The main aim of the project is to develop an innovative, catalytic, and thermal-based eco-friendly method for the preparation of artificial humic-like acids (HLAs) from agricultural and forestry waste biomass. The obtained preparations will constitute a basis for the production of effective conditioners that enhance the chemical, physical, and mechanical properties of soils contaminated with Pb and Cd. In particular, the application of HLAs could modify the mobility and bioavailability of heavy metals and improve soil structure, and the level of soil organic carbon. The proposed idea is based on linking of the torrefaction and oxidation processes catalyzed by “green” and cost-effective iron-based materials, initiating Fenton- and Maillard-like processes of the biomass conversion to HLAs.

The project will last 36 months and will be divided into three work packages that contain eight research tasks. In the first stage, the eight different biomasses will be analyzed to select two of them with optimal properties for the development the method of HLAs preparation. The procedure will be optimized in terms of numerous process parameters. The protocols providing preparations with the best properties and yields will be applied to obtain larger amounts of HLAs for use in further stages of the project. The effect of selected HLAs conditioners will be tested on five soils contaminated with Pb and Cd, differed in terms of granulometric composition. Soil textural properties are predicted to be a key factor in determining the scale of HLAs effect. Research on the impact on soil will be carried out in two directions. In the first variant, the effect of HLAs on the structure, physicochemical, and mechanical properties of soils will be examined. Simultaneously, the influence of HLAs on the mobility of heavy metals and soil sorption properties will be assessed. Additionally, an attempt will be made to explain the chemistry of the interactions of Pb and Cd ions with HLAs under various pH conditions. The final stage of the project will include an analysis of the impact of selected HLAs preparations on the growth of plants on different soils contaminated with Pb and Cd. All the above works will be carried out using modern instrumental techniques, among others: mercury porosimetry, adsorption of vapor or gases, tests of mechanical stability of aggregates, elemental analysis, potentiometric titration, dynamic light scattering technique, thermogravimetry coupled with Fourier infrared and quadrupole mass spectrometry, ion selective electrode technique, as well as fluorescence, atomic absorption, and UV-Vis spectroscopies.

The project will have a novel nature due to the development of an innovative, catalytic-thermal, and eco-friendly method of the HLAs preparation from waste biomass with the supportive action of a “green” catalyst. The approach used in the project will be comprehensive which enables to develop and optimize the efficiency of the process and the quality of the final product. The studies will cover the full analytical path from the selection of the optimal biomass to the assessment of the product effects on the final "beneficiaries" i.e. various soils and plants. For the first time, the tests will be carried out on complex substrates of various waste biomass (not pure lignin), for very wide processing parameters, and in the context of HLAs’ use as an organic conditioner for the improvement of various soils contaminated by heavy metals. The developed method will be an important, environmentally friendly step toward solving the problem of waste biomass management.

The results of the project will contribute to the development of different branches of science. Particularly, a new knowledge and data will be valuable to:

- Environment protection and ecotoxicology: studies on novel conditioner will contribute to finding an effective solution for the remediation of metal-contaminated soils. The obtained data will allow us to understand the mechanisms of interactions between heavy metals and HLAs, which will be used for optimization of HLAs application to reduce the bioavailability of these metals with the highest efficiency.
- Sustainable agriculture: developed preparation is expected to have high potential as an effective plant growth promoter and organic conditioner, improving soil properties. The obtained product will also support the mitigation of excessive loss of organic carbon in soil.
- Studies on eco-friendly technologies for effective biomass management: research will have the potential to be developed in the future from the lab to industrial levels for large-scale applications. The arguments for a wider use of the method will be: a small (catalytic) amount of non-toxic iron compounds, high efficiency, simplicity, low cost, and a lack or low number of toxic by-products. The wide availability of agricultural and forest biomass is also a beneficial aspect of developing this technology.