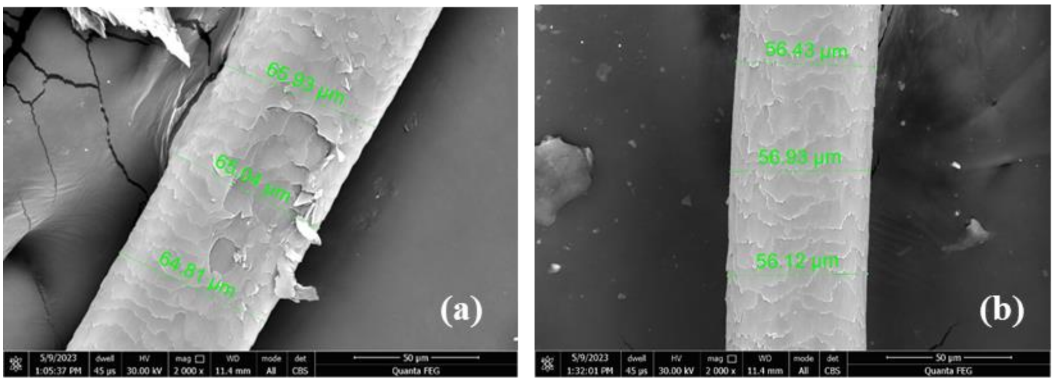

Fig. 1: SEM analysis for participants in the age category 20-30 years

Similarly, Fig. 1b illustrates the sample analyzed by scanning electron microscope (SEM) for the same age category, a different aspect of the hair sample. It can also be seen that at 2000x size in this subject, the hair thickness is 56.49 µm (significantly smaller compared to the sample taken from the first subject). The hair structure is much more homogeneous, mainly due to the presence of keratin.

EDS analysis

In this analysis, prior to the SEM analysis, a surface of interest was chosen from the hair structure, and the component elements were determined. It should be noted that the presence of Au is due to the process of sampling hair samples with a gold target, as described in the subchapter on the preparation method.

For the sample taken from the participant, Fig. 2 illustrates the surface selected for analysis, the main chemical elements and their percentage in the hair. The presence of the elements Cu, Zn, Al, Si, Ca and V in less than 1% is noted. The presence of the elements C, N, O and S in a high percentage is due to the chemical composition of keratin (its chemical formula is $C_{28}H_{48}N_2O_{32}S_4$).

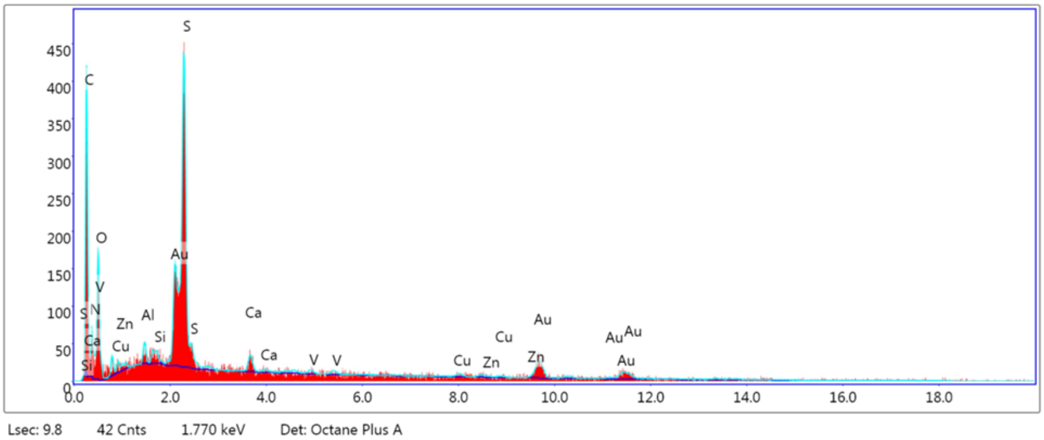

Fig. 2: EDS analysis for the participant of the age category 20-30 years

Similarly, for the sample taken from another participant, Fig. 3 represents the area selected for analysis, together with the main chemical elements and their percentage in the hair analyzed. The presence of the elements Al, Nb, Ca, Mn, and Cu in a proportion of less than 1% is observed, except for Nb in a proportion of 1.86%. Also, the high percentage of the elements C, N, O, and S is due to the chemical composition of keratin.

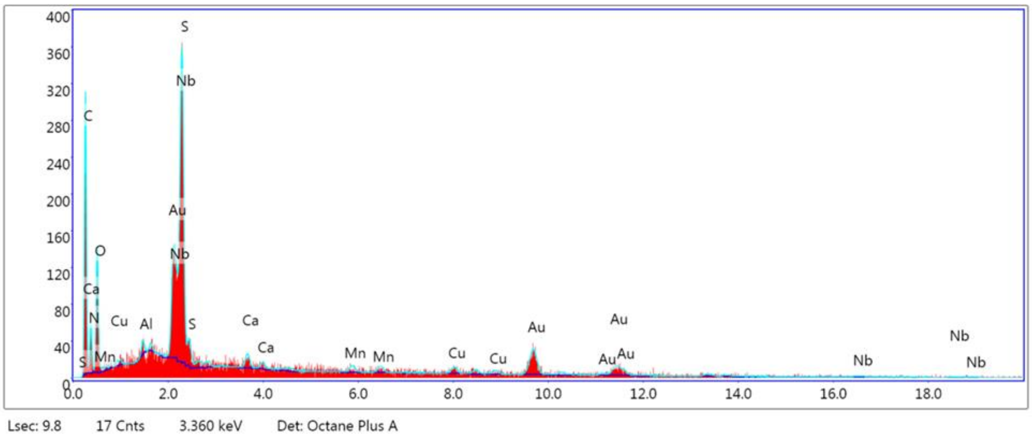

Fig. 3: EDS analysis for another participant in the age category 20-30 years

The results for the participants in the 20-30 age group are slightly different, which is due to the way the hair is groomed and most likely to lifestyle. In terms of the chemical elements determined on the hair, the highest percentages are C, N, O, and S, but these are elements specific to keratin. In addition, the percentage of chemical elements differing from one subject to another does not exceed 1%, except for Nb found in the second hair sample.

Age category 40-50 years

SEM analysis

Fig. 4a shows the scanning electron microscope (SEM) analysis of the first participant in the 40-50 age category. It can be seen that at 2000x size in this subject, the hair thickness is 74.5 µm. Analyzing the structure of the hair, it is homogeneous, and smooth, which is due on the one hand to the existence of keratin in the hair and on the other hand to the dyeing process to which it has frequently been subjected.

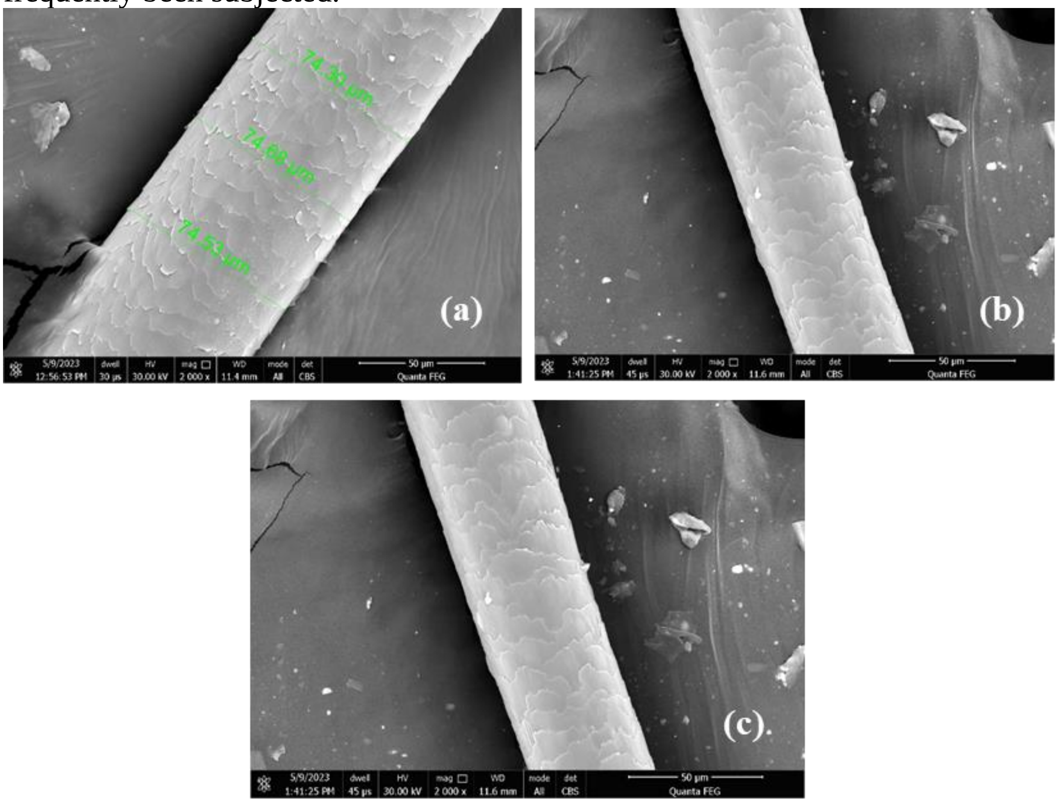

Fig. 4: SEM analysis for the participants in the age category 40-50 years

Fig. 4b represents the scanning electron microscope (SEM) analysis result for another participant from the same age category. The thickness of the hair that can be seen at a magnification of 2000x is 58.89 µm. Making an analysis of the structure of the hair and comparing it with the sample taken from the first participant of the category, in this case, we have a structure not as homogeneous or smooth, there are small areas more exfoliated than the others.

The third SEM analysis for the last participant in the 40-50 age category is shown in Fig. 4c. The hair thickness appears much smaller compared to the first 2 participants, the structure however is observed generally homogeneous and smooth.

***EDS* analysis**

This analysis was carried out in a similar way as for the first age group. Specifically, an area of interest was chosen from the hair structure and the chemical constituents present in the sample were determined. For the sample taken from the first participant of the category, Fig. 5 illustrates the surface selected for analysis, the main chemical elements, and their percentage in the hair. The presence of the elements Cu, Na, Mg, Al, and Ca is observed, most of them in a proportion of less than 1%, except for Cu with 1.27%. As already mentioned, the high percentage of the elements C, N, O, and S is due to the chemical composition of keratin.

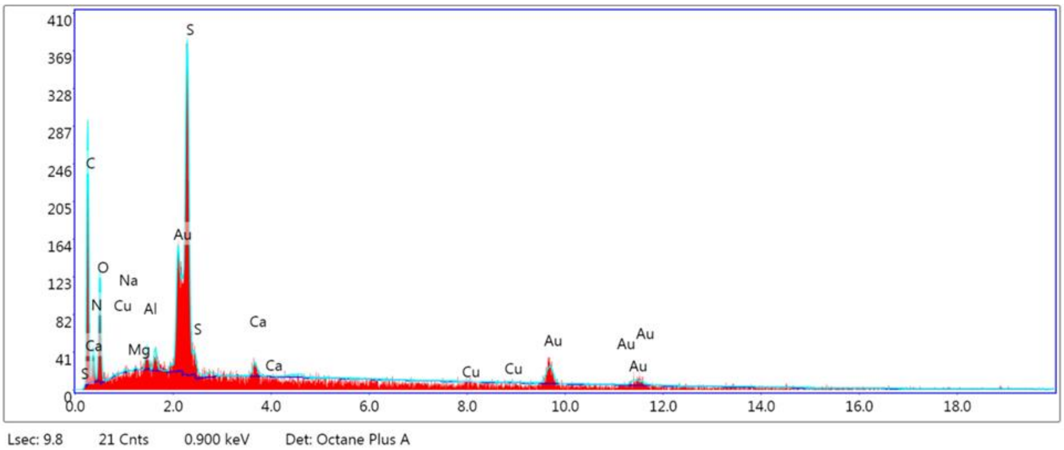

Fig. 5: EDS analysis for the first participant of the age category 40-50 years

For the sample taken from the participant, Fig. 6 shows the area selected for analysis, together with the main chemical elements and their percentage in the hair analyzed. The presence of the elements Al, Nb, Ca, Mn, and Cu in a proportion of less than 1% is observed, except for Nb in a proportion of 1.86%.

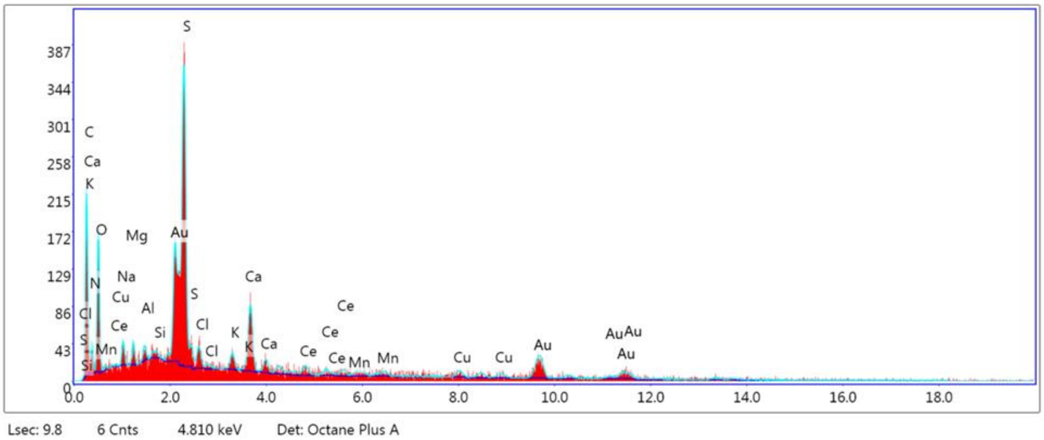

Fig. 6: EDS analysis for the second participant of the age category 40-50 years

For the sample belonging to the third participant in the age category 40-50 years, Fig. 7 shows the area selected for analysis, the main chemical elements, and their percentage in the hair. The presence of the chemical elements Cu, and Zn is confirmed.

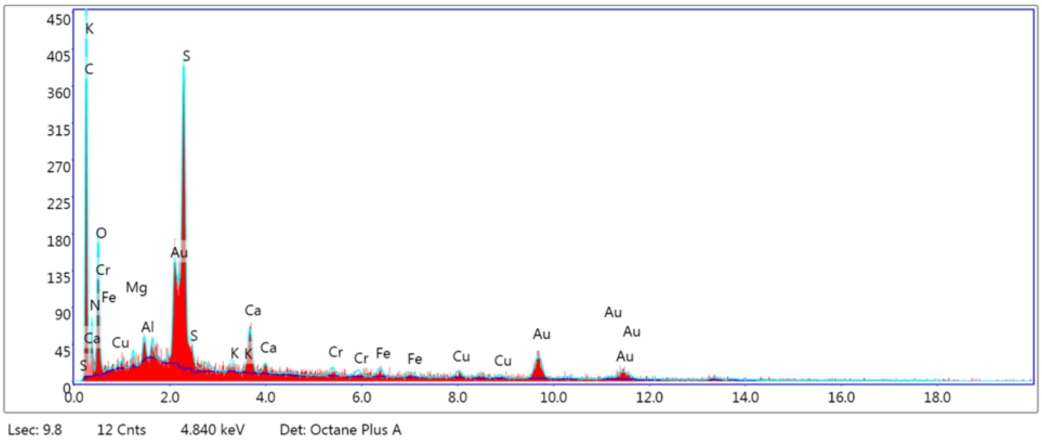

Fig. 7: EDS analysis for the third participant in the age category 40-50 years

The results of the samples taken from the participants in the 40-50 age group are quite different. A variety of chemical elements such as Cu, Ca, Al, Cr, Fe, Ce, Mn, etc. can be observed on the hairs and their percentage varies considerably from one sample to another.

Data interpretation

Fig. 8 shows a comparison between the percentages of chemical elements found in the analyzed hair samples. In the case of the category 20-30 years resulted in a percentage of 44.03% C, 16.7% N, 22.24% O, and 17.01% represent the percentage of other elements detected, such as Cu, Al, Ca, Mg, and so on. In the case of the 40-50 years category, a percentage of 41.38% C, 14.10% N, 24% O, and other elements found (such as Mg, Ca, Al, Ce, Si, etc.) are in the proportion of 23.18%.

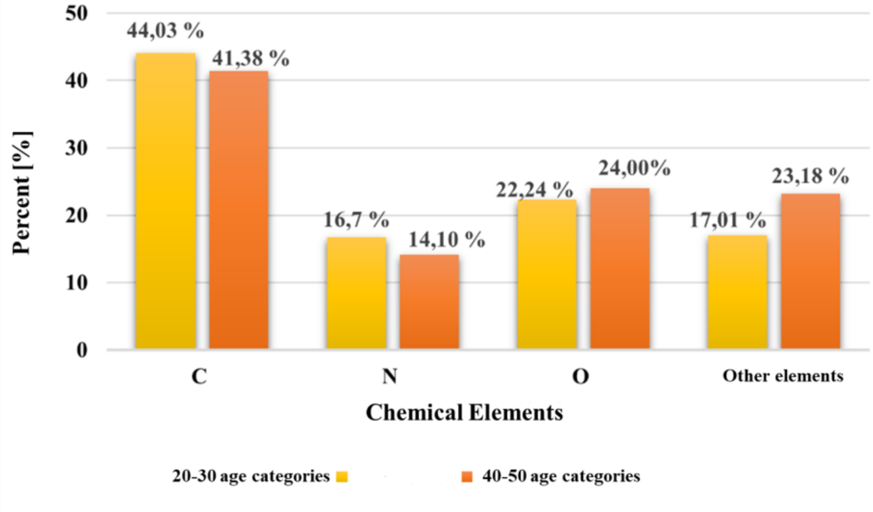

Fig. 8: Percentages of chemical elements for both age groups

The difference in the results obtained can be explained by the large differences between the participants whose hair samples were analyzed. A significant factor is the areas, i.e. the districts in which they live.

In this paper, the participants in the 20-30 and 40-50 age categories live in different sectors of Bucharest. Thus, for the 20-30 years category: the participants live in Sectors 2, 3, and 6. For the 40-50 years age category, the participants live in sectors 2, 3, 4, and 6. According to ANPM data, atmospheric pollution in Sector 3 of Bucharest is mainly caused by particulate matter (mainly PM10) and nitrogen dioxide (NO_2). After monitoring the air pollution level in this sector for six days (24.05.2023-29.05.2023), the data shown in Fig. 9 are obtained by comparing with the PM10 level at the end of 2022 (22.12.2022), a considerable decrease in particulate matter is observed.

Index	2023-05-24	2023-05-25	2023-05-26	2023-05-27	2023-05-28	2023-05-29	2022-12-22
PM10	19 Good	19 Good	14 Good	18 Good	14 Good	14 Good	45 Moderate
NO2	35 Good	23 Good	25 Good	22 Good	11 Good	15 Good	- Good

Fig. 9: Air pollution data in Sector 3 [13]

Similarly, air pollution in Sector 4 of Bucharest is caused by particulate matter (mainly PM10) and nitrogen dioxide (NO_2). Monitoring of air pollution levels in this sector over the same six-day period (24.05.2023-29.05.2023) yields the data shown in Fig. 10.

Index	2023-05-24	2023-05-25	2023-05-26	2023-05-27	2023-05-28	2023-05-29
PM10	22 Moderate	21 Moderate	19 Good	18 Good	15 Good	14 Good
NO2	34 Good	34 Good	32 Good	31 Good	18 Good	24 Good

Fig. 10: Air pollution data in Sector 4 [13]

Finally, air pollution in Sector 6 of Bucharest is caused by three types of pollutants: particulate matter (specifically PM2.5 and PM10), ozone (O_3) and nitrogen dioxide (NO_2). Monitoring of air pollution levels in this sector over the same six-day period (24.05.2023-29.05.2023) yields the data shown in Fig. 11.

Index	2023-05-24	2023-05-25	2023-05-26	2023-05-27	2023-05-28	2023-05-29
PM2,5	11 Good	9 Good	9 Good	9 Good	9 Good	10 Good
PM10	21 Moderate	19 Good	16 Good	17 Good	16 Good	16 Good
O3	67 Good	72 Moderate	78 Moderate	69 Good	78 Moderate	61 Good
NO2	25 Good	23 Good	18 Good	16 Good	13 Good	19 Good

Fig. 11: Air pollution data in Sector 6 [13]

By analyzing the air quality provided by the environmental organization's OpenAQ platform and the data obtained from the hair samples taken from the target participants, a link can be made between the amount of particulate matter in the atmosphere and sector health. Thus, subsequent analyses of the composition of particulate matter are also important because they can help to correlate with the elemental analysis of the investigated hair samples.

4. Conclusions

The variation in the results obtained can be explained by the large differences between the participants whose hair samples were analyzed. There is a major difference between hair types, the hair care products used by the subjects, and also the concern they give to hair care (e.g. use of hair treatments, dyeing or bleaching process, or even thermal styling). All these aspects are related to each subject's lifestyle, preferences, and habits. Another important factor is also the areas in which the participants whose samples were analyzed live.

Following the analysis, both previous observations and the literature indicate that data on the influence of air quality on hair should be collected over a much longer period of time and also taking into account aspects such as the medical history of the participants whose hair samples are analyzed, together with monitoring of the air quality in which they have lived throughout their lives.

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