

STATEMENT



on a dissertation for obtaining the educational and scientific degree of “Doctor” in: field of higher education 4. Natural Sciences, Mathematics, and Informatics, professional field 4.4. Earth Sciences, scientific specialty “**Ecology and Ecosystem Protection**”

Author of the dissertation: Maria Radkova Ihtyarova, part-time doctoral student at the Department of Chemistry, Phytopharmacy and EOSS at the Agrarian University, Plovdiv

Dissertation topic: Phytoremediation of soils contaminated with heavy metals using plants from the Asteraceae family

Reviewer: Assoc. Prof. Dr. Penka Stancheva Zaprianova-Aleksieva, Agrarian University, Department of Agroecology, field of higher education 4. Natural Sciences, Mathematics, and Informatics, professional field 4.4. Earth Sciences, scientific specialty “Ecology and Ecosystem Protection”, appointed as a member of the scientific jury by Order No. RD-16-809/29.06.2026 of the Rector of AU.

1. Relevance of the problem.

The problem of soil contamination with heavy metals is complex and interdisciplinary, covering soil geochemistry, plant behavior, and applied ecology. Special attention should be given to plants with high ecological plasticity, rapid growth, and significant biomass, which combine adaptability to heavy metal contamination with good productivity. Among these, members of the Asteraceae family stand out. The choice of plants from the Asteraceae family as the subject of this dissertation underscores the unquestionable relevance of the research, as it lays the groundwork for developing sustainable and economically efficient strategies for managing contaminated soils.

2. Purpose, objectives, hypotheses, and research methods

The seven research tasks outlined are a logical consequence of the conducted literature review and are aimed at the main goal: to carry out a comprehensive assessment of the behavior of the heavy metals Pb, Cd, and Zn in the 'soil – plant – essential oils' system under conditions of anthropogenic pollution by studying their bioavailability in the soil, accumulation and translocation in plants, evaluating the phytoremediation potential of the studied species, and analyzing their impact on the chemical composition, quality, and safety of the obtained essential oils. The study was conducted as a field experiment on industrially affected soils in the area of KCM – Plovdiv. Five aromatic and medicinal species from the Asteraceae family were included: *Achillea millefolium* L., *Artemisia absinthium* L., *Artemisia dracuncululus* L., *Tanacetum balsamita* L., and *Tanacetum vulgare* L.

In the 'Materials and Methods' section, the methods of sampling, preparation, and analysis of soils and plants, as well as essential oils, are described in great detail. For this purpose, established BDS and ISO standardized methods and high-quality modern equipment were used.

To assess the level of contamination and the bioavailability of metals, the bioavailability coefficient (Availability), contamination factor (CF), geoaccumulation

index (Igeo), pollution load index (PLI), and Nemerow pollution index (NPI) were calculated.

Statistical processing and graphical presentation of the results were carried out using specialized software, including: Microsoft Excel – for initial data processing and organization; SPSS – for statistical analysis and significance assessment; OriginPro – for graphical presentation of results; R software – for performing hierarchical cluster analysis (HCA) and visualization through dendrograms.

3. Visualization and presentation of the obtained results.

The dissertation is 148 pages long and very well illustrated. It contains 21 tables and 11 figures. The largest part of the dissertation is the 'Results and Discussion' section. This section includes experimental data on soil characteristics and heavy metal contamination, elemental composition, accumulation, and organ-specific distribution in the studied plant species. A quantitative assessment of the phytoremediation potential of the plants and their tolerance to heavy metals in representatives of the Asteraceae family was carried out. Results on the chemical composition and chemotype classification of the essential oils are also presented.

4. Discussion of results and literature used.

I am impressed by the large amount of experimental work done in the dissertation. The discussion of the obtained results and their comparison with those of other authors shows a deep understanding of the topic and excellent awareness on the part of the doctoral student. The citations in the text are correct. The listed literature sources provide sufficient scientific information. The style of presentation is consistent both scientifically and grammatically. A total of 241 literature sources were used, of which 7 are in Cyrillic and 234 in Latin script, ranging from 1969 to 2025, with a predominance of recent years. As a result of the analysis of the experimental activity results, 9 conclusions were formulated, 6 scientific contributions made, 4 scientific-applied contributions, and 8 recommendations were given.

5. Contributions of the dissertation.

The conclusions and contributions of the dissertation fully correspond to the set tasks and the achievement of the main goal. The contributions can be grouped into 2 categories.

Scientific contributions

The dissertation provides a comprehensive analysis of the behavior of heavy metals Pb, Cd, and Zn in the 'soil – plant – essential oil' system through a combined soil-chemical, phytoremediation, and pharmacognostic approach.

The results obtained show that the accumulation and transfer of heavy metals in plants is a complex process, determined by the interaction between the geochemical characteristics of the soil, the physiological features of the plants, and the technological processes used to obtain essential oils.

It has been found that the studied species from the Asteraceae family show a clearly distinct species- and organ-specific accumulation of heavy metals, where the root system acts as the main barrier and detoxifying structure, and the aboveground organs are the main accumulation sites. It has been proven that high concentrations

of Pb, Cd, and Zn in plant biomass do not lead to corresponding accumulation in essential oils. Essential oils can be considered a regulatory safe and selectively 'purified' fraction within the soil–plant–product system, even when derived from plants with high phytoremediation potential.

Scientific-applied contributions

The identified separation between the accumulation of heavy metals in plant biomass and the characteristics of essential oils as the end product highlights the potential of essential oil plants for use in phytoremediation technologies. At the same time, it is possible to obtain essential oils with unchanged chemotype characteristics and without detectable heavy metal contamination. This allows combining the ecological role of phytoremediation with the economic use of plant biomass through essential oil extraction.

Due to the accumulation of heavy metals in the vegetative organs of species from the Asteraceae family grown on contaminated soils, their plant biomass should not be used for direct consumption as herbs or spices.

6. Critical notes and questions.

I have no critical notes or questions. I believe that in terms of volume, justification, execution of experiments, and originality of results, the proposed material exceeds the requirements for obtaining a PhD degree.

7. Published articles and citations.

The doctoral candidate's publication activity includes five articles in journals that are refereed and indexed in world-renowned scientific databases. Four of the articles are in the Web of Science, one of which is in Web of Science (CABI). A total of 4 citations have been recorded for 2 of the articles.

The presented abstract is 41 pages long and objectively reflects the structure and content of the dissertation.

CONCLUSION:

The dissertation submitted to me for review meets all the requirements of the Law on the Development of the Academic Staff in the Republic of Bulgaria, the Regulations for the Application of the Law, and the Regulations of the Agrarian University. I am convinced that its development has contributed to the growth of doctoral student Ihtyarova as an independent researcher, capable of obtaining, analyzing, and presenting original scientific results. This gives me reason to give a **POSITIVE** assessment of the conducted research.

I allow myself to also suggest to the esteemed Scientific Jury to vote **POSITIVELY** and to award Maria Radkova Ihtyarova the educational and scientific degree of "Doctor" in the professional field 4.4 Earth Sciences, scientific specialty Ecology and Ecosystem Protection.

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