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AGROCENOSES AIR IMPROVEMENT FOR LONGER A ND HEALTHIER PEOPLE LIFE

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Abstract. In 2019, 99% of people in the world lived in areas violating WHO's recommended air quality indicators. By WHO's estimation, in 2019, air pollution caused 4.2 million premature deaths worldwide. The most harmful are PM2.5 particles, which penetrate the blood through the aerogematic barrier causing cardiovascular and respiratory diseases and cancer. PM10 can pass deeply into the lungs, but they are not so harmful. People always believed that rural air is healthy. Research at the University of Minnesota showed that 18 000 Americans die every year due to air pollution by agriculture, primarily, ammonia (NH_3) from the decomposition of fertilizers and livestock waste (12.4 thousand deaths), and PM2.5 particles (4.8 thousand deaths). In polluted areas, plants have more aggressive allergenic pollen. Agricultural waste management and optimization of landscapes are effective ways of solving the problem. In this work, solutions are proposed to improve the air safety of agrocenoses. Minimization of contact of waste with air and its utilisation as soon as possible allows for avoiding decomposition. Converting to gasification boilers/ovens avoids releasing PM2.5 by heating. In addition, plants capable of purifying the air from relevant pollutants should be introduced in agrocenoses. The places for planting are forest protection strips, free places near roads, residential and administrative buildings, etc. In particular, the use of hedges with such plants can provide a local oasis of clean air around houses. In the case of dense land use and lack of free space, it is possible to introduce "green structures" on buildings. An assortment of plants for different regions of Ukraine is offered.

Keywords: air quality; air pollution; agrocenoses; PM2.5; agricultural waste; plant air purifying.

Introduction

In 2019 99% of people in the world lived in areas violating WHO's recommended air quality indicators [1]. In the same year, air pollution caused 4.2 million premature deaths worldwide [1]. The most harmful are PM2.5 particles. They can pass lungs deeply causing alveolar wall irritation, corrosion and breathing malfunction [2]. PM2.5 penetrate the blood through the alveolar-capillary barrier [3] causing cardiovascular and respiratory diseases and cancer. Moreover, today, we know about the destruction of the inner blood-retinal barrier [4], epithelial barrier in human nasal epithelial cells [5] and skin barrier [6]. PM10 also can penetrate deeply into the lungs and cause health problems [7], but they are not so harmful. Research at the University of Minnesota [8] showed that 17 900 Americans die every year due to air pollution by agriculture, primarily, ammonia (NH_3) from the decomposition of fertilizers and livestock waste (17.9 thousand deaths), and PM2.5 particles (4.8 thousand deaths). In polluted areas, plants have more aggressive allergenic pollen [9]. Agricultural waste management and optimization of landscapes are effective ways of solving the problem. In Ukraine, new laws and regulation system related to waste management is now being developed. It should take into account the current state of waste treatment, the best world practice and national peculiarities. The recommendations for increasing the rural air quality is the goal of the work.

Materials and methods

We should find possibilities to improve the air safety of agrocenoses. It requires changing the biowaste management and heating to minimise air pollution. It is necessary to observe the current state of waste handling, which is systematically performed for the first time. Rural heating should be analysed. It is necessary to quantitatively estimate the effectiveness of gravitational waste gas motivation, which is a new result allowing to choose a more effective and environment-friendly solution between deep heat recovery with mechanical motivation and releasing hot waste gases without a fan. After that, it is necessary to recommend improvements. The other solution is to use the most natural way of air cleaning – plants that can precipitate particles and absorb pollutant gases.

Results and discussion

1. Biowaste management

Today in Ukraine, there are no special rules for biowaste treatment. Upon entry into force of the Law of Ukraine "On Waste Management" on 09.07.2023, biowaste treatment will be regulated. Biowaste is defined as "waste that has the property of undergoing anaerobic or aerobic decomposition, such as food waste or food industry waste at all stages of production and consumption, waste from green spaces". Biowaste producers will be able to independently process the waste on homestead, country and garden plots through composting following the rules established by the central executive authority. The law provides for a reduction in biodegradable waste disposal, which fully meets the requirements of EU Council Directive No. 1999/31/EC of 26 April 1999 "On the disposal of waste" as amended by the Regulation (EC) 1882/2003. The authors' observations show, that the biowaste of plant care in urban green areas or rural agriculture is usually primarily accumulated near production (Fig. 1). It is right because it avoids additional transportation for each piece. In Poland, waste management, including biodegradable waste, is regulated by the Act of 14 December 2012 on waste (consolidated text, Journal of Laws 2022.699).

a  b 

Fig. 1. **Examples of waste near to generation:** a – a felled tree; b – fallen leaves

But if the waste will not be utilised as soon as possible, it will be a culture medium for different microbes, fungi and moulds. The last ones produce carcinogenic, teratogenic, immunotoxic mycotoxins such as ochratoxin A [10], aflatoxins [10], deoxynivalenol [11], fumonisin [12]. In natural conditions, such mediums are distributed, which cause low concentration of pathogens. In the garbage, the concentration can be very high causing pollution of air, soil etc. Some fungi give spores of size 1-2 μm. This pollutes the air with PM2.5, which can pass to the lungs and blood causing mycoses. Some other fungi give PM10, which also can produce lung mycoses. The products of garbage decomposition pollute the air with PM10 and PM2.5, and also the ground. In addition, this process depreciates waste as a secondary resource. By the authors' observations at the end of 2022 (Fig. 2), some irresponsive people in rural regions or urban private sectors move the waste near household trash cans or trash can areas, or in other places.

Thus, to avoid secondary pollution we should utilise the waste as soon as possible minimising contact with open air and ground. It is possible to use garbage removal by special institutions, especially in the urban territory, but in rural lands, other methods can be applied locally to avoid additional transport emissions. The directives above recommend composting as the most common promising technology. We can compost leaves, pruning, garden waste and separately picked food waste. We should avoid mixing waste with other waste types.

The range of composting technologies is extremely wide, covering simple, open methods (side composting in the open air, in open rolls (sides), which are regularly mixed using special equipment) and closed systems with technical complexity and precise control, where various parameters are regulated, such as temperature, humidity and oxygen supply (tunnel composting). The simplest method is the use of individual composters in private plots of individual buildings in the city (private sector houses). Composting produces commercial compost, reduces the waste amount for damp disposal and makes the waste less dangerous. To obtain quality compost, the material should correspond to the following criteria: no components releasing pollutants; the material structure should provide good aeration; relation of carbon to nitrogen (20÷40):1 at proper humidity; optimal humidity 50÷60%.

More nitrogen is prohibited because it will be converted to ammonia by bacteria. At pH > 7, ammonia will pollute the atmosphere. For killing pathogens and weed seeds, the composting material

should be treated at a temperature not less than 55 °C for two weeks continuously or 65 °C (in closed equipment – 60 °C) for one week. Technology water should be properly treated before disposal.

a) b)

c) d)

Fig. 2. **Unauthorised damps:** a – near trash cans; b – near a trash can area; c – in a private houses area; d – at a street

The simplest centralised composting method with minimum investments is an open clamp. Recommended parameters are 2.5÷3 m of height, 10÷50 m of length, 3÷4 m of width at the bottom, 30÷200 m^2 of the bottom area, 2÷3 m of the top width, 65÷525 m^3 of volume. The composting time is 2.5÷7 weeks. In Ukraine, the demand for commercial compost is too low, so the method is not widely used. In utilities, it is introduced in Lviv by the "Zelene misto" company. Commercial waste from markets is composted by "Pasternak Bio" company in Lutsk. But compost can be used by the standard SOU ZhKG 10.09-014:2010 as a fertiliser in the rural economy, forest state and green constructions, for land reclamation, as well as fuel after briquetting with drying up to 3÷8% of humidity and pressing. Compost of falling leaves should be used in greening and land reclamation. Thus, the centralised composting areas should be placed at the corresponding institutions.

The market price of 620 UAH·t^{-1} (approx. 17 USD·t^{-1}) belongs to the first compost group by the standard above – for use as fertilisers (or for making compost) in doses adequate to standard fertilisers. The second (for use in a dose of 4÷5 t·hm^{-2} per year by dry matter or no more than 15 t·hm^{-2} once every 3 years) and the third (for use in a dose of 5÷6 t·hm^{-2} by dry matter once every 5 years with mandatory control of the background content of elements) groups have no market price.

There are other technologies of waste treatment, which can give more value. Trunks and some other parts are predominantly used as firewood. It is inadmissible because it should be used more effectively. The centralised collection allows producing contemporary and the driest fuel – brackets, granules, pellets etc. Also, it can be products of deep wood processing – construction materials [12] and structures and other consumer products. Trunk parts of felled trees, not damaged by mushrooms or fungi, after drying can be used for crafts, which can decorate rooms or give additional earnings. Simple tables or seats are the traditional applications, which can decorate interiors or exteriors. The most polluting disposal is incineration in the open air. It is a very old tradition that arose when there was no industrialisation and a stable climate. Thus, air pollution was admissible. Now it will overlap with other pollutions causing serious influence. As we observe over the last few years, climate changes cause easier ignition of surrounding plants. One small bonfire can ignite large wildfires with deadly effects and the strongest damage to constructions and the environment. Thus, the sanitary rules were accepted forbidding incineration of waste outside special equipment, and owners are personally responsible for burning. In martial law, incineration can be treated as sabotage.

Special care should be applied to livestock waste. Some cases of storing and fertilising by it without composting were observed. This causes double danger. If the waste decomposes in the open air, ammonia and other toxic substances will pollute the atmosphere. Bacteria, spores and eggs of microflora and helminths are released with the waste. As it is observed, one small plot treated by non-composted waste can infect a large area. Pathogens are moved on the paws of animals or birds. Some berries such as raspberry or strawberry in these conditions require careful heat treatment losing nutrients. The only possibility to avoid them is propaganda and tough sanctions.

2. Firewood heating

One of the most powerful sources of PM2.5 and harmful gases in rural territories is decentralized firewood heating. Firewood can be assumed as solar energy storage as the biomass is produced by photosynthesis sequestrating carbon dioxide, which will be returned during burning. If the ash will be used for fertilisation or construction materials [13-14], we can organise closed energy and substance loops. This is only if we will avoid atmospheric pollution. There are two reasons of the pollution – smoke-generative burning and not enough energy efficiency. Traditional solid fuel burning causes releasing of very fine particles of evaporated and condensed incombustible components. Individual chimneys on separately standing buildings are not so high – not less than 0.5 m above the roof [15] in any case, not exceeding 1 m of the maximum roof height by observations. The smoke cannot dissipate enough, so it pollutes the outdoor air at the breathing level. Also, traditional boilers are usually regulated by lowering the air supply. This causes a decrease in the efficiency of burning with more carbon monoxide generation. To avoid this, heat storage should be used to run the boiler at optimal burning conditions and supply the heat later. For houses with high thermal inertia and good insulation, periodical heating can also be used.

High chimneys are not good for individual houses. They spoil the exterior and do not suppress the total environmental pollution. We should use smokeless burning. Gasification is not good, especially during the Russian war, because it violates energy independency and breaks the loop of carbon dioxide sequestration and release except for enough availability of local biogas. A better idea is solid fuel gasification in ovens or boilers. This process almost avoids releasing particles as gas burning is near to complete. The best way is using condensing boilers [16], but due to very low additional effectiveness for dry solid fuel (only 2...3%) and very high price because of using corrosion-resistant materials, this solution is now a prerogative of rich and environment-responsible people. In [16], we propose the modernisation of non-condensing boilers using a specially designed external polyethene condensing economiser. Sometimes, some irresponsible people burn inappropriate waste (plastic, rubber, etc.) polluting the atmosphere. It should be strictly prohibited with the toughest sanctions.

The most significant problems introducing gasification boilers are high prices, the strict requirement of dry fuel and dependency on electricity for smoke exhauster. The first problem sometimes requires an initial subsidy, which will return by fuel economy. The second problem significantly increases air pollution even for traditional burning due to lowering the burning efficiency. Thus, wet fuel should be avoided in any case. The third one corresponds to very low efficiency using gravitational motivation [17] causing high heat losses with disposal gases. Let us use the same approach to test the effectiveness of using gravitation with acceleration g, $m \cdot s^{-2}$. If the gases with the temperature T_ℓ, K, and density $\rho_\ell = 353/T_\ell$, $kg \cdot m^{-3}$, go through a chimney of height H, m, above air intake to the atmosphere with temperature T_{ext}, K, and density $\rho_{ext} = 353/T_{\ell ext}$, $kg \cdot m^{-3}$, the gravitational pressure is $\Delta p_{gr} = (\rho_{ext} - \rho_\ell) \cdot g \cdot H = 353 \cdot g \cdot H \cdot (T_{ext}^{-1} - T_\ell^{-1})$, Pa or $J \cdot m^{-3}$. This pressure is fully used to overcome the chimney pressure losses and to dissipate the gases. Thus, it is usable energy per waste gas volume. The gases with isobaric specific heat c_p, $J \cdot kg^{-1} \cdot K^{-1}$ have sensible heat over the atmosphere $Q = c_p \rho_\ell (T_\ell - T_{ext}) = 353\ c_p (T_\ell - T_{ext})/T_\ell$, $J \cdot m^{-3}$. Let us assume that the gas is dry, which underestimates the heat per latent one. Thus, Q is the full energy per volume. The effectiveness formula (1) is analogical to [17] (less than or equal sign shows possible underestimation excluding latent heat):

$$\eta_{gr} \leq g \cdot H/(c_p \cdot T_{ext}). \quad (1)$$

The effectiveness by equation (1) is very-very low (Fig. 3) – at least three orders of magnitude smaller than the efficiency of steam locomotives, which are obsolete one century ago. Thus, we should get energy from waste gases as much as possible and use mechanical motivation.

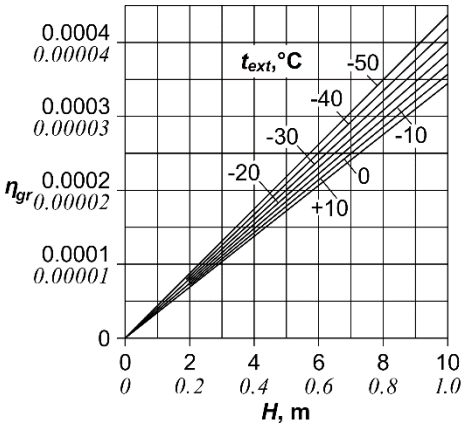

Fig. 3. **Maximum effectiveness of gravitational waste gas motivation** ([17], rescaled for individual and small boiler houses)

3. Dust and gaseous pollutant suppression

The measures above can decrease PM10 and PM2.5 release, but not avoid it. The agricultural processes release particles themselves. Also, transportation and walking by dirt roads and paths kick up the dust of different fractions. In Ukraine, the most of the country's roads are covered by asphalt, which decreases dust generation. But it is usually impossible to asphalt all possible paths. In addition, fertilisers and livestock produce toxic gases such as ammonia.

The only way to suppress outdoor dust and gases is phytofiltration. As afforestation was the most important factor of ancient rural development [18], forests performed this function in ancient times. Today, often ground parts unused for agriculture, passage or decoration are left intact. Walking by a road, we can see directly fields or pastures, vegetable gardens etc. This means no protective measures around the road. It is necessary to plant trees and shrubs, which precipitate dust and absorb gases. On highways, there are few traffic lights and relatively high speeds allowed. This causes the high efficiency of engines and low traffic fumes. But if we grow shrubs around a road, they will absorb the fumes and make the environment and agriculture the safest and cleanest. For example, the authors observed how junipers and coniferous around a building in Warsaw make the adjoining territory smokeless during traffic jams.

We propose to grow the air-cleaning plants on all unused parts of the territory – around the roads, between fields/gardens/vegetable gardens etc. It is better to avoid fruit plants. Fruits from trees near roads absorb harmful substances and become dangerous to nutrition. Overripe crushed fruits rot, which leads to additional waste, insects, fungi/mould and microbial contamination, discomfort for pedestrians and vehicles (especially bicycles, bikes and small personal electric cars), spoils the aesthetic appearance of the territory. For landscaping, we offer fast-growing decorative phytoncide shrubs *Berberis*, *Cotoneaster lucidus*, *Cornus alba*, *Ligustrum vulgare*, *Physocarpus opulifolius*, *Philadelphus coronaries*, *Spiraea*, different shrub forms of *Cupressáceae* incl. *Juníperus*.

If possible, hedges should be preferred instead of construction fences. If hedges are not possible, most fences can be easily vertically greened by creepers (*Parthenocíssus*, *Hédera*, *Clematis*, *etc*.). Analogical vertical (on façades) and vertical-horizontal (covering walls and roof) greening can give, in addition, passive air-conditioning and thermal insulation. And for very intensive usage of the ground without empty places, we can use green roofs and terraces on buildings, which also provide thermotechnical and solar radiation improvements [18-20].

Conclusions

1. The rural environment is not enough safe and healthy, causing 17,9 thousand premature deaths in the USA. The most harmful pollutants are PM2.5, PM10, ammonia and other gaseous products. Using open fire causes dangerous wildfires.
2. To make the rural environment safer and healthier, the first principle is to treat biowaste as soon as possible minimising uncontrolled contact with the open air. The authors' observations show cases of unauthorised damps, which cause air pollution by microbes, fungi and moulds, especially,

carcinogenic mycotoxins. For leaves, food waste and livestock waste we should use composting. For hard parts, making fuel briquets, granules, pellets, making crafts, simple tables, sits etc. are very good actions, which can be performed at the place.

3. Burning the garbage outside special equipment is now strictly prohibited. To decrease PM2.5 and toxic gases, smokeless gasification burning should be used in ovens and boilers.
4. For maximum effectiveness, we can cool waste gases as deep as possible and use smoke exhausters. For dry solid fuel, condensing gives only 2...3% of energy. In this case, the authors' cheap polyethylene economiser is recommended. It is more effective compared to using gravitational motivation. The calculation shows max. 0.04% effectiveness, which is at least three orders of magnitude less than the efficiency of steam locomotives, which a century ago stay obsolete.
5. Finally, phytofiltration should be used by growing the corresponding trees and shrubs, using hedges and vertically or vertically-horizontally greened buildings. The plant assortment is proposed – Berberis, Cotoneaster lucidus, Cornus alba, Ligustrum vulgare, Physocarpus opulifolius, Philadelphus coronaries, Spiraea, different shrub forms of Cupressáceae incl. Juníperus. For regions with very intensive ground usage without empty spaces we can use green roofs and terraces.

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Author contributions

Conceptualization, T.T. and I.S.; methodology, T.T., V.M. and I.S.; formal analysis, V.M. and I. S.; investigation, I.S. and A.U., writing – original draft preparation, V.M. and I.S.; writing – review and editing, T.T. and A.U.; project administration, T.T.; funding acquisition, T.T. All authors have read and agreed to the published version of the manuscript.

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