Identification of Organic Matter Dispersions Based on Light Scattering Matrices Focusing on Soil Organic Matter Management

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ABSTRACT: The origin of organic matter, its spread, scattering, and functioning are influenced by the physical structure of liquid or dispersed media of organic matter. Refractive indices of fodder yeast grown on paraffin oil (paprin) and natural gas (gaprin) as well as Lycoperdon spore and organelles were measured by laser phase microscopy. The scattering matrices of aqueous suspensions of paprin, gaprin, and Lycoperdon spores were measured using a laser polarimeter with the scattering angle ranging from 20 to 150°. The experimentally measured scattering matrices have been approximated by the weighted sum of theoretically calculated scattering matrices using the T-matrix code developed by Mishchenko. Most of the particle radii in the filtered fraction of paprin and gaprin were within the range of about 0.05−0.12 μm. Particle radii of the Lycoperdon spore suspension were within the range of 0.4−2.4 μm, which corresponded to both whole spores and their separate organelles. A possibility of identifying a suspension by its scattering matrices was shown for a small difference in the real parts of the refractive index in the example of paprin and gaprin. The measurements of the light scattering matrix showed that for a small size parameter of about 1, the identification of paprin and gaprin can be based only on a difference in the particle shape. Refractive index difference is manifested for the size parameter values higher than 3. An example of a suspension consisting of micron-sized spores and their submicron organelles shows high sensitivity of the scattering matrix to the composition of the dispersed material. The presented data and models help to extrapolate the results of the light scattering matrix study to a vast spectrum of media of organic matter origin and functioning. This study focused on the Biogeosystem Technique (BGT*) transcendental methodology to manage soil as an arena of biodegradation and organic synthesis. A BGT*-based robotic system for intra-soil pulse continuous−discrete water and matter supply directly into the dispersed−aggregated physical structure of the soil media was developed. The system enables transformation of soil into a stable highly productive organic chemical bioreactor for better controlled nanoparticle biomolecular interactions and adsorption by biological and mineral media. The scattering matrix measurement unit is supposed to be used in the robotic system as a diagnostic tool for the dispersion composition of soil organic components.

1. INTRODUCTION

The physical structure of liquid and solid media influences the origin, spread, scattering, and functioning of organic matter as dispersed media. Soil is an important dispersed and aggregated media for biological processes. The challenge is to understand the drivers of organic and mineral phase interactions, to control the process of organic matter synthesis and optimize the trophic chains in the soil as in a large organic chemistry reactor. Recognition (identification) of dispersed media and organic matter by their scattering matrices is of great fundamental and applied importance. Studies on dispersed media are linked to the new technologies of production of artificial mineral and organic matter. Different techniques and models are used for the quantitative characterization of dispersed media. New technological conditions are promising for increased target product output. Characteristics of the natural and artificial organic chemistry products depend on both the properties of production medium and the medium of organic matter application. The properties of organic matter applied to the soil influence the phytopathological status of agroecosis and a quality of yield. Organic substances applied

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to the soil provide a higher plant resistance to pathogens. Hence, it is highly important to obtain all possible information about newly invented unnatural products, especially the organic synthesis products. The importance of the new approaches in a multifaceted study of organic products becomes even higher in the example of soil organic matter (SOM), which is crucial for the pedosphere as an indispensable agent for full-scale functioning of the biosphere.17 SOM in the field of soil science was previously characterized by the humus content. The traditional humus study methodology is focused on C content determination. The presumption of the humus methodology was based on the resemblance of the natural SOM synthesis process in different soils.18 Humus content comparison has been accepted as a reliable method to compare different soils and assess which soil has highly productivity. Currently, increased technological influence on soil distorts an acceptability of the humus criterion. The C content of soil can be increased artificially in the current standard technology framework. But this is not a reliable basis for the subsequent assessment of the soil fertility because the standard technologies lead to uncertain consequences in the soil system.19 On the contrary, the up-to-date soil management technology based on the new Biogeosystem Technique (BGT*) methodology can provide a higher level of certainty of the soil system and lead to higher soil productivity even with a small increment in the humus content.20−25 In this case, the use of the standard data on the soil C content leads to the underestimation of soil productivity. Agrophysical assessment of alluvial calcareous soil of the Cumra Region of Central Anatolia in Turkey showed that this soil is highly fertile, but the soil humus content is less than 2%. The latest humic substance studies are based on the up-to-date high tech equipment for SOM molecular composition research. The corresponding high-level software is used.26−28 The methodology helps to characterize humic substances in more detail.

Currently, SOM manifestations in the soil are very modest compared to the strictly coordinated structural polymicrobial biofilms present in the colon of a live organism.29−31 Soil and human (or soil and animal) microbiomes are closely interrelated, and it is highly probable that they are driven by analogous mechanisms and similar organized consortia.32−35 There are no reliable data on the occurrence of polymicrobial communities and the structure and composition of polymicrobial biofilms in soil.29 Current studies reveal new uncertainties in organic matter and soil health understanding. A need for new findings in this area of research is becoming obvious.34−37 In particular, this will motivate studies on higher resistivity of plants to pathogens and pathogen suppression.38 In soil science, a physical research methodology is important for the correct interpretation of different organic chemistry applications taking into account the long-term biogeochemical changes.39 The wider use of physical methods is promising for the multifaceted study of organic matter. This is linked to different media, different chemical production strata, and diverse biogeochemical regimes.

The scattering matrix element values depend on the properties of dispersed particle. The determination of the physical parameters of particles is currently possible only for a limited set of dispersed media. This is an additional inspiration for new studies concerning the measurement of multilevel continuum—individual organic-mineral aggregates in soil and/or biofilm structure and dimensions. This work aimed at determining the effect of the microphysical parameters of dispersed organic matter for its identification via light scattering matrix measurements in the example of protein—vitamin concentrates (PVCs)—paprin and gaprin. Another aim was to extrapolate the result of the light scattering matrix study to a vast spectrum of media of the organic matter, focusing on the application of the BGT* transcendental methodology to soil as an arena of biodegradation and organic synthesis.24,25,40

2. RESULTS AND DISCUSSION

2.1. Theory/Calculation. 2.1.1. Theory. Scattering matrices of dispersed media are important for organic matter identification. The current approach for the characterization of organic matter (in particular SOM) is a preliminary study of its molecular composition. This approach is insufficient for the coordinated organic-mineral structures of multilevel architecture in soil. Physical methods are crucial for studying soil as the most complicated chemical reactor of vital importance. Soil as a continuum of the most complex biomaterial on the earth is important for the proper management of the environment.17

The application of the humic substances (HS) to the soil is an attempt to increase the SOM content.29 The merit of the HS methodology in this case is its advantageous ability to characterize the SOM molecular composition as a whole, both concerning natural or artificial organic substances.18,26−31

A chemical methodology of organic matter selection or synthesis underestimates the fact that the physical structure of organic molecules depends on the properties of the synthesis medium, in particular, its multilevel architecture. The interrelation of the physical and chemical methods decides the result of organic matter production as well as the subsequent successful application of the new organic matter. In this context, a quantitative physical methodology for characterization of organic matter is of high importance. This methodology, together with chemical and biological methods, provides an adequate description of the form of the studied object and its structure and coordination in the surrounding liquid and/or solid space.

An understanding of the organic matter uncertainties requires new findings. A physical research methodology is vital for correct interpretation of the nature of the organic-mineral product. In our research, physical methods were used for obtaining reliable quantitative data on the size distribution parameters of organic matter in a rather narrow field of PVC synthesis and its control. Theoretical interpretation of the results obtained is promising for a wider range of organic matter production and application media, including soil. A feature of the system under study is the fact that suspensions of protein-containing substances are characterized by relative refractive index values that are closer to unity.7 When analyzing the recognition conditions, it is assumed that the preparation procedure of the suspension samples is the same and provides approximately equal average size of suspended particles with the smallest possible particle size deviation. In addition, the used concentration of suspended particles, on the one hand, provides a satisfactory signal-to-noise ratio during the detection of the scattered radiation and, on the other hand, ensures single scattering.

The values of the scattering matrix elements depend on the size of the dispersed particles. The type of their size distribution, their shape and structure, orientation, degree and nature of the agglomeration, complex refractive index (n +
Figure 1. White light microphotographs of paprin (a) and gaprin (b) powder and Lycoperdon spores (c) on a substrate in air. The size of the white frame is 8 μm × 8 μm.

\[ r_{\text{eff}} = \frac{\int_0^\infty p(r)r^3 \, dr}{\int_0^\infty p(r)r^2 \, dr}, \quad \nu_{\text{eff}} = \frac{\int_0^\infty p(r)(r - r_{\text{eff}})^2 \, r^2 \, dr}{\int_0^\infty p(r)r^2 \, dr} \]

(1)

where \( p(r) \) is the density of distribution of probability. The shape-determining parameter is also important in the model of spheroidal particles \( e = a/b \), where \( a \) and \( b \) are the semiaxes of the ellipsoid.

The scattering matrices were modeled for the particle size parameter from 3 to 30. Correspondingly, the particle distribution width was \( \nu_{\text{eff}} = 0.1 - 0.3 \). The imaginary part of the refractive index \( (k) \) was within the range from 0 to 0.1. The latter is a standard characteristic of proteins.\(^{43} \) It is important to note that if the relative refractive index value of suspended particles is close to unity, the change of distribution width leads to a small change in the dependences \( F_{11}(\theta), F_{12}(\theta), F_{33}(\theta), F_{44}(\theta) \), and \( f_{44}(\theta) \), and the matrix element values change correspondingly. The increase of the imaginary part of the refractive index leads to a shift of the dependence \( f_{44}(\theta) \). In turn, the maximum of dependence \( f_{44}(\theta) \) for the size parameter \( x_{\text{eff}} \leq 30 \) shifts toward a smaller \( \theta \) value. In addition, our calculations indicated that the manifestation of absorption reduces the difference in the matrix element values, and thereby the scattering media recognition procedure becomes less effective.

To determine the dispersed composition, the experimentally measured scattering matrix was approximated by a commonly used weighted sum of the theoretically calculated scattering matrices of model particles of various sizes (grades)

\[ f_{ij}^{\text{calc}}(\theta_{\text{c}}) = \frac{\sum_p \alpha_p C_p^{\text{ca}} f_{ij}^p(\theta_{\text{c}})}{\sum_p \alpha_p C_p^{\text{ca}}} \]

(2)

where \( \theta_{\text{c}} \) is the scattering angle, \( \alpha_p \) is the contribution of the corresponding particle type to the scattering matrix form, \( C_p^{\text{ca}} \) is the scattering cross-section, and \( F_{ij}^p \) are the matrix elements of the \( p \)th type of particles calculated in the model of spheroidal scatterers.

Corresponding weight values providing the minimum mean square deviation of the theoretical and experimental data determined the particle size distribution. The Levenberg–Marquardt algorithm was used for the optimization procedure.

2.2. Experimental Study of the Organic Matter Dispersion in an Example of Paprin, Gaprin, and Mushroom Spores Based on Laser Diagnostic Methods.

The particles of PVC powder and Lycoperdon spores on a substrate in air are shown in the white light microphotographs (Figure 1). The particles of PVC powder and Lycoperdon spores were imaged by a laser phase microscope.\(^{44} \)
The micrographic data (Figure 1) suggest that the particle shape was close to spherical, as the ratio of the longitudinal size to the transverse size of the particle was about 0.5−2.

Two-dimensional (2D) distribution of the optical path difference (OPD) in the vicinity of PVC particles on a substrate in air is shown in Figure 2. Measurements carried out using a laser phase microscope showed (Figure 2) that the real part of the refractive index for paprin and gaprin was 1.46 and 1.52, respectively. These values agree with the relative refractive index in water $n_r = 1.1−1.14$ (Figure 3). The imaginary part of the refractive index of proteins, depending on the light wavelength, is limited in the visible range to the value about 0−0.143. The OPD distribution of Lycoperdon spores most likely shows the topography of the spore wall, so that the average refractive index of the spore as a whole is difficult to estimate. The real part of the refractive index of the spore organelle was estimated to be 1.37.

In Figure 3, the effect of the particle refractive index on the angular dependence of the scattering matrix elements of nonabsorbing spheroidal particles, calculated for two values of the size parameter, is theoretically revealed. It is obvious that an increase in the refractive index leads to a shift of zero $f_{34}(\theta)$ and maximum $f_{12}(\theta)$ toward higher values of $\theta$, as well as to a change in the shape of $f_{12}(\theta)$. A change in the refractive index has little effect on the dependence of $F_{11}(\theta)$ at the size parameter of 0.3. The maximum values of $f_{34}(\theta)$ increase with the increasing refractive index.

The possibility of identifying substances with a small difference in refractive indices was analyzed from the dependence of the scattering matrix on the scattering angle $\theta$ (Figure 4). The calculations were done using the model of spheroidal scatterers for two fractions of nonabsorbing particles: fine ($x_{\text{eff}} = 3$) and large ($x_{\text{eff}} = 30$). The following regularities were revealed. Fine particle identification by the dependences of $f_{12}(\theta)$ and $f_{34}(\theta)$ is reliable for no or weak radiation absorption by PVC particles ($k \ll 0.1$). In the absence of absorption, the identification of a larger fraction of particles can be done by the dependences of $F_{11}(\theta)$, $f_{12}(\theta)$, $f_{34}(\theta)$, and $f_{34}(\theta)$. Radiation absorption by the particles of suspensions ($k \approx 0.1$) significantly impaired the procedure of scattering matrix identification.

The experimental dependences of matrix elements on the scattering angle of paprin, gaprin, and Lycoperdon spore suspensions are shown in Figure 5. By $f_{ij}$ we mean the matrix elements $F_{ij}$ normalized to $F_{11}$ ($f_{ij} = F_{ij}/F_{11}$). The measurement error of $F_{11}(\theta)$ $f_{ij}$ lay within the limits specified in the Experimental Section and Computational Methods section.

The data on the size distribution of paprin and gaprin particles indicated identification of distribution for both suspensions (Figure 6). Nevertheless, differences in the $f_{12}(\theta)$ values were observed even for suspensions characterized by a size parameter $x_{\text{eff}} \approx 1$. Such differences can be explained by the difference in the particle shape from the spheroidal one. Differences include the flat faces, edges, sharp edges, surface roughness, and asymmetry of shapes.

The data showed that the small surface irregularity in the value $<\lambda$ does not lead to a noticeable change in the matrix element.45,46 The scattering matrices of polyhedral straight prisms with 4−7 side faces are largely similar.47 A change in

![Figure 2. Laser interferograms displaying 2D distribution of the OPD in the vicinity of a single particle: paprin (a), gaprin (b), Lycoperdon spores (c), and spore organelles (d).](http://pubs.acs.org/journal/acsodf)
Figure 3. Scattering matrix elements as a function of scattering angle $\theta$ ($f_{ij} = F_{ij}/F_{11}$), calculated for nonabsorbing spherical particles with different relative refractive indices $n_i$ in two cases of the size distribution parameters $x_{eff}$, $v_{eff}$: $x_{eff} = 3$, $v_{eff} = 0.3$ ($n_i = 1.05$—red solid line, $n_i = 1.2$—blue solid line, $n_i = 1.35$—green solid line); $x_{eff} = 30$, $v_{eff} = 0.3$ ($n_i = 1.05$—red dashed line, $n_i = 1.2$—blue dashed line, $n_i = 1.35$—green dashed line).

The smaller $f_{12}$ values and the larger $f_{44}$ values for Lycoperdon spores as compared to PVC are explained by the large average particle size.

The distributions of particle size of paprin, gaprin, and spores in the suspensions (Figure 6) have been restored using the obtained scattering matrix data (Figure 5). We used a model of elongated ellipsoid of revolution to describe the size of PVC particles ($\epsilon = 0.7$). Most of the particle sizes are in the range from 0.05 to 0.12 $\mu$m. Relative contribution of the coarse particle fraction of paprin and gaprin was about $10^{-4}$—$10^{-5}$ in the range from 0.35 to 1.0 $\mu$m (not shown in Figure 6).

The particle fraction distribution restored for the spore suspension indicates its multicomponent nature with a predominance of individual organelles, which apparently formed as a result of ultrasonic treatment. It can be concluded that a relatively small number of large particles (whole spores) against the background of small particles (organelles) significantly disturb the scattering matrix. In this case (in contrast to paprin and gaprin), the product of the fraction of large particles by their scattering cross-section becomes comparable to the analogous product for the small particles.

2.3. Prospects of the Organic Matter Study Using Physical Methods Focusing of the BGT* Methodology.

The data on organic particles can be extrapolated to the framework of the BGT* transcendental methodology. The BGT* synthesizes soil geophysical micro- and macro-aggregate multilevel architectures via intra-soil milling. Focusing on soil organic matter management, the BGT* chemical soil engineering addresses environmental safety concerns of ecosphere management. The BGT* includes intra-soil pulse continuous—
discrete soil watering, intra-soil waste recycling, intra-soil milling, and other technical and technological possibilities. The BGT* methodology ensures a well-dosed intra-soil pulse continuous−discrete water and matter supply directly to the rhizosphere.51 This kind of watering of the soil is sufficient for plant and biota nutrition. The well-controlled and rather low-dosage watering excludes the over-moistening stage of soil, which is typical for both standard rainfed agriculture and irrigation. In the case of standard technology, the soil water regime is closely related to the plant organogenesis. At the same time, the soil continuum remains stable under the intra-soil pulse continuous−discrete watering in the absence of over-moistening. Moreover, intra-soil pulse continuous−discrete watering is safe and improves the soil structure and architecture. Natural aggregates and newly formed quasi-crystals and the corresponding quasi-aggregates in soil are not degraded. Soil quasi-crystals are a product of the freshly synthesized organic matter and soil mineral−matter interactions.52 The soil structure and architecture provided by the BGT* method suits plant organogenesis. Low water supply to the soil helps achieving the goal of overcoming global water scarcity.53 The BGT* methodology ensures environmentally safe organic and mineral waste recycling.55,54 It is also capable of transforming the soil into a more stable highly productive

Figure 4. Scattering matrix elements as a function of scattering angle $\theta$ ($f_\theta = F_\theta/F_{11}$), calculated for nonabsorbing particles with close relative refractive indices $n_r$ in two cases of the size distribution parameters $x_{eff}$, $v_{eff}$. $x_{eff} = 3$, $v_{eff} = 0.3$ ($n_r = 1.1$—orange line, $n_r = 1.14$—cyan line); $x_{eff} = 30$, $v_{eff} = 0.3$ ($n_r = 1.1$—purple line, $n_r = 1.14$—blue line). The shaded areas correspond to variations in the ratio of the transverse particle size to the longitudinal particle size (shape parameter) in the range from 0.7 to 1.

Figure 5. Scattering matrix elements $F_{11}(\theta)$, $f_{12}(\theta)$, and $f_{44}(\theta)$ of aqueous suspensions of paprin of paprin (red dots), gaprin (blue dots), and Lycoperdon spore (black dots) depending on the scattering angle $\theta$. 
organic chemical bioreactor, providing the soil regime and evolution conditions closer to those required for the functioning of the colon of a living organism. BGT ensures higher efficacy of HS and nanoparticles, and higher certainty of nanoparticle biomolecular interactions and adsorption in complex biological media.

A robotic system for intra-soil pulse continuous—discrete water and matter supply directly to the rhizosphere has been developed (Figure 7). The goal was to transform the soil into a more stable highly productive chemical organic bioreactor, providing the soil regime and evolution conditions closer to those required for the functioning of the colon of a living organism. BGT ensures higher efficacy of HS and nanoparticles, and higher certainty of nanoparticle biomolecular interactions and adsorption in complex biological media.

Figure 6. Particle size distribution histograms of aqueous suspensions of paprin (red bars), gaprin (blue bars), and Lycoperdon spores (black bars).

Figure 7. Intra-soil pulse continuous—discrete water and matter supply robotic system.
excessively excluded from the soil biological process and is lost in vain. Current outdated agrarian technology restricts the soil organic matter turnover. The humic substances functioning in the soil are supposed to have an influence on the media as a chemical agent. Improved soil structure and architecture are important for a better effect of nanoparticles on crops and soil microbial communities as well for many other soil management applications.51

Physical methods for studying the longitudinal to transverse size ratio of organic matter particles in real soil is a promising field for better understanding of the ways of organic matter management into the multilevel mechanical carcass systems.5,8,11−13,15 Important issues are the nanoparticle biomolecular interactions and adsorption in the soil, which provide uncertainty of complex biological media.9,10

Restrictions of organic matter synthesis in soil can be characterized by comparing the organic matter degradation in soil and in the colon of a living creature. The productivity of the biological process in the colon is manifold higher than that in soil.9,30,33 Soil improvement is needed for organic matter degradation and synthesis. This will provide a higher organic matter turnover rate and higher soil biological production. This is important as a promising way to maintain the global biogeochemical cycle and obtain natural products originating via photosynthesis rather than the current organic matter synthesis in artificial media. There are promising methods to characterize soil biological processes in soil and other linked soil properties using the term “soil health”. But the number of soil health criteria is huge. Moreover, different authors propose different criteria.36 We think that a quantitative physical approach will be highly productive for obtaining most valuable soil health criteria, focusing on the soil mechanical structure, architecture, and dead-end porosity as conditions for the soil organic matter structural physical characteristics and turnover. This approach is promising with a focus on the BGT* possibilities for soil structure, architecture, and dead-end porosity management and long-term control.19,59 New design of the soil continuum ensures first highly intensive degradation of organic matter, followed by the synthesis of fresh organic matter. The BGT* robotic system ensures well-dosed intra-soil pulse continuous−discrete water and matter supply directly to the rhizosphere (Figure 6).34 This kind of watering of the soil is sufficient for plant and biota nutrition. This well-controlled and rather low-dose watering excludes the over-moistening stage of soil, which is typical for both standard rainfed agriculture and irrigation. In the case discussed, the soil water regime type is closely related to the plant organogenesis. At the same time, the soil continuum remains stable under the intra-soil pulse continuous−discrete watering in the absence of over-moistening. Moreover, intra-soil pulse continuous−discrete watering is safe and improves the soil structure and architecture. Natural aggregates and newly formed quasi-crystals and corresponding quasi-aggregates in soil are not degraded. Soil quasi-crystals are a product of the freshly synthesized organic matter and soil mineral−matter interactions.52 The soil structure and architecture suits plant organogenesis. Low water supply to the soil helps achieving the goal of overcoming global water scarcity.35 The BGT* methodology ensures environmentally safe organic and mineral waste recycling.53,54 It is also capable of transforming the soil into a more stable highly productive organic chemical bioreactor, providing the soil regime and evolution conditions closer to those required for the functioning of the colon of a living organism. BGT* ensures higher efficacy of HS and nanoparticles and higher certainty of nanoparticle biomolecular interactions and adsorption in complex biological media.9,10,22,23,28,29,42

The BGT* approach (Figure 6) provides better prerequisites for the organogenesis and productivity of plant at a high rate.58,25 We propose to use this condition as a soil health criterion.33,35−37 There are possibilities of new physical studies of organic matter synthesis and evolution in the newly designed porous media soil continuum. This will help in overcoming the current conflict between the biosphere and agro-ecosystem.62 A new possibility will be opened to study the higher resistivity of plants to pathogens and pathogen suppression.38 The scattering matrix measuring block will be an important diagnostic and control tool for the robotic system operation. The system will provide control over the soil physical structure, which has an influence on the origin of the organic matter, its scattering, and proper functioning.1

3. STUDY IMPLICATIONS AND OUTLOOK

Studies of aqueous suspensions of PVC (paprine and haprin) and mushroom spores, including experimental measurements and theoretical modeling of light scattering matrices, allowed us to conclude that two types of scattering matrix-based identification are possible for a dispersed organic medium.

First, with a known (controlled) dispersed composition of the suspension, particles of different matters can be reliably identified due to the difference in the refractive index by comparing the angular profiles of their scattering matrix elements (Figure 3), even when the refractive indices are close (Figure 4). Second, if the refractive indices of the particles that are supposed to be present in the suspension are known, then the angular dependences of the scattering matrix make it possible to determine the disperse composition (particle size distribution) with good accuracy, as shown in the example of multicomponent Lycoperdon spore suspension (Figure 6). Furthermore, the presence and number of particles of interest in the tested soil sample (transformed to a suspended form) can be identified by their characteristic size in the size distribution histogram. In this way, the presence of inorganic components such as nanoparticles added to the soil via BGT* methods can also be monitored. In addition, this technique can be used to detect agglomerates formed in the process of collective interaction of nanoparticles with biorganic components in the soil.63

It should be noted that when the scattering matrix is detected directly from the soil, identification will be difficult (at least if the measurement is made at only one wavelength) due to non-single scattering. Therefore, the measurement procedure must include some sample preparation; in our case, it was the preparation of an aqueous suspension, in which the particles of interest were suspended at a concentration corresponding to a single scattering. In addition, to control the dispersed composition of the suspension, some filtration methods should obviously be applied.

The proposed diagnostic methodology of dispersed organic materials based on the scattering matrix can enhance the BGT* transcendental possibilities to ensure the suitability of soil as an arena of biodegradation and organic synthesis and a biological driver of the biosphere stability and climate system certainty.64 A robotic system for intra-soil pulse continuous−discrete water and matter supply directly to the rhizosphere is capable of transforming the soil into a more
stable highly productive organic chemical bioreactor, providing controlled nanoparticle biomolecular interactions and adsorption in complex biological media. Further studies on the scattering matrix as a tool for disperse composition determination in the framework of the BGT methodology are of high importance.

4. EXPERIMENTAL SECTION AND COMPUTATIONAL METHODS

Quantitative techniques and models of the dispersed medium studies were considered in this research. Aqueous suspensions of fodder yeast (PVC), paprin (grown on paraffin oil), and gaprin (grown on natural gas), as well as mushroom spores, were studied by the following methodology. The PVC suspensions obtained after mixing of the powders with water were filtered through a paper filter. To obtain a uniform dispersion, the spores were mixed with water using ultrasonication, which in particular led to a significant increase in the number of individual spore organelles in the dispersion. White light microphotographs of the powders were made on a substrate in an air atmosphere. A laser phase microscope, which displays a 2D distribution of the OPD in a plane transverse to the laser beam, was used to measure the refractive index of dispersed submicron particles.

The light scattering matrices of the suspensions were measured using a laser polarimeter in a scattering angle range from 20 to 150°. A single-mode He–Ne laser with a wavelength of 0.63 μm and a power of 7 mW was used as a radiation source. Measurements could not be carried out at the scattering angles less than 20° and greater than 150° due to laser radiation blocking by the photo-receiving part of the setup. The reliability of the matrix element experimental dependence on the scattering angle θ was restricted by the measurement error of $f_{ij}$ ($i,j = 1,...,4$), denoting the matrix elements $F_{ij}$ normalized to $F_{11}$ ($F_{ij} = F_{ij}/F_{11}$). The measurement error of $F_{11}(θ)$ was assessed as acceptable when its value was inside the experimental point size frame (Figure 4). The corresponding error was about 0.03 for the normalized matrix elements $f_{ij}$.

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Notes

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