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Phytoarchitecture Design for Public Roads to Combat Air Pollution Resulting from Transport Operations

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ABSTRACT

Public roads and all their activities interact with the environment outside. The interaction was related to transportation pollutants and their recipient bodies, plants, air, and soil. The interaction of these environmental components can produce air pollution and requires prevention solutions. Plants are considered capable of weakening pollution; thus, this study aims to design a novel phytoarchitecture for public roads where roadside plants reduce air pollutants. The method for achieving this goal was based on selected empirical research, which was searched, collected, and selected using the Mendeley reference manager platform with the search phrase: roadside plants, heavy metals, and gaseous pollutants. The selection of hundreds of literatures was carried out in three screening stages. The organisation of this literature review used the ecological approach of transportation pollutants and roadside plants. With the intended methodology, the results of this study indicate that gaseous pollutants and heavy metals arise from public road transportation activities. Traces of pollutants can be measured on the surrounding land and especially on plants. There are five functional characteristics of plants, including phytotreatment, which reduces air pollution; phytoaccumulation to store pollutants; phytoindicators to indicate the presence of excessive concentrations; phytotoxicity in response to toxic levels; and phytomonitoring, which can provide early warning system. Finally, an ecological design is proposed for new roads and improving, operating, and maintaining existing roadside plants. In conclusion, the plant roles can be applied as criteria in the architectural design of public roads.

1. Introduction

The public road environment can be viewed as an open ecosystem with general traffic movement on land transportation. The definition of a public road may vary from country to country. Still, apart from railroads and lorries, a public road is intended for general traffic along with complementary infrastructure, such as bridges, traffic signs, road shoulders, and road medians [1,2]. While outside, the road is referred to as the roadside, where there are pedestrian paths, plant placements [3,4], or

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others. As is well-known about the nature of open ecosystems, all road components interact dynamically.

A person's presence outdoors, including transportation on the road, is much shorter than his or her presence in various indoor spaces, approximately 80%-90% a day [5-9]. However, many people travel, so roads may be used most of the time, which in turn causes transportation pollution all the time. In addition, outdoor pollutants, including transportation activities, are more numerous and higher in concentration than housing [10-14]. Furthermore, the movement of road traffic is related to various social and economic interests, both of which express dynamics and environmental pressures. Therefore, public transport need to be harmonised with the surrounding environment to fulfil the sustainability of these activities [15-17], including safety for everyone.

So far, there are almost no documented reports of traffic accidents caused by contaminated substances from transportation activities. However, it does not mean there is no threat of transportation pollution for drivers and passengers and their vehicles, acutely or chronically. In this regard, one can identify possible transportation pollutants that can negatively affect transportation health [18–20]. With this understanding, preventive mitigation can be designed to prevent traffic accidents caused by pollutants from transportation activities.

Within the framework of preventive mitigation, the pressure of pollution from transportation activities on the environment does not need the pollution level because even the slightest but repeated pollution can cause chronic problems [21-23]. Meanwhile, controlling pollution at the source may be difficult due to the complexity of the interaction of transportation components.

Therefore, this paper discusses the approach to controlling pollution of transportation activities in the receiving environment. In addition to air dilution and soil absorption, this paper focuses on the ability of plants along the roadside to control this pollution. In the end, an ecological architecture on public road design is proposed.

2. Methodology

This approach examines empirical research on pollutants related to transportation activities and assesses plant responses. Finally, the main findings were used as the basis for ecological architecture on public road design, as shown in Figure 1.

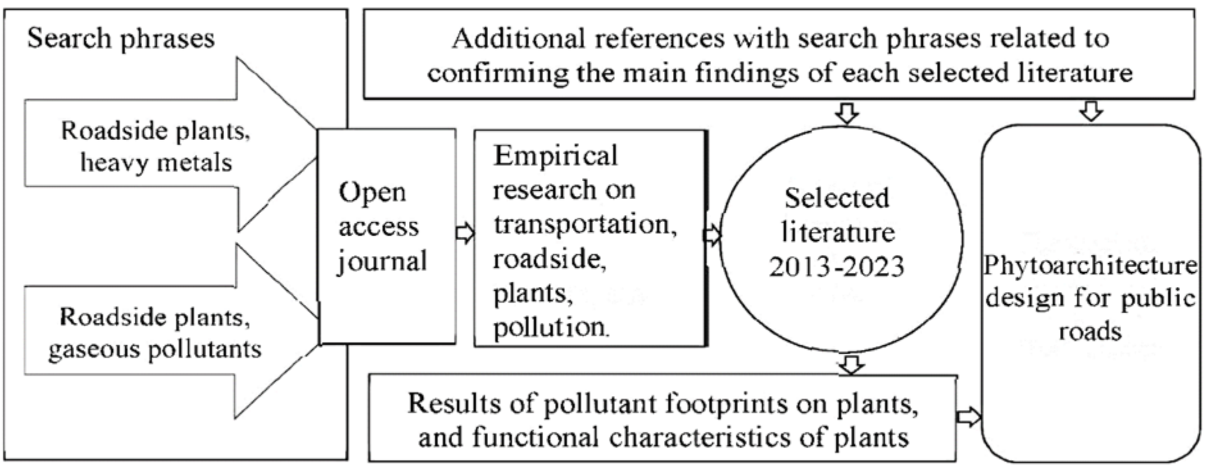

Fig. 1. A framework of materials and methods

The studied materials were searched, collected, and selected using the Mendeley Reference Manager platform with the search phrase: roadside plants, heavy metals, and gaseous pollutants. The screening was carried out in three stages, the first covering the criteria for the types of journal documents and the types of online publications. The second screening includes criteria entirely in English, which can be included in the library, and there are files and metadata, full paper availability, and empirical research related to transportation and roadside activities. In the second stage, articles were selected as the primary review material for the 2013-2023 publication period. The third screening is intended to add several articles that strengthen the findings of the selected empirical papers in the second stage. At this stage, the selected literature uses several search phrases related to pollutants and plants, and roadside features without a time limit for publication.

The problem analysis was based on essential findings from each selected literature, explored through abstracts, results, and conclusions. The organisation of this literature review used the categories of pollutant footprints and roadside plant response. The results identified functional characteristics of plants in eliminating and monitoring roadside pollutants as criteria for designing phytoarchitecture on public roads. The design is intended for the construction of new roads and also for managing the maintenance of existing roadside vegetation or modifications in the process of new plantings.

3. Results and Discussion

Various empirical studies on north-south-oriented planting show that plants are the main component of the global carbon cycle. Net primary productivity and carbon storage for hundreds of subtropical and tropical tree species exhibit steadily increasing mass growth rates. These results explain the same treatment of sunlight for each plant to absorb carbon in the process of photosynthesis. While planting in the east-west direction shows a dominant effect on the weakening of land surface temperatures. Planting in the direction of the sun's trajectory makes the plant a protector of the land surface from the sun's rays.

3.1 Pollutant Footprints

The method for identifying sources of pollution from transportation activities was carried out by analysing the contaminants in the soil/dust and plants along the road. Figure 2 is a schematic of pollutant measurements on soil/dust media and plant media, including their parts. This approach produces functional characteristics of plants in their interactions with gaseous and metallic pollutants.

Abbreviations of pollutants are as follows. Al: Aluminium, As: Arsenic, Ca: Calcium, Cd: Cadmium, Co: Cobalt, CO_2: Carbon dioxide, Cr: Chromium, Cu: Copper, Fe: Iron, Mg: Magnesium, Mn: Manganese, Ni: Nickel, PAHs: Polycyclic aromatic hydrocarbons, Pb: Lead, PM: Particulate matter, TPH: Total petroleum hydrocarbons, Zn: Zinc.

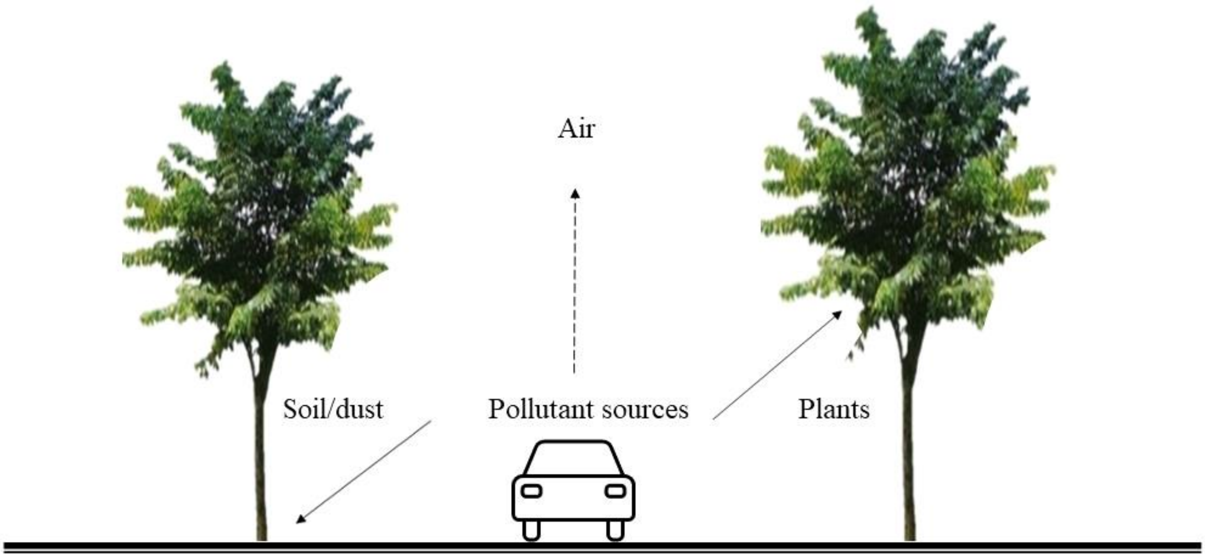

Fig. 2. Schematic of pollutant measurement of transportation activities

3.1.1 Gaseous forms

Until now, transportation activities still rely on energy sources from petroleum fuels. The fuel is an organic material, which in the combustion process produces CO_2. The presence of this gas always appears in the road ecosystem, although it is challenging to identify traces in plants because CO_2 is needed by plants for photosynthesis. In addition, it mixes with other sources of activity, including the plant product itself at night and the natural environment. Therefore, this CO_2 gas is not a specific gas generated by transportation activities.

Traces of gas generation from transportation activities can be identified through the source, in this case, the composition of fossil fuels. Fossil fuels generally contain saturated hydrocarbons, aromatic hydrocarbons, resins, and asphalts [24-27]. Of course, refined oils such as gasoline differ in chemical composition, most of which are unsaturated hydrocarbons [28,29]. Research on gaseous pollutants related to road plant transportation activities is less than on heavy metals. The data collected shows some of the following studies.

Vegetation can accumulate fuel oil pollutants in the form of PAHs from the air around the road. Research on the PAH concentration in various plants shows that the leaves are the site of accumulation of these substances. PAHs in leaves are measured as phenanthrene, pyrene, and fluorene [30]. Likewise, the roadside plant *Ficus benghalensis* accumulates high levels of total PAHs above 20 ng/m^3 from fuel oil sources [31]. Sources of total PAHs from transport activities were confirmed through investigations of roadside soils, which were higher in concentration than surrounding industrial and residential soils [32].

3.1.2 Heavy metals

There is a direct correlation between heavy metal accumulation from road traffic and proximity to the roadside [33-35]. The summary was made in three groups, first covering various plant species (Table 1), second for one whole plant species (Table 2) and third covering plant parts (Table 3). The number of asterisks in the table indicates the measured pollution level in a particular place.

Table 1
Summary of pollutant traces in various plant species

Heavy metals	Various distances from the road	Soil/ dust	Leaf	Whole plant	Various plants	References
Pb, Cd, Cu, Zn, Cr, Ni		**			*	[36]
Cd, Zn, Cu, Cr, Pb, Ni	*	*		*	*	[37]
Pb, Zn, Cu, Cd	*	*		*	*	[38]
Ni, Pb, Cd	*	*		*	*	[39]
Zn, Cu	*			*	*	[40]
Pb, Cr, Cd			*		*	[11]
Pb, Cd			*		*	[41]

A study has revealed that the heavy metal content of Pb, Cd, Cu, Zn, Cr, and Ni in the soil was, on average, almost 30% lower than in roadside dust from long-term pollution. Meanwhile, road dust is easily affected by natural or human disturbance, which reflects the pollution emission in a short time. Therefore, dust is a health risk factor that needs to be considered [36].

An investigation of the Cd, Zn, Cu, Cr, Pb, and Ni content was carried out on plant samples of *Kyllinga pumila michx, Kyllinga squamulata, Cenchrus biflorus*, and soil along the transportation road in plants found high concentrations of Pb, Cu, Zn, Cd, Cr, and Ni. The soil contains high Pb, Cu, Cr, and Ni [37]. The heavy metals of Pb, Zn, Cu, Cd pollution levels were observed from the roadside and 50m away. It was found that higher concentrations of all these heavy metals were in dandelion plants than in grass, depending on the distance from the road [38]. High to low concentrations of the heavy metals Ni, Pb, and Cd were found at distances up to 1000 m from the roadside in the soil and vegetables of bottle gourd and pumpkin. Except for Cd, the concentrations of all heavy metals differed significantly with the distance from the source of pollution. However, all metals have significantly different concentrations in the two types of vegetables [39].

In all variations of plant distance from the roadside, between 1 m - 15 m, the highest concentration of Cu was found in *Taraxacum spec*. and the lowest Cu in *Rumex acetosa*. The highest Zn was found in both plants, but the lowest was in *Vicia cracca*. Also found near the road is Cu in the plant *Achilea millefolium* [40].

Research to identify types of pollutants from transportation activities was carried out through analysis of the content of heavy metals in medicinal plants *Azadirachta indica*, *Magnifera indica,* and *Newbouldia laevis*, cultivated near the road. The leaf analysis results showed that the highest to the lowest heavy metal concentrations were Pb, Cr, and Cd, which exceeded the permissible concentration limits for medicinal plants [11]. The leaves of the roadside trees are used to investigate several heavy metals from transportation activities. The investigation showed that high levels of Pb and Cd were found in *Pongamia pinnata*, which were more abundant than in *Peltophorum pterocarpum*. The difference was probably due to the large leaf surface of the first plant [41]. Other similar studies also confirmed the strong correlation between the amount of pollutant deposition and leaf area [42-44].

Table 2
Summary of pollutant traces in whole one plant species

Heavy metals	Various distances from the road	Soil/ dust	Whole plant	References
Pb, Fe, Cu		*	**	[45,46]
Zn, Mn, Cu, Mg	*	*	**	[47]
Fe, Mn, Mg, Zn, Pb, Ni, Cu, Cd, Co, Cr	*	*	*	[47]
Fe, Mn, Zn, Pb, Ni, Cu, Cr, Cd		**	*	[48]

Studies found that Pb, Fe, and Cu elements showed higher levels in canola plants, including roots, aerial parts, and seeds, than in cultivated soil. In addition, t three heavy metals were shown to contaminate plants through air transport [45,46].

Another study determined the concentration of selected heavy metals Cd, Pb, Zn, Cr, Fe, Mg, Mn, Co, Ni, and Cu. Several soil samples were taken at various distances from the roadside, and several depths, while plant samples were random. The concentration of heavy metals in the soil showed the order of Fe, Mn, Mg, Pb, Zn, Ni, Co, Cu, Cr, Cd, and for plants Fe, Mn, Mg, Zn, Pb, Ni, Cu, Cd, Co, Cr. Heavy metal concentrations decreased with increasing distance from the roadside and soil depth. The concentration of heavy metals Zn, Mn, Cu and Mg in plants compared to the soil was found to be more significant than 1 [47]. A type of grass *Stenotaphrum sp.,* on the roadside and soil was analysed for the total content of heavy metals Cd, Pb, Zn, Cr, Fe, Mg, Mn, Co, Ni, and Cu in plants and soil. The concentration of heavy metals in soil is, on average, nine times higher than in grass tissue. The largest to slightest concentrations of heavy metals from the source of road activity were found with the order Fe, Mn, Zn, Pb, Ni, Cu, Cr, Cd [48].

Table 3
Summary of pollutant traces in plant parts of one plant species

Heavy metals	Various distances from the road	Soil/ dust	Root	Leaf	Bark	Fruit	References
Cr, Pb, Ni, Co, Cd, As		*		***	**		[49]
Pb, Zn, Cd	*			*			[50]
Zn, Mn, Cu, Co, Cr, Pb, Cd, Ni	*	*		*		*	[51]
Cu, Pb, Cr, Fe, Cd, Zn				*			[52]
Fe, Mn, Cd, Cu, Pb, Cr				*			[53]
Cu, Fe				*			[54]
Cd, Cr, Ni, Fe, Pb, Mn, Cu, Zn				*			[55]
Cd, Pb			*				[54]

Meanwhile, the concentrations of metals Cr, Pb, Ni, Co, Cd, and As were found in the leaves of the *Azadirachta indica* plant, which was higher than in the bark of the plant, and all of them exceeded the concentration limits of the World Health Organization standard for medicinal plants. However, compared with the concentration of these metals, the dust is the lowest. The results indicate that all these metals come from transportation activities [49].

The leaves of the vegetable plant *Corchorus olitorius*, cultivated on the roadside, contain Pb, Zn, and Cd. The highest concentrations of all three metals were found in plants near the road and decreased in concentration as the plants were further away. The results indicate that the three pollutants originate from transportation activities [50].

Investigations of heavy metals Zn, Mn, Cu, Co, Cr, Pb, Cd, and Ni were investigated for mulberry cultivation soil and plants on leaves and fruit. The distance variation is 20m-100m from the roadside. The results show that all heavy metals, except Ni, contaminate the soil and plants at the closest distance to the road. Nevertheless, at further distances from the road, Ni and Pb contaminate the mulberry fruit [51].

The roadside heavy metals research showed that the soil contained Cu, Pb, Cr, Fe, and Cd. Meanwhile, Cu, Cd, Zn, Pb, Fe, and Cr were concentrated in plant leaves. Among the heavy metals, only Pb in soil and plant leaves was found in concentrations exceeding the recommended limits of the World Health Organization. In this case, there is a potential risk of Pb to human health through the food chain [52].

Along the road around the industry, heavy metals were found in the dust in the order of the largest to slightest concentrations: Fe, Mn, Pb, Cu, Cr, Cd. The order changes to Fe, Mn, Cd, Cu, Pb, Cr in plant leaves. Especially Cd, the leaf concentration was more significant than dust [53].

The plant roots are slightly enriched with Cd and Pb from the soil, while the leaves absorb and accumulate Cu and Fe [54]. Similar studies have shown that the high absorption of heavy metals by plants growing near the roadside is due to intensive motor vehicle traffic pollution. For example, was found 30 m from the road, the heavy metal content in the leaves of *Alcea rosea* L. was arranged from most significant to most minor as follows: Cd, Cr, Ni, Fe, Pb, Mn, Cu, Zn, all of which were lower than roadside plants [55].

3.2 Roadside Plant Response

In general, plant responses to pollutants can be categorised into the ability to accumulate pollutants and treat pollutants. In both processes, plants monitor the dynamics of pollutants to act as a phytomonitoring system. Regarding monitoring capability, plants can experience an adverse effect known as the phytotoxicity of pollutants on plants. Therefore, plants can be an indicator of a certain level of pollution.

3.2.1 Phytoaccumulation

This study summarises the ability of plants to accumulate pollutants, with the characteristics of plants not experiencing adverse effects and death. This condition follows the understanding of bioaccumulation [56-58].

In a phytocenosis, which includes *Scrophulariaceae, Compositeae, Rubiaceae, Poaceae, Fabaceae, Polygonaceae, Umbellíferae* plants, accumulation of heavy metals Cr, Cu, Ni, Pb, Sr, Zn was found. *Pinus sylvestris* L. needles mainly accumulate Cr, Cu, Ni, Sr. Meanwhile, *Betula pendula* Roth leaves accumulate large amounts of Pb, Zn, and small amounts of other metals [59].

There are fifteen grass cultivars of five grass species along the roadside, which have been planted for two years. This study's results demonstrated grasses' ability to accumulate large amounts of Cu and Zn from the soil and transfer them to aboveground biomass. The best grass type for roadside plants, with the highest bioconcentration factor values for the studied metals, was *Lolium perenne* [60].

A study was conducted to observe the accumulation of heavy metals in the fruit and leaves of *Punica granatum* L. with variations in distance from the roadside. Co, Ni, and Cr accumulations were found in the fruit samples, which differed significantly over the distance from the roadside. Meanwhile, Ni accumulation was found in leaf samples [61].

A study has examined heavy metals in several species of wild plants growing along roadsides. Heavy metal Pb was found to accumulate in plants *Acacia nilotica* L., *Ziziphus mauritiana* L. and *Calotropis procera* L. Heavy metals Mn, Zn, and Fe accumulated in plants *Ricinus communis* L. and *A. nilotica*.

Particulate matter (PM) deposition from transport generation was observed in some roadside plants *Alstonia schlolaris, Bauhinia variegata, Ficus benghalensis, Ficus religiosa, Cassia fistula,* and *Mangifera indica*. The highest particle deposition was in the *Ficus benghalensis* plant, while the lowest was in the *Bauhinia variegata* plant. It was revealed in the study that the deposition of particles on the leaves was inversely proportional to the accumulation of heavy metals Cr, Cu, Fe, Mn, and Zn [62]. Therefore, these plants do not experience adverse effects and become natural biofilters [63,64] to control pollution from transportation activities.

Similar studies reveal that different plant species are different in their ability to accumulate PM. These observations were obtained from research on roadside trees of *Buxus koreana, Taxus cuspidate, Rhododendron yedoense,* and *Chionanthus retusa*. The concentration of PM10 was deposited on the leaf surface of the tree, which was greater than that of PM2.5-10. *R. yedoense* plants with furrows and hairs on the leaf surface retained PM particles longer, but the highest PM accumulation was in *B. koreana* and *T. cuspidate* trees with wax. PM contains heavy metals, such as Al, Ca, Mg, Fe, Cu, Pb, Zn. It was found that leaf Mn, Cd, Cu, Ni, Pb, and Zn concentrations were strongly correlated with PM2.5-10, indicating that PM was absorbed through tree leaves [65].

3.2.2 Phytotreatment

The following empirical studies demonstrate the ability of plants to reduce pollutant concentrations without harming the plants themselves. Plants that can restore environmental conditions are known as phytoremediators in polluted conditions. Several research results show the following facts.

Some native plants in the tropics can control high concentrations of TPH. However, plant growth under these conditions marks its potential as an environmental phytoremediator [66-68]. Therefore, investigation on decorative sunflower plant, *Helianthus annuus*, was also investigated for its ability to reduce TPH and PAHs contaminants simultaneously with Pb and Zn metals, besides being able to control heavy metals [69,70]. The combined results showed a decrease in Pb and Zn concentrations of around 50%, while a decrease in TPH and PAHs was around 35% [71].

There is research on the effects of traffic-related contaminants on the soil on the roadside. Therefore, soil samples up to 500m at a depth of up to 30 cm were investigated for the total content of TPH and PAHs. Correspondingly, the investigation was aimed at plants with *Hordeum vulgare* L. and *Lepidium sativum* L. The general results showed a decrease in pollutant concentrations in soil, due to phytotreatment, by moving away from the roadside [72-74].

3.2.3 Phytomonitoring

The definition of phytomonitoring is a plant as a medium for monitoring environmental pollutants. Plant standards as a comparison for polluted plants are healthy, both structurally, such as regular growth rate, and functionally, such as average rate of photosynthesis. On the other hand, when a pollutant has an abnormal effect on plants, the pollutant is phytotoxic. Whereas a pollutant that has a specific effect on plants, such as leaf necrosis, then the pollutant becomes a phytoindicator. Some of the results of phytomonitoring studies have been documented as follows.

A study examined the impact of PM contaminants on leaf stomata morphology in twelve roadside plants. The PM content contained Fe, Cu, and Zn metals. It was found that the most significant decrease in stomata size was found in *Ficus benghalensis* leaves, and the lowest was in *Bauhinia variegate* leaves. The study concluded that common roadside plants were adversely affected due to higher concentrations of air pollutants, and caused some changes in leaf morphology [75]. The change in plant morphology is one example of a form of pollutant phytotoxicity to plants [76,77].

Research carried out to characterise exposure to gaseous pollutants from transportation is the effect of these pollutants on plants. Specifically, research on the toxic effects of pollutants from transportation activities on soil and several plants was conducted at distances up to 50m from the roadside. The investigation was directed at the content of PAHs and TPH and heavy metals Cu, Pb, and Zn. The results show a decrease in pollutant toxicity to the soil with increasing distance from the road. Meanwhile, plant parameters against pollutant toxicity were root and shoot length, resulting in the sensitivity of roadside plants from most significant to lowest, *Lepidium sativum* L., *Hordeum vulgare* L., *Sinapis alba* L., *Raphanus sativus* L. [78]. In addition, *Hordeum vulgare* L. and *Lepidium sativum* L. were exposed to the toxic effects of TPH and became an indicator of PAHs pollution [73].

Effects of heavy metals Pb and Mn were studied on roadside trees *Conocarpus erectus*. The plant has a physiological response to exposure to these two heavy metals. The result shows that there is a type of plant that can be a good phytoindicator of the accumulation of heavy metals [79].

Heavy metals are one of the air pollutants from transportation activities. Heavy metals are not easily damaged and tend to accumulate in nature. Therefore, heavy metals can be used as pollutant parameters for determining pollution indicators. One of the phytoindicators that has been tested is the *Pinus sylvestris* for monitoring Ni, Cr, and Zn, with variations in distance from the roadside up to 100 m. In addition, t pine plant was an excellent phytoindicator for changes in Cr concentration [80].

Plant leaf samples were collected from various transportation activities and analysed for the heavy metal content of Fe, Mn, Co, and Ni. The analysis showed a significant correlation between Fe and Ni content in the same season. Furthermore, high Fe concentrations and low Ni concentrations were found in the leaves of *Dalbergia sissoo* Roxb., *Prosopis juliflora* L., and *Eucalyptus* spp. Thus, the three plants were considered suitable as phytoindicators of Fe and Ni [81].

3.3 Operation and Maintenance Design

Recently, populated areas have grown in population and economic activity, which has resulted in the growth of transportation roads. The increase in all social, economic, and physical aspects gives the consequence of increased pollution [82-84], especially the road environment. Therefore, for the balance between pollutant exposure and environmental receiving bodies, an ecological approach is needed regarding the ability of plants along the road to control pollution, apart from air and soil.

3.3.1 Phytoarchitecture for roads

It has been learned from a series of research results above that plants could have at least the following five functions. The first is to accumulate pollutants (phytoaccumulation), the second is to reduce the concentration of pollutants in plants (phytotreatment), the third is to indicate the presence of certain pollutants (phytoindicators), the fourth is to respond to the adverse effects of pollutants (phytotoxicity), and fifthly, all of them can be used as a vehicle for monitoring pollution (phytomonitoring), especially in transportation activities. In this regard, an ecological architecture on public road design is proposed schematically in Figure 3 for ideal conditions. Design variations can be made according to local conditions.

Figure 3 shows the need for plant biodiversity to fulfil its five functions. The placement of plants with all their functions is free, which can be on the roadside or median. The freedom of placement is given to accommodate considerations outside the five functions, such as traffic safety, aesthetics, preference for plant species, ease of maintenance, regeneration, and plant diversity [85–87]. In Indonesia and possibly other countries, the placement and choice of plant species consider local wisdom [88-90].

Specifically for Figure 3 on the roadside, the distance between plants lengthwise is determined based on the potential width of the canopy that can intersect with each other. This condition can maximise pollutant filtering so that it does not spread far beyond the road area. Therefore, the distance between these plants depends on the type used. Moreover, using zigzag planting and plant types of different heights is better. This configuration makes the plant spacing wider and a more expansive canopy than inline planting.

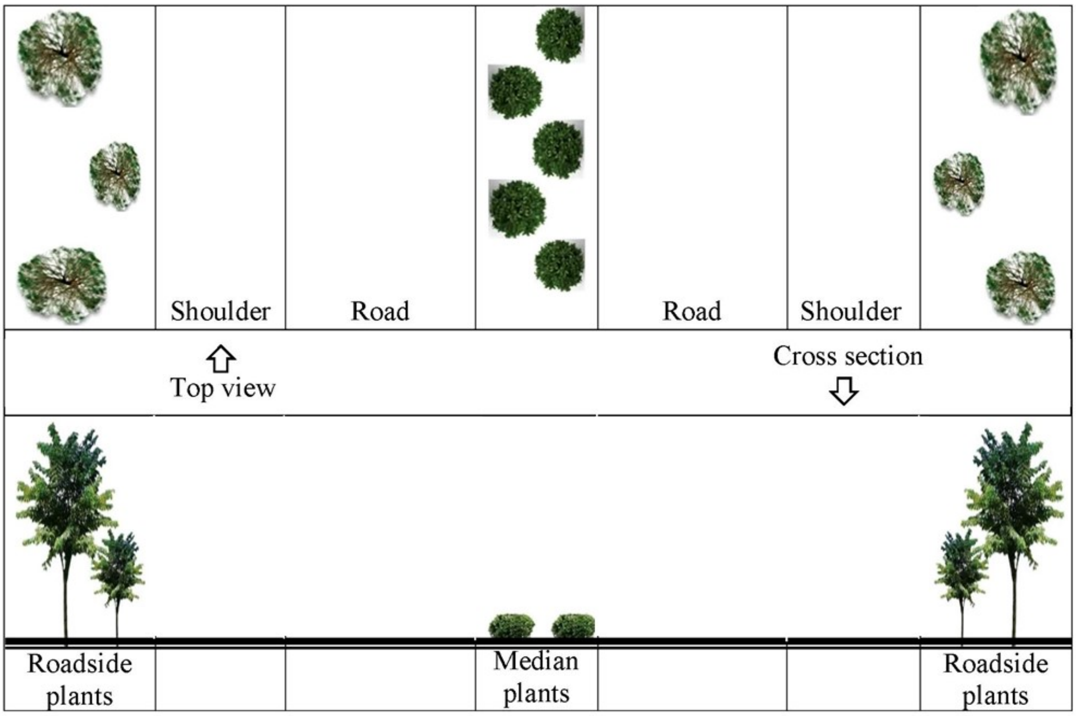

Fig. 3. Schematic of phytoarchitecture on public road design

Widening plant spacing and canopy area provides at least the following advantages. First, various heights, distances, and canopies of plants increase the efficiency of depollution of heavy metals from the air since the reduction of the metal is affected by distance, plant cover, and relative elevation [91-93]. Second, expansion of the leaf surface can increase particulate matter deposits [94-96]. Third, various leaf areas and their number provide maximum opportunity for the interception of sunlight [97-99], including exposure, transmission, and reflection of light between trees, which is very beneficial for the availability of energy for the photosynthesis process, so that the plant growth process is maintained. Fourth, zigzag planting generates turbulent airflow [100,101] to lift gaseous pollutants into the air beyond the height of the human inhalation zone. In addition, zigzag planting can deflect wind direction and reduce pressure on trees [102] so that the trees are not easy to fall, especially in anticipation of the rainy season.

3.3.2 Ecological maintenance of roadside plants

The design and implementation of planting on roads that have been built must be accompanied by adequate plant maintenance for the sustainability of their use. Plants, as living organisms, can experience various forms of structural damage in addition to disturbing public facilities. The following examples are plant conditions that require intensive maintenance, i.e., plants on the paths that interfere with electricity and telephone lines, old plants that can fall at any time and endanger the public interest, and plants that are exposed to diseases that can harm other trees.

Plant maintenance remedies polluted environments and pollutant treatment, minimally pruning branches, twigs, and leaves. Pruning leaves is necessary to increase the assimilation capacity of gases [103,104] to maximise the absorption of carbon dioxide and gaseous pollutants. In this regard, ecologically, the ability of plant functions to be maximised when exposure to solar energy can be efficiently absorbed. For each plant species, high efficiency of solar energy will be obtained for heterogeneous shaped canopy conditions [105,106] and leaf layers and leaf pruning at the bottom.

A coarse canopy captures solar radiation through many leaves [107,108]. Therefore, the multi-layered leaves allow maximum absorption. Meanwhile, the lower leaves, which do not receive enough solar energy, undergo a breakdown of biomass into carbon dioxide. Thus, the correct pruning pattern is the upper and lower leaves to increase the assimilation capacity of gaseous pollutants and prevent the loss of carbohydrates.

Pruning the leaves should not be carried out simultaneously for a group or series of plants. Instead, pruning should be made alternately in a group or a series of plants, as shown in Figure 4. Plants that have been pruned will grow faster than those that have not been pruned because the carbohydrate turnover of trimmed plants is not as much as before. The difference in growth will make the canopy of a series of plants heterogeneous and produce a configuration of leaf arrangement in layers, which is ecologically beneficial.

The existing roadside plants can be maintained for cities with built road infrastructure. However, ecological improvement can use the maintenance above, and if possible, planting new plants in a zigzag shape, as shown in Figure 4.

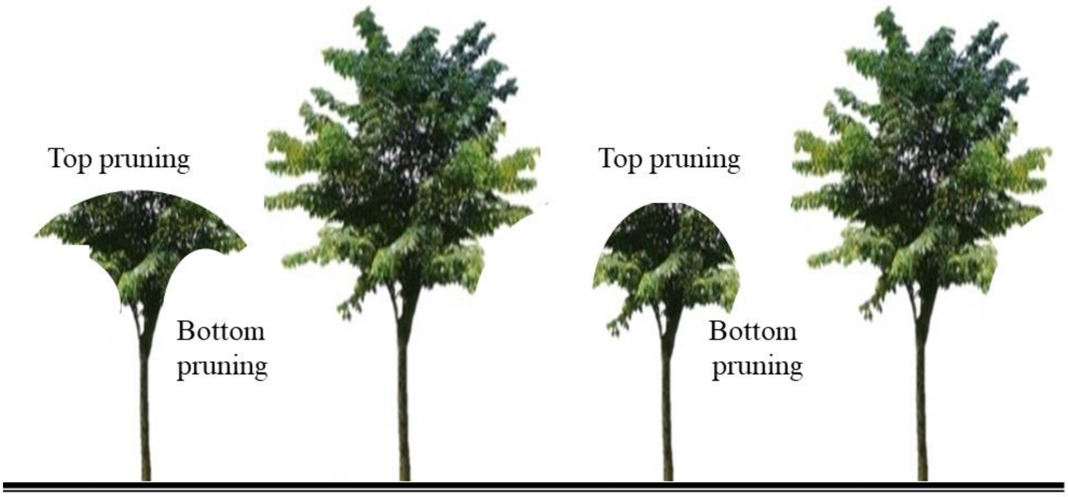

Fig. 4. Schematic of ecological maintenance on long section roads

4. Conclusions

The progress of empirical research has resulted in an in-depth understanding of the approach to identifying pollutants from transportation activities using plant media. Different types of plants respond differently to the same substance, which indicates that the depollution of pollutants is plant specific. Heavy metals, inorganic chemical pollutants, and some gaseous organic pollutants have opened up the functional properties of plants by eliminating these substances. The five functional characteristics of plants, viz. phytotreatment, phytoaccumulation, phytoindicators, phytotoxicity, and phytomonitoring, can be proposed and applied in ecological architecture on public road design. Due to the response to pollutants from transportation activities being plant-specific, further empirical research is needed on selecting plant species for each of their functional characteristics.

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