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CLASSIFICATION AND DESCRIPTION OF THE MOST WELL-KNOWN ENVIRONMENTAL APPROACHES USED FOR THE MAINTENANCE AND IMPROVEMENT OF FOREST MANAGEMENT

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ABSTRACT. The importance of forests in our society is extremely significant, with multiple benefits for both the environment and people. Considering the high importance of forests and the need for responsible and sustainable utilization, various approaches have been developed to promote sustainable forestry in different ways. This paper focuses on identifying, classifying, and analysing these approaches in Romania and at the European level.

Firstly, the legislative system, through its crucial role in establishing rules for different sectors, plays an important role in ensuring sustainable forestry. The entirety of laws that impact forests form the regulated tool of the state. On the other hand, organizations that benefit from goods and services provided by forests aim to assure customers that their activities do not have a negative impact on forests. Taking these factors into account, non-governmental organizations have developed different standards and policies to maintain and improve forest practices. These systems are not regulated by the state; rather, they are voluntary instruments. Their use depends on the willingness and interest of the forest owner or manager. Both types of instruments aim to improve forest practices and promote a sustainable approach to the utilization of forest resources.

Key words: *Responsible forest management, voluntary system, reglemented system.*

INTRODUCTION

The importance of forests in our society is extremely significant, with multiple benefits for both the environment and people. Human needs, such as agriculture, fire, and other wood uses, have altered the balance between agricultural and forest land. The first concerns regarding forest management emerged during the Roman Empire period (Duduman, 2019). By 1850, the general perception was that "the application of theoretical knowledge to control nature had been achieved. The application of knowledge is beneficial because the result was purely positive, people know what they want and what they have" (Wiersum, 1995).

The first regulatory instrument in the field of forestry is Forest Legislation. For example, in the case of Romania, the Forest Code was approved in 1881, stating that the protection of vulnerable forests can be done regardless of ownership type, as it influences the public interest (Duduman, 2019). With the introduction of Forest Legislation, the concept of "Forest Management Plan" also emerged, aiming to regulate the zonal functions of the forest. In Romania, this concept appeared as a result of the influence from the French school (Duduman, 2019).

At the beginning of the 20th century, with population growth and industrialization, concerns about forest quality became increasingly important, questioning the *status quo* (Joffe et al., 1990; McCormick and Mitchell, 1989; Shabecoff, 1993). For example, Shabecoff (1993), identified that the main enemy of the environment is man and the decisions made by him. McCormick and Mitchell (1989) identified that human rights are not fully respected in the United States.

Currently, we understand that the aforementioned aspects have great importance in sustainable management. The effects of this practice are best observed over time. The fact that we have a forest in 2020 reaching the age of 120 years is the first sign indicating that since 1900, that land area has been sustainably managed, considering all the challenges of that period. Considering the high importance of forests and the need for responsible and sustainable utilization, various approaches have been developed to promote sustainable forestry in different ways. This paper focuses on identifying, classifying, and analysing these approaches in Romania as well as in 10 European countries.

The methodology used is based on literature review, which involves conducting a comprehensive analysis of existing literature sources to gather relevant information and insights on environmental approaches used for the maintenance and improvement of forest management. The research is based on the following research questions: What are the main environmental approaches utilized for forest management?, How are these approaches classified and described in the literature?, What are the benefits and limitations associated with each approach?.

Literature review is used often to document and identify topics already covered by multiple researchers. It's practically a systematic search across various academic databases, journals, books, reports, and relevant online sources to identify relevant literature. Use appropriate keywords and search terms such as "environmental approaches for forest management" or "sustainable forest management practices".

TYPES OF CLASSIFICATIONS

Classification based on the method of implementing defined requirements

There are many approaches developed by different organizations. One classification was made by Bemelmans-Videc, which indicates the existence of approaches that impose constraints in case of non-compliance - the stick (Bemelmans-Videc et al., 2010; Zimmermann et al., 2018). On the other hand, there are approaches that offer a reward in case of implementing a measure - the carrot (Bemelmans-Videc et al., 2010; Zimmermann et al., 2018).

Classification based on the entity developing the requirements

Another type of classification is based on the entity developing the requirements. Considering this, we can distinguish between a regulated system and a voluntary one.

The regulated system encompasses all actions and regulations established by government institutions. These requirements often have a mandatory character. Non-compliance with these regulations may result in penalties and coercive measures (e.g., revocation of operating rights, sales bans). This type of instrument is characterized by the implementation of constraints - the stick (Bemelmans-Videc et al., 2010; Zimmermann et al., 2018) - to ensure that organizations comply with the requirements. Although by the 1980s, some countries had fairly effective regulated systems for environmental protection, each country has sought additional measures. With the establishment of the European Union, a unified approach has been pursued to ensure environmental protection. The core of the regulated system is represented by forest legislation, which establishes the minimum set of regulations (figure 1).

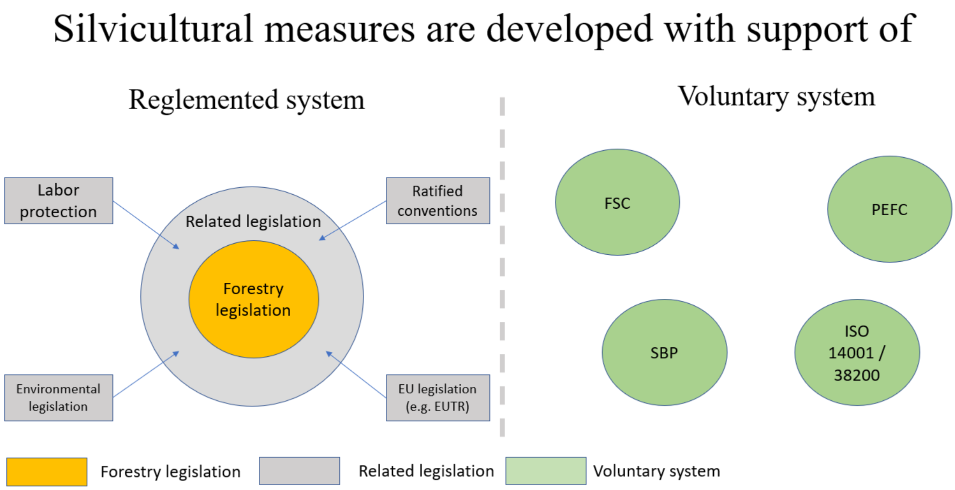

Fig. 1. *Systems used for the development of silvicultural measures based on the entity that develops the requirements*

The voluntary system is often developed by non-profit organizations that aim to establish a benchmark for making statements about an organization's level of involvement in sustainable development or responsible management (figure 1). This type of instrument is characterized by the implementation of incentives - the carrot (Bemelmans-Videc et al., 2010; Zimmermann et al., 2018), - to ensure adherence to principles and standards.

Classification based on the degree of regulation

Each country has implemented forest legislation with the purpose of regulating the functioning of the field and establishing specific rules. In this process, countries can regulate sustainable development, close-to-nature forestry, or responsible management at various levels. The level of regulation in each country takes into account the political history and the historical involvement of a country in environmental protection concerns. At the same time, each country can define and regulate terms such as illegal logging or deforestation in different ways.

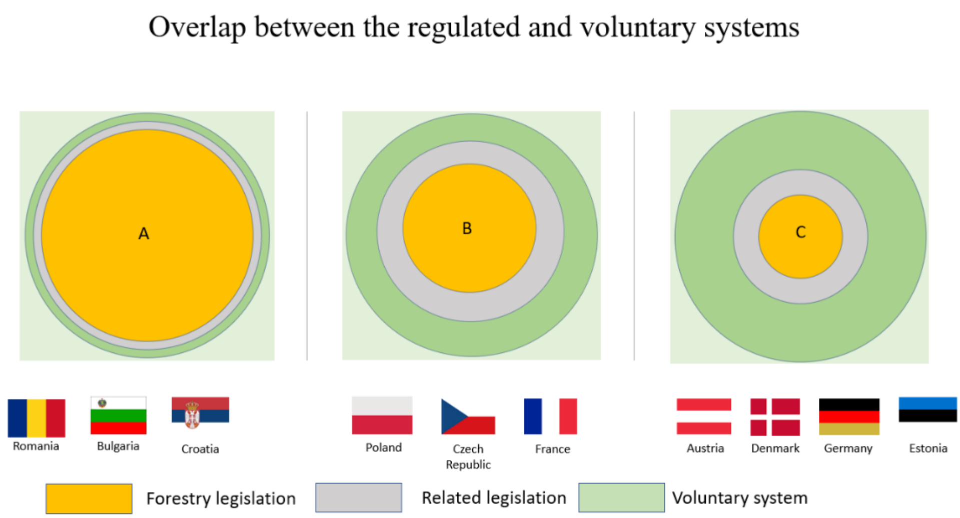

Fig. 2. *Graphic representation of the overlap between the regulated and voluntary systems based on a study conducted in 2018* (Nichiforel et al., 2018a)

At the European level, a study was conducted to assess the rights of forest owners in 30 countries. The results of this study reveal a significant difference in the requirements imposed on forest owners. This discrepancy can influence the degree of involvement in the sustainable development of forests in terms of the "stick" concept (Nichiforel et al., 2018b). In countries where forest-related legislation is not very strict, these gaps can be compensated for by implementing voluntary instruments that provide access to subsidies for meeting certain indicators (figure 2). However, currently, there is no study analysing the subsidies implemented in different countries to support sustainable development (Nichiforel et al., 2018a).

It is important to mention that differences in requirements within the regulated system across European countries can create discrepancies in the approach to sustainable forest development. While some countries may have strict and mandatory rules, others may adopt more flexible approaches based on voluntary instruments and subsidies. These differences can influence the level of involvement and the success of implementing sustainable practices in the forestry sector in each country.

Therefore, a more detailed evaluation of the subsidies implemented in different countries is necessary to better understand how they can support sustainable forest development and to identify best practices that can be applied across the European Union.

Classification based on indicators that indicate the credibility of a country

Internationally, several indicators are defined to classify countries. One of the most well-known indicators is the Corruption Perceptions Index (CPI). This index is maintained by Transparency International and updated annually. Countries with a score above 60 are considered to have a strong legislative system that ensures rigorous implementation (Transparency International, 2021). Another internationally developed indicator is the Governance Effectiveness Index created by the World Bank, which measures the level of governance efficiency (World Bank, 2015). Another indicator is the Fragile States Index (FSI) developed by The Fund for Peace. This index highlights countries where the legislative system does not function at the highest level and countries at risk of instability (The Fund For Peace, 2022).

REGLEMENTED SYSTEM

The regulated system is represented by the existence of forest legislation along with related legislation. The regulated system refers to a framework of rules, regulations, and policies that govern a particular domain or industry (figure 3). In the context of forest management, the regulated system entails the establishment and enforcement of laws and guidelines related to the sustainable use, conservation, and protection of forests. It aims to ensure compliance with specific requirements, standards, and practices for managing forests in a responsible and environmentally sustainable manner. The reglemented system plays a crucial role in promoting the long-term health, biodiversity, and socioeconomic benefits of forest ecosystems.

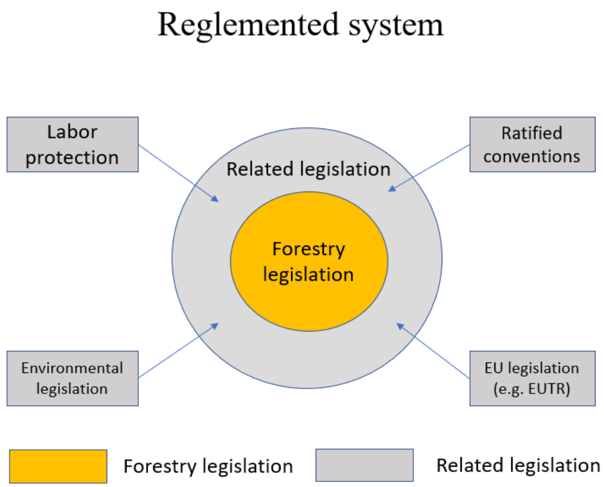

Fig. 3. *Reglemented system used for the development of silvicultural measures*

Forestry legislation

Forest legislation can be defined as the collective body of laws, orders, and regulations that define the functioning of the forestry sector. Based on this definition, the following subsections aim to create a profile for each country included in this study and describe their forest legislation.

In Romania, the Forestry Legislation does not differentiate between forms of ownership. The forestry regime encompasses a set of “forestry technical, economic, and legal norms regarding forest management, exploitation, protection, and safeguarding of the forest resources, with the ultimate goal of ensuring the sustainable management of forest ecosystems.” (Romanian Parliament, 2008). To implement the forest regime in all forests, regardless of ownership type, two definitions are used: the Production Unit (UP) (based on territorial units), which are organized in the same way regardless of ownership, and the Forest Management Plan (FMP) for each UP (Preferred By Nature, 2017g). Forest management units (FMUs) represent divisions within the PU, and they can be assigned a functional group for production and projection or solely for protection. The functional group, along with other characteristics, determines the type of work that can be carried out (Preferred By Nature, 2017g).

Bulgarian forests are managed in accordance with the requirements of the Forest Act (Bulgarian Parliament, 2011a), the Ordinance on Defining Maximum Allowance (Bulgarian Parliament, 2011b) and administrative acts (orders, instructions, etc.) issued by the executive director of the Executive Forest Agency (EFA) and the Minister of Agriculture and Food. Forests are divided into three functional categories: protection forests, forests with special use, and production forests. As a result of the establishment of the Natura 2000 network, a significant portion of forest areas has special and/or protective functions. Special and/or protective functions are found in almost 70% of the forest area (Preferred By Nature, 2017a).

In the national legislation of Latvia concerning forestry, there is no specific definition of forest types and functions. Land use regulations and property classification define forest land as “land where the primary commercial activity is forestry,” encompassing production and protection activities, as well as forest infrastructure, harvesting areas, swamps, and meadows. Forest land may include agricultural land, provided that it does not constitute the majority of the land and agriculture is not the primary economic activity (Preferred By Nature, 2019b).

Forests in Poland are classified into three main categories: production forests, protection forests, and social forests. Production forests are managed to ensure their sustainability in terms of timber and forest product exploitation, tourism development, income generation from timber sales, and provision of hunting services. Protection forests serve as a refuge for biodiversity, housing a variety of habitats and animal species. Social forests contribute to improving recreational opportunities (Preferred By Nature, 2017f). In state forests, the process of obtaining logging authorization involves multiple stages. Firstly, the Forest District approves the annual harvesting inventory. Then, forestry personnel issue logging permits to companies. In Poland, logging is exclusively carried out by contractors. After the logging process is completed, harvested timber is marked by foresters as legally sourced.

In Denmark, only forest reserves (fredskov) are regulated by the Forest Act and managed accordingly (Preferred By Nature, 2017b). Forests that are not classified as reserves can also be used for forest conservation but are not subject to the same law. All public forests are considered forest reserves. A forest can be excluded from a forest reserve at the request of the relevant municipality. If a forest reserve is cancelled by the Ministry of Environment and Food, another area of similar size is declared as a forest reserve or afforested (Preferred By Nature, 2017b). Forest management in Denmark is primarily regulated by the Forest Act. It does not include many measures regarding forest management techniques such as harvesting, planting, or thinning. Harvesting within forest reserves and outside of them does not require a harvesting permit. However, if harvesting needs to take place in a Natura 2000 area, it is subject to a notification system. Forest managers are required to inform the authorities when certain types of activities occur in Natura 2000 areas (Preferred By Nature, 2017b).

In Estonia, the definition of a forest is presented in the Forest Act. There are three main categories of forests: commercial forests, protection forests, and protected forests. To carry out forest harvesting operations, a valid forest inventory or management plan is required. Additionally, a harvesting permit issued by the Environmental Board is necessary. The forest legislation does not apply to forest land smaller than 0.5 hectares. Harvesting up to 20 cubic meters of timber per Production Unit (PU) is allowed without a harvesting permit (Preferred By Nature, 2017c). If a forest owner intends to harvest more than 20 cubic meters for each PU, they need to complete a harvesting permit and submit it to the Environmental Board for approval. This can be done either in paper format or electronically. The harvesting permit is valid for 12 months from the approval by the Environmental Board. All harvesting permits and data from the forest inventory are available in the public forest management system (Preferred By Nature, 2017c).

All forestry activities in Finland are subject to the same legislative framework. The same legislation applies, with a few exceptions, to all forests, whether owned by the state, municipalities, companies, or individuals (Preferred By Nature, 2017d). In 2014, the forest legislation underwent significant revisions, increasing the freedom of choice for forest owners in managing their forest properties, improving the profitability of forestry and the timber industry, and promoting forest biodiversity. Among the notable changes were the recognition of uneven-aged stands, the removal of age criteria and diameter limits in regeneration, the diversification of tree species used, and the increased importance given to habitats (Preferred By Nature, 2017d). Forest owners are required to submit a “forest use declaration” to the Forest Center at least 10 days prior to commencing harvesting. The Forest Center constantly monitors the quality of harvesting and other forest operations (Preferred By Nature, 2017d). Certain types of harvesting are exempt from the forest use declaration, such as personal use harvesting, harvesting in accordance with a forest management and regeneration plan, harvesting of small trees, harvesting for the construction of a road, ditch, water pipe, power line, or similar purposes (Preferred By Nature, 2017d).

According to the legislative system in Italy, forest management activities must not compromise the continuity of the forest, and therefore, changing the land use is not permitted. Additionally, 87% of Italian forests are subject to hydrogeological restrictions. Forest operations in these areas require authorizations from designated regional authorities, while all forests are subject to landscape restrictions (Preferred By Nature, 2018). At the national level, the Ministry of Agriculture, Food, and Forestry is responsible for defining the strategic objectives for forestry policies. Since 1977, the competences and responsibilities in the field of agriculture and forestry have been transferred to regional administrations. Each regional administration has established its own primary and secondary legislation in forestry matters (Preferred By Nature, 2018). Therefore, planning and harvesting procedures differ, and the corresponding authorizations are issued in accordance with regional/ provincial legislation (Preferred By Nature, 2018). As a result, the forest legislative framework is vast, encompassing 19 regional laws, two provincial forest laws, and additional secondary legislation. Monitoring of harvesting operations, including the issuance of sanctions, is the responsibility of forest personnel (Preferred By Nature, 2018). Given the highly diverse regulatory framework, harvesting authorizations have different names and follow different issuance procedures. In this context, authorizations can be classified into two main categories: harvesting notifications, required for small-scale harvesting operations (e.g., small areas, limited volumes, etc.), especially in old-growth forests, and usually involve a simple and fast procedure.

The Forestry Service within the Department of Agriculture, Food and the Marine is the primary authority for regulating forestry activities in Ireland. A felling license issued by the Minister for Agriculture, Food and the Marine provides the permission to fell one or more trees and thin a forest for silvicultural reasons. Typically, the felling of a tree is accompanied by the obligation to replant (Preferred By Nature, 2019a). The Forestry Service within the Department of Agriculture, Food and the Marine is the primary authority for regulating forestry activities in Ireland. A felling license issued by the Minister for Agriculture, Food and the Marine provides the permission to fell one or more trees and thin a forest for silvicultural reasons. Typically, the felling of a tree is accompanied by the obligation to replant (Preferred By Nature, 2019a). In some cases, felling license applications are circulated to various national government agencies and local authorities. They can provide comments and recommend specific conditions to be attached to the felling licenses based on the impact on the felling activities. After the issuance of a felling license, the state agency is responsible for monitoring compliance with the license conditions during the timber harvesting process.

Norwegian forests are primarily managed as “LNFR areas” (Landbruks-Naturog Friluftsformål samt Reindrift, meaning areas for agriculture, nature, outdoor activities, and reindeer grazing) according to the general plans of each municipality for the designated areas (Preferred By Nature, 2017e). In most forest areas, no permits are required prior to forest exploitation. However, in protective forests bordering the mountains, selected coastal areas, Marka (adjacent to Oslo), and northern Norway (Nordland, Troms, and Finnmark), various forms of notification or applications must be submitted and approved by local forestry authorities before forest exploitation can take place. Most logging and planting activities are carried out by specialized companies engaged by clients interested in timber (Preferred By Nature, 2017e). The Norwegian timber exploitation sector is predominantly controlled by approximately 10 companies, which can be either local divisions of a forest company, forest owner organizations, or independent commercial enterprises. The certification system used in Norway is PEFC, which allows for group certification at the timber exploitation company level (Preferred By Nature, 2017e). If a forest owner has a business relationship with multiple timber buyers, the owner is covered by each group certificate. The planning of exploitation is typically done by the timber buyer, and the actual harvesting is carried out by a contracted team working for the timber buyer (Preferred By Nature, 2017e). The forest owner typically establishes the contract with the timber buyer, while the harvesting team is usually chosen by the buyer.

The Forestry Act in Sweden aims to support sustainable and long-term wood production while protecting the environment during forestry operations (Preferred by Nature, 2017). The definition of productive forest land is land capable of producing at least 1 m^3 of solid wood, including bark, and is not used for other purposes such as agriculture, buildings, or infrastructure (Preferred by Nature, 2017). Most provisions of the Forestry Act apply to activities carried out on productive forest land. However, there are also regulations aimed at protecting conservation values on unproductive forest land. In general, the Forestry Act mandates forest regeneration on forest land, prohibits harvesting of trees below a certain age, limits the size of harvesting areas and young forests within a single property, and requires prevention of pest outbreaks. However, the law does not specify specific obligations regarding silvicultural measures such as pre-commercial or commercial operations (thinning) (Preferred by Nature, 2017). Determining what forestry actions are legal or illegal in the Swedish context is a complex process. Most of the detailed requirements set by authorities such as the Swedish Forest Agency or the Swedish Work Environment Authority are not directly sanctioned by fines or imprisonment (Preferred by Nature, 2017). Instead, these requirements are used as a basis for issuing specific injunctions to forest owners or purchasers of harvesting rights. Typically, these injunctions are used preventively. Without the issuance of injunctions, it is not evident that an action violates regulations and should be considered "illegal" (Preferred by Nature, 2017). Harvesting permits are only required for certain forest land, such as mountainous areas, but final fellings on areas smaller than 0.5 ha need to be notified in advance to the National Agency. Since 1993, production and environmental objectives have received equal importance in forestry legislation (Preferred by Nature, 2017). The Swedish Forest Agency has also established detailed regulations regarding requirements for species and environmental protection. However, these requirements cannot result in significant economic losses for the landowner without adequate compensation (Preferred by Nature, 2017).

Related legislation

At the international level, there are various environmental approaches that can improve the functioning of the forestry sector and facilitate the implementation of different concepts. These approaches may not automatically be part of forest legislation, as each country has the discretion to decide what to implement.

Here are some examples:

- The United Nations Framework Convention on Climate Change (UNFCCC) sets targets and principles to counter climate change. Within the UNFCCC, there are specific mechanisms that address forest-related issues, such as the Clean Development Mechanism (CDM) and the Reducing Emissions from Deforestation and Forest Degradation (REDD+) initiative (United Nations, n.d.-a);
- The Paris Agreement: It is a global agreement adopted under the UNFCCC aimed at limiting the global temperature increase to below 2 degrees Celsius above pre-industrial levels. Forests and their sustainable management play a crucial role in national strategies for adaptation and greenhouse gas emissions reduction (United Nations, n.d.-b);
- The United Nations Environment Programme (UNEP): UNEP promotes the conservation and sustainable use of natural resources, including forests. Through UNEP, projects and initiatives are carried out to protect and sustainably manage forests (United Nations, n.d.-a);

- The Food and Agriculture Organization of the United Nations (FAO) provides guidance and assistance in the development and implementation of global forest policies, including the establishment of international standards and norms for sustainable forest management FAO, n.d.);
- The Convention on Biological Diversity (CBD) aims to conserve and sustainably use biodiversity. Forests are recognized as habitats for a large number of species and are essential for biodiversity conservation. The CBD promotes actions to protect and restore forest habitats and the species that depend on them (Convention on Biological Diversity, n.d.).

These internationally regulated instruments reflect the international community's commitment to addressing environmental issues and promoting sustainable forest management. Through these instruments, the aim is to ensure responsible utilization of forest resources, contributing to biodiversity conservation, environmental quality protection, and the fight against climate change.

Labor protection and ratification of International Labor Organization conventions

All the countries studied have ratified multiple conventions developed by the International Labour Organization (ILO). These conventions include Convention 87/98 on the right to freedom of association and collective bargaining; Convention 29/105 on the elimination of all forms of forced or compulsory labor; Convention 182 on the elimination of the worst forms of child labor; and Convention 100/111 on the elimination of all forms of discrimination in employment and occupation (ILO, 2023). However, one of the most important conventions applicable in the forestry sector is Convention 155, which provides minimum standards for occupational safety and health (ILO, 2023). Although the ILO does not provide detailed rules for each type of personal protective equipment (PPE) in forestry, it emphasizes the importance of using PPE and that employers should provide adequate PPE and ensure that employees are properly trained on its use. Additionally, employees need to be aware of the importance of using PPE and wear it correctly during work. Through ratification, the signatory countries commit to implementing in their national legislation requirements that cover at least the ILO recommendations (ILO, 2023). In other words, the implementation of safety and protection measures in the workplace is necessary in all the countries studied.

Legislation developed at European Union level for wood products

An increasingly important aspect promoted at the European and international level is ensuring that products entering the market are legally sourced in the country of origin. Due to significant differences in forestry legislation, this objective is not uniformly implemented in terms of the concept of sustainable development (EC, 2021).

Illegal logging and/or trade of illegally harvested timber have major social and economic consequences, with a significant impact on the environment. Illegal logging disregards the intention to comply with legislation and, consequently, to responsibly manage forests. Often, this phenomenon leads to forest degradation and deforestation, resulting in the disruption of forest-dependent communities (EC, 2021). In tropical regions, these activities have led to species extinction and the destruction of important habitats for species survival. Additionally, illegal activities result in significant losses of assets and revenues from public goods through tax and royalty losses for developing countries. Recognizing the multiple implications of this type of activity, governments and non-governmental organizations are seeking the most effective way to ensure compliance with legislation in the country of origin or throughout the supply chain (EC, 2021).

The establishment of policies addressing illegal logging and/or trade of illegally harvested timber began timidly in 2008 in the United States with the enactment of the Lacey Act (Prestemon, 2015). A significant subsequent step was taken by the European Union through the implementation of the "European Regulation laying down the obligations of operators who place timber and timber products on the market" (European Parliament, 2010). Currently, several countries are implementing different systems to promote legality in supply chains (e.g., Australia, Switzerland, the United Kingdom). These policies have had a partially positive impact by raising awareness among actors in the timber and paper supply chains and highlighting the negative effects of illegal logging and/or trade (Holopainen et al., 2015).

With the creation of the European Union, an attempt was made to implement a similar set of measures in several countries. Thus, in 2010, the European Parliament adopted the European Regulation laying down the obligations of operators who place timber and timber products on the market (European Parliament, 2010). It took approximately four years for the legislation to be transposed in all countries, and effective implementation began. This regulation imposes obligations on companies that place timber and timber products on the market - defined in the regulation as operators. Specifically, companies must ensure that the timber is harvested in accordance with the legislation of the country of origin (European Parliament, 2010).

VOLUNTARY SYSTEM

In the dynamic discussions and decisions related to the forestry sector, it is not only government authorities that play an essential role. The voices of other stakeholders, such as consumers of wood products and various non-governmental organizations focused on environmental protection and human rights advocacy, are increasingly being heard. They have made significant contributions to shaping a non-governmental approach, reflecting the diverse involvement of society in the protection and responsible management of forest resources (Kiker and Putz, 1997).

In the context of globalization, we have witnessed the formation of complex and transnational supply chains. An example of this could be a book that is currently printed in China, using pulp obtained from three different countries in South America. This highlights the deep interconnections that are formed in the timber industry and its products, with environmental impacts occurring in various corners of the world.

The existence of these long and complex supply chains has led to the need for increased responsibility and transparency measures in the industry. As a result, certain stakeholders in the sector have chosen to join voluntary systems that demonstrate that their products have no negative impact on the environment or local communities. Essentially, these voluntary approaches function as marketing tools, providing an opportunity for environmentally conscious consumers to support sustainable practices. These consumers can consciously choose products that are associated with voluntary certification systems.

To facilitate the identification of these environmentally responsible products, the concept of eco-labelling has emerged. This has further evolved into a more formal certification system, which allows for independent verification and validation of sustainability claims. As a result, consumers can make more informed choices, supporting companies that are committed to protecting and responsibly managing forest resources (Sedjo and Swallow, 2002).

Forest certification is a process through which a written proof is obtained from an independent third-party organization, certifying the location and management of a forest according to the standards issued by the certification scheme owner (Kiker and Putz, 1997). This process involves assessing the quality of forest management against a predefined set of principles and criteria. Furthermore, forest certification provides consumers with a credible assurance that the product comes from a management system that complies with developed standards, which in some cases can be considered equivalent to sustainable development, responsible management, or close-to-nature forestry concepts (Forest Stewardship Council, n.d.-a).

A certification scheme may utilize one or more types of certification in varying proportions. Most forest certification schemes encompass two essential components of the process that address different aspects of production and trade:

1. Forest management certification refers to the assessment and certification of forest management practices. It aims to ensure that forests are managed in a manner that respects the principles of sustainability, including the protection of biodiversity, the respect for the rights of local and indigenous communities, and the promotion of sustainable economic returns. Forest management certification involves the direct assessment and monitoring of forest sites, with a focus on the processes and practices of forest management itself (Overdevest and Rickenbach, 2006). This certification often includes a combination of system and performance certification.
2. Chain of custody certification, on the other hand, refers to the process of tracing forest products throughout the supply chain, from the forest where the timber was harvested to the final product. It ensures that products labelled as coming from responsibly managed or certified forests are actually derived from those sources (Overdevest

and Rickenbach, 2006). Chain of custody certification does not involve the evaluation of forest management practices themselves, but rather the system of record-keeping and control that allows for the tracking of forest products along the supply chain. This certification often includes a combination of product certification, transformation certification, and system certification.

Forest Stewardship Council (FSC)

The Forest Stewardship Council (FSC) is a non-profit international organization established in 1993, following the success of the Rio Conference, with the aim of promoting responsible forest management. Initially, its focus was on tropical forests, but over the past three decades, it has not been able to attract a significant number of forests in this region. Currently, the majority of certified areas are found in developed countries. This voluntary system is considered by many experts to be the most well-developed and credible system that has successfully engaged stakeholders. At present, there are over 200 million hectares of certified forests and more than 40,000 organizations with chain of custody certifications (Forest Stewardship Council, n.d.-b).

The certification system operates through audits conducted by third-party organizations known as Certification Bodies (CBs). These CBs are overseen by a single Accreditation Services International (ASI) (ASI, n.d.). In terms of the materials that can be included in certified products, they are divided into two main categories: wood sourced from certified supply chains or wood sourced from uncertified supply chains, for which a risk-based approach is implemented to ensure that these materials meet a minimum set of requirements. Wood sourced from certified supply chains is referred to as “Controlled Wood.”

Regarding the standards, the main standard that forms the basis of certification is the Forest Management (FM) certification standard (Forest Stewardship Council, 2023). This standard is applicable internationally and consists of 10 principles and 70 criteria. Based on this standard, national standards/approaches can be developed to ensure better integration of the internationally defined requirements at the local level.

Pan European Forest Certification (PEFC)

PEFC, the Programme for the Endorsement of Forest Certification, was founded on June 30, 1999, in Paris, with the aim of promoting sustainable forest management through third-party certification (Programme for the Endorsement of Forest Certification, n.d.-b). PEFC is an organization that promotes the principle of mutual recognition among numerous national certification standards. Essentially, PEFC is a union of national standards implemented in different parts of the world (Programme for the Endorsement of Forest Certification, n.d.-b, n.d.-a). Although initially created to address the European situation, the PEFC approach has now become global. The opposite characteristic compared to FSC is the encouragement of a bottom-up approach through collaboration with multiple stakeholders in the development of national certification standards and the respect for the use of regional policy processes to promote sustainable forest management as the basis for certification standards (Michal et al., 2019). This makes the certification system more closely aligned with the governmental side compared to FSC. In some cases, the organizations that established the national system are actually government associations. For example, the national scheme in Poland is actually established and supported by the state forest administrator.

The scheme recognizes the standards of the national forest certification system. The process of recognition and incorporation of new national forest certification systems into the PEFC family is known as “endorsement” and involves assessments carried out by an independent evaluator and recognition by the PEFC Council (Programme for the Endorsement of Forest Certification, n.d.-a). After five years from the date of endorsement, the approved systems should initiate a process of revising the national standard. In practice, this does not always happen, with some national schemes still using standards developed in 2010 as of 2021. Additionally, the certification scheme has faced criticism as it was revealed in an investigation that any type of organization could obtain certification under this scheme. In the investigation, a nightclub and a nuclear power plant were able to obtain certification (EIA, 2017).

Despite the existence of national systems, the certification scheme includes international standards that must be applied in each national standard. One of these standards is the Forest Management (FM) standard, which is based on 6 criteria and 94 requirements (Programme for the Endorsement of Forest Certification, n.d.-c). Another important standard is the Chain of Custody standard, which incorporates the method for incorporating non-certified materials into certified products.

Other certification schemes

SBP (Sustainable Biomass Program) is a certification scheme that accepts contributions from other major and well-known certification schemes (currently approved schemes are FSC, PEFC), as well as inputs within its own assessment framework. Products certified through its own standard are based on risk assessments. The credibility of the SBP scheme largely depends on the strength of the schemes it approves – currently, schemes approved by FSC and PEFC. As indicated in the certification scheme's name, this system is primarily designed for biomass producers in Northern and Northeastern Europe (Sustainable Biomass Program, n.d.).

Certification bodies have also developed verification schemes that primarily focus on legality verification. One such system is "Origine et Légalité des Bois" developed in 2004 by Bureau Veritas Certification, while another system is "Legal Source" developed in 2014 by Preferred by Nature. These schemes typically do not allow the use of claims on final products (Bureau Veritas, n.d.; Preferred by Nature, n.d.).

Another standard that uses a different approach is "ISO 38200:2018 Chain of Custody of Wood and Wood-based Products," which sets requirements for a chain of custody system to enable the exchange and tracking of information about wood and wood-based products throughout the supply chain. In this system, there are no normative requirements developed for accrediting certification bodies that certify to the standard, and it is important to note that the standard is not intended solely for certification. The standard allows for the use of other certification schemes as long as they meet the requirements. Additionally, the standard itself does not specify requirements or limitations regarding communication about the use of the standard. This aspect of ISO 38200 means that any claim must be carefully evaluated to understand what it covers (ISO, 2018).

CONCLUSIONS

Firstly, the legislative system, through its important role in establishing rules for different sectors, plays a crucial role in ensuring sustainable forestry. The entirety of laws that impact forests forms the regulated instrument of the state. On the other hand, organizations that benefit from goods and services provided by forests seek to assure their customers that their activities do not have a negative impact on the forests. Taking these factors into account, non-governmental organizations have developed various standards and policies aimed at maintaining and improving forestry practices. These systems are not regulated by the state; instead, they are voluntary tools. Their use depends on the willingness and interest of the forest owner or administrator. Both types of instruments aim to improve forestry practices and promote a sustainable approach to the use of forest resources.

Taking into account the first three classifications, we can say that the foundation is represented by forestry legislation. This often applies constraints in case of non-compliance, but there are also cases where rewards are implemented (e.g., tax exemptions for owners who choose to be certified). Additionally, related legislation represents the next level that must be followed. Similar to the first level, it often applies constraints. There are no known cases where related legislation provides rewards. The third level is represented by the voluntary system, which is primarily based on a rewards system. If the requirements are met, a certificate is granted that can be used towards the end consumers of products and services. However, the voluntary system also employs constraints: if a certain indicator is not met, this will be made public. In practice, we can say that based on these classifications, each country (sometimes region) can have a different set of approaches and varying levels of promotion of sustainable forestry.

In post-socialist countries such as Bulgaria, Estonia, Latvia, Poland, and Romania, the forestry sector has undergone significant changes following the collapse of communist regimes. These countries had to transition from a centralized and collective forest management system to one based on market principles and private management (Albulescu et al., 2022). In Bulgaria, after the change of regime, the forests were privatized and private owners were encouraged to manage their forests. However, the process of privatization and restitution of forest property was challenging and faced multiple issues and disputes (Preferred By Nature, 2017a). Estonia, with its large forest area, stands out as the post-socialist country with the most impressive changes in forestry legislation. It has managed to rapidly improve its forest resource management system and is recognized for its use of advanced technologies and implementation of international forest management standards (Preferred By Nature, 2017c). Latvia, being a country with a rich forestry tradition, has had a relatively smooth transition to private forest management. Forest ownership is largely private, and many Latvian forests are certified according to sustainable management standards (Preferred By Nature, 2019b). In Poland, the privatization of forests has been a complex and lengthy process. Forest ownership is divided between the state, local administrations, and private owners. Poland has implemented FSC forest certification, but currently the state has started to withdraw from this type of certification (Preferred By Nature, 2017f). In Romania, the transition to private forest management has been challenging and uncertain. A large portion of forests is state-owned, and privatization has been partial and accompanied by controversies and litigation (Preferred By Nature, 2017g). Overall, post-socialist countries in Eastern Europe have faced challenges in transitioning to private forest management. These challenges include difficulties in forest privatization and restitution, inadequate regulations, outdated infrastructure, and the need to develop administrative capacity and expertise in the forestry sector. However, these countries have made significant progress in adopting sustainable forest management practices and implementing international standards. Forestry in Western countries such as Denmark, Finland, Italy, Ireland, Norway, and Sweden is characterized by a long-standing tradition and sustainable forest management. These countries have abundant forest resources and have developed policies and practices to promote sustainable management and biodiversity conservation. In general, forestry in these countries is less regulated, giving owners the right to exploit the forest at their discretion. Various incentives are introduced when owners decide to protect the forest. Denmark, although it has a small forest area, focuses on sustainable forest management and the ecosystem services provided by forests, such as biodiversity conservation and soil protection(Preferred By Nature, 2017b). Finland has a long tradition in forestry and is one of the major producers of forest products in Europe. Forest management practices are rigorous and focus on sustainability, biodiversity conservation, and addressing climate change (Preferred By Nature, 2017d). Italy has a diverse range of forests and promotes an integrated approach to forest resource management. However, forest legislation varies greatly across regions, resulting in different levels of forest practice development (Preferred By Nature, 2018). Despite having a smaller forest area, Ireland focuses on the conservation and development of existing forests. Projects have been implemented to protect biodiversity and fragile forest ecosystems (Preferred By Nature, 2019a). Norway has sustainable forest management practices and places particular emphasis on biodiversity conservation and ecological forest management. Norway has also developed international partnerships to address global forest issues and climate change (Preferred By Nature, 2017e). Sweden is recognized as a leader in sustainable forest management. It has a considerable forest area and emphasizes biodiversity conservation and sustainable use of forest resources (Preferred by Nature, 2017). In general, Nordic and Western countries are committed to responsible forest management, biodiversity protection, and combating climate change through more relaxed policies and practices compared to post-socialist countries.

In addition to regulated instruments, there are also voluntary tools that encourage the adoption of better practices and promote transparency and accountability in forest management. The most well-known voluntary instrument is forest certification. The most recognized forest certification systems are the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC). These systems are independent of regulated instruments and function by granting a certificate to forest owners and companies that demonstrate their commitment to their standards. Other types of regulatory instruments include best practice guides, collaborative initiatives, and information exchange platforms. These provide resources and guidance for improving forest management and facilitate the exchange of knowledge and experiences among different industry stakeholders.

Both approaches developed by regulated instruments and voluntary ones play an essential role in the development of sustainable forest practices. Regulated instruments establish a legal framework and ensure compliance with minimum requirements, while voluntary instruments provide additional opportunities for forest owners to demonstrate their commitment.

With the growing concept of certification, numerous certification programs have emerged, each developing in different directions. These programs cover various aspects of forestry, ranging from global to national and regional levels. However, in terms of importance, the Forest Stewardship Council (FSC) and the Pan European Forest Certification (PEFC) systems can be considered the prominent ones. The other systems can be grouped into a third category.

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Appendix 1. Comparison of regulated systems from multiple countries in Europe

Type of classification	Implementation Method of Regulations	Degree of Regulation	Other Indicators		
Romania	More using constraints	A	CPI 45	WBI 00047,60	FSI 53
Bulgaria	More using constraints	A	CPI 42	WBI 47,12	FSI 51,8
Latvia	Using constraints and rewards	B	CPI 59	WBI 77,40	FSI 43,3
Poland	More using constraints	A	CPI 56	WBI 63,46	FSI 45,2
Denmark	More using rewards	C	CPI 88	WBI 99,04	FSI 17,9
Estonia	More using rewards	C	CPI 74	WBI 89,42	FSI 38,6
Finland	More using rewards	C	CPI 88	WBI 98,56	FSI 16
Italy	Utilizes a different approach in each region	B	CPI 56	WBI 64,90	FSI 42,6
Ireland	More using constraints	B	CPI 74	WBI 92,31	FSI 19,5
Norway	More using constraints	A	CPI 85	WBI 98,07	FSI 14,5
Sweden	More using constraints	A	CPI 85	WBI 96,15	FSI 20,6

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ENVIRONMENTAL ASSESSMENT OF NITROGEN COMPOUNDS IN THE SURROUNDINGS OF A FERTILIZERS INDUSTRIAL PLANT

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ABSTRACT. The present study was conducted in the proximity of a chemical plant from Târgu-Mureș (Romania), where nitrogen-based fertilizers were produced. The quality of the environmental components was assessed in terms of general physico-chemical parameters and the content of nitrogen dissolved ions (NO_3^-, NO_2^-). The nitrate content in soil varied depending on the distance from the source and land use at sampling point. The nitrite content was correlated with possible transformations from the nitrate forms. For water, special attention should be paid to the nitrate content from the industrial effluent, which in one sample proved to be higher than the national legislation.

Key words: *nitrogen-based fertilizers, surface water pollution, soil pollution*

INTRODUCTION

Soil N is an essential component for the normal development of plants and crops. Because soil organic N can be lost due to plant removal, leaching or volatilization, the use of nitrogen compounds was developed (Jenkinson, 2001). In the natural N cycle, the input, transformation, and output of N were found in an equilibrium, but the intensive use of nitrogen fertilizers has conducted to significant drainages of nitrates or nitrites into surface and underground water (Peigne and Girardin, 2004).

Nitrogen compounds contamination of soil and surface or underground water is a well-known environmental problem, mostly associated to urbanized and agricultural areas (Soldatova et al., 2017; Jang and Liu, 2005). In order to support the worldwide need for food, nitrogen-based fertilizers were used in agricultural activities from many countries, and the excessive use of these products has led to environmental contamination. Thus, agricultural activities represent an important source for nitrogen compounds contamination known even from the past (Commoner 1970; Madison and Brunett, 1984). The need for fertilizers has led to the development of high-capacity plants, which now represent another source for nitrogen compounds contamination, especially due to industrial effluents (Kanu and Achi, 2011; Madhav et al., 2019).

The contamination with nitrogen compounds in Romania was evaluated also in other studies (Lupei et al., 2014; Rotaru and Răileanu, 2008), indicating that this is an environmental problem linked to industrial platforms. The presence of these contaminants was observed in various environmental compounds, such as soil, surface water and underground water.

The present study aims to analyze the quality of soil and surface water in the surroundings of a chemical plant from Târgu-Mureș, Romania. The activity of the plant consists in the production of nitrogen-based fertilizers. The quality of the environmental components was assessed in terms of nitrogen dissolved ions (NO_3^-, NO_2^-) content and correlated with the physical-chemical parameters.

MATERIALS AND METHODS

The study area was located in Târgu Mureș city (Romania), nearby an industrial plant which produces nitrogen-based fertilizers, rich in nutrients like nitrogen, phosphorus, potassium, calcium, sulphur, magnesium, boron and zinc. The nitrogenous fertilizer plant consisted of three main producing plants (ammonia, nitric acid and ammonium nitrate). In the last two years, because of the increase price of the energy, several high energy consumers from the older installations had been temporarily shut down. The activity of the fertilizer plant may have an impact on the atmosphere through emissions of ammonia, nitrogen oxides and particulate matter (EPA-Mureș). According to the legislative requirements and the environmental authorization, the plant owner performs determinations of specific contaminants (ammonia and nitrogen oxide) imissions into the atmosphere, at fixed self-monitoring points. There were several periods (e.g., 2003) when slight exceedances of the allowed value for the average daily ammonia concentration were recorded in the monitoring points (EPA-Mureș). Over time, the owner of the fertilizer plant has made significant investments in equipment modernization to reach the best practices in fertilizers manufacturing, in order to reduce the possible impact on the environment and inhabitants' health.

The interest for a clean environment is given by the population living areas and the agricultural fields found in the proximity. For this reason, 10 soil samples (P1 – P10) were collected from 5 cm depth (after vegetation removal) (figure 1), and one reference sample (P Martor) was collected from an area considered to be unaffected by the industrial activity. Their distance from the industrial source varies and they are placed on the main wind directions (ENE), except the reference sample.

Since the Mureș River is located at 300 m in the northern part of the industrial platform, 5 water samples were collected for the study (figure 2). The water sampling points are located at approximately 500 m from each other. Two industrial effluents were found in the field, so a water sample was collected from each discharging point (P Dev and P Dev Ep). The reference water sample (P Martor) was collected upstream from these two dispersion points, while the other two samples (P1 and P2) were collected downstream.

Fig. 1. *Study area with soil sampling points (P1 – P10)*

Fig. 2. *Study area with water sampling points*

Soil samples were collected by a stainless steel hand auger and transferred to polyethylene bags, while water samples were collected directly in clean plastic bottles. All the samples were transported to laboratory at a constant temperature (4ºC) and in the absence of light.

The physico-chemical parameters (pH, redox potential (Eh), electrical conductivity (EC), total dissolved solids (TDS) and salinity) were determined using a portable multiparameter (WTW Multi 350i, Germany). For the soil samples, the physico-chemical parameters were measured in the aqueous extract of soil/water (5:1 ratio), which was obtained according to SR ISO 10390:1999 protocol.

To determine the dissolved ions, the water samples were previously filtered through filter paper, followed by ultrapure water (0.055 μS/cm; 18.2 MΩ/cm) dilution to reach electrical conductivity below 100 μS/cm. For soil samples were used the aqueous extracts of soil/water (5:1 ratio) (LAQUA, 2015). The content of anions (NO_3^-, NO_2^-) was assessed using an ionic chromatography system (IC 1500 Dionex).

RESULTS AND DISCUSSION

Soil samples

The $N\text{-}NO_3^-$ content in soil ranged between 1.6 and 72.1 mg/kg (figure 3). Some of the analyzed soil samples (P1, P2, P6 and P9) had a low content of $N\text{-}NO_3^-$ (<10 mg/l) (LAQUA, 2015). Most of the soil samples had a $N\text{-}NO_3^-$ content between 10 and 50 mg/kg, which is considered the amount required in soil for specific crops, although nitrate content can fluctuate widely depending on soil water movement (LAQUA, 2015). Based on nitrate content, soil sample P3 corresponds to a high content of $N\text{-}NO_3^-$ (>50 mg/kg) (LAQUA, 2015). P3 and P4 samples were taken from a neighborhood of houses, and the sampling points are found at the highest distance (more than 1,2 km) from the chemical plant. Since gardening activities are taking place in the proximity of P3 and P4 sampling points, the nitrate content might be correlated to fertilizers usage. In the case of P7 and P10, the situation is quite the opposite, because these sampling points are found the nearest to the industrial platform, collected from agricultural fields. The nitrate content in these samples was almost 7 times higher than the reference, while the other soil samples

(P5, P6, P8, P9) taken from the same type of soil use revealed similar nitrate content as the reference sample (P. Martor). Several studies have indicated that uncontrolled leaching from different sources (e.g., waste storage, industrial effluents etc.) might be responsible for nitrate accumulation into the soil (Kanu and Achi, 2011; Madhav et al., 2019).

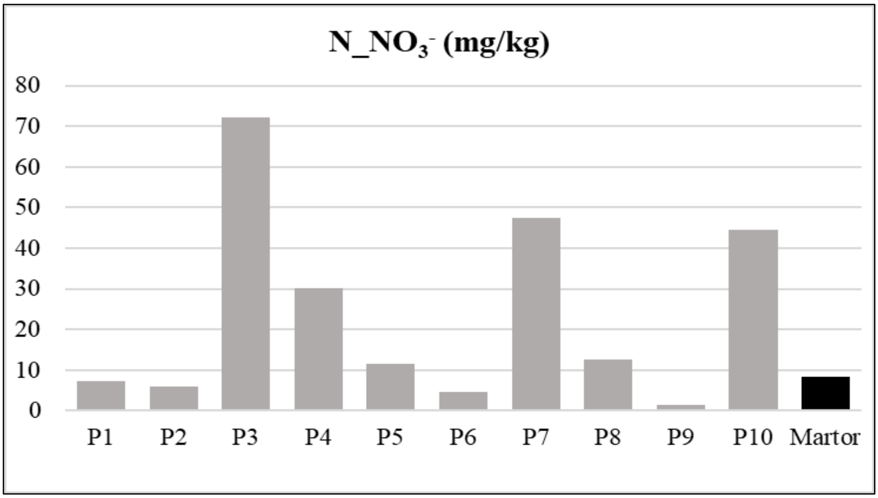

Fig. 3. *Content of N-NO_3^- in the analyzed soil samples*

The presence of nitrate in soil implies various discussions. First, is important to mention that nitrate can be present in soil from mineralization of the organically bound nitrogen originating from crop residues, soil organic matter and organic manures or as a consequence of intensive use of nitrogen-based fertilizers (Jenkinson 2001). Additionally, human activity can lead to nitrate contamination. Regardless the source of nitrate, leaching is the main environmental threat.

There are studies (Robson, 1989) which highlighted the fact that usage of nitrogen-based fertilizers can be associated with soil acidification. Compared with the analyzed physical-chemical parameters (table 1), indeed most of the sampling points with increased nitrate content (P3, P7 and P10) revealed a pH varying between 6 – 6.6, indicating the acidification of soil, while the other samples had a neutral to slight alkaline pH (7.1 – 7.6). The reducing conditions of the analyzed soil samples do not enhance the presence of nitrate, which tend to increase if redox potential is higher than 300 mV (Dayo-Olagbende et al., 2022). Some researchers (Patriquin et al., 1993) found a direct correlation between EC and the nitrate content. A similar trend was found in the present study too. The values for EC and TDS were higher in the samples with high nitrate content (P3, P4, P7 and P10), situation which in is favor for nitrate leaching considering also the acidic pH in these investigation points.

Table 1. *General physico-chemical parameters of the soil samples*

Soil sample	pH	ORP (mV)	EC (µS/cm)	TDS (mg/l)	Salinity (‰)
P1	7.1	+9.8	111.8	73	0.0
P2	7.5	-15.5	77.9	51	0.0
P3	6.6	+35.7	280	182	0.1
P4	7.8	-34.3	329	214	0.0
P5	7.3	-1.7	114.1	72	0.0
P6	6.2	+62.6	70.6	46	0.0
P7	6	+71.0	134.5	89	0.0
P8	7.1	+9.5	98	64	0.0
P9	7.2	+0.8	70.5	46	0.0
P10	6.1	+66.7	140.7	92	0.0
Martor	7.6	-19.6	129.8	84	0.0

Under anoxic conditions, nitrate can be reduced to nitrite by the process known as denitrification (Wrage et al., 2001). Nitrite concentrations were revealed in P4 and P10 (figure 4) previously found with high nitrate content. Other samples also revealed nitrite accumulations (P1, P2, P6 and P8) similar with the reference point (Martor), while in other samples (P3, P5, P7 and P9) it was absent (figure 4). The presence of nitrite in soil can be associated to transformations from the nitrate form, since all the soil samples were characterized by the presence of nitrate. Nitrite was not identified in P3 and P7, even though these samples had elevated nitrate content. Since the soil samples were collected from 5 cm depth, and the soil pH features acidic conditions, it can be assumed that, leaching at higher depts might have occurred due to soil water transport of nitrate (Pilegaard, 2013).

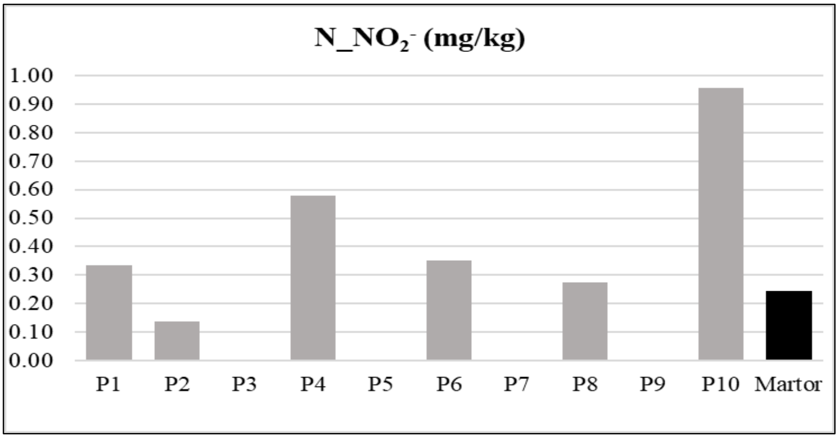

Fig. 4. *Content of N-NO_2^- in the analyzed soil samples*

The presence of nitrite in soil samples poses health threats for the inhabitants living in the study area. Nitrite poisoning was correlated with infant methemoglobinemia and different reactions at stomach or lungs level, including cancer (Serio et al., 2018). For these reasons, the water content of nitrates and nitrites was subjected to environmental legislation.

Water samples

Furthermore, the nitrate concentrations in water samples are listed in figure 5. The industrial effluent from sampling point P DEV EP had a considerably low content of nitrate, which might prove the efficiency of the wastewater treatment from the fertilizer plant. An alarming exceeding of the Romanian national threshold for industrial effluents release in water bodies (Decision 352/2005) was observed in P DEV, the water sample collected at the discharging point of one of the industrial effluents coming from the industrial platform. Despite the high content of nitrate from the effluent point (P DEV), due to high dilution, the nitrate level from Mureș River upstream and downstream from discharging point, was low and did not reach a significand increase. Based on the nitrate level from Mureș River in the proximity of fertilizer plant, the water corresponds to Ist quality class (a very good ecological status) (Order 161/2006). The nitrite content was below the detection limit in all the analyzed water samples.

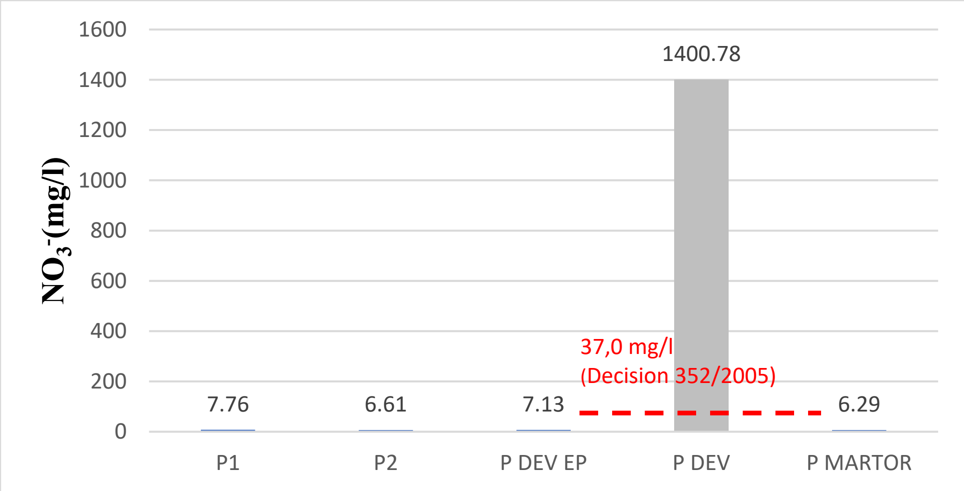

Fig. 5. *Nitrate content in the analyzed water samples*

Correlated with the physical-chemical parameters (table 2), the water pH has not indicated an acidification of the environment as in the case of soil. Even in the water sample with critical nitrate content (P DEV), the pH indicated a neutral feature of the surface water. No significant fluctuation was identified in oxido-reduction conditions, the ORP ranged between -22,1 and +11,2 mV. Except sample P DEV, all the samples indicated similar water quality in terms of electrical conductivity, total dissolved solids, and salinity.

Table 2. *General physico-chemical parameters of the water samples*

Water sample	pH	ORP (mV)	EC (µS/cm)	TDS (mg/l)	Salinity (‰)
P1	7.6	-22.1	243	158	0.0
P2	7.4	-12.3	223	145	0.0
P1 DEV EP	7.3	-5.5	219	142	0.0
P DEV	7.1	+11.2	2106	1398	0.0
P MARTOR	7.3	-7.8	221	144	0.0

CONCLUSIONS

Nitrate compounds under the form of nitrate and nitrite were identified in the soil of the analyzed area. Most of the analyzed soil samples had a $N\text{-}NO_3^-$ content suitable for crops. Only one soil sample proved to have a high nitrate content. The $N\text{-}NO_2^-$ content was correlated with nitrate transformation, and possible leaching into the soil depth. Since agricultural activities are taking place in some parts of the investigated area, it is difficult to indicate the real source of nitrate presence in soil. As a consequence, no direct correlation can be identified between the air emission generated by the fertilizers plant and the nitrate and nitrite content found the soils located in the proximity area.

For water, most relevant samples were represented by the industrial effluent discharging points. One of the industrial effluents had a low content of nitrate, while the second industrial effluent had a high nitrate content, exceeding the limit imposed by Romanian national legislation. However, the high content of nitrate has not generated a decrease of the surface water quality in the Mureș River due to significant dilution upstream and downstream the discharging point. A supplementary investigation is needed to identify if there was an accidental release of contaminant in the river and to identify the remedial measures.

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EVALUATION OF GROUNDWATER QUALITY. CASE STUDY: SEINI CITY, MARAMUREȘ COUNTY, ROMANIA

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ABSTRACT. In the present study, in was investigated the groundwater quality from several private wells located in Seini city, Maramureș County (northwestern part of Romania). The investigated quality parameters were pH, redox potential, electrical conductivity, total dissolved solids, salinity, dissolved ions and heavy metals. The analysis showed that some of the investigated wells had a high content of nitrate, ammonium, and heavy metals. The continuous consumption of water from these sources can be a real threat for consumers' health. The inhabitants should limit as much as possible the usage of water from these wells for drinking purposes and they should use the water from the local distribution network.

Key words: *ground water quality, drinking water, chemical quality parameters*

INTRODUCTION

Water pollution is, by a general definition, a direct or indirect change in its normal composition because of human activity, in such extent that it is affecting all other possibilities to use the water in its natural state. Water pollution involves the biological, physical, and chemical pollution and ultimately leads to changes in the ecological balance.

Generally, groundwater is considered to have a higher quality than surface water. During the time when it passes through the soil and rocks, they can act as a filter for both chemical and bacteriological contaminants (Baldwin and McGuinnes, 1963). Nevertheless, contamination can occur, and there are cases when the consumption of groundwater's can be associated with human health risk. Over the last decade increasing attention has been paid to the population's access to water of adequate sanitation. As it is mentioned in the Resolution no. 64/292 of the UN General Assembly, "the right to safe and clean drinking water and sanitation is a human right essential for a normal life and the exercise of all human rights" (Neamțu et al., 2017).

The present paper presents the study regarding the groundwater assessment in the city of Seini, Maramureș County. The water samples used in the study were taken from ten different private wells from the city.

STUDY AREA

The territory of Seini is located in the western part of Maramureș County, at a distance of 26 km from Baia Mare and 41 km from Satu Mare (Seini, 2021) (figure 1). Predominantly on the territory of the city are the luvosols and eutricambosols, which occupy more than half of the territory (Hotima et al., 2018). The climatic regime of Seini city is characteristic of Maramureş county, framed in the continental-temperate climate sector, with cold winters and long and hot summers. The proximity of the mountainous area gives a moderate thermal regime, with relatively high humidity and rich atmospheric precipitation. Air temperatures record annual values between -1°C and +9°C. The annual amount of precipitation is between 700 and 1.400 mm (Hotima et al., 2017).

The inhabitants use the water from their private wells, which are generally shallow wells, having 6 to 8 m in depth and the water from the network system, which undergoes a chlorination treatment (ANPM, 2021).

In figure 2 it is presented the sampling network used to evaluate the groundwater in the city of Seini, Maramureș County. The main objective of this study is to assess the quality of groundwater in ten private wells, located in the city of Seini (Maramureș County). The monitoring and evaluation of the well water quality were performed by analyzing certain chemical quality parameters regulated in the national legislation (Law no. 458 from July 8, 2002). The water samples were collected on October 18-19, 2020.

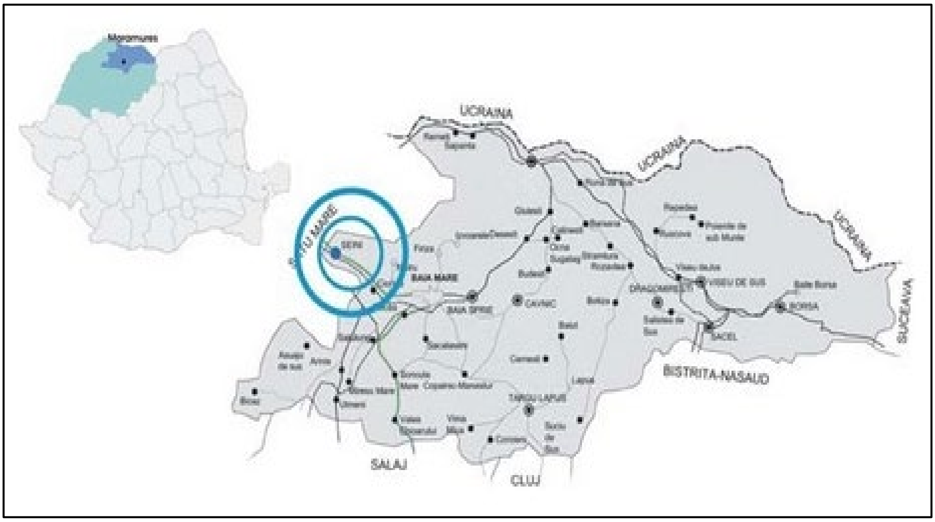

Fig. 1. *Geographical location of the city of Seini (Seini, 2021)*

Fig. 2. *Study area (Seini City, Maramureș County) with sampling points location*

MATERIALS AND METHODS

Water samples were taken from the wells of 10 families at considerable distances from each other (from all parts of the city). It should be mentioned that the wells from where the samples were taken are located in people's yards, the only exception is the sample A2, which is a fountain located in an access area for everyone.

The multiparameter WTW multi350i was used to measure the general physico-chemical parameters: pH, redox potential (ORP), electrical conductivity (EC), total dissolved solids (TDS), and salinity. The dissolved anions (F^-, Cl^-, Br^-, NO_3^-, NO_2^-, SO_4^{2-}, PO_4^{3-}) and cations (Li^+, Na^+, K^+, NH_4^+, Ca^{2+}, Mg^{2+}) were analyzed with ion chromatography, using the IC DIONEX 1500 system. Heavy metals (Ni, Cd, Cr, Pb, Zn, Cu, Fe, Mn) were analyzed by flame atomic absorption spectrometry, by using an AAS ZEEnit 700 Analytik Jena system.

RESULTS AND DISCUSSIONS

In table 1 there are presented several general aspects regarding the depth, age, or the proximity of possible pollution sources of the investigated wells.

Table 1. *General aspects regarding the investigated wells*

Well no.	Depth (m)	Age (years)	Chemical treatment	Possible pollution sources in proximity	Usage purposes
A1	4-5	>50	No chemical treatment	No possible pollution source	Human and animal consumption
A2	4	>200		Animal stable	human and animal consumption
A3	6-7	100		Toilet	Irrigation
A4	12	>100		Gardens with flowers	Irrigation
A5	3-4	>10		Vegetables garden	Irrigation
A6	10	80		Animal stable, green house	Irrigation and animal consumption
A7	10	>100		Animal stable	Irrigation and animal consumption

Well no.	Depth (m)	Age (years)	Chemical treatment	Possible pollution sources in proximity	Usage purposes
A8	5-10	>70		No possible pollution source	Human consumption
A9	5-6	15		Toilet (at a distance of 15 m)	Irrigation and animal consumption
A10	10	>50		Toilet (at a distance of 15 m)	Human and animal consumption

Interpretation of data and the determination of exceeding the maximum permitted concentrations were made using the legislation in force; for the quality of drinking water is Law no. 458/2002. As it can be seen in figure 3, all the physico-chemical parameters were within the maximum permissible limits. The pH presented values within the minimum and maximum limits (6.5 – 9.5), allowed according to Law no. 458 of July 8, 2002. The electrical conductivity showed values far below the maximum allowed limit (2500 µS/cm) and the total dissolved solids showed values below the WHO recommendations (500 mg/l) (CG, 2021).

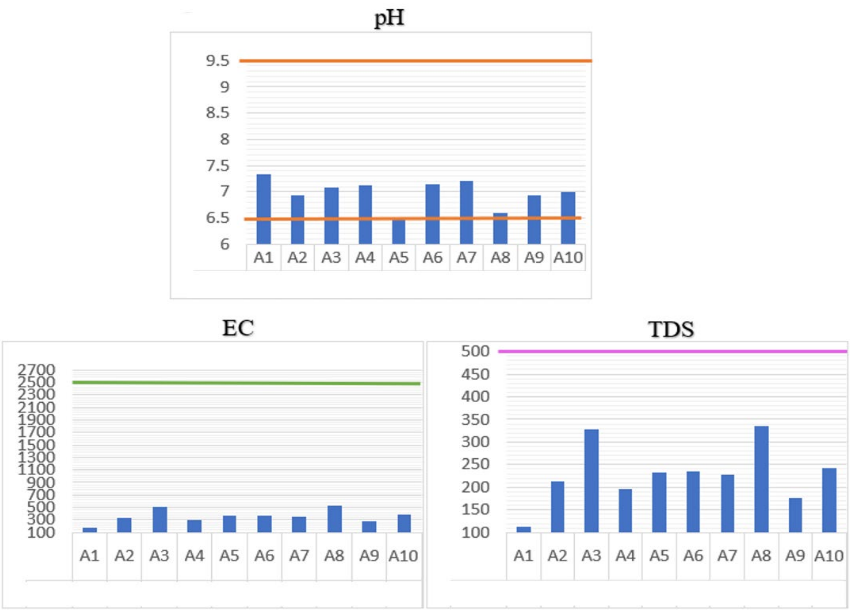

Fig. 3. *The values of pH, electrical conductivity (EC) (µS/cm) and total dissolved solids (TDS) (mg/l) compared to the limits imposed by national legislation (Law 458/2002 for pH and EC) and the WHO recommendations (for TDS)*

Generally, the content of the analyzed dissolved ions was within the safe limit for human consumption (figure 4). Still, in the case of A3 and A5 samples, the content of nitrate and ammonium were higher than the permissible

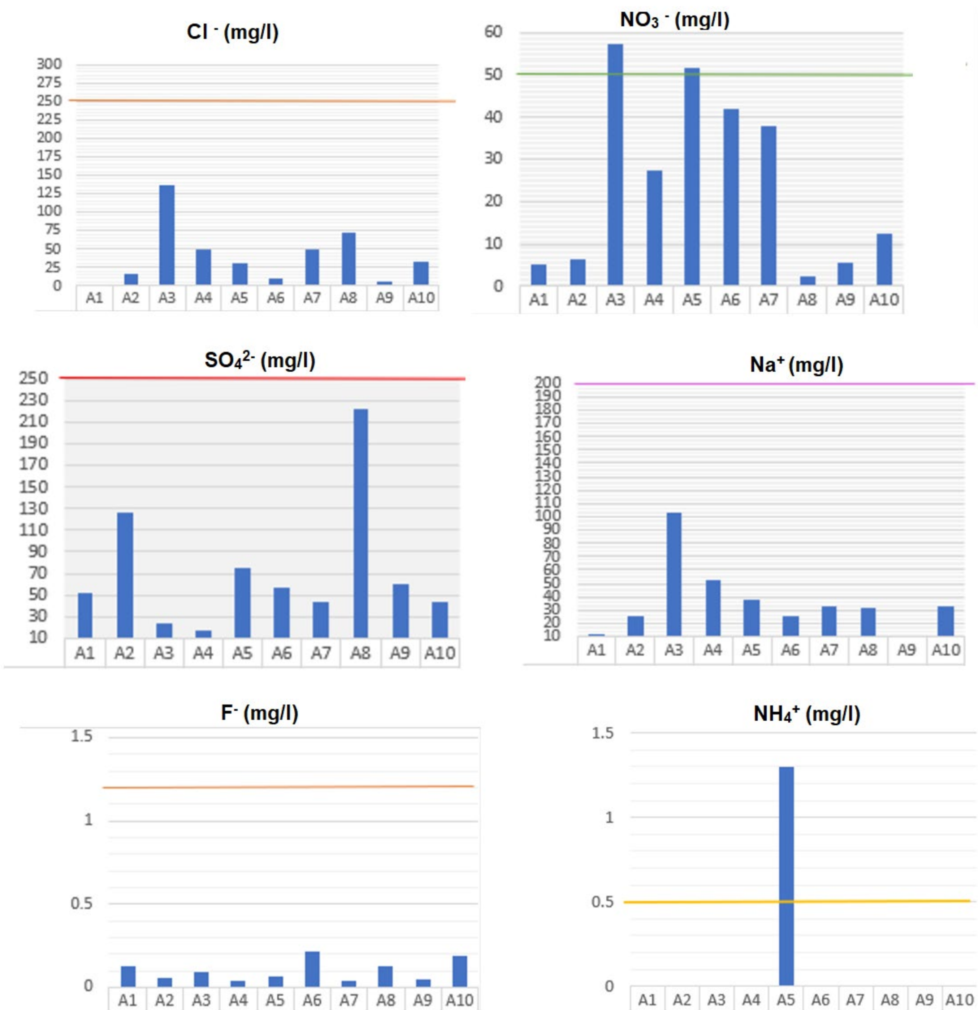

Fig. 4. *Ions content in the analyzed wells versus the maximum permissible limits imposed by national legislation (Law 458/2002)*

limits. The well A5 had the lowest depth (3-5 m) which can indicate a high vulnerability to anthropic pollution. Furthermore, the high content of nitrate from well A3 can be correlated with the presence of a toilet in proximity. The presence of nitrates in water is very dangerous, having the greatest effect on infants. Acute infantile methemoglobinemia, a condition also known as acute nitrate poisoning or the blue sickness of newborns, is the first consequence of the consumption of well water polluted with nitrogenous substances by children in the age range of 0-1 years, water used in the preparation milk powder (Iacob et al., 2012). This nitrogen excess generally moves through the soil into groundwater or is carried by precipitation into surface water. Some natural degradation may occur, for example denitrification. Other sources of nitrates are sewage, sewage treatment plants, private septic systems, manure, and leguminous crops (Kross, 2002).

Chlorine showed concentrations in the range of 2-138 mg/l, being below the maximum allowed limit (250 mg/l), according to Law no. 458 of July 8, 2002. The highest concentration was found in area A3, 137 mg/l, this well, being located in the center of Seini. The concentration of SO_4^{2-} showed values in the range of 23-223 mg/l, being below the maximum allowed limit (250 mg/l), according to Law no. 458 of July 8, 2002. The highest value was found in sample A8, but it is kept below 250 mg/l, so there is no cause for concern. The concentration of Na^+ showed values in the range of 11-103 mg/l, being below the allowed limit value (200 mg/l), according to Law no. 458 of July 8, 2002. The highest value was recorded in sample A3 (103 mg/l). The F^- concentration showed values between 0.04 and 0.22 mg/l, being below the maximum permissible limit (1.2 mg/l) (Law 458/2002). The highest value was recorded in sample A6 (0.22 mg/l).

The analyzed wells proved to have a low level of Cu, Cd, Pb and Zn, being within the safe limit for human consumption (figure 5). Lead was not detected in any of the analyzed samples.

On the other hand, the iron (Fe) concentration was above the maximum allowed limit for the majority of the analyzed samples (figure 5). The increased amount of iron worsens the taste, facilitates the development of iron bacteria and the continuous consumption of water with a high content of iron can lead to health negative effects such as the development of liver diseases, allergic reactions, etc. (Ciobanu, 2009). The high iron content from wells can be correlated with natural sources, the presence of minerals rich in iron from the background.

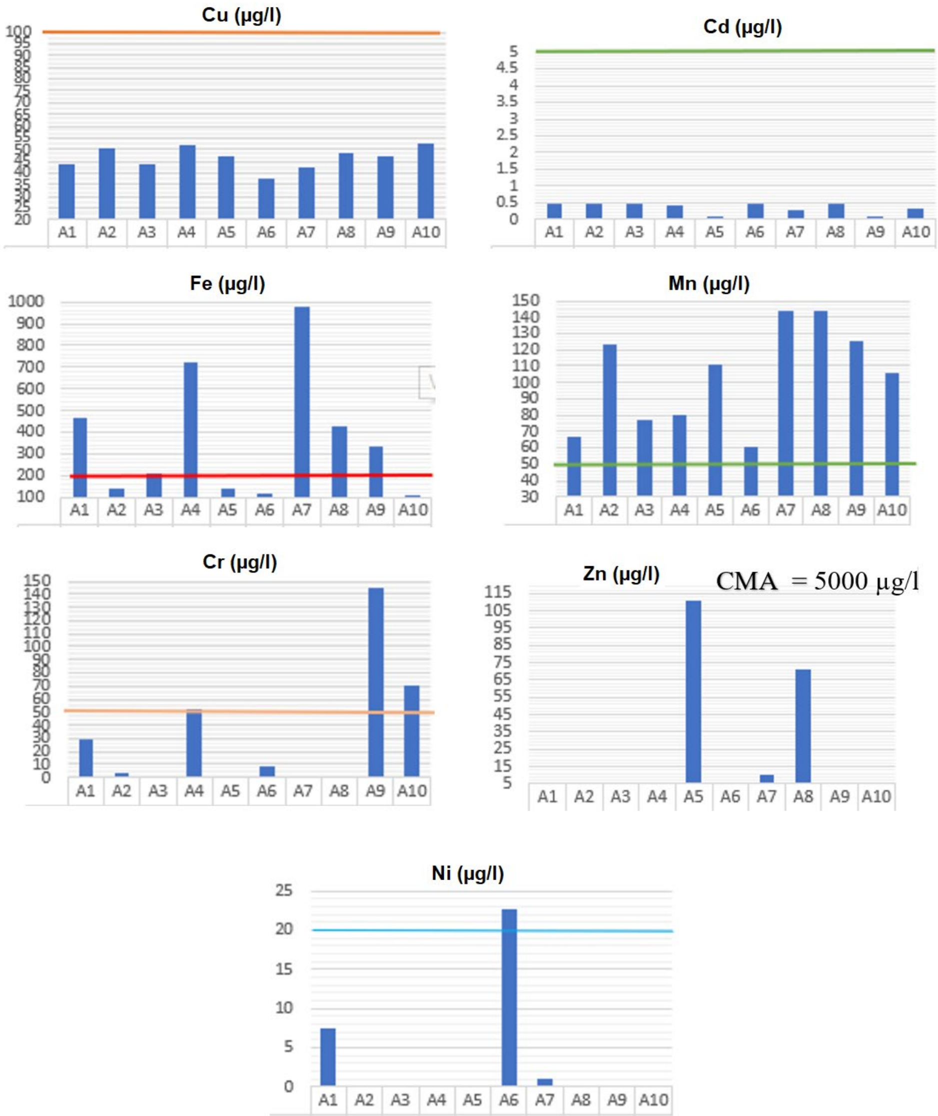

Fig. 5. *Heavy metals content in the analyzed wells versus maximum permissible limits imposed by national legislation (Law 458/2002)*

All the investigated wells had a high content of manganese, exceeding the safe limit imposed for human consumption (figure 5). Manganese concentration showed values in the range of 60-144 μg/l, far above the maximum allowed limit (50 μg/l) (Law 458/2002). The presence of high Mn levels in ground water can be associated with natural sources, like the presence of rocks rich in manganese minerals. Also, high concentrations of manganese can cause problems with memory, attention, and motor skills (MDH, 2021).

The chromium (Cr) was detected only in six samples, three of them being above the maximum allowed limit. The samples that exceeded the limit are A4, A9 and A10. Excessive consumption of water with high content of chromium can cause digestive problems, hypoglycemia, and damage the liver, kidneys, and heart.

Nickel had a low level, except for sample A6 where the maximum permissible limit was exceeded. Continuous consumption of water with high nickel content can lead to negative impact causing lung tissue disease with the slow development of malignant formations, teratogenic effects, such as exencephaly, fragility of the ribs and decomposition of the soft palate (Purici, 2013).

The presence of high levels of heavy metals in the investigated wells cand be associated with the anthropogenic activities from the area, namely the former metallurgical activities.

CONCLUSIONS

Considering the high content of nitrate, ammonium and heavy metals, the continuous consumption of water from these sources can be a real threat for consumers' health. The inhabitants should limit as much as possible the usage of water from these wells for drinking purposes and they should use the water from the local distribution network.

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OCCURRENCE, AND SOURCES OF PERSISTENT ORGANIC POLLUTANTS IN UPPER URBAN SOIL OF CLUJ-NAPOCA, ROMANIA

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ABSTRACT. Most persistent organic pollutants (POPs) were made for specific purposes due to certain characteristic and properties. They can cause various diseases and are problematic for the environment due to their high persistence and toxicity. This study attests the presence of three classes of POPs namely polycyclic aromatic hydrocarbons (PAHs), organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs) in the upper urban soils of Cluj-Napoca, Romania. Soil samples were collected from 10 sampling points areas with heavy traffic. For determination of the compounds, gas chromatography coupled with mass spectrometry and with electron capture detector was used. The obtained results indicate a low level of pollution, the concentrations ranging between 8.83–184.92 ng/g for PAHs, 5.36–112.35 ng/g for PCBs, and 25.96–334.83 ng/g for OCPs. To identify the pollution emission sources, different PAHs and OCPs diagnostic ratios have been applied.

Key words: *persistent organic pollutants, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, organochlorine pesticides, upper urban soil*

INTRODUCTION

Around half of the world's population lives in urban areas, and by 2050, an increase to 68.7% is expected (Luo et al., 2012). Anthropogenic pollution has been created by human society due to industrialization, urbanization and transportation (Orazi et al., 2020).

Persistent Organic Pollutants (POPs) are ubiquitous compounds that have caused concern worldwide, and for almost one hundred years, they have been produced and used for various industries and agriculture. They represent a serious negative impact in a series of adverse effects on both human and environmental health (Barakat et al., 2013).

An important factor for both humans and environment is the soil, having many functions: bio-chemical transformations, the cycle of elements, water filtration, support for plants, infrastructure and for recreational activities (Metfaul et al., 2020). In this regard, in the global cycle of persistent organic pollutants (storage, redistribution, transfer), soil has a significant role, the organic matter being the "sink" of POPs in the soil matrix and in the same time it is the secondary source of POPs too, due to natural phenomena, being carried by the winds, reaching very large distances from their initial area (Ma et al., 2011).

Among the classes of persistent organic pollutants, the most commonly found are polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs). They are most often of anthropogenic nature, and their toxicity is attested by their inability to biodegrade, semi-volatile nature and by the fact that they are carried over very long distances, they can bioaccumulate and biomagnify in adipose tissues (Pokhrel et al., 2018).

PCBs, considered "legacy POPs" are a group of 209 compounds, each having between 1 and 10 chlorine atoms grafted onto the structure, called congeners, and depending on the position and number of chlorine atoms they can present different toxicity and physico-chemical properties. They are considered human carcinogens, endocrine disruptors, and neurotoxins and can negatively affect human and ecosystems health (Wang et al., 2017; Jafarabadi et al., 2019; Bartlett et al., 2019). PCB congeners: PCB-77, -81, 105, -114, -118, -123, -126, -156, -157, -167, -169 and -189 presents a level of toxicity comparable to that of dioxins (Saija et al., 2016).

Organochlorine pesticides are also a part of the persistent organic pollutant category. Some OCPs compounds have been included in the “dirty dozen” list of the Stockholm Convention from 2001. The representatives have decided to take all measures necesary to reduce, to eliminate, and to stop the production of aldrin, chlordane (CHL), dieldrin, endrin, heptachlor, dichlorodiphenyltrichloroethane (DDT), hexachlorobenzene (HCB), mirex and toxaphene. Hexachlorocyclohexane (HCH) was also added later, along with the isomers α-HCH, β-HCH, γ-HCH (Saija et al., 2016; Bandow et al., 2020). OCPs have been used in industry, agriculture and pest control (Joseph et al., 2020; Yu et al., 2020; Neves et al., 2018). Following continuous exposure to OCPs, endocrine, reproductive and nervous system dysfunctions were observed (Joseph et al., 2020;).

PAHs form a group of ubiquitous and persistent toxic organic pollutants with mutagenic and carcinogenic potential, consisting of two or more condensed benzene nucleus with various structures (Wang et al., 2020; Orazi et al., 2020; Neroda et al., 2020). They can be divided into two categories: PAHs with low molecular mass (LMW) containing between 2 and 4 aromatic rings, which are volatile, and those with high molecular mass (HMW) having between 4-6 aromatic rings, being generally found in solid form (Orazi et al., 2020). The most well known are: 2 rings: Naphthalene (Nap), 3 rings: Acenaphthylene (Acy), Acenaphthene (Ace), Fluorene (Fle), Anthracene (An) and Phenanthrene (Ph), 4 rings: Fluoranthene (Flu), Pyrene (Pyr), benz [a]anthracene (BaA), and Chrysene (Chr), 5 rings: Benzo[b]fluoranthene (BbF), Benzo[k]fluoranthene (BkF), Benzo[a]pyrene (BaP), and Dibenz[a,h]anthracene (DahA), 6 rings: Benzo[ghi]perylene (BghiP) and Indeno[1,2,3-cd]pyrene (Ind) (Neroda et al., 2020).

PAHs can result from anthropogenic activities (burning of gasoline, coal, wood and waste, use of oils) and natural activities (forest fires, volcanic eruptions, oil spills, the activity of microorganisms) (Wang et al., 2020). The majority of PAHs are of pyrogenic origin, formed following the thermal decomposition and recombination of organic molecules (pyrolysis and pyrosynthesis), and petrogenic origin formed during the oil maturation process, at low temperatures (Neroda et al., 2020).

Over time, countless studies have been developed on the soils of rural or industrial areas (Croes et al. 2012; Pozo et al. 2012; Wong et al.2009). The tendency was to analyze areas that already had a history of using specific pesticides, or industrial areas whose processes lead to the production of residues with a high content of PCBs. This is how the need to analyze urban soils appeared, to be able to get an idea about the areas where there is no intensive agriculture and no industry at a high level (Pokhrel et al., 2018; Yu et al., 2020).

However, regarding the evaluation of urban soil pollution in Romania, few studies have been done (Covaci et al., 2001; Preda et al., 2011; Tarcau et al., 2013; Ivanescu, 2015). Therefore, this study aims to evaluate the prevalence of persistent organic pollutants (PAH, PCB, POC) in the upper soil within the area of Cluj-Napoca, as well as to identify the sources of POPs pollution in urban environment.

MATERIALS AND METHODS

Chemicals and reagents

In this study, standard mixtures of different types of POPs have been used for qualitative and quantitative analysis. EPA CLP Organochlorine Pesticide Mix (2000 µg/mL in hexane:toluene (1:1 *v/v*)) containing 20 compounds: Tecnazene, α-HCH, Hexachlorobenzene, γ-HCH, Quintozene, Heptachlor, Aldrin, Heptachlor exo-epoxide, Heptachlor endo-epoxide, Trans-Chlordane, 2,4′-DDE, α-Endosulfan, Cis-Chlordane, Dieldrin, 4,4′-DDE, 2,4′-DDD, Endrin, β-Endosulfan, 2,4′-DDT, 4,4′-DDT was provided by Supelco (Merck Romania SRL, Bucharest, Romania). A mix of 12 PCB congeners (10 µg/mL, in heptane): PCB-18, -28, -31, -52, -44, -101, -114, -149, -153, -138, -180, -194 was obtained from Supelco (Merck Romania SRL, Bucharest, Romania). CRM EPA Method 8310 PAH Mixture (500 µg/mL, in acetonitrile:toluene mixture (92:8 *v/v*)), containing a number of 16 compounds such as: Naphthalene (Nap), Acenaphthylene (Acy), Acenaphtene (Ace), Fluorene (Fle), Phenanthrene (Phe), Anthracene (An), Fluoranthene (Flu), Pyrene (Pyr), Benz[a]anthracene (BaA), Chrysene (Chr), Benzo[b]fluoranthene (BbF), Benzo[k]fluoranthene (BkF), Benzo[a]pyrene (BaP), Dibenz[a,h]anthracene (DahA), Benzo[g,h,i]perylene (BghiP), and Indeno[1,2,3-cd]pyrene (Ind) was purchased from Restek (Restek Corporation, Bellefonte, United States). Silica, alumina, granular anhydrous sodium sulphate (Merck, Germany), copper of 99.5% purity (Sigma-Aldrich, Merck, Germany) were used. The reagents used in the analysis were acetone, acetonitrile, dichloromethane, and hexane, acquired from Merck (Germany).

Sample collection

The city of Cluj-Napoca is located in the central area of Transylvania, in the basin of Someșul Mic, in northwestern Romania. At the beginning of March 2020, 10 soil samples were collected from the upper soil layer (0-20 cm). To minimize sampling errors, each sample was a mix of 5 other smaller samples from an area of 1x1 m^2. A metal scoop was used for collection, and soil samples were stored in clean zip-lock plastic bags, transported to the laboratory and stored at 4°C until extraction. The location of each sample and each point it was collected from and geographical coordinates is shown in table 1.

Table 1. *Location of sampling points*

Sample Code	Sample Descriptor	GIS Coordinates
S1	Fany bus station	46°47’06.5”N; 23°34’55.2”E
S2	Bio-Nano-Science Institute	46°47’47.1”N; 23°36’15.8”E
S3	Iulius Mall park	46°46’22.7”N; 23°37’33.0”E
S4	Expo Transilvania park	46°46’53.2”N; 23°37’58.5”E
S5	Botanical Garden Alexandru Borza	46°45’45.3”N; 23°35’19.5”E
S6	Faculty of Environmental Science and Engineering	46°46’04.7”N; 23°32’59.5”E
S7	Str. Calea Florești	46°45’25.3”N; 23°32’36.4”E
S8	Unirii Square	46°46’11.0”N; 23°35’22.4”E
S9	Str. Observator	46°45’21.8”N; 23°35’46.2”E
S10	Mărăști square	46°46’42.9”N; 23°36’51.4”E

Sample preparation

The collected soil samples were left at room temperature for 24h to dry, the plant remains were removed and then they were grated. For the extraction of target compounds, 8 g of soil sample were spiked with 100 ng mixture 1 (Naphthalene-d8, Anthracene-d10, Fluoranthene-d10 and Perylene-d12) and 20 ng PCB-30 followed by the addition of 30 mL mixture of acetone:*n*-hexane (1:1, *v/v*), and ultrasonicated for 20 minutes. The sample was subjected to centrifugation for 5 minutes (3000 rpm) and the supernatant was collected. The extraction procedure was repeated 2 more times with fresh solvent mixture. The three extracts collected were combined and left overnight with 1 g of copper for desulphurization. The following day, 10 mL of *n*-hexane was added, the copper was removed by decantation and the resulting extract was concentrated to approximately 2 mL via rotary evaporation, and subjected to the purification procedure, (Barhoumi et al., 2019).

A purification column (from top to bottom) consisting of 1 g anhydrous sodium sulfate, 4 g of activated alumina, and 4 g silica gel was used. The column was conditioned with 20 mL of hexane, after which the sample is loaded into the column. The compounds (PAHs, PCBs, OCPs) are eluted from the column with 20 mL of hexane and 40 mL of a mixture of *n*-hexane:dichloromethane (80:20, *v/v*). The obtained fraction is concentrated on a rotary evaporator to 1-2 mL, then spiked with 100 ng of PAHs multistandard mixture (IS2) (Acenaphtene-d10, Phenanthrene-d10 and Chrysene-d12) and 20 ng of PCB-155 and evaporated to dryness under a stream of nitrogen. The residue is redissolved with 300 µL of *n*-hexane:dichloromethane (80:20, *v/v*), and the resulting sample is analyzed by GC-MS, respectively GC-ECD.

For the quantification of OCPs and PCBs, PCB-30 and PCB-155 were used as internal standards. As for PAHs, a deuterated standard (IS1) to assess the extraction recovery and another one (IS2) containing 3 deuterated compounds for quantitative analysis of PAHs respectively.

Instrumentation

For the determination of polycyclic aromatic hydrocarbons, the obtained extracts were analyzed by gas chromatography coupled with mass spectrometry using a GC-MS with an autosampler (Thermo Eletron Corporation DSQII; Focus GC; TriPlus Autosampler). X-Calibur software was used for the acquisition of data. The separation was performed on a TR-5 MS column (30 m x 0.25 mm x 0.25 μm i.d.) starting from initial temperature of 60°C with a temperature gradient of 10°C/min up to 130°C and 3°C/min up to 300°C. The temperature of the ionization source was 200°C, the transfer line 300°C, and the injector temperature 310°C, the ionization current was 70 eV. Selected ion monitoring (SIM) mode was used for data acquisition. The injection volume was 1 μL, splitless, with helium as carrier gas at a constant flow of 1.2 mL/min.

For OCPs and PCBs, the analysis was performed by GC-ECD, using a gas chromatograph model Trace GC equipped with a ^{63}Ni electron capture detector, and a TriPlus Autosampler (Thermo Electron Corporation). Acquisition of data was performed using Chrom-Card software. The separation was carried out on a capillary column model HP-5MS (30 m x 0.25 mm i.d., 1.0 μm film thickness, Agilent). The gradient temperature program was 70°C to 180°C at a rate of 25°C/min, from 180 to 200°C at 1°C/min, from 200 to 260°C at a rate of 2°C/min, and from 260 to 300°C at 5°C/min with a holding time of 5 min at 300°C. The carrier gas was nitrogen with a constant flow rate of 2 mL/min. The temperatures of the injector and detector were set at 270°C and 300°C. Identification of OCPs and PCBs compounds was made on the retention time of the standard mixtures.

RESULTS AND DISCUSSIONS

PAH concentrations in soil samples

Throughout the 10 analyzed samples, we detected all the compounds. The richest sample in PAHs is S10, where we had a total PAHs concentration of 126.53 ng/g, being the only sample out of the 10, in which we found all the compounds from the standard list. There were 3 samples that lacked in PAHs diversity, namely S2, S3, S6, which only had 12 out of the 16 standard compounds present.

The sample with the highest concentration was S7 with 184.92 ng/g, while S8 is the second one with 178.71 ng/g. Both of them are situated very close to the most circulated roads from Cluj-Napoca, so that might be the best way to explain these values. The lowest concentration found was in sample S5, with 8.83 ng/g, sample which was taken from the botanical garden. The low value compared to the other samples is obvious, because the botanical garden represents an area with high vegetation, containing plants which are beneficial for the air quality improvement (table 2).

The PAH diagnostic ratios were applied for the identification of their sources. Ratios of ΣLMW/ΣHMW (sum of PAH with LMW and sum of PAH with HMW) were calculated, and it appears that petroleum is the source in all analyzed samples (figure 1). If the ΣLMW/ΣHMW ratio is greater than 1 the source is petrogenic (fossil fuels, oil and coal), and if the ratio is less than 1, the source is pyrogenic (combustion processes and volcanoes) (Zhang et al., 2008).

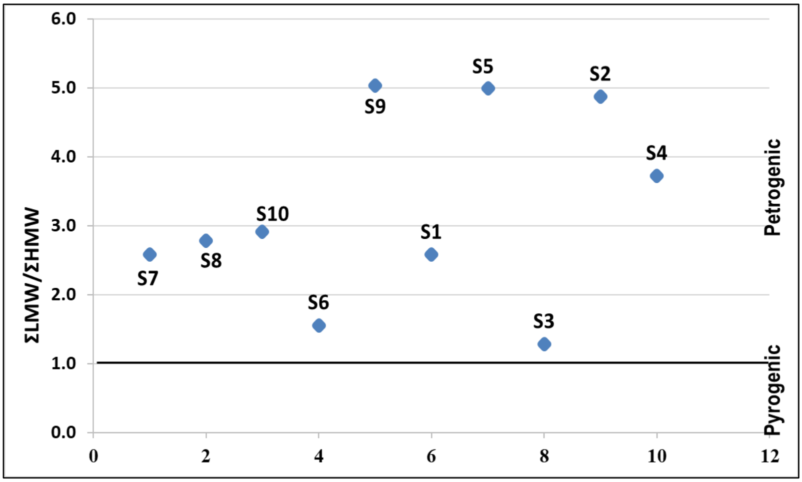

Fig. 1. *Isomeric ratios of ΣLMW/ΣHMW*

Secondly, the results from the An/(An+Ph) ratio had a value under 0.1 which usually indicates a petrogenic source, and greater than 0.1, a pyrogenic nature. A ratio of Flu/(Flu+Pyr) below 0.4 indicates a petrogenic source, ratios between 0.4 and 0.5 are more characteristic to fossil fuels combustion and greater than 0.5 indicates grass/wood/coal combustion (Orazi et al., 2020). These values can be explained by the fact that BbF and Ind are markers for diesel engines, and for gasoline engines, Ind, Ph, Flu, Pyr and An are specific markers of coal and biomass combustion, and Nap results mainly from incomplete combustion (Zhang et al., 2008; Orazi et al., 2020).

From the ratios of An/(An+Ph) and Flu/(Flu+Pyr) the results suggest that the PAHs present at samples S8 and S2 are of pyrogenic nature, S10, S3, and S6 are from combustion of fossil fuels, S1, S7, S5, and S4 are from combustion of petroleum, coal, biomass, and the sample S9 is of petrogenic source (figure 2).

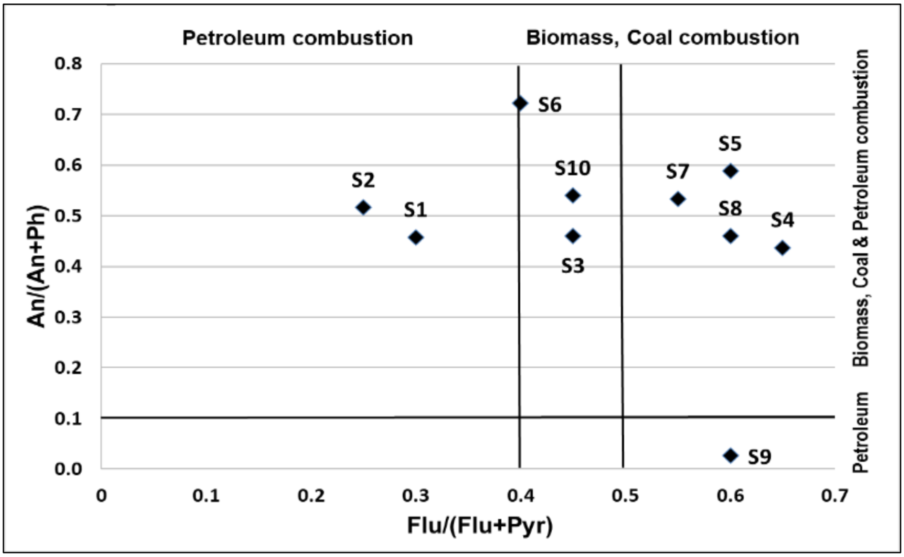

Fig. 2. *Isomeric ratios of An/(An+Ph) versus Flu/(Flu+Pyr) in soil samples*

Table 2. *Concentrations of polycyclic aromatic hydrocarbons (ng/g soil) in different sampling points*

Compound	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Nap	27.52	20.60	3.23	24.40	0.97	26.13	12.04	13.19	20.30	21.01
Acy	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.24
Ace	0.88	nd	nd	nd	0.10	nd	2.14	2.14	1.19	0.28
Fle	0.31	0.94	0.32	0.31	0.48	0.10	5.25	3.69	1.13	0.89
Ph	25.90	29.33	12.76	5.22	4.00	2.28	51.21	44.96	18.84	39.49
An	11.10	9.78	10.44	9.69	6.00	1.52	62.59	67.44	28.26	32.31
Flu	7.92	1.93	2.32	1.22	1.66	0.10	7.38	15.89	0.06	15.18
Pyr	9.40	1.81	2.72	1.57	0.64	0.07	6.46	18.66	2.22	12.95
Chr+BaA	0.21	0.04	0.28	0.08	0.85	0.19	4.93	8.74	0.07	1.77
BbF + BkF	0.13	0.15	0.38	0.21	0.15	0.04	0.95	1.92	0.42	1.72
BaP	7.74	8.45	15.11	7.29	0.09	6.85	22.81	0.17	10.25	0.25
BghiP	nd	nd	nd	nd	nd	nd	7.50	1.47	0.69	0.10
Ind	0.04	nd	0.05	0.25	0.04	nd	1.39	0.29	0.08	0.02
DahA	0.05	0.07	nd	0.02	0.01	0.01	0.24	0.19	0.07	0.38
Total PAHs	91.18	73.14	47.59	50.28	8.83	43.51	184.92	178.71	83.61	126.53
LMW/HMW	2.58	4.87	1.28	3.72	4.99	1.56	2.58	2.78	5.03	2.91
An/(An+Ph)	0.3	0.25	0.45	0.65	0.6	0.4	0.55	0.6	0.6	0.45
Flu/(Flu+Pyr)	0.46	0.52	0.46	0.44	0.59	0.72	0.53	0.46	0.03	0.54

nd- not detected

PCBs concentrations in soil samples

From all of the analyzed samples, the highest PCBs values were PCB-31 (nd–39.63 ng/g), PCB-44 (nd–27.14), and PCB-52 (nd–47.65). These three were abundant in all samples in comparison to the other PCBs from the standard. PCB-101 and PCB-114 were undetectable in any of the analyzed samples.

There were three samples that had the highest concentrations of PCBs: S4 (112.35 ng/g); S10 (106.48 ng/g); and S3 (79.28 ng/g), all of them being close to one another (distances of hundreds of meters between them). The best explanation for these values could be their positions and that there are industrial emissions from the nearby production of electronic equipment's, since this area is relatively close to the industrial parks like Tetarom 2 and Emerson. Meanwhile, the samples with the lowest concentrations were S7 (5.36 ng/g), S1 (12.31 ng/g), and S2 (31.21 ng/g) (table 3).

Low molecular weight PCBs are used in transformers, capacitors, and lubricants and high molecular weight PCBs are commonly used in paints and plasticizers (Xu et al., 2019). This suggest that the PCBs found in this study are from plastic or paint manufacturing and from electrical capacitors. To understand the extent of PCBs pollution, more information is needed due to the small number of PCBs and samples analyzed, requiring more detailed studies in the future.

Table 3. *The concentrations of polychlorinated biphenyls (ng/g soil) found in different sampling points*

Compound	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
PCB-18	1.22	nd	7.80	22.23	nd	nd	nd	nd	nd	19.29
PCB-31	1.21	11.78	20.20	18.39	12.01	nd	1.29	nd	14.76	39.63
PCB-28	0.87	7.37	5.14	5.90	nd	nd	0.70	10.44	7.40	7.60
PCB-44	1.54	7.59	15.43	4.97	8.84	nd	nd	21.12	21.17	27.14
PCB-52	nd	nd	3.56	47.65	19.10	13.73	0.97	7.44	3.29	8.90
PCB-101	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
PCB-114	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
PCB-149	nd	nd	nd	nd	nd	12.25	0.76	0.42	nd	0.27
PCB-153	5.60	1.58	24.90	10.58	10.52	4.27	0.05	9.72	1.75	2.12
PCB-138+180	1.10	0.91	0.85	0.47	0.43	3.92	0.87	1.68	0.47	0.92
PCB-194	0.77	1.95	1.41	2.17	0.84	3.40	0.73	2.48	0.31	0.60
∑PCBs	12.31	31.21	79.28	112.35	51.74	37.58	5.36	53.29	49.15	106.48

nd- not detected

OCPs concentrations in soil samples

Twenty-one organochlorine pesticides were determined in the analyzed samples with a concentration of total OCPs ranging from 58.24 ng/g soil in sampling point S2 to 334.83 ng/g soil in sampling point S6. The most encountered compounds were 4’4-DDT (nd-88.28 ng/g soil), α-HCH (2.65-47.10 ng/g soil) and Heptachlor-exo-epoxide (1.17-43.34 ng/g soil), with the highest values being found in samples S6 and S4 (table 4). Other compounds with high concentrations were HCB (1.32-54.68 ng/g soil) and Heptachlor (0.69-25.07 ng/g soil), the highest values being found in S10 and S4 for HCB and S4 and S5 for heptachlor. The least encountered compounds were β-endosulfan (9.22 ng/g soil), 2’4-DDE (1.02 ng/g soil), and Heptachlor-endo-epoxide (0.24 ng/g soil), each being found only in one sample, β-endosulfan and Heptachlor-endo-epoxide in S9, and 2’4-DDE in S8. Methoxychlor, 2’4-DDT, and α-Endosulfan were not detected in any of the samples.

For a better estimation of the type of OCPs used, the analyzed compounds were divided as follow: HCH residues (*α*- and *γ*-HCH); DDT residues (2*,*4`-DDT, 4*,*4`-DDT, 2*,*4`-DDD, 4*,*4`-DDD, 2*,*4`-DDE, Methoxychlor); Endosulfan residues (*α*- and *β*-Endosulfan); Chlordane related compounds residues (*cis*-Chlordane *(CC)*, *trans*-Chlordane (TC), Heptachlor and Heptachlor Epoxide) and Cyclodiene pesticides residues (Aldrin, Dieldrin, Endrin).

α-HCH (2.65–47.10 ng/g) was found in all analyzed samples and γ-HCH isomer was only found in two samples (S1 and S6) indicating the use of the HCH technical mixture instead of pure lindane (γ-HCH). HCB (1.32–54.68 ng/g) was also found in all analyzed samples, indicating their use together as technical HCH.

Aldrin was used to control pests, and following the transformation processes it transforms in Dieldrin (Meftaul et al., 2020; Joseph et al., 2020). Concentrations of Aldrin were found in S10 (5.33 ng/g), S8 (6.23 ng/g) and S9 (5.15 ng/g), and Dieldrin in S3 (20.50 ng/g), S6 (84.37 ng/g), S7 (1.00 ng/g) and S8 (6.43 ng/g). Endrin was detected in samples S9 (1.13 ng/g) and S6 (10.43 ng/g), indicating historical pollution.

Due to the very low rate of degradation and persistence of 4,4-DDT, 4,4-DDE and 4,4-DDD which are its metabolites are usually identified together in the analyzed samples. A possible route of exposure is construction materials that contain and gradually release these substances in the environment (Bandow et al., 2020). 4,4-DDT was detected in almost all samples, missing only from sample S2, with values between 0.81–88.28 ng/g soil, while 2,4-DDT was not detected in any of the samples. 2,4-DDD (nd–20.55 ng/g soil) was prevalent, missing only from one sample, namely S6. 4,4-DDD (nd–33.97 ng/g soil) was found only in four samples, S3, S6, S7 and S10. 2,4-DDE could only be found in one sample, S8 with a value of 1.02 ng/g soil.

Four ratios were calculated to identify the sources of OCPs such as: ΣDDTs/ΣHCHs, α-HCH/γ-HCH, (DDE + DDD)/ΣDDTs, and CC/TC (Hitch and Day, 1992; Lee et al., 2001; Jiang et al., 2009; Sultana et al., 2014) (table 5).

The results from the first ratio, ΣDDTs/ΣHCHs, are used to determine which if the important source of OCPs, and mainly to establish the dominance of DDTs or HCHs. A ratio value higher than 1 reflects a long term usage of DDTs, while a value lower than 1 approves the use of HCHs (Barhoumi et al 2019). Values under 1 were found in three out of ten samples, respectively in S2, S8, and S9.

The ratio of α-HCH/γ-HCH can be used as an indicator of the source of HCH but also to determine the history of HCH use. If the result of the α-HCH/γ-HCH ratio is closer to 0, it attests a presence of a higher amount of lindane (γ-HCH) in the sample. Between the values of 1 and 3, it may indicate that the input of HCH was a mixture of technical HCH and lindane. If the value is greater than 4, it means that technical HCH is predominant (Law et al. 2001). In the case of this study, there are only two samples in which we could find γ-HCH, so the value of this ratio could only be established for two samples, S1 (4.32) and S6 (9.27), from both resulting values that attest the use of technical HCH instead of lindane.

(DDE + DDD)/ΣDDTs ratio is mostly used to determine the source of DDTs. If the ratio result is greater than 0.5, then a historical accumulation of DDT is attested, while values lower than 0.5 could suggest recent discharges

(Kassegne et al. 2020). In this study, S2, S5, S7 and S10 confirm the presence of historical DDT sources, with values higher than 0.5, while the other 6 samples prove the presence of recent DDTs.

CC/TC ratio is used to indicate the type of chlordane present in a sample. Values over 1 correspond to technical mixture, meaning that trans-chlordane has a higher presence in samples, while values under 1 attest a higher presence of cis-chlordane (Lee et al. 2001). In our case, all the samples had values higher than 1, which corresponds to technical mixture.

The Romanian environmental law (OM no. 184/1997) provides that acceptable soil concentration of α-HCH must not exceed 100 ng/g, and DDT 250 ng/g, for residential use. In the case of the carried study these values are not exceeded, which makes them appropriate.

Table 4. *The concentrations of organochlorine pesticides (ng/g soil) from different sampling points*

Compound	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
Tecnazene	0.68	7.69	13.66	14.76	12.42	8.86	0.48	5.55	4.39	9.90
α-HCH	2.65	28.63	20.51	46.21	35.82	47.10	2.90	31.53	26.43	20.00
HCB	4.62	1.32	34.17	11.85	2.25	4.01	1.89	2.41	19.08	54.68
γ-HCH	0.61	nd	nd	nd	nd	5.08	nd	nd	nd	nd
Quintozene	nd	nd	nd	nd	nd	1.56	0.09	6.14	nd	1.74
Heptachlor	0.69	9.27	8.18	25.07	21.88	7.83	2.22	13.97	20.35	10.56
Aldrin	nd	nd	nd	nd	nd	nd	nd	6.23	5.15	5.33
Heptachlor-exo	28.66	4.65	27.62	62.08	4.55	43.34	4.59	1.17	11.17	4.54
Heptachlor-endo	nd	nd	nd	nd	nd	nd	nd	nd	0.24	nd
Trans-Chlordan	7.17	2.99	8.37	19.35	19.24	nd	0.89	nd	1.25	3.07
α-Endosulfan	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cis-Clordan	8.01	nd	20.10	21.59	19.80	nd	2.26	nd	1.47	4.39
Dieldrin	nd	nd	20.50	nd	nd	84.37	1.00	6.43	nd	nd

Compound	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Endrin	nd	nd	nd	nd	nd	10.43	nd	nd	1.13	nd
β-endosulfan	nd	nd	nd	nd	nd	nd	nd	nd	9.22	nd
2,4-DDE	nd	nd	nd	nd	nd	nd	nd	1.02	nd	nd
2,4-DDD	8.69	3.68	17.84	17.10	20.55	nd	3.30	3.14	3.89	6.71
4,4-DDD	nd	nd	2.90	nd	nd	33.97	1.14	nd	nd	3.73
2,4-DDT	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4,4-DDT	23.15	nd	20.19	70.50	60.26	88.28	5.27	0.81	4.81	14.97
Methoxychlor	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
∑OCPs (ng/g)	84.93	58.24	194.04	289.41	196.75	334.83	25.96	78.42	108.45	139.6

nd- not detected

Table 5. *Distribution of organochlorine pesticides in urban soils*

Sample Code	ΣHCHs (ng/g)	ΣDDTs (ng/g)	ΣEndosulf (ng/g)	ΣChlordane (ng/g)	ΣCyclodiene (ng/g)	ΣDDTs/ ΣHCHs	α-HCH/ γ-HCH	(DDE+DDD)/ ΣDDTs	CC/TC
S1	3.26	31.84	nd	15.18	nd	9.76	4.32	0.27	1.12
S2	28.63	3.68	nd	3.00	nd	0.13	nd	1	nd
S3	20.50	40.93	nd	28.47	20.50	2.00	nd	0.51	2.40
S4	46.21	88.5	nd	40.94	nd	1.92	nd	0.2	1.12
S5	35.82	80.81	nd	39.04	nd	2.26	nd	0.25	1.03
S6	52.18	122.25	nd	nd	94.80	2.34	9.27	0.28	nd
S7	2.89	9.66	nd	3.15	1.0	3.34	nd	0.45	2.53
S8	31.53	4.96	nd	nd	12.66	0.16	nd	0.84	nd
S9	26.43	8.62	9.22	2.72	6.28	0.33	nd	0.44	1.17
S10	19.99	25.41	nd	7.46	5.33	1.27	nd	0.41	1.43

nd- not detected

Following the obtained results, we can conclude that in the area of the city of Cluj-Napoca we meet different values of POPs, depending on the area of the sampling and the intensity of anthropic activities (figure 3).

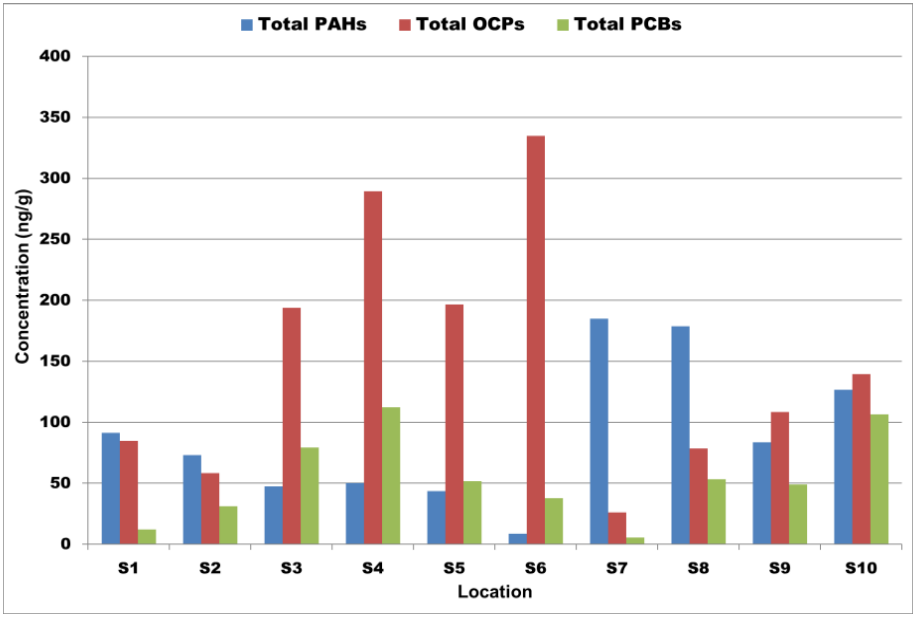

Fig. 3. *The concentration of POPs found in the soil samples*

Other studies performed in Romanian show the presence of POPs in urban soil as follow:

- different regions of Romania, (ΣHCH 28.4±33.7 ng/g; ΣDDT 226.9±157.2 ng/g; ΣPCBs 4.0±2.5 ng/g) (Covaci et al., 2001);
- Bucharest PCBs 0.5–21.3 ng/g, (Preda et al., 2011) and PCBs 1.1–128 ng/g (Ivanescu, 2015);
- eastern Romania, (ΣDDT: 4.4–79 ng/g; ΣHCH 1.1–9.8 ng/g), (Tarcau et al., 2013).

Comparing the results of these studies we can conclude that the concentrations of PCBs found in Cluj-Napoca (PCBs: 5.36–112.35 ng/g) are lower than the ones found in Bucharest by Ivanescu (2015), but higher than the ones found by Preda (2011). For the ΣDDT, the concentrations found in Cluj-Napoca (3.68–122.25 ng/g) are lower than the ones found by Covaci (2011) in urban soils from Romania, but the concentrations of ΣHCH in Cluj-Napoca (2.89–46.21 ng/g) are higher than the ones found by Covaci (2011) and Tarcau (2013).

CONCLUSIONS

In the present study we assessed the widespread distribution of PAHs, PCBs and OCPs, even though they were banned many years ago. The concentration of POPs in the surface soils of Cluj-Napoca according to the class of compounds found are between 8.83 and 184.92 (ng/g) for PAHs, between 5.36 and 112.35 (ng/g) for PCBs, and between 25.96 and 334.83 (ng/g) for OCPs.

The presence of pollutants in the urban environment can be explained by the burning of fossil fuels, atmospheric deposition, industrial activities, waste incineration and actual use. Even if the concentrations found are low, they can still represent a risk through ingestion, inhalation and dermal contact.

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INTERPRETING DISASTER SCIENCE, DEFINING ITS OBJECTIVES AND RANGE

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ABSTRACT. The article aims to define, interpret, and identify the aims of Disaster Science, and to delimit the individual components along the examination of its disciplinary nature.

Definition of the concept of Disaster Science, delimitation of its individual components from its concept, and further terminological examination of related elements. On the one hand, this is conducted with the help of the Internet and the so-called keyword search method in the Google search engine, specifically by searching for definitions, then by collecting the individual publications and the relevant bodies and organisations, and analysing their use of terminology.

The frequency of occurrence of disasters around the world is constantly increasing, their destructive effects can increasingly be felt. Their averting and elimination generally exceed the national level of protection, so the research results should be given priority. Among the conclusions of this publication stands the research priorities of Disaster Research having different disciplines, and due to its multi-, inter- and transdisciplinary nature, there is no unified consensus regarding the methodology and terms. The availability of literature of sociological origin is ensured, however, few works have been produced in Hungary on this topic, for instance, and even in the field of analysis of the effects of natural disasters.

The Author analyses the elements of Disaster Science in an interdisciplinary manner, combining several disciplines, provides insight into Disaster Science and its research areas, and in terms of literary resources, the reader can get to know many, primarily international literature.

Key words: *Disaster science, disaster risk management, discipline, disaster, hazard, risk.*

INTRODUCTION

The first event considered a 'modern disaster' was the Lisbon earthquake of 1755, the interesting thing about which, from a social science perspective, is that it happened on the first day of November, on All Saints' Day, during the period of ideological disagreements between those representing Enlightenment and religion (Etkin, 2016). This extraordinary event attracted the attention of the world of science and art at an international level. The description of the ruins and their depiction on canvas and the dissemination of related information started an international dialogue, which gave impetus to the reporting of disasters. This was the first event where the state introduced a crisis response typical of a special legal regime period other than normal administration which included, among other things, the system of tasks for the elimination and reconstruction of today's disaster control, emergency management, law enforcement, public security, urgent measures related to fatalities, food supply, logistics, the involvement of forces, the construction of more earthquake-proof properties, etc. (Araújo, 2006; Papp, 2021).

In the 17-19th century, several developments of natural science nature were realised, which also helped the development of social sciences, as a result of which the professional study of disasters, the mapping of their characteristics and the results of it, an increasingly comprehensive picture of disasters emerged. Increasing attention was paid to the causes of a disaster.

The twentieth century marked the era of disasters. Based on the statistical data of the 21st century (see EM-DAT, NatCatSERVICE, Reliefweb, Sigma, Statista) a certain increase in intensity is described which requires global action plans for disaster risk reduction and dynamic co-operation in international aid seeking and delivery (see Sendai Framework, 2015, UNDRR). In other words, based on the rising number of disaster events, the system of disaster control is a global response postulate. Regarding this, not only the maintenance of the standards of living (adherence, dependence on serving infrastructures) is the goal of modern society, but also the long-term provision of conditions for survival. This makes the population and the built environment particularly vulnerable and exposed in today's globalised world. A progressive theoretical solution to this can be researched in the field of disaster science, which is in its heyday in terms of topicality (due to the disasters that have occurred) and increasing demand can be observed in terms of their results.

INTERPRETATION, OBJECT, AND PURPOSE OF DISASTER SCIENCE

Disasters are global threats whose significance and professional (here: disaster management-related) analysis is essential and relevant. The theoretical and practical issues of disaster science receive continuous attention, and the results of the discipline help to achieve inter- and transdisciplinary (research) results and their successful implementation into practice. Clarifying the theoretical questions of disaster management research is essential to understanding modern disaster science, taking into account variables from other disciplines to answer its theoretical and practical questions (Papp, 2022).

Disaster science studies the impact of disaster events of natural and built environments in multi-, inter- and transdisciplinary contexts. Furthermore, it studies the environmental, social, cultural, political and economic aspects of the effects of disasters on humans. The subject of disaster science focuses on the planning of effective management of identified disasters, the mitigation of harmful and negative effects, the response to them and the development of strategies aimed at the speedy recovery from them, and the return to normal life. Disaster science is also referred to as an independent discipline, however, when examined more closely, it is a mixture of different ones. It deals with all incidents that cause damage in a populated area. The severity of such events depends on the number of human fatalities, the economic damage and losses, the coping potential and the capacity of the population for recovery and reconstruction. Thus, according to disaster science, a disaster is only such an event whose damage extends to populated areas, i.e., in its interpretation, a flood does not qualify as a disaster if it occurs in an uninhabited area. It deals with risk reduction and management of general and individual events, which in terms of its processing methodology provides horizontal and vertical opportunities for communication between researchers, decision-makers and practitioners around the world. Disaster science covers pre-event situations, such as risk reduction, reduction of probability of occurrence, the building of preventive measures, preparation for the event itself, development of protection against expected disasters, the establishment of emergency systems and development of the existing ones, enhancement of intervention capabilities during the event, expansion and strengthening of response competencies, creation of post-event recovery, mitigation of harm caused, compensation (state, municipal, private and non-profit sectors alike), reconstruction capacities. Fields of investigation for disaster management also include quantification, analysis and modelling of risk and exposure using statistical methods.

From the scientific description of certain disaster events to the development of disaster management as a system of measures and tasks, through international disaster theories, the research lines of world disaster summits, the widespread acceptance of international emergency management co-operations, to the development of a prevention and risk reduction focus, numerous research results have been obtained from which Hungary may also benefit, and the innovative renewal of the domestic defense administration, national defence and disaster management administration system, and the added value of international (disaster) diplomacy may be achieved.

Research on disaster science requires the involvement of multiple disciplines, as disaster science is located at the intersection of natural, social, and economic systems and the built environment.

The path leading to the emergence of disaster science

Disaster science was created at the beginning of the 20th century, and investigated individual disasters with scientific pretentiousness, from the perspective of social sciences (Prince, 1920; Papp, 2021). In the process of researching individual events, and analysing their impact on societies, many theories were born and schools were formed, which led to the delineation of the terminological background related to disaster science (Perry and Quarantelli, 2005; Papp, 2021). Given that several disciplines (earth sciences, environmental sciences, sociology, economics, meteorology, mathematics, engineering, political and legal sciences, etc.) are necessary for the understanding of disaster science, the development of terminology cannot be simple, as different approaches, differentiated methodology, linguistic and cultural diversity produce different conceptual results. There have been several comprehensive works that have tried to examine the basic concepts and explain them according to different approaches. Some works are regarded as classics of this topic, as they are accepted by the international community, and while some works study the results of the past, starting from the classical disciplines, on the basis of newly published ones, but on the basis of new perspectives (Perry and Quarantelli, 2005; Rodríguez et al., 2007; Etkin, 2016). Currently, there is no unified international system of criteria, and the path to the research results is determined by the main mainstream trends and positions of experts related to the discipline, however, it depends on the personality, the initiation of interoperability between the disciplines, and the chemically pure or mixed application of the accepted methodology. Overall, terminological approaches to disaster science vary widely for this reason (Papp, 2020).

The development of disaster science was certainly facilitated by ancient records and observations; numerous events occurred in world history, the analysis of which and the responses (a) formed important system elements, (b) developed into significant disciplines separately, (c) and together formed the systems of tools and tasks of disaster management focused prevention and risk education, preparation, defense, crisis response, intervention, during event damage control and post-event reconstruction as we know today. There were significant part of this, such as the aforementioned

Lisbon earthquake of 1755 or the boat accident in the Canadian Port of Halifax, which occurred on 6 December 1917. A Belgian aid ship and a French munitions carrier collided, resulting in the death of some 2,000 people and injuring 9,000, damaging 1,600 buildings, due to which 31,000 people lost their homes or were seriously affected by their housing situation (Ruffman and Howell, 1994; Scanlon, 1998). Father Samuel Henry Prince has discussed this in his doctoral thesis titled *Catastrophe and social change* (Dahlberg et al., 2016). The thesis studied sociological changes in people living in disaster-affected area, government measures, and conditions for emergency assistance. The paper is also significant since it analyses the disaster from a sociological point of view with scientific sophistication, from the post-occurrence community collapse through the discussion of the relevant disaster psychology to the restoration of the affected areas (Prince, 1920). Interestingly, the Columbia University Publishing House reissued the thesis in 2020, which costs 23-24,000 Hungarian Forints in well-known Hungarian online bookstores. Overall, this was the first scientific paper to study the sociological effects of disasters. The earthquake of 1755, in practice, and the doctoral thesis of 1920, in theory, contributed if not to the whole of the creation process, but certainly to parts of disaster science. Today, some of Father Samuel's theses are considered obsolete and debatable, however, he is considered the father of disaster sociology (Quarantelli, 1998). Father Samuel's work is recognised by many sociologists, social scientists, and experts in disaster analysis; his 1920 paper was even reissued a hundred years later (as a tribute as well), which is a sign of appreciation. According to the Author's judgement, if the father of sociology is Samuel Henry Prince, then the *Handbook of Disaster Research* written by Havidán Rodríguez et al. in 2005 is a ground-breaking piece of modern disaster research. According to the Author's judgement, one of the editors of the mentioned handbook, sociologist Enrico L. Quarantelli is the most influential figure in modern disaster sociology. The 74-author, 32-publication, 638-page book has, according to Springer, 4.44 million downloads (access) to date (an average of 137,000 clicks per article), which is not only significant but also amazing (Perry and Quarantelli, 2005). It is interesting and also an important moment of international discourse that this benchmark paper clearly recognises the 1920 thesis of Father Samuel, while also considers the article of Lowell Julliard Carr in 1932 as relevant, which states, among other things, that all social changes follow a specific sequence pattern, however, also deals with the search for possible analogies of cultural lag, etc. (Carr, 1932). Staying with Springer Publishing, after entering the key word 'disaster science', setting the search period (between 1833-2022), the page found a total of 244,908 results. Narrowing the search of relevance, it shows one article published in the journal of *International Journal of Disaster Risk Science* (Dickinson et al., 2016). The article deals with disaster risk reduction and global communication on the Sendai Framework Agreement. The second book, *Disaster Risk Science* was written by Shi Peijun, a professor at Beijing Normal University, in 2019, and received almost ten thousand downloads. It is interesting to note that Professor Shi Peijun is also one of the editors in chief of a relevant journal called the *International Journal of Disaster Risk Science*. So far, it may be noted that materials regarding the analysis of disasters were written in the first and last third of the 20th century, to which publications after the 2000s commonly refer. In terms of discourse, in addition to the case study of disasters, research on topics related to disaster risk reduction activities and communication, as well as adaptation and resilience are essential elements. This already foreshadows the pillars of disaster science.

The link between disaster science and disaster risk management

Disaster science does not have an organisational or research group or state responsibility, some of its parts can be linked to someone or something, although they have been dealing with its theoretical and practical questions, goals, methodology and object of investigation for several decades.

Since the 2015 Sendai Framework Convention, disaster risk management has become an increasingly common term, which is the application of disaster risk policies and strategies to prevent new disaster risks, and mitigate existing ones, helping to strengthen resilience and reduce disaster losses. Disaster risk management is covered in more than eighty different journals that identify the moments of international dialogue. An aid to disaster risk management is the planning system, which, as a curiosity, should already be adapted to sustainable development and climate change adaptation plans from 2015. The reason for this lies in the fact that 2015 was not only relevant for disaster management, and disaster risk reduction/ management aspects but also for the adoption of the seventeen sustainable development goals and the Paris Climate Agreement.

Disaster reduction is of paramount importance in the disaster management assessment of sustainability and the fight against the negative effects of climate change (Uitto and Shaw, 2016). According to Indrajit Pal et al., the Sendai Framework for Disaster Risk Reduction (SFDRR), Paris Agreement, and Sustainable Development Goals (SDG) promote the effectiveness of (disaster) risk reduction mechanisms and government activities in this direction by addressing central issues such as sustainable, fair (impartial) economy, society and environmental development (Pal et al., 2020). Based on the knowledge of disasters, data collection and statistical analysis results, recommendations can be proposed to the government and decision-makers (Papp, 2019). Indrajit Pal et al. (2020) say disaster risk management (SFDRR) contributes to sustainable development and the SDGs support disaster risk reduction (Pal et al., 2020).

The United Nations Office for Disaster Risk Reduction (UNDRR) co-ordinates international policies, dialogues, co-operation between governments, NGOs, civil organisations, and disaster relief efforts globally. In other words, the UN is responsible for the operation of the International Disaster Assistance System, for risk-related communication, for building a prevention-centred system of tasks, as well as for promoting national resilience, training professionals, forming networks and creating protection capabilities proportionate to each threat, and for managing international offerings. The world disaster management conferences of 1994, 2005 and 2015 were milestones of this. At an international level, the 2005 Hyogó Action Plan, which was taken into account in the 2015 Sendai Disaster Risk Reduction Framework, can be considered an achievement. As its technical successor, it contains seven objectives, justifications supporting four priorities for action and thirteen guiding principles for the 2015–2030 period. The Sendai Framework Convention brought about significant changes in the thinking and practical implementation of Disaster Risk Reduction (DRR) (Ferencz and Teknős, 2020). In the spirit of prevention, the scope of action has been broadened, i.e., emphasis has been placed on environmental and sustainability aspects, technological and biological hazards and risks, including pandemics, health resilience, etc. on governance structures at local levels, facilitating the measurement of disasters with data, strengthening disaster statistics, integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures (UNISDR, 2015). The overall objective is to reduce exposure to hazard, reduce vulnerability to disasters as far as possible, increase preparedness, strengthen responsiveness, and enhance recovery capabilities.

The existence of consistent, reliable, accessible data is essential for the effectiveness of disaster risk management, ensuring their continuous access, storage and transmission. Quantitative data helps to carry out planning, organisation and decision-making tasks before, during and after the event, to ensure satisfactory governance (for risk-based policy decisions), to motivate adaptation to negative impacts, to assess economic damage and costs, to build and develop early warning systems and to create disaster databases.

The priorities of the Sendai Framework Convention include the measurability of the characteristics of disasters, their trend variables and their demonstration with data, which are simplified products of certain reports, foundations on which decision-making task preparations and specifically government decisions are based. Therefore, disaster science relies on disaster statistics, and in many cases – as in this monograph – uses it as a method of disaster analysis (Mileti, 1999; Dilley et al., 2006; Kelman, 2006; Nel and Righarts, 2008). Different databases use different methods, so there will be differences in terms of data as statistical inputs. In any case, this monograph uses data from the EM-DAT database, while for NatCatSERVICE and Sigma, the author analyses only reports drawn from their data. Based on the foregoing, three databases should be considered globally. Although there are differences in their methodology and the range of registered events, disaster risk can be determined based on data from Sigma, NatCatSERVICE and EM-DAT.

Introduction of the Basic Systems and Disciplines of Disaster Science

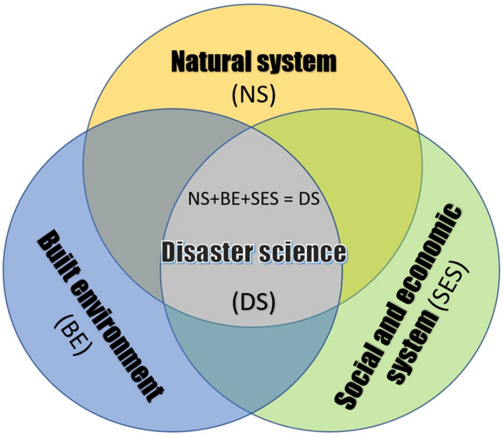

Fig. 1. *Basic System of Disaster Science*
Source: edited by the Author

Figure 1 shows disaster science at the intersection of natural, social, economic systems and the built environment. Two of the three factors are related to humans, while the natural environment is not, although the anthropogenic origin is all part of the natural environment. In the case of disaster science, these basic systems are also worth mentioning as they are the agents that can be clearly damaged, harmed or physically hurt by disasters. The natural system (NS) consists of natural elements, factors, however, anthropogenic activity does belong to this group. However, it is important that human activity is concentrated in the built environment (BE) and in the social and economic system (SES), in which it does not matter whether natural or human-related systems predominate in a given geographical area (Dúll and Dósa, 2005). In many cases, as a result of green innovation and sustainable urban development, there are green surfaces that look natural in the artificial environment (these will be the natural environment in summary). The natural environment is significantly affected by the climate system due to its changes (Kuti and Nagy, 2015). The built environment itself is a settlement, a city, an agricultural area, industrial parks, etc. Whichever base system we look at, all of them can be damaged, and vulnerable, i.e., the subject of the study of disaster risk reduction should cover these systems. At international levels, the disaster system is regarded as the primary object of study defining disaster risk science and is the most and most frequently dealt with, which can be considered from two sides, such as structural and functional aspects (Shi, 1991; Shi et al., 2020).

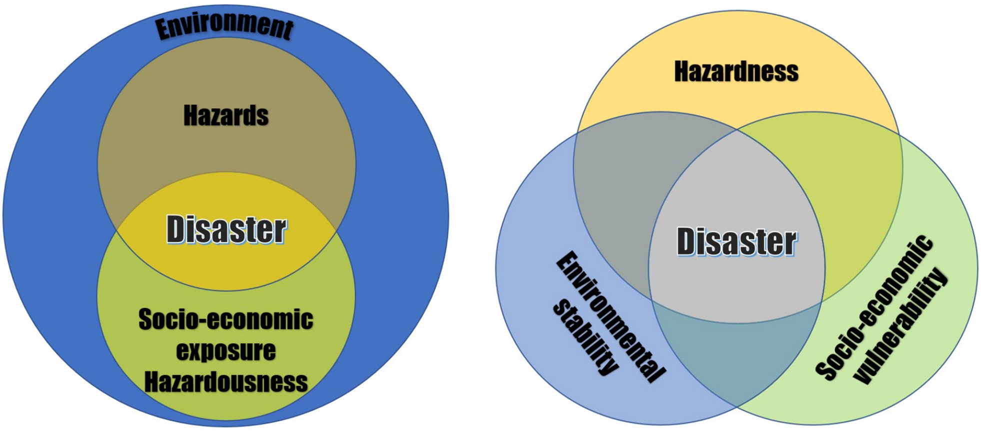

Fig. 2. *Conceptual Model of the Disaster System by Structural (left) and Functional (right) Division*
Source: Edited by the Author based on the works of Shi, 2005 (Shi, 2005).

According to the principled models created by Professor Shi Peijun, disasters arise from the presence of hazards and socio-economic exposure (Wisner, 1994). This also confirms the results of previous research, according to which a disaster, as a qualified event, must have its effects in a human-populated environment, i.e., even if there is a hazard that destroys in a non-populated area, it is not a disaster either. Disasters are an integral part of the environment, however, in accordance with the global principles for disaster risk reduction, which have intensified since 2015, it is imperative to reduce the likelihood of occurrence of the causes leading to their occurrence (the hazards according to this chart), but also to reduce exposure. This includes increasing the disaster resilience of society, increasing the resilience of the economy and its individual segments, reducing the effects of the domino principle, and organising control of dependence and interdependence.

An illustrative formula can be attached to the right side of Figure 2:

DF = S \ H \ V which is

Disaster Frame = Sensitivity \ Hazardousness \
Vulnerability (of environmental stability) (Shi, 2005).

The development of a disaster depends on the sensitivity, hazardousness, and vulnerability of environmental stability, which (see Figure 2) together determine the state and operation of the disaster system. Vulnerability plays a key role in the development of disasters (Burton et al., 1993). Vulnerability is used to characterise the effects of threats on communities. It has many aspects, which consist of physical, social, economic, environmental parts.

Risk analysis is also necessary to reduce vulnerability

Risk: probability of occurrence of certain types of disasters in a given space and time (Papp, 2020).

Risk = Hazard (H) × Vulnerability (V) × Capacity (C).

This formula is interpreted by Stefan and co-author Daniele Ehrlich as meaning that the capacity should be replaced by the exposure, which is how they describe it:

R ah = H ah × E a × V ah = Risk (ah = subscript, the type of hazard and its geographical area) = Hazard × Exposure (ah = subscript, indicates the coping capacity of the affected area and its residents) × Vulnerability (ah = subscript, the affected area and its residents).

Based on this formula, vulnerability depends on the type and intensity of the threat. For instance, properties can be prepared to a certain extent (according to standards) against earthquakes, making them more earthquake-proof, yet still sensitive to the effects of floods. As for the threats, human activity causes the most problems, so the human factor is even more dominant than the natural one (White, 1978). Hazard and exposure can be used for physical parameters or demographic data sets.

A hazard is a phenomenon, human activity, circumstance, or material element that can cause injury or other health effects, damage to property, loss of livelihoods and services, and economic disruption or environmental damage. Hazard is the probable occurrence of the causes of certain disasters, for which it is essential to create and implement the technical-technological conditions of predictability. Its source always arises from social, biological, and physical system interactions. Highlighting natural hazards (geophysical, meteorological, climatic, hydrological, biological, extraterrestrial), their severity depends on the physical nature of the extreme phenomenon, and human development decisions. Extreme phenomenon: it is basically an unusual event, it does not necessarily cause damage.

The interactions between environmental stability, hazardousness and vulnerability certainly affect the function of the disaster system (Shi et al., 2014). In the complex interpretation of disaster science, it is important to analyse (disaster) vulnerability, since (a) the classical and problem-oriented school of disaster science deals with it in detail, (b) it analyses, collects and examines the related figures of disaster events, (c) it is necessary for identifying the causes of disasters, (d) based on the above formulas, the risks and hazards of a community, society and its natural and built environment, hazarding factors, and the exposure to effects are all definable, and those serve primary information about plans related to risk management, disaster reduction, and civil defence.

The link between disaster science and disaster theories

The detailed analysis of schools related to disaster theories is not covered in this publication, however, the excellent Hungarian doctoral thesis *Study of models of co-operation in Southeast Asia used in the protection against natural disasters for Hungary and Central Europe* written by Bendegúz Papp is highly recommended, especially its first chapter which is devoted to schools (Papp, 2020).

Papp discusses the emergence of several theoretical trends in connection with the research of disasters, among which the social sciences, natural sciences, anthropology, and heuristic trends should be highlighted, since their analytical and evaluative professional content, methods of study, represented values, theoretical frameworks, concepts, and the subject of their study all contributed to a better understanding of disaster science. Disaster science is made scientific if it has a theoretical basis, i.e., the definition of concepts and phenomena under study is indispensable. The vast majority of the works related to disaster science, disaster risk science, disaster risk reduction, etc. belong to the schools of natural and social sciences (Papp, 2021).

Interpretation of certain disciplines that make up disaster science

As for disaster science as a discipline, the vast majority of research is multidisciplinary, interdisciplinary and transdisciplinary in nature. This is explained by the fact that individual publications and professional opinions cross disciplinary boundaries. Today, so many schools of disaster theory have emerged and research networks have developed, resulting in at least a multidisciplinary research approach.

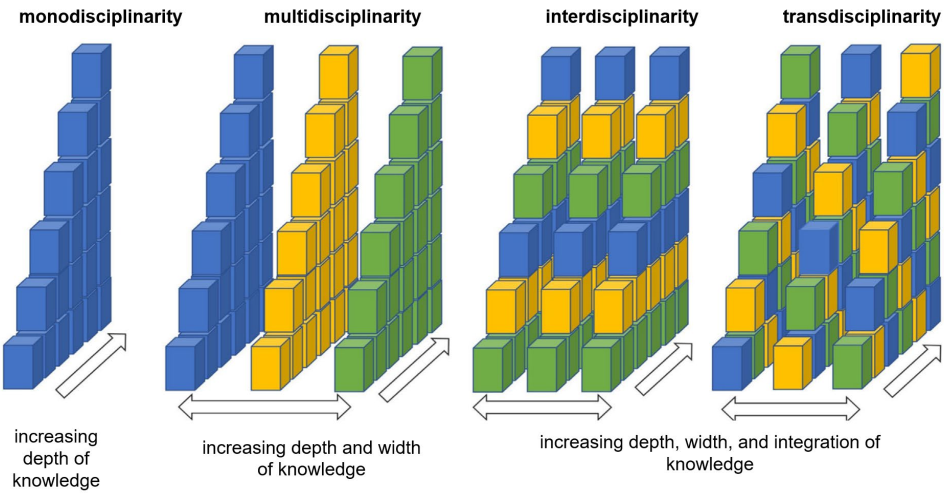

Figure 3. *Illustrating the degrees of disciplinary integration across the boundaries of the scientific field (Peek and Guikema, 2021)*

The characteristic of cross-disciplinary research promotes the updating of previous positions and trends related to disaster science. In connection with the changing environment and demographic variables, the classical contexts are constantly in need of renewal. For instance, the epoch-making paper written by Father Samuel Henry Prince in 1920 is already considered an ‘old school’ work in 2022, since with the development of natural and social sciences, it no longer corresponds to some scientific-research conceptual methods. At the international level, it is more noticeable that several researchers come together and work on the elaboration and processing of a problem, each author bringing along their own scientific aspects (Peek and Guikema, 2021) (Figure 3). The majority of the authors of Hungarian disaster research with scientific degrees are active in the military-technical discipline and are generally professional members of some national defence, law enforcement body or organisation. This limits the Hungarian-related theoretical framework, methodology and subject of investigation of disaster science. Information, and resources may be found in the publications accessible in The Scientific Library of Hungarian Scientific Works, The Library of the Hungarian Academy of Sciences, and via Google Scholar and Public Service Knowledge Portal.

In the case of researchers in different disciplines, it is important to emphasize that the application of a common professional and scientific language, methodology and dental framework is the key to the success of the research. It increases the effectiveness of communication, a better understanding of the research area of the study (Klein, 1990; Siedlok and Hibbert, 2014; Davidson, 2015; Kelman, 2018; Miller et al., 2018).

Disaster science focuses primarily on the structure, function, properties, and dynamics of disaster management systems (Figure 4). Research on the functioning of disaster management systems includes achievement products (written materials) dealing with threats, socio-economic impacts, vulnerability, and environmental stability. Overall, these are also areas of research.

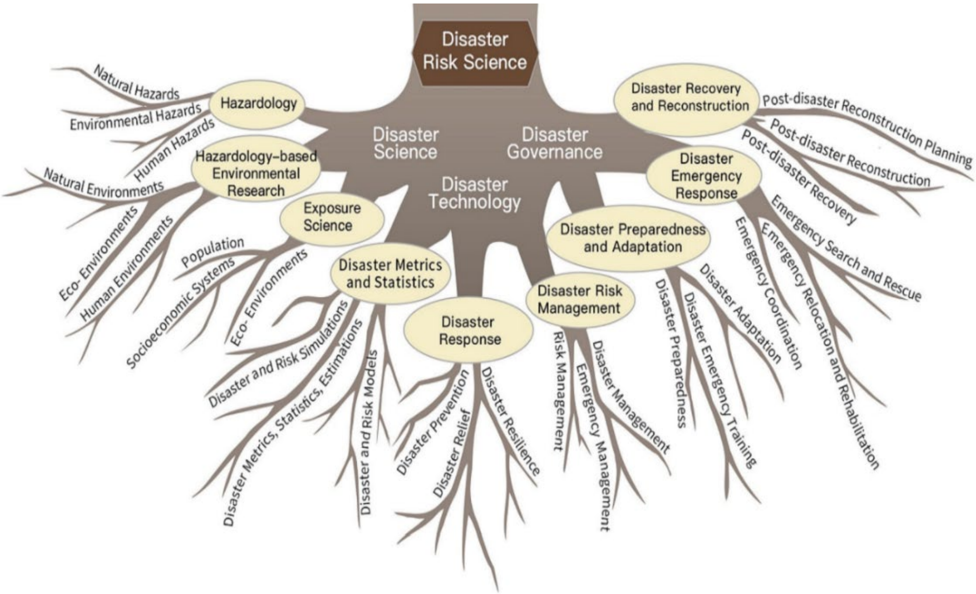

Fig. 4. *Framework for disaster risk science research – Diagram of the three-layer disciplinary structure (Shi, 2005)*

Within disaster risk science, the authors place the disaster science itself, disaster technology (which deals with the technical and technological background of disaster response, as well as disaster management options, disaster monitoring, monitoring, forecasting, early warning, modeling), and disaster management. The latter means administration, governance, management, planning, and organization. Disaster risk science can be broken down into three main pillars: research-analysis, engineering-technology and management-planning contents, which are further divided into nine main areas, culminating in a total of twenty-seven research areas. According to Professor Peijun Shi et al., disaster risk science as a superdisciplinary field requires researchers to be proficient in areas such as earth sciences (geology, geography), atmospheric sciences, oceanology, geomathematics, geophysics, geochemistry, geometry, geospatial studies, mathematics, physics, chemistry, life sciences (biology, ecology, medicine, pharmacy, etc.), economics, management, information science and technology, language and literature, history, philosophy, sociology, political science, and law. Overall, the disciplinary elements of disaster science as a discipline are formed by the research areas included in the diagram of the three-layer disciplinary structure.

The frequency of occurrence of disasters around the world is constantly increasing, their devastating impact affects more and more people, causing death, suffering and significant economic damage (Kopcsó and Balázs, 2016; Teknős and Debreceni, 2022). Their elimination usually goes beyond national level, requires international co-operation, and more efficient and faster implementations require global action programmes (Hetesi and Kiss, 2018).

CONCLUSIONS

In international co-operation, not only practical, specific intervention and post-event activities are important, but also multi-, inter- and transdisciplinary theoretical research. In connection with the research of Hungarian literature on disaster science, *it should be noted* that few works exist on natural disasters in Hungary, therefore, further analytical and evaluation work is needed in this area, the feasibility of which would be supported by a unified disaster database based on Hungarian data, researching domestic peculiarities. However, this was not only a challenge in literary research, but also in the identification, typing and tendential examination of events of natural origin – the monograph studied only this. The development of theoretical disciplines of disaster research can be traced back several decades, nowadays several theoretical trends and schools have been developed. It should be noted here that the research priorities vary, and this is reflected in international research in disaster science. Several renowned experts prefer disaster risk science or disaster risk reduction, while some prefer operational tasks, and others study sociological aspects to a greater extent. The analytical work was made more difficult by the fact that a very different set of concepts is used in International Disaster Science and Disaster Management than in Hungarian terminology. The use of common language and the use of uniform professional jargon is emphasized by several recognized researchers, and almost all materials that deal with conceptualisation and terminological analysis in detail suggest common collective terminological use. This will also make research into disaster science more understandable, which will have a methodological impact on disaster statistics.

In relation to the research of disaster science, although the performance of a researcher is extremely outstanding in a global context, it is rather the common thinking that is characteristic. It could also be said that (a) theoretical and practical issues are discussed in multi-author journal articles and books, (b) considering words and opinions of one another, (c) and the research results of other studies are further developed and considered. Regarding disaster science the multi-, inter-, transdisciplinary versions of research and topic processing can clearly be found. The difficulty of research lies in this, as one field of science can influence another with its own system of aspects, and disaster science is an extremely broad discipline, so the probability of this can be realized. This is both an advantage and a challenge, although it cannot be called a disadvantage, as excellent writings have been created that have created, improved and supported disaster control systems of countries.

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