On the applicability of the ‘humic acids’ nomenclature from natural ecosystems to engineering sciences

Xinyu Zhao a,b, Beidou Xi a,b,*, Wenbing Tan a,b, Xiang Li a,b, Qiuling Dang a,b, Renfei Li c

a State Key Laboratory of Environmental Criteria and Risk Assessment, Chinese Research Academy of Environmental Sciences, Beijing, 100012, China
b State Environmental Protection Key Laboratory of Simulation and Control of Groundwater Pollution, Chinese Research Academy of Environmental Sciences, Beijing, 100012, China
c State Environmental ProSchool of Environment Tsinghua University, Beijing, 100084, China

Keywords:
Humic acid
Engineering sciences
Natural ecosystems
Alkaline extraction technique

‘Humic acids (HA)’ are the major constituents of natural organic matter (NOM) derived from the plant or biological residues by decomposition and synthesis in natural ecosystems. They have been defined as relatively high molecular weight aggregates of macromolecules associations with series of highly reactive functional compounds, and considered to be as irreplaceable roles (such as the impact on global carbon and nitrogen dynamics, atmosphere, living plants, chemically reactive and NOM structure stabilization) in natural ecosystems [1]. In addition to the ecological function, ‘HA’ can also be widely applied for a variety of purposes in engineering application as commercial humates, biological detoxification, pharmacology and medicines. Advances of ‘HA’ optimization and application open a new perspective in the engineering sciences [1].

However, nowadays, there is an increasing divergent view of the existence of ‘HA’ nomenclature in natural ecosystems. The core argument is that all of such universality, functionality and significance of ‘HA’ with large, stable, complex molecules in natural ecosystems we recognized is mostly based on alkaline and acid extraction technique. Although the extraction technique has undergone several improvements, the principle has remained identical. These processes may change the chemical molecular structures of NOM from natural environmental matrices into artifacts [2,3]. Accordingly, the formation of operationally defined ‘HA’ linked to the artificial extraction cannot explain for the real content, structure as well as ecological functions of in situ NOM in natural ecosystems.

Nevertheless, it is undeniable that the alkaline-extracted ‘HA’ with various ecological functional groups (carboxylic, phenolic, hydroxyl, carbonyl, and quinone) does indeed have the function of providing cation exchange capacity, chemically reaction, sorption, complexation and particularly relevant for biogeochemical models [1]. It is precisely depending on their intrinsic functions and chemical characteristics that alkaline-extracted ‘HA’ becoming increasing popular in engineering applied science and industry for various purposes. Hence, we hold the viewpoint that ‘HA’ nomenclature cannot be abolished at least from engineering sciences.

Early perception of association of ‘HA’ with global carbon and nitrogen cycling, organic matter for aquatic health, soil carbon-climate interactions, land management, and even predictions of NOM response to global climate change, are all based on the artificial extraction technique [2,3]. It now appears at variance with objective reality. We now understand that alkali extraction technology does change the molecular structures of NOM. In fact, only smaller, simpler molecular structures are visualized in situ observations, rather than the large, complex molecules [4]. In that way, molecular weight and complexity of NOM are overestimated by alkaline extraction. Nevertheless, up till today, it has not yet been possible to insight into how and what structural changes exactly happens to the functional groups and compounds of NOM by alkaline extraction technology, which has always been a ‘black box’ in natural ecosystems (Fig. 1). In addition, the response of the alkaline extraction process to the changes of molecular structure in NOM cannot be generalized. It significantly depends on their intrinsic inter-molecular forces, such as hydrophobic interaction, van der Waals forces, and hydrogen bonding among molecular structures in NOM, especially interacted with different environmental mediums [5]. If these changes do not influence the critical
functionality and feature of the molecular structures of NOM, they can be still called ‘HA’ in natural ecosystems. Therefore, prior to figuring out what and how the alkaline extraction process influences these functional groups or compounds in NOM, it is too premature to question whether it will be abandoned from natural ecosystems.

Uncovering this ‘black box’ has crucial importance, not only we will better able to understand and forecast a more accurate and realistic NOM based on the known ‘HA’ extracted by alkali, but also provide the guidance for engineering applications. It will be the vital connective between the real structure of NOM in natural ecosystems to the known ‘HA’ in engineering sciences (Fig. 1). One should note here that the conversion of organic components in NOM are lasted not for weeks but for decades in natural ecosystems. The spatial arrangement of heterogeneous organic constituents in natural ecosystems on the space scale and timescales of a response to alkaline extraction are far more complex than the behaviors at a specific spatial scale. This will require developing entirely new and comprehensive lines of research that the influencing law by alkaline extraction on the structure of NOM across space and time scales. (1) Long-term experiments and practices are vital to insight into the influence of alkaline extraction on the mechanisms of biological process, protection resistance to decomposition, and the heterogeneity at fine-scale processes. In addition, more effort is needed to obtain the appropriate data for parameterization and testing by advanced analytical techniques such as molecular tagging and molecular simulation, which make possible more predictable by the mechanisms and observed data. (2) Joining forces and connecting the underlying changes of NOM by alkaline extraction to climate, land-use type, and agricultural practices. The reward will be more opportunities for redirecting the existing research in modelling global carbon and nitrogen cycle, agricultural productivity, and global climate stability, issues critical for developing future resource evaluation, climate change, and land use policies. (3) Developing an integrative and high-performance computational database include the detailed changes representing mechanisms driving the molecular structure of NOM response to alkaline extraction in global ecosystems. The characteristics rules of chemical structural changes and the corresponding biological transformation process can be conducted by machine learning methods to facilitate model evaluation. This will be extremely useful in studying, managing and predicting NOM cycling matter in natural ecosystems on the base of known ‘HA’ extracted by alkali. In turn, there are also great opportunities for progress in operating the commercial products rational synthesized in a predictable manner based on the data model in applied science and industry.

The integrative database on how alkaline extraction technique influences heterogeneous NOM at the space-time scale can not only help us better to understand and predict what is essentially a ‘black box’ extracted by alkali in natural ecosystems, but also promoting to design and regulate the functional groups for a specific purpose with economical, ecological, and social benefit in engineering sciences. There will be great opportunities for progress in explaining the NOM in natural ecosystems, and in providing a more mechanistic basis for the development of engineering applications, supporting science that bridges the gap between natural ecosystems and engineering sciences. Correspondingly, the transparency of such ‘black box’ allows for more sensible discussions on the applicability of the ‘HA’ nomenclature from natural ecosystems to engineering sciences.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We thank the editor and three anonymous reviewers for their insightful comments that greatly improved this manuscript. This work was supported financially by the National Natural Science Foundation of China (Nos. 51808519 and 41977030) and the National Key Research and Development Program of China (2019YFC1906403).

References

[1] C.J. Newcomb, Humic Matter in Soil and the Environment: Principles and Controversies, CRC Press, 2014.
[2] J. Lehmann, M. Kleber, The contentious nature of soil organic matter, Nature 528 (2015) 60–68.
[3] M. Schmidt, M.S. Torn, S. Abiven, Soil organic matter persistence as an ecosystem property, Nature 478 (2011) 49–56.
[4] D. Marios, N. Antonio, P. Humoconics Alessandro, A key to unravel the humus pentagram, Appl. Soil Ecol. 123 (2018) 513–516.
[5] M. Kleber, K. Eusterhues, M. Keiluweit, C. Mikutta, P.S. Nico, Mineral—organic associations: formation, properties, and relevance in soil environments, Adv. Agron. 130 (2015) 1–140.