Global Soils: Germany

Soil Microbial Indicators and their Environmental Significance

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Soil can provide a wide variety of functions. Such functions as transforming, storing, and cycling energy-rich organic compounds are biological. Soil microbial biomass is one of the more important soil biological attributes. This parameter regulates many critical ecosystem processes, including biophysical integration of organic matter with soil solid, aqueous, and gaseous phases. It also becomes vital in regulating the quantity and quality of components in the hydrologic cycle and in greenhouse gas emission. Several methods are used today to study soil microbial biomass. The so-called substrate-induced respiration method (SIR) and the fumigation-extraction method (FEM) have become the most frequently used methods for biomass determination. These methods have also been adopted by national authorities for routine soil surveys within 'Monitored Soil Observation Areas' (Bodendauerbeobachtungsflaechen program). In scientific studies, the measurement of microbial biomass is useful for describing biomass turnover in different cropping systems or for indication of heavy metal pollution in urban areas. The recent studies on microbial biomass in agroecosystems (Institute of Soil Ecology, Research Center for Environment and Health, Neuherberg, Germany) showed that values of total microbial carbon pool, active microbial biomass, and real specific growth rates of the microbial community were respectively up to 3, 5, and 3 times greater for rhizosphere compared to bulk soil. There is an obvious gap in our knowledge concerning the microbiological status of anthropogenically modified or disturbed soils in urban areas. In spite of high concentrations of Pb, Zn, Ni, Cr, Cd, and Cu, the microbial biomass carrying capacity in urban soils can attain the same and higher values to those found for native soils (Institute of Soil Science, University of Halle, University of Stuttgart).

The best index of the whole metabolic activity of soil microbial populations is still carbon dioxide evolution (soil respiration), a traditional method since the beginning of soil microbiology. For ecosystem studies, in situ determinations are preferred, although laboratory tests are seen to be sufficient and therefore very often used for decomposition or side-effect studies. Soil respiration is a robust parameter that may rapidly, and reproducibly, be determined. It allows gross comparisons of soils, and reflects soil management changes, or impact of elevated atmospheric CO_2 on soil microorganisms. In field experiments (Institute of Agroecology, Federal Agricultural Research Centre, Braunschweig, Germany), microbial specific respiration rate in soil under conditions of CO_2 enrichment differs from those found in control soil at ambient CO_2 concentrations. A higher level of root exudation in cases of CO_2 enrichment seems to stimulate the microbial activity as compared to the control variant. The recording of soil respiration rate provides qualitatively new information about the state of the soil microbial community and changes in its activity under altered environmental conditions.

In addition to microbial biomass and soil respiratory activity, soil enzymes can be estimated. Enzymes in soil act as transformation agents for organic substances like cellulose, lignin, sugar, and amino acids. Soil enzymes are predominantly of microbial origin and are closely related to microbial biomass. Numerous enzymes have been tested on their suitability for soil investigations. The enzyme method will be chosen dependent on the specific element (C, N, P or S) under study. Dehydrogenase is one of the most frequently used enzyme tests. Because the dehydrogenase activity indicates very sensitive organic and inorganic pollution, it should be an integral parameter of a soil quality assessment. The dehydrogenase activity showed a steep decline after Cd-Zn-mixture application and, in contrast to microbial biomass, an antagonistic effect between Cd and Zn (Institute of Soil Science, University of Bonn, Germany). Soil enzyme assays alone cannot provide answers on observed changes so that additional methods are necessary.

The ability of soil microflora to utilise a set of up to 95 different substrates is described as community-level physiological profiling (CLPP) and is another type of biochemical activity. CLPP assays don't reflect the actual microbial activity well, but they are quick monitoring tools and sufficiently describe the functional structure of microbial communities in a polluted area (UFZ, Centre for Environmental Research, Leipzig, Germany; Department of Geoecology, University of Vechta, Germany). The microorganisms of the area demonstrating the most impact were able to utilize carbohydrates, polymers, aromatic and phosphorylated substrates very fast. It is possible to transfer the results obtained directly to concepts of succession and therefore to indicate the dominance by r- or K-strategists.

Despite all attempts to measure microbial biomass and biochemical activity, the soil microflora still remained a black box [1], since the actors determining the energy and element flows were unknown. For this reason, the studies on microbial community structure obtain interest increasingly. Concepts of the structure of soil microbial communities have greatly developed since the beginning of the 20th century: new directions of investigation (functional, morphological, taxonomic, ecological) appeared, the set of the scales of research increased (from microlocal to geographical and global), and quantitative estimations gradually replaced qualitative descriptions. The unique possibility for investigation of soil microbial communities is the DNA extraction from soil. Several methods are used today to study soil DNA. The DNA extraction and polymerase chain reaction (PCR) now allow a qualitative and quantitative determination of the actors' microbially-related transformation processes in soil. An example is the study on CO_2-fixing bacteria in arable soils under different use (Institute of Soil Ecology, National Research Center for Environment and Health, Neuherberg, Germany).

The prospects for further development of soil microbiology are embedded in the simultaneous use of different methods to obtain a comprehensive characteristic of soil microbial communities.

[1] Insam H (2001): Developments in soil microbiology since the mid 1960s. Geoderma 100, 389–402