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Possibilities of Sustainable Development including Improvement in Air Quality for the City of Murmansk-Examples of Best Practice from Scandinavia

Miłosz Huber [1,*], Adrianna Rusek [2], Marija Menshakova [3], Galina Zhigunova [4], Stanisław Chmiel [5] and Olga Iakovleva [6]

1 Department of Geology, Soil Science and Geoinformacy, Faculty of Earth Science and Spatial Management, Maria Curie-Skłodowska University, 2d Kraśnicka Ave., 20-715 Lublin, Poland
2 Faculty of Geography and Geology, Jagiellonian University, 3a Gronostajowa St., 30-387 Kraków, Poland; ada1236@onet.pl
3 Laboratory Monitoring and Preservation of Natural Ecosystems of the Arctic, Murmansk Arctic State University, Captain Egorov, 15, 183038 Murmansk, Russia; dendrobium@yandex.ru
4 Department of Philosophy and Social Sciences, Murmansk Arctic State University, Captain Egorov, 15, 183038 Murmansk, Russia; galina-zhigunova@yandex.ru
5 Department of Hydrography and Climatology, Faculty of Earth Science and Spatial Management, Maria Curie-Skłodowska University, 2d Kraśnicka St., 20-715 Lublin, Poland; stanislaw.chmiel@mail.umcs.pl
6 Department of Applied Linguistics, Faculty of Humanity, Maria Curie Skłodowska-University, 5 Maria Curie-Skłodowska Sq., 20-031 Lublin, Poland; olga.iakovleva@mail.umcs.pl
* Correspondence: milosz.huber@mail.umcs.pl; Tel.: +48-815376800

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Abstract: The Russian city of Murmansk has about 300,000 inhabitants and is located inside the Arctic Circle in NE Scandinavia (Russia). It has one of the largest such concentrations of people in the Arctic. The city is a scientific, industrial, cultural, and transportation centre (an ice-free port in the so-called Northern Sea Route, connecting Europe with Asia). Currently, air pollution in the city is associated with outdated city heating technology, coal dust from the port and vehicular traffic, and so-called "small emissions". The authors propose practical solutions based on known examples of Scandinavian cities with similar climatic conditions such as: the modernisation of heat energy acquisition; diversification of energy acquisition including renewable sources; thermal insulation of buildings; arrangement of urban greenery with dust-catching plants, and proposals for changing the habits within the population by promoting the use of public transport.

Keywords: sustainable development; Arctic; Murmansk; air pollution; render; *Plantago major* L.; environmental protection; Scandinavia

1. Introduction

The city of Murmansk, located inside the Arctic Circle in NE Scandinavia, is a vibrant city. With a population of about 300,000 [1], it is one of the largest cities in the Arctic and claims to be the "Capital of the Arctic" [2–6]. It is located on the Kola Gulf adjacent to the Barents Sea, with an ice-free harbour in winter (Figure 1) [2,7–12]. The port is currently an important hub for the transfer of goods between Russia and Europe, and America and Asia [13]. For this purpose, icebreakers are stationed in the city, paving the way for ships across the Arctic Ocean.

Murmansk is a thriving city with two universities (Arctic State University, Murmansk State Technical University, and many other universities and educational establishments), regional administration, and important railways (running to St. Petersburg and Moscow and the rest of Russia), roads (connecting Murmansk to Finland and Norway), and airways (an international airport). The diplomatic consulates of Scandinavian countries are also located in this city. Therefore, it is a cultural and industrial centre of supra-regional importance. It was founded in 1916 after the completion of the railway line from St. Petersburg, a little further north than the town of Kola (which has been in existence since 1517) [8,14]. There are many similar towns related to the Russian settlement in the region from the XII century onwards, scattered mostly along the coast of the Kola peninsula. There are also numerous archaeological sites associated with the Saami people (labyrinths, petroglyphs, megalithic forms) [15]. These factors contribute to Murmansk's historical and cultural value [16,17]. Despite its location inside the Arctic Circle, the climate here is rather mild [18,19]. In winter, the temperature rarely drops below minus 30 °C, while in summer it is usually recorded around 15 °C, although there are extreme days when it rises to plus 33 °C (e.g., in 2018) [9,10,20]. This is influenced by the Norwegian Current, a branch of the Gulf Stream, which significantly moderates the temperature amplitude while contributing to high cloud cover and precipitation in the region. The Murmansk region has a relatively short plant vegetation period from May to October [21–23].

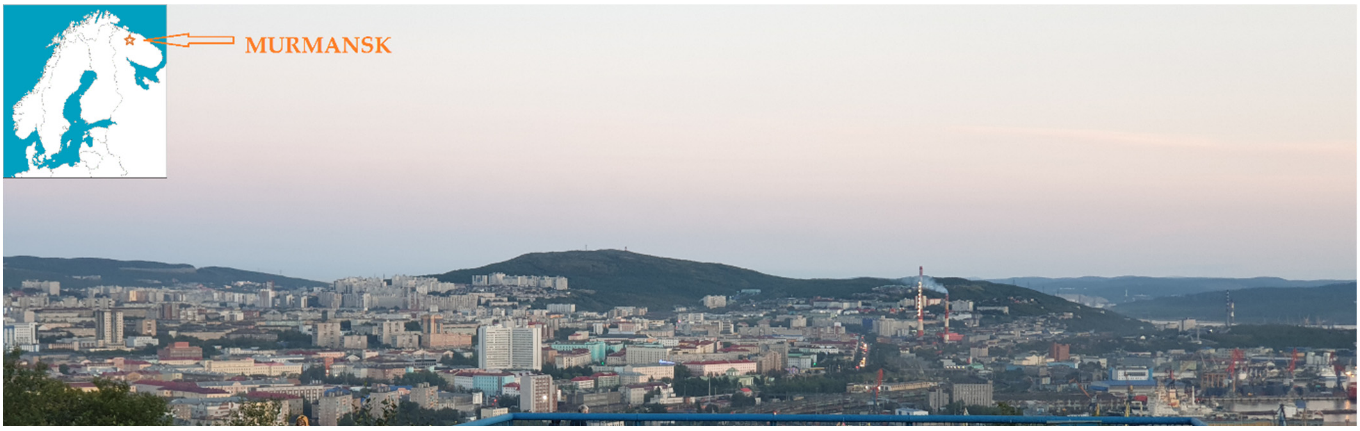

Figure 1. Murmansk panorama and contour map showing the location of the city against the background of Scandinavia. Chimneys visible in the picture are thermal power plants providing water heating in the city.

Murmansk city is located on the NE Fennoscandian Shield [24–34] in the vicinity of Archean [28,35] and Paleoproterozoic metamorphic rocks [30,36,37] with addition of the Pleistocene glacier sediments [38]. The soils mostly have an initial character (regolith) [39]. The city area is densely built up with multi-storey houses and blocks of flats of up to ten storeys. High population density, vehicular transport, and industrial activity influence environmental pollution in Murmansk [40–42]. A significant problem are the thermal power plants that run on fuel oil (masut), and the coal handling port [13,39,43–53]. The technical condition of cars driving around Murmansk is also an important contributor. Due to the short vegetative period of plants, the city's air can form dangerous aerosols, especially when the much warmer Gulf waters clash with cooler air to create localised haze [46,49,54–59]. This creates a pressing need for significant changes in city operations to improve atmospheric conditions in and around the city centre [60,61]. This study aims to analyse applied technologies in similar cities in Scandinavia that, if adapted to local conditions, can improve air and environmental quality. The authors cite their studies of dust accumulated on plants, and facades to demonstrate the state of the environment. The authors also propose scenarios for the introduction of various innovations that can significantly improve the air quality and environment in the city.

2. Materials and Methods

The field study was conducted in the summer of 2016 in the city centre area, where soil and render samples were collected for the study of environmental quality and cumulative pollution values of the city [41,43,60–63]. A lot of Arctic and Boreal plants, lichen, and mosses are present in the forest-tundra [64–66], but the *Plantago major* L. exists only in the human activity territory. Plant samples were collected in the vicinity of rendered buildings. The exact location of the samples is provided on a map in Figure 2. From these samples, preparations were made, and micro-area studies were conducted using a Hitachi SU6600 scanning electron microscope with an Energy Dispersive Spectroscopy (EDS) attachment. In addition, the collected dust from the plants was conducted into a solution and analysed using the Inductively Coupled Plasma Mass Spectrometry (ICP-MS) technique in the case of a plasterwork surface. Testing for heavy metal content was performed. Samples of *Plantago major* L. leaves were subjected to analyses, which were previously dried, milled, and dissolved using royal water (Nitrohydrochloric acid). In the first stage of the study, calibration curves for metal ions were prepared determining the tested samples. Absorbance parameters were measured, its quantity value changed during the measurement, showing a signal as a peak. Analysis results were stored in a specialised program Cs Aspect, wherein the measured absorbance values were read out as the concentration (mg/L), in relation to a calibration curve. The results are shown as the arithmetic mean of obtained values. The results were developed mathematically using Microsoft Excel and Surfer. Between 2020 and 2021, several comparative studies were carried out in Scandinavia to find suitable practices that, if adopted by the region, can significantly influence the air quality in the city [50,62].

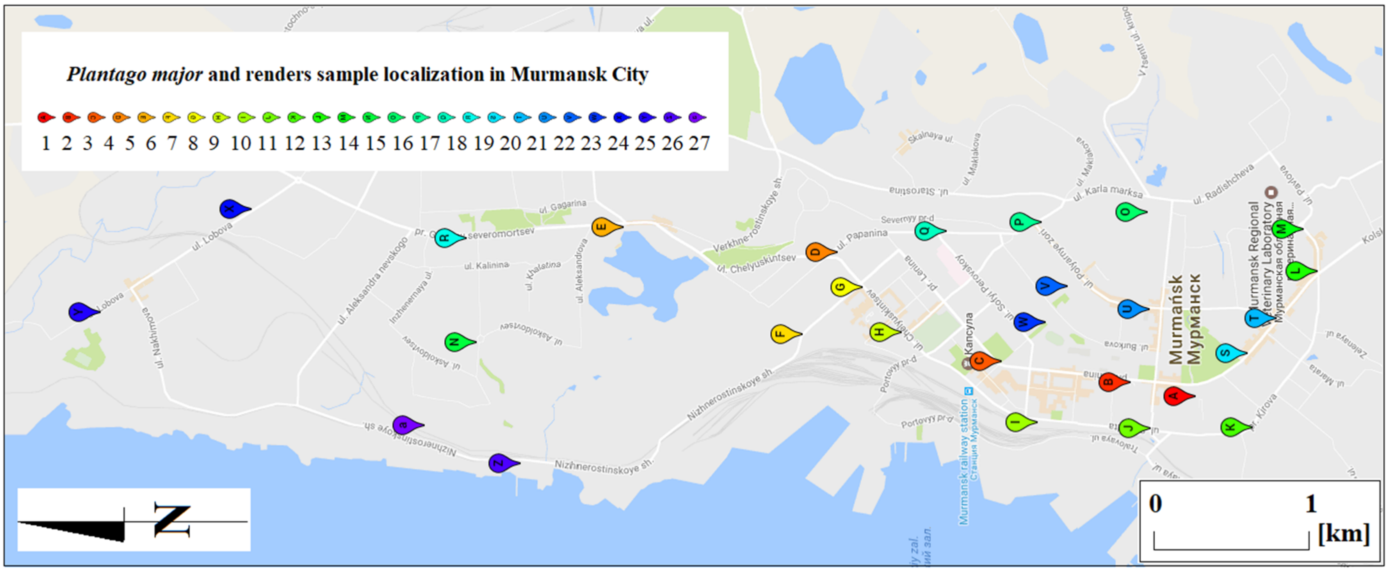

Figure 2. Location of *Plantago major* L. and render sampling on the background of Murmansk city map.

3. Results

Murmansk is a densely built-up city, supplied with central heating. This has a positive impact on the environment, as the so-called small emissions do not represent a large share of air pollution. However, this is changing as, since the beginning of the 21st century, single-family housing estates have been built which are not always connected to the city's heating system. A serious shortcoming is also the fact that combined heat and power plants strongly affect air pollution due to outdated technology of operation [40,67,68]. The waste segregation system introduced in 2017 failed due to the low environmental awareness of the inhabitants. Some examples of innovation were the screens erected to hide loading and unloading processes from view, reduce noise, and catch the coal dust in the vicinity of the port in the city centre [53]. There is also hope for the construction of a large port "Lavna" on the opposite side of the Gulf. In 2016, dust samples were taken in the summer from plants of broad-leaved plantain (*Plantago major* L.) in the city centre and facade samples from houses located in Murmansk. The results of this research were published in the form of an article [69] and a monograph [70]. For illustrative purposes, the main conclusions of this research are cited below.

3.1. Render Surface Analysis

Murmansk's oldest buildings date back to the mid-20th century due to significant war damage; they were rebuilt after the end of World War II in a neoclassical style modelled after St. Petersburg [8,10]. The surrounding newer buildings mainly represent the grand slab style. Micro-area studies indicate that the greatest diversity of contaminants is shown through samples 20, 28, 25, and 29 from Lenina Prospekt, Murmansk Iskustva University, Polarnye Zori 10 Street, and Pietrovskoy 12/Profsojuzov intersection, respectively. Relatively a lot of contamination was also found in samples 21, 22, 34, and 35 from 65 Lenina Street, the vicinity of the Drama Theatre (Lenina), and in the harbour area, respectively. The content of metals in the discussed samples represents quite a significant share of these elements, this especially concerns zinc and copper. Significant contamination with lead and nickel is visible, especially in some samples. Moreover, a relatively large share of chromium was found.

In the case of Zn content, relatively high contents were found in the area of Semyonovsky Lake, Cheluskincev, and Papanina Streets, for samples 01–05 and 13, and in the area of Vorovskogo Street (samples 27 and 28) where the concentration of this metal exceeds 920 ppm, while the lowest content of this metal within the limits below 50 ppm was found in sample 35 in the area of Nizhnierostinskoye Shosee Street. In the case of copper, its highest content was recorded in samples 02 and 34, reaching the level of 200 ppm in the area of Cheliskincev and Verkhnerostinskoe Shosee streets, and Lobova street, respectively. In other places, this content rarely exceeds 50 ppm, and for samples 11, 17, and 32 it reaches about 10 ppm. In the case of arsenic, the highest content was found mainly in sample 03 (over 17 ppm) in the area of Semyonovsky lake, (Figures 1 and 3), and the lowest content was found in sample 11. In the case of lead, by far the highest content was found in sample 33 (3158 ppm) in the area of Vodoprovodnyi per street (near the military base) and Cheluskintsev street, and relatively high content in samples 02, 04, 05, and 19 are within about 90 ppm in the area of Cheluskincev street. The lowest content of this metal was found in the area of Chumbarova Luchinskovo Street and Polarnye Zori, in samples 07–09, 17, and 18, and sample 31 below the detection limit of this element of 0.1 ppm. In the case of nickel, the highest concentrations of this element were found in the area of Pietrovskoi street and Cheluskintsev street near Semyonovsky lake, in samples 02, 28, and 31 where it reached values over 170 ppm, in other areas it is at the level of about 30 ppm. The lowest contents were found in the area of Kirov street in sample 11 (below 7 ppm). In the case of chromium, the highest content of this element was found in the area of the intersection of Radishcheva and Pavlova streets, in sample 15, Polarnye Zori (sample 27), and the traffic roundabout at the intersection of Chumbarova-Luchinskovo and Askoldovcev streets (sample 30), where it reached a value close to 110 ppm, while the lowest content was found in the examined samples 11, 13, 20, and 34, from the area of Kirova street, the intersection of Pavlova and Lenina streets, and Lobova, reaching a level below 10 ppm. In the case of cadmium, the highest content of this element was found in samples 06 and 18 reaching the value of over 60 ppm located in the area of Cheluskincev and Liebkniehta streets and Papanina, respectively. The lowest content of this metal is found in samples 07, 17, 23, and 35 in the area of Lenina Street. Their values did not exceed the threshold of quantification of this element, which is up to 0.01 ppm.

3.2. Plantago major L. Surface Dust Analysis

This plant (*Plantago major* L.) is characteristic of habitats associated with significant anthropogenic pressure. The plant typically grows in verges, parks, and green spaces with increased foot traffic. Analyses of the study area, as well as adjacent areas, indicate that it does not occur in the natural environment of the region and has been brought in/introduced by humans [43–47,71]. Studies in the ICP-MS of dust collected on the leaves of the common plantain collected in Murmansk showed the presence of metal oxides such as mercury, cobalt, cadmium, chrome, nickel, lead, and copper (Figure 4). Sulphides, sulphates of phosphorus compounds, and halides and soot were also found [68,72]. These results are detailed below.

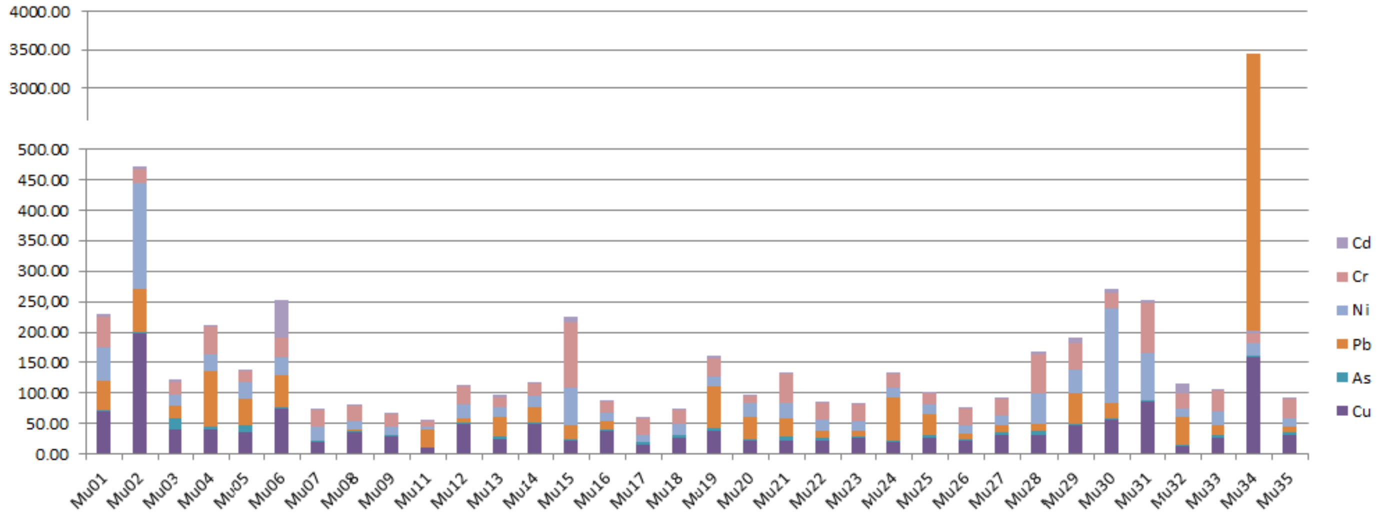

Figure 3. Contents of selected studied metals in analysed render samples based on ICP-OAS analysis (ppm).

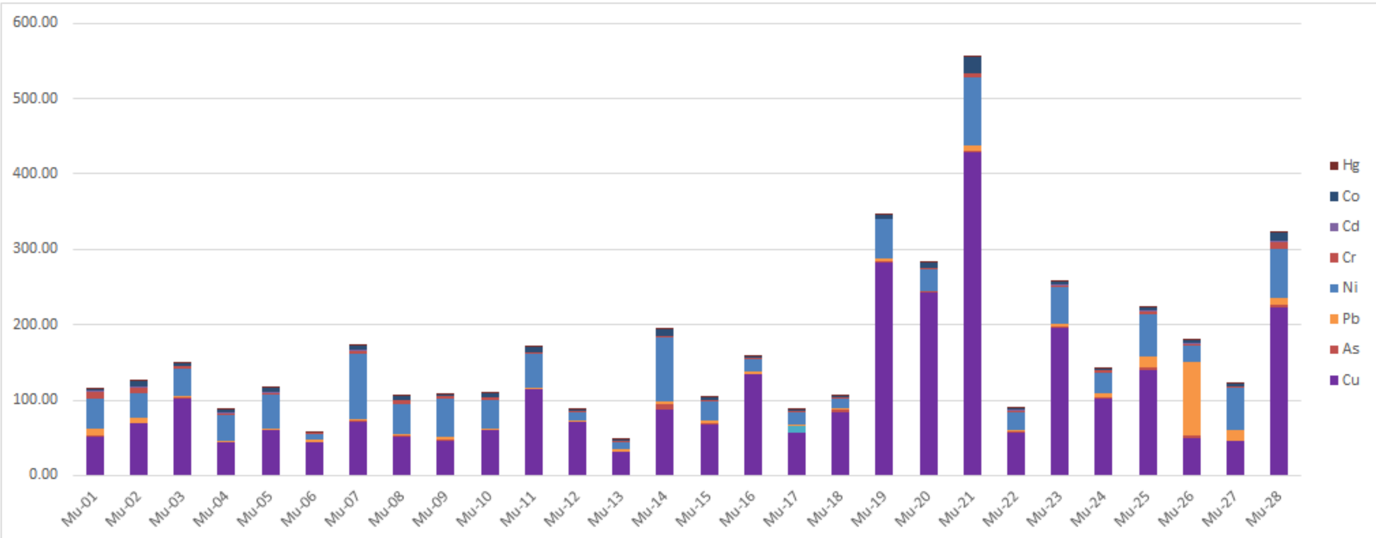

Figure 4. Schematic of dust chemical composition (selected metal) on *Plantago major* L. leaf surface by ICP-MS.

For total heavy metals (Cr, Co, Ni, Cu, Zn, As, Ag, Cd, Hg, and Pb), the highest contents were found in samples 21 Mu (1446 ppm), 19 Mu (1050 ppm), 28 Mu (836 ppm), 07 Mu (816 ppm), 25 Mu (815 ppm), as well as in samples 11 Mu (595 ppm), 02 Mu (592 ppm), and 23 Mu (507 ppm). The lowest values of these metals were found in samples 13 Mu (119 ppm) and 06 Mu (146 ppm), as well as 12 Mu (191 ppm), 27 Mu (2019 ppm), 24 Mu (234 ppm), and 01 Mu (246 ppm). In the remaining samples, the values are in the range 256–498 ppm (Figure 4). Among the heavy metals, the highest concentration is for lead (for contents varying in the range: 1.137–98.18 ppm). In the case of this metal, it should be noted that its high content is a sign of significant environmental pollution [73,74]. In the case of heavy metals, after the aforementioned lead, is the concentration is: Co-21, Cd-16, Ag-15, Cu-14, As-13, Zn-12, Ni-12, Cr-9, and Hg-7. Analysing the spatial distribution of the studied elements in plant samples, it can be concluded that in the case of heavy metals the highest concentrations of lead are found in the northern part of the city near the port, in the case of cobalt and cadmium in its southern part in the area of Lenina and Polarnye Zori streets. In the case of Arsenic, the highest content was found in the southwestern part of the city at 11 Papanina Street, and in the Chumbarova-Luchinskovo area. The distribution of mercury content is similar, while for nickel the highest content was found in the southern part of the city near Polarnye Zori Street and the intersection of Liebkniechta and Cheluskintsev Streets and in the northern part of the city in the Chumbarova-Luchinskovo area.

3.3. Summarising the State of Pollution within the City of Murmansk

Air pollution by solids associated with human activities is the cause of visible amounts of dirt and dust that are found on the surface of facades [45,49,75,76]. The city has heavy vehicular traffic and a large transshipment port which is a source of many pollutants [53,54,73,77–83]. In addition, some of the pollutants come from thermal power plants, which are involved in heating the city in winter. However, an analysis of the air in winter indicates that it is not as polluted as in other European cities [51,55–57,84–89]. This is probably due to the nature of the city's location in varied terrain, the presence of frequent winds, and the low emissions associated with the connection of houses to the central network that heats the city. As a result, the amount of these pollutants is high in the vicinity of busy roads and the port [60]. It is known that the content of heavy metals in plant tissues depends on many external factors (soil acidity, humus, oxygen content, and moisture content) and internal factors (life forms, physiological characteristics of species, and plant age) [63,90,91]. In particular, birch has been shown to intensively accumulate copper, spruce-zinc, manganese, and Siberian pine-lead [92,93]. In many respects, the content and mobility of heavy metals in the soil depends on the bedrock [94]. The significant content of lead is due to its high content in roadside soils. It is widely believed that road transport is the main source of lead in soil, as lead tetraethyl was previously used to increase the octane number of petroleum [95]. Currently, the use of this carcinogenic organometallic substance is significantly decreased, but lead accumulated in previous years is poorly mobile in soil and takes a long time to be washed away. Divalent heavy metal cations are actively absorbed by plants "by mistake" because they are equal in charge to calcium ions. Coal handling and the operation of coal-fired boiler plants contribute significantly to the replenishment of the soil pool of heavy metals [47]; this includes lanthanum, cadmium, lead, and many others. The significant content of lead, nickel, and many other metals in the plasterworks can also be partly explained by the long-term transport of compounds of these elements in the composition of aerosol pollution from metallurgical enterprises operating within the Monchegorsk and Pechenga regions [59,73,96,97]. The comparison of heavy metals in different parts of the city reveals the highest concentrations on streets adjacent to the port. In our opinion, the source of these compounds is coal dust, which spreads according to the wind speed and direction. In addition to the coal itself, it can contain arsenic, lead, and other dangerous pollutants. Metal oxides, which are processed in large quantities in the installation of metal structures, have a larger particle size, so they do not travel beyond the port limits [98].

4. Discussion

Murmansk is a densely built-up city. The predominant buildings are multi-storey apartment buildings and pre-cast concrete slab buildings (Figure 5B), with brick buildings in the city centre (Figure 5A). At the beginning of the 21st century, new single-family buildings could also be seen in the city; they are concentrated in the form of small housing estates mainly in the outskirts (Figure 5C). Multi-family housing in the city is based on the system of common heating through a hot water supply from the combined heat and power plant (Figure 1).

Figure 5. Housing types in the city centre (**A**), large-panel estates (**B**), and new single-family detached houses (**C**).

At present, these buildings have outdated heating technology based on burning masut. This causes pollutants to escape from chimneys, which are then dispersed around the city and its surroundings. Air quality research carried out by ecologists indicates that the main heavy metal pollutants are industrial plants, including facilities that burn products consisting of anthracite and oil [73]. It has also been shown that these pollutants influence the formation of CO_2 aerosols and subsequent acidification of soils and waters [68,72,73,99,100]. New single-family buildings being constructed are often not connected to the heating system, which in the future may lead to increased air pollution due to so-called "small emissions". Another problem facing the city of Murmansk is the port zone (Figure 6), where cargoes including coal are transshipped. Coal dust is another source of air pollution in the city [101]. Improvements to the natural environment, including the state of the air, should therefore be based on the reduction in emissions from the thermal power station and better protection of the city from dust originating from the port (in 2020, a screen was erected to protect the city from coal dust pollution within the city, and also on the other side of the Kola Gulf, a new port named "Lavna" is being built, which will eventually alleviate some environmental issues affecting the city).

Figure 6. Murmansk port zone with a visible yellow-green screen offering protection from coal dust.

Reduction in air pollution emissions from the city can be achieved by modernising the thermal power plants by installing filters on the chimneys and subsequently switching to less polluting technologies (e.g., natural gas). Reducing heat loss in multi-family apartment blocks is also an important factor. They are built by combining large concrete components pre-cast in factories, are without insulation, and some blocks have heating pipes embedded in the walls, causing substantial heat losses. The task of reducing energy emissions through buildings is a well-known problem around the world. According to Ding et al. [102], buildings currently account for 30% of energy consumption in cities. This coefficient in Murmansk is higher due to the nature and proliferation of the apartment blocks. Therefore, an important factor is the insulation of buildings, which by using a relatively inexpensive procedure can reduce energy losses by 30% [102,103]. When warm air is cooled by cold building elements, the water vapour it contains condenses, and dust and mould spores in the air settle much faster, damaging not only walls and ceilings but also putting people's health at risk [104,105]. An interesting idea for insulating a building is to put turf on the roof surfaces. More than 10,000 green roofs have been created in the Augustenborg city in Denmark, which absorbs rainwater and contributes to air purification by trapping pollutants [106]. Mobile and vertical greening of buildings can also have a positive impact on air quality. This approach, which is used around the world, can be applied in Murmansk by creating green mobile modules of northern grasses, shrubs, and rock mosses on the walls of some buildings. During the renovation of buildings, it is also worthwhile to adopt a policy of painting houses in bright colours, which has a positive impact on the environment during winter and on the well-being of residents. For new buildings, models known in Scandinavia can be used. In countries such as Sweden or Finland, passive houses are very popular. This is important not only because of the higher comfort of living in such houses, with lower expenses for heating, but also for ecology purposes. Passive houses have almost eight times lower energy demand than standard houses [107]. Such houses are built to recover energy that comes from nature, such as solar energy. They are built with windows exposed to the south so that as much natural light as possible reaches the interior of the house. On the north side, it is best not to install such windows at all, or small ones with double-glazed sealed units, because that is where energy losses are the greatest.

An important solution to the problem of heat production used in Scandinavia is the incineration of rubbish, which also provides energy while utilising waste (in Malmö [108], food waste, converted into biogas, is used by public transport). In Stockholm, waste incinerators generate 14–16% [109] of the electricity and heat demand. The entire southern area of Stockholm is heated by municipal and industrial waste, which is incinerated at the Högdalen incinerator. Each year, 500,000 tons of municipal waste and 250,000 tons of industrial waste produce 1700 GWh of heat and 450 GWh of electricity. There is a total of twenty-eight such plants in Sweden. They are equipped with flue gas and wastewater treatment technology and meet stringent environmental standards. In Sweden, the correct separation of waste at the source is as high as 45%. The waste generated is recycled. A wind power plant is also being built near Murmansk, which by providing energy from renewable energy sources (RESs) can help to reduce emissions of harmful pollutants. It is worth mentioning that the existing nuclear power plant on the Kola Peninsula has a surplus of energy production [verbal information, 2021]. These surpluses can also be redirected for city heating purposes. The practice of using solar panels to support wind turbines is also known in Scandinavian cities [110]. In 2020 the Polar Day phenomenon in Murmansk began on 20 May, and the sun did not set until 22 July. In turn, the Polar Night lasted from 2 December to 11 January [9,10,18,20]. This means that after the winter season, these cells can convert solar energy into electricity. In summer this process can be particularly efficient and can be used, for example, to power the installation of traffic lights, which in Murmansk are fitted with LED technology.

The comfort of the urban environment in general, and the cleanliness of the air in particular, largely depends on the condition of the city's green areas. Green areas in Murmansk are currently difficult to assess unambiguously: on the one hand, there are no parks in the traditional sense within the city limits, and the patches of green areas do not meet recognized standards. On the other hand, the city is surrounded by forests, which partially compensate for the lack of parks within the settlement. The problem of comfort in the urban environment is particularly acute in the summer: even a slight increase in the temperature in the city above 20–22 °C can be dangerous for people suffering from cardiovascular diseases, because, due to the high relative humidity in Murmansk, the mechanisms of natural thermoregulation in humans do not work. In other words, sweating in such conditions does not naturally cool the body because water cannot evaporate [19,111]. In warm weather, another problem arises: the ground surface within the city heats up much faster than the air in the suburban forests and on the opposite side of the Kola Bay, so cooler air currents enter the city from the outskirts, and an increase in wind speed and force raises dust [101,112]. The city's underdeveloped urban architecture cannot cope with the streams of road dust amplified by coal dust. The redevelopment of the green zone of the city is not carried out properly: a lot of attention is paid to creating modern footpaths, installing benches, small patches of green recreational spaces, and artistic objects, which do not have a positive impact on the atmosphere within the city. Many green areas in the settlement zones are arranged by residents through their own private initiatives (Figure 7). However, this is not enough for a city the size of Murmansk.

Figure 7. An example of a green space in a residential area carried out by private initiative.

The replacement of old trees with new ones, as well as optimisation of tree and shrub planting, is not carried out. When creating green areas in the last century, specialists were guided primarily by the resistance of plants and ornamental values in the sub-Arctic city. There was an opinion that coniferous trees are extremely sensitive to polluted city air, so their use in Murmansk's landscape architecture was inexpedient. The result of these mistaken actions was the almost complete absence of conifers in the Murmansk landscape, except for a few dozen larches. It is now known that most conifers tolerate urban conditions well, even in northern Polar regions, and these trees are only sensitive to high concentrations of acid gases such as Sulphur Dioxide [68,72]. Car exhaust and boiler emissions are not an obstacle to the use of these valuable plants in landscaping within Murmansk. In recent years, coniferous trees such as western cattail, mountain pine, varieties of common or prickly juniper, and European spruce have been increasingly used in greening projects [93,104]. In particular, a small square near the new Puppet Theatre building has been adorned with conifers. Another problem of the Polar cities is the almost complete impossibility of establishing full-fledged verges alongside the highways because, with very long winters and heavy snowfalls, the perennial grasses are badly damaged and have no time to regenerate during the short northern summer. The grass-covered soil surface becomes an additional source of dust during dry weather.

Another step to reduce air pollution in the city is to restrict private vehicle travel through the historic centre. The Five Corners Central Square redevelopment project involves widening the pedestrian zone at the expense of the roadway. Undoubtedly, this approach meets with great resistance from car owners, but the need for such measures, successfully operating in many cities of the European Union, is beyond doubt. Integration of different types of transport is also an important factor. A railway line running parallel to the roads may significantly reduce the load and speed up urban transport by using railbuses connecting northern and southern districts, which would take about 20 min to cross the city in exchange for nearly an hour of travel on public roads. Such solutions have been established in many European cities, where the so-called transport hubs are created with the possibility of access from other parts of the district. An effective incentive to switch to public transport is to speed up its travel time (building separate lanes for existing trolleybus lines in Murmansk) and to organise 'car-free days' and actions to promote public transport by allowing drivers to travel at discounted rates or for free [42].

The renovation of existing green areas in the city can contribute to improving air quality. These measures should include the replacement of low-value tree and shrub species (cherry birch and various species of willow hybrids) with more valuable species capable of producing phytoncides, good dust retention, air ionization, reducing the velocity of air currents, and enhancing wastelands and areas not suitable for sewerage [93]. The lack of large open spaces in the city can be compensated by planting trees and shrubs on various unmanaged surfaces such as the numerous slopes scattered around the city, with different genesis and significant total area. It is not possible to create full-fledged parks and squares on them, but locating them on the slopes of the banks, impeding the breezes blowing from Kola Bay, would significantly reduce wind speed, the concentration of dust particles in the air, and saturate them with phytoncides. In addition, the use of gravel chippings instead of sand for road gritting during the winter is intended to control ice and reduce dust in the spring. This technique was applied for the first time in Murmansk in winter 2021 [own observations].

Developing a network of cycle paths to reduce private car traffic is a difficult task. There are particular difficulties with this approach in Murmansk because of the varied terrain (numerous hills with relative heights of up to 300 m a.s.l.). Even if designated lanes are available, only a small number of physically fit citizens are able to cycle to work. Nevertheless, bike lanes (especially in the southern and central parts of the city) would allow a significant number of citizens to use a bicycle as a serious alternative to motorised transport. In addition, there are well-known solutions of so-called bicycle elevators which permit bikes to go uphill (example of Trondheim in Norway, Figure 8B). In the city of Rovaniemi, Finland, located within the Arctic Circle, bicycle paths on the outskirts of the city are used in winter for travelling by snowmobile [author's observations]. Many cities also use a rental network of electric scooters, which help people to move around the city while having zero-emissions. For the above indications to be effectively implemented, parallel legislative and educational activities must also be carried out [4,107,112–114].

Figure 8. Example of a cycle path in the centre of Murmansk (**A**) and a bicycle lift in Trondheim (**B**) Author: HuBar [113].

5. Conclusions

Due to its location beyond the Arctic Circle, the city of Murmansk has great potential [3,5,42]. The varied relief relatively influences the city's landscape and its interesting appearance, although, on the other hand, it contributes to the city's narrow development belt and strong meridional extension. Currently, the air quality in the city is poor due to the city's outdated heating technology, vehicular transport, and the port area (also settling on the surface of renders and plants). However, this can be significantly improved by introducing techniques for the modernisation and thermal insulation of existing houses, burning of waste, diversification of energy generation including the use of RES, etc. In addition, air quality will be improved by introducing urban greenery, increasing conifer planting in the city, encouraging residents to use public transport, and building a network of cycle paths. These solutions are widely recognised and undertaken in many European cities, including those in Scandinavia where similar climatic conditions prevail.

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