Greenery Planning for Improvement of Urban Air Quality—A Review [†]

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[†] Presented at the Innovations-Sustainability-Modernity-Openness Conference (ISMO'19), Bialystok, Poland, 22–23 May 2019.

Abstract: On the basis of Polish and foreign literature on the subject, the impact of vegetation on air pollution (e.g., particulate matter) was described, as well as what significance its proper arrangement has. Reviewing findings carried out by various researchers, the criteria of selecting plants were collected and specified. Only those criteria that contribute to obtaining optimal results in the fight against air pollution were taken into consideration. Also, based on the collected data, a set of guidelines was developed that could eventually serve as a tool for more effective planning of urban greenery.

Keywords: urban greenery; planning; trees; shrubs; air pollution; particulate matter; phytoremediation

1. Introduction

Along with the continuous process of urbanization, standards of air purity are increasingly being exceeded, and smog is becoming an increasingly common phenomenon. Currently, constant actions are being undertaken to change this situation by limiting both current and future pollutant emissions. The first solution can be facilitated by using various methods. One of these methods is the phytoremediation method, i.e. using plants. However, in order to make this process optimal, it is also necessary to plan vegetation in the cities in an appropriate way. This is because plant arrangements in urbanized areas can affect the flow of air and this has direct influence on its quality.

Urban greenery can be understood as being all areas that are biologically active within cities, regardless of who owns them and how they are used [1]. These are mainly areas designed and maintained by humans as well as natural greenery preserved during the process of creating the city [2]. Because of the ability to purify the air, Professor Gawroński has stated that urban greenery along with a providing a number of functions such as oxygen production, raising air humidity, providing noise suppression or providing aesthetic benefits, also act as the "green liver" of the cities [3]. Most air pollution is caused by low-stack emissions (emissions from sources with a height lower than 40 m) and its main source is domestic heating and traffic that are emits many dangerous toxic substances such as: heavy metals (HM), polycyclic aromatic hydrocarbons (PAHs), nitrogen oxides (NO_x), ozone (O_3), airborne particulate matters (PM10 and PM2.5). The last two substances have been recognized in recent years as some of the most dangerous air pollutants, but plants can absorb and accumulate all of the aforementioned pollutants from soil, water and air [3–6].

The main aim of this article is to raise the issue of planning urban greenery in the context of reducing air pollution. First of all, the article aims to reveal that properly arranged trees and shrubs, depending on their location, can contribute to the reduction of air pollution to a greater extent than in case, where only aesthetic aspects were taken into account when the trees and shrubs were planted.

2. Greenery Planning

Asani [7] in her publication by referring to Greinert [8], postulates that aesthetic planning of urban green areas is a complex process and is subject to generally formulated composition principles. Therefore, there should be aspects included in this process such as: unity, consistency of composition, balance, harmony, dominant, rhythm, and communication. However, in order to ensure that urban greenery is conducive to the reduction of pollution, benefits such as air circulation and the ability of individual plants to absorb pollutants should be considered. Therefore in this case, the other aspects related to aesthetic benefits should be taken into account afterwards.

2.1. Circulation of Air

Many factors affect the state of the air in urban areas, including having good ventilation [9]. Therefore, planning a large number of tree plantings does not always prove to be a better solution for improvement of urban air quality. Depending on the type and layout of the buildings (most often located in the vicinity of communication routes), it may turn out that planting shrubs is a more effective solution despite the large trees' ability to accumulate pollutants [10]. An important factor is therefore to keep the surface roughness as small as possible on the main directions of the airing [9]. Some studies are being carried out on the air flow operates in canyon streets, the way that pollutants are being distributed in these areas and the effects of trees and shrubs on this phenomenon [10–17].

2.2. Air Pollution Removal

However, choosing the right type of greenery depending on the location is not the only factor to consider. There are also other important aspects that are worth taking into account, such as species selection. This is necessary because some plants are characterized by a greater ability to accumulate pollutants or oxygen production [2,18]. Some plants show good abilities to gain large amounts of green weight, while the others are less resistant to the conditions prevailing in cities. Currently, many studies have been carried out on plants in order to find those with the best air pollutants removal abilities [19–21]. Among these there are many species of trees but the shrubs could fulfil these functions as well. Some of them have better accumulation PMs (e.g., *Betula pendula*, *Platanus acerifolia*) while other have better absorption of pollutant gases (e.g., *Hedera helix*, *Acer platanoides*). There are also plants that also retain their full air pollutant removal abilities in winter. These are mostly coniferous but it is worth considering evergreen broadleaves species as well [22].

3. Plant Selection

Of course, there is a need to take into account the general environmental requirements of plants and the fact that, despite everything, it is desirable that the composition of greenery from a given place presents high aesthetic values [23]. But the most important factor is that plants must be resistant to urban conditions. However, while taking many criteria into consideration, it should be possible to choose a proper composition of the plant species so that it will be also the most optimal solution in the given place for improvement of the urban air quality and increase the aesthetic values of space [24]. The following guidelines must be met to make it happen:

- high resistance to the urban environment (low sensitivities to the pollutants and water stress),
- high stomatal conductance of leaves,
- avoiding the planning of an excessive amount of high plants with dense canopy in street canyons,
- planning varied plantings that are both deciduous and coniferous,
- planning plants with low negative impacts on air quality (that are producing few bio-aerosols such as allergenic pollen and mold spores),
- plants with pollution avoidance mechanism are not recommended,
- at least medium aesthetic values (as much as possible),
- ease of maintenance.

The plants listed in the Table 1 can be successfully used for optimal planning of urban greenery in the context of improving air quality.

Table 1. List of examples of plants that are recommended (sorted alphabetically).

Botanical Name	Suitable for Street Canyons [1]	Evergreen	Aesthetic Values	Position [2]
Acer campestre	-	-	+	S, HSh
Acer ruburum	-	-	++	S, HSh
Betula pendula	-	-	+++	S
Acer platanoides	-	-	+	S, HSh
Gleditsia triacanthos	-	-	++	S
Hedera helix	+	+	++	HSh, Sh
Hydrangea arborescens 'Anabelle'	-	-	+++	S, HSh, Sh
Pinus nigra	-	+	++	S
Platanus acerifolia	-	-	++	S, HSh
Quercus Ilex	-	+	+	S
Robinia pseudoacacia	-	-	++	S
Sorbus intermedia	-	-	++	S
Spirea vanhouttei	+	-	+++	S
Syringa meyeri 'Palibin'	+	-	+++	S, HSh
Pinus mugo 'Columbo'	+	+	+++	S
Tilia × europea 'Pallida'	-	-	++	S, HSh
Tilia cordata	-	-	++	S, HSh
Tilia tomentosa	-	-	++	S, HSh
Ulmus glabra	-	-	+	S

[1] in natural form; [2] S—sunny, HSh—half shaded, Sh—shaded.

4. Conclusions

The ability of plants to collect heavy metals, accumulate a waxy coating of polycyclic aromatic hydrocarbons, and accumulate micro particles (airborne particulate matter: PM10 and PM2.5), i.e. the main products of low-stack emissions, make phytoremediation an attractive technology for urbanized areas [25]. Even in winter, when leaves of deciduous plants are falling away, their purifying abilities do not have to decrease at all [26]. Despite this fact, pollution usually increases anyway due to the increase in domestic heating during this time of year. However this phenomenon has not been completely explored. In case of planning trees in canyon streets, it is important to conduct proper maintenance such as pruning to achieve desirable forms. Nevertheless, the constant observation of specific areas of the city remains very important, so that decisions can be made on the basis of the collected data on introducing potential corrections in planned plantings. Furthermore, urban greenery also has many other functions beyond improving air quality. For this reason, it is difficult to create an optimal set of plants species that would be completely universal. Achieving this aim depends entirely on the location and the needs for which the given planting is planned.

Author Contributions: Authorship is limited to the one author—K.R.

Conflicts of Interest: The author declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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