– державна підтримка громадам у вигляді спеціальної програми з очищення води малих річок, та доведення води в них до питної якості;

– системна робота Держави по масовій екологічній освіті громадян в області збереження найціннішого ресурсу Планети Земля – питної води.

## PROMOTING SAFE AGRICULTURAL PRODUCTION: SELECTION OF BIODEGRADABLE WASTE RECYCLING TECHNOLOGIES IN THE POSTWAR PERIOD

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Military operations put significant pressure on the soil and environment and have a regional impact. In addition, new challenges are emerging due to the use of new types of weapons and the intensity of the war currently taking place in Ukraine. Understanding the mechanisms of soil health changes due to these operations is crucial, followed by identifying suitable areas for agricultural use, requiring soil health restoration and maintenance measures.

Recycled Nutrient Fertiliser (RNF) holds substantial potential in addressing soil degradation linked to military activities. In particular, it has been found that hostilities cause different levels of physical (vibration, radioactive, thermal radiation), chemical (pollution with heavy metals, organophosphates), mechanical (deformation of the soil cover due to compaction or formation of large pores) and biological (death of beneficial microflora, development of facultative saprophytes that can be phytopathogenic, reduction of soil enzyme activity) changes in soils (Голубцов et al., 2023). However, choosing the right biodegradable waste recycling technology is pivotal for effective soil restoration and agricultural productivity post-war.

Presently, the most researched biodegradable waste (BDW) recycling technologies for RNF production include aerobic and anaerobic digestion, pyrolysis, and hydrothermal carbonisation. These technologies exhibit both positive and negative aspects, resulting in RNF products with varying chemical, biological, and physical characteristics, thereby influencing soil processes differently.

The predominant approach to BDW treatment in Ukraine is composting (aerobic digestion). It's the enzymatic breakdown of organic matter, usually containing various polymeric organic compounds (lignin and cellulose), into soluble organic carbon and sugar by microorganisms with access to oxygen (Manyapu et al., 2022). Compost might be the best alternative for soils with minimal content contamination, some structural disturbance and soil organic matter (SOM) loss, e.g. due to burning. The available nutrients and organic matter in the compost improve soil properties, enrich the SOM content and stimulate microbial activity. However, employing simple composting methods, for example open windrows or piles lacking proper design considerations, can exacerbate issues by causing nutrient losses that contaminate the atmosphere and groundwater. In regions impacted by hostilities, this will intensify ecosystem pressures. Therefore, the use of modern composting approaches is highly important. For example, the use of tunnel composting for segregated BDW or the use of rotating drum reactors can minimise greenhouse gas emissions and accelerate the elimination of pathogens, which is typically achieved within 2 weeks and 1-3 days, respectively (Michel et al., 2022). The produced solid can be stabilized using an aerated static pile or controlled windrows to produce a high-quality fertiliser and reduce the environmental impact of composting.

Anaerobic digestion of BDW is a process that uses anaerobic bacteria to break down waste in a low-oxygen condition to produce biogas (methane and carbon dioxide) and digestate (Yan and Salman, 2023). It's while more costly to implement, reduces organic matter loss and generates biogas, advantageous post-war. The process duration varies (10-40 days) based on raw material type and digester design. Digestate, unlike compost, typically contains higher moisture levels, which can be managed through pretreatment methods. For instance, screw press and centrifuge separation can effectively separate the solid fraction rich in phosphorus from the liquid fraction containing nitrogen (Pantelopoulos and Aronsson, 2021). This approach allows for better BDW management and nutrient redistribution, ensuring their efficient utilization while minimizing environmental impact. However, the use of digestate requires careful research due to potential phytotoxicity and incomplete stabilisation, which can exacerbate existing issues. Implementing post-treatment techniques such as composting, thermal drying, gasification, hydrothermal carbonization, pyrolysis, membrane filtration, struvite precipitation, ammonia stripping (Kovačić et al., 2022) enables the full utilisation of digestion benefits, enhancing soil ecosystem functions.

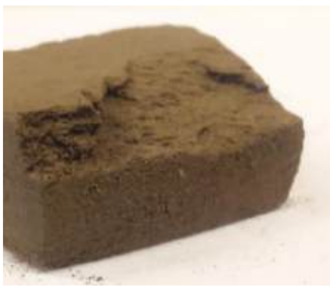
Pyrolysis is a complex thermal process that occurs at temperatures between 400 and 800 °C without oxygen and produces gas, oil and biochar as by-products (Sharma et al., 2023). It is a crucial tool for soil remediation post-war due to its ability to immobilize wide various soil contaminants. Biochar has a positive impact on the rhizosphere ecology, changes the distribution of pores in the soil and contributes to natural processes due to its higher stability compared to other sources of organic matter such as manure or compost (Anand et al., 2022; Jaafar et al., 2015).

Different types of BDW and pyrolysis temperatures can change the characteristics of biochar, affecting its use as a fertiliser (Anand et al., 2022; Lu et al., 2023). For instance, utilizing manure at lower temperatures (up to 300°C) yields biochar rich in nutrients, carbon, and higher cation exchange capacity. Such biochar benefits crop nutrition, restores soil fertility, especially when combined with phytoremediation using energy crops or grass-legume cultivation, leading to faster soil recovery and reduced environmental impact (Garau et al., 2024; Pinna et al., 2024). In heavily contaminated or structurally disturbed soils, biochar made from cellulose-rich feedstocks (e.g. paper and wood waste) at temperatures above 400°C may be preferable. This biochar has a higher specific surface area and aromatic content, which improves moisture holding capacity, pollutant absorption, and reducing nutrient losses. Its higher CN ratio also supports humification processes (Huang et al., 2023). Further detailed research is necessary to explore biochar's potential in addressing specific post-war soil challenges effectively.

**Compost**

**Digestate**

**Biochar**



**Hydrochar**

Hydrothermal carbonisation of diverse biomass wastes is performed in a closed reactor at a temperature range of 180–280 °C under pressure for 5 to 240 min and produced coal-like product called hydrochar and also produces aqueous (rich in nutrients) and gas phases (mainly $CO_2$) as byproducts (Yoganandham et al., 2020). Hydrochar is distinguished by its high carbon content, stability, and specific surface area. Similar to biochar, hydrochar holds substantial potential post-war due to its impact on chemical and biological nutrient cycles and soil physical attributes. Notably, hydrochar exhibits enhanced heavy metal and pollutant immobilization (Mahmood Al-Nuaimy et al., 2024; Wang et al., 2018). However, the technology, on the one hand, allows the use of raw materials with a wide range of moisture content, and on the other hand, requires more careful control of the technological process.

**Rotating drum reactors**

**Tunnel composting system**

The successful choice of recycling technologies for restoring conflict-affected areas depends on several important factors. First, the quantity and quality of the BDW, including the composition of nutrients and contaminants, must be assessed. Additionally, economic viability plays a key role, requiring consideration of infrastructure costs, geographical factors, human resource availability and fundraising potential. Furthermore, evaluating the environmental impact of the technology is crucial, ensuring alignment with environmental principles and the ability to alleviate ecosystem pressures.

**Close windrows**

Moreover, soil health state should be taken into account, paying attention to the particularities of degradation processes. Finally, selecting a technology that can be easily integrated with broader restoration and socio-economic development goals is of central importance. This holistic and integrated approach ensures the selection of sustainable recycling technologies that not only restore environmental balance but also promote socio-economic growth, ultimately reducing ecosystem pressures and enhancing the overall well-being of affected regions.

## ПРОБЛЕМИ, ПЕРСПЕКТИВИ ТА ЗАБЕЗПЕЧЕННЯ СТАЛОГО РОЗВИТКУ ПТАХІВНИЦТВА

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Птахівництво є світовим лідером серед підгалузей тваринництва за темпами нарощування виробництва (м’ясо різних видів птиці та харчове яйце). Більше того, завдяки технологічності та наукоємності, птахівництво, як галузь є унікальною, оскільки здатна