Organic matter

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Organic matter, **organic material**, or **natural organic matter** (**NOM**) refers to the large pool of carbon-based compounds found within natural and engineered, terrestrial and aquatic environments. It is matter composed of organic compounds that has come from the remains of organisms such as plants and animals and their waste products in the environment.[1] Organic molecules can also be made by chemical reactions that don't involve life.[2] Basic structures are created from cellulose, tannin, cutin, and lignin, along with other various proteins, lipids, and carbohydrates. Organic matter is very important in the movement of nutrients in the environment and plays a role in water retention on the surface of the planet.[3]

Contents

Formation

Living organisms are composed of organic compounds. In life they secrete or excrete organic materials into their environment, shed body parts such as leaves and roots and after the organism dies, its body is broken down by bacterial and fungal action. Larger molecules of organic matter can be formed from the polymerization of different parts of already broken down matter. The composition of natural organic matter depends on its origin, transformation mode, age, and existing environment, thus its bio-physico-chemical functions vary with different environments.[4]

Natural ecosystem functions

Organic matter is present throughout the ecosystem. After degrading and reacting, it can move into soil and mainstream water via waterflow. Organic matter provides nutrition to living organisms. Organic matter acts as a buffer in aqueous solution to maintain a neutral pH in the environment. The buffer acting component has been proposed to be relevant for neutralizing acid rain.[5]

Source cycle

A majority of organic matter not already in the soil comes from groundwater. When the groundwater saturates the soil or sediment around it, organic matter can freely move between the phases. Groundwater has its own sources of natural organic matter also:

- "organic matter deposits, such as kerogen and coal
- soil and sediment organic matter
- organic matter infiltrating into the subsurface from rivers, lakes, and marine systems"[6]

Note that one source of groundwater organic matter is soil organic matter and sedimentary organic matter. The major method of movement into soil is from groundwater, but organic matter from soil moves into groundwater as well. Most of the organic matter in lakes, rivers, and surface water areas comes from deteriorated material in the water and surrounding shores. However, organic matter can pass into or out of water to soil and sediment in the same respect as with the soil.

Importance of the cycle

Organic matter can migrate through soil, sediment, and water. This movement enables a cycle. Organisms decompose into organic matter, which can then be transported and recycled. Not all biomass migrates, some is rather stationary, turning over only over the course of millions of years.[7]

Soil organic matter

The organic matter in soil derives from plants and animals. In a forest, for example, leaf litter and woody material falls to the forest floor. This is sometimes referred to as organic material.[8] When it decays to the point in which it is no longer recognizable it is called soil organic matter. When the organic matter has broken down into a stable substance that resist further decomposition it is called humus. Thus soil organic matter comprises all of the organic matter in the soil exclusive of the material that has not decayed.[9]

One of the advantages of humus is that it is able to withhold water and nutrients, therefore giving plants the capacity for growth. Another advantage of humus is that it helps the soil to stick together which allows nematodes, or microscopic bacteria, to easily decay the nutrients in the soil.[10]

There are several ways to quickly increase the amount of humus. Combining compost, plant or animal materials/waste, or green manure with soil will increase the amount of humus in the soil.

1. Compost: decomposed organic material.
2. Plant and animal material and waste: dead plants or plant waste such as leaves or bush and tree trimmings, or animal manure.
3. Green manure: plants or plant material that is grown for the sole purpose of being incorporated with soil.

These three materials supply nematodes and bacteria with nutrients for them to thrive and produce more humus, which will give plants enough nutrients to survive and grow.[10]

Factors controlling rates of decomposition

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    - **Environmental factors**
        - 1. Aeration
        - 2. Temperature
        - 3. Soil Moisture
        - 4. Soil pH
    - **Quality of added residues**
        - 1. Size of organic residues
        - 2. C/N of organic residues
- **Rate of decomposition of plant residues**, in order from fastest to slowest decomposition rates:
    - 1. Sugars, starches, simple proteins
    - 2. Hemicellulose
    - 3. Cellulose
    - 4. Fats, waxes, oils, resins
    - 5. Lignin, phenolic compounds

Priming effect

The *priming effect* is characterized by intense changes in the natural process of soil organic matter (SOM) turnover, resulting from relatively moderate intervention with the soil.[11] The phenomenon is generally caused by either pulsed or continuous changes to inputs of fresh organic matter (FOM).[12] Priming effects usually result in an acceleration of mineralization due to a *trigger* such as the FOM inputs. The cause of this increase in decomposition has often been attributed to an increase in microbial activity resulting from higher energy and nutrient availability released from the FOM. After the input of FOM, specialized microorganisms are believed to grow quickly and only decompose this newly added organic matter.[13] The turnover rate of SOM in these areas is at least one order of magnitude higher than the bulk soil.[12]

Other soil treatments, besides organic matter inputs, which lead to this short-term change in turnover rates, include "input of mineral fertilizer, exudation of organic substances by roots, mere mechanical treatment of soil or its drying and rewetting."[11]

Priming effects can be either *positive* or *negative* depending on the reaction of the soil with the added substance. A positive priming effect results in the acceleration of mineralization while a negative priming effect results in immobilization, leading to N unavailability. Although most changes have been documented in C and N pools, the priming effect can also be found in phosphorus and sulfur, as well as other nutrients.[11]

Löhnis was the first to discover the priming effect phenomenon in 1926 through his studies of green manure decomposition and its effects on legume plants in soil. He noticed that when adding fresh organic residues to the soil, it resulted in intensified mineralization by the humus N. It was not until 1953, though, that the term *priming effect* was given by Bingeman in his paper titled, *The effect of the addition of organic materials on the decomposition of an organic soil*. Several other terms had been used before *priming effect* was coined, including priming action, added nitrogen interaction (ANI), extra N and additional N.[11] Despite these early contributions, the concept of the priming effect was widely disregarded until about the 1980s-1990s.[12]

The priming effect has been found in many different studies and is regarded as a common occurrence, appearing in most plant soil systems.[14] However, the mechanisms which lead to the priming effect are more complex then originally thought, and still remain generally misunderstood.[13]

Although there is a lot of uncertainty surrounding the reason for the priming effect, a few *undisputed facts* have emerged from the collection of recent research:

1. The priming effect can arise either instantaneously or very shortly (potentially days or weeks)[12] after the addition of a substance is made to the soil.
2. The priming effect is larger in soils that are rich in C and N as compared to those poor in these nutrients.
3. Real priming effects have not been observed in sterile environments.
4. The size of the priming effect increases as the amount of added treatment to the soil increases.[11]

Recent findings suggest that the same priming effect mechanisms acting in soil systems may also be present in aquatic environments, which suggests a need for broader considerations of this phenomenon in the future.[12][15]

Decomposition

One suitable definition of organic matter is biological material in the process of decaying or decomposing, such as humus. A closer look at the biological material in the process of decaying reveals so-called organic compounds (biological molecules) in the process of breaking up (disintegrating).

The main processes by which soil molecules disintegrates are by bacterial or fungal enzymatic catalysis. If bacteria or fungi were not present on Earth, the process of decomposition would have proceeded much slower.

Organic chemistry

Measurements of organic matter generally measure only organic compounds or carbon, and so are only an approximation of the level of once-living or decomposed matter. Some definitions of organic matter likewise only consider "organic matter" to refer to only the carbon content, or organic compounds, and do not consider the origins or decomposition of the matter. In this sense, not all organic compounds are created by living organisms, and living organisms do not only leave behind organic material. A clam's shell, for example, while biotic, does not contain much organic carbon, so may not be considered organic matter in this sense. Conversely, urea is one of many organic compounds that can be synthesized without any biological activity.

Organic matter is heterogeneous and very complex. Generally, organic matter, in terms of weight, is:[5]

- 45-55% carbon
- 35-45% oxygen
- 3-5% hydrogen
- 1-4% nitrogen

The molecular weights of these compounds can vary drastically, depending on if they repolymerize or not, from 200-20,000 amu. Up to one third of the carbon present is in aromatic compounds in which the carbon atoms form usually 6 membered rings. These rings are very stable due to resonance stabilization, so they are difficult to break down. The aromatic rings are also susceptible to electrophilic and nucleophilic attack from other electron-donating or electron-accepting material, which explains the possible polymerization to create larger molecules of organic matter.

There are also reactions that occur with organic matter and other material in the soil to create compounds never seen before. Unfortunately, it is very difficult to characterize these because so little is known about natural organic matter in the first place. Research is currently being done to figure out more about these new compounds and how many of them are being formed.[16]

Organic matter in water (Aquatic)

Aquatic organic matter can be further divided into two subsections: dissolved organic matter (DOM) and particulate organic matter (POM). They are typically differentiated by that which can pass through a 0.45 micrometre filter (DOM), and that which cannot (POM).

Detection of aquatic organic matter

Organic matter plays an important role in drinking water and wastewater treatment and recycling, natural aquatic ecosystems, aquaculture, and environmental rehabilitation. It is therefore important to have reliable methods of detection and characterisation, for both short- and long-term monitoring. A variety of analytical detection methods for organic matter have existed for up to decades, to describe and characterise organic matter. These include, but are not limited to: total and dissolved organic carbon, mass spectrometry, nuclear magnetic resonance (NMR) spectroscopy, infrared (IR) spectroscopy, UV-Visible spectroscopy, and fluorescence spectroscopy. Each of these methods has its own advantages and limitations.

Water purification

The same capability of natural organic matter that helped with water retention in soil creates problems for current water purification methods. In water, organic matter can still bind to metal ions and minerals. These bound molecules are not necessarily stopped by the purification process, but do not cause harm to any humans, animals, or plants. However, because of the high level of reactivity of organic matter, by-products that do not contain nutrients can be made. These by-products can induce biofouling, which essentially clogs water filtration systems in water purification facilities, as the by-products are larger than membrane pore sizes. This clogging problem can be treated by chlorine disinfection (chlorination), which can break down residual material that clogs systems. However, chlorination can form disinfection by-products.[16]

Potential solutions

Water with organic matter can be disinfected with ozone-initiated radical reactions. The ozone (three oxygens) has very strong oxidation characteristics. It can form hydroxyl radicals (OH) when it decomposes, which will react with the organic matter to shut down the problem of biofouling.[17]

False positives

Many water quality groups, such as the North Carolina State University Water Quality Group, believe that having too much organic material will cause deoxygenation and essentially remove oxygen from the water.[18] Although organic material, which consists of many hydrocarbon and cyclic carbon chains, is susceptible to attack by oxygen, it would be sterically unfavorable to attach oxygens to every single carbon.

Of course, there are exceptions, such as varying the temperature at which these reactions occur. As the temperature becomes much higher, there is a better chance that an unfavorable reaction will occur because molecules move around faster increasing the randomness of the system (entropy).

Vitalism

The equation of "organic" with living organisms comes from the now-abandoned idea of vitalism that attributed a special force to life that alone could create organic substances. This idea was first questioned after the artificial synthesis of urea by Friedrich Wöhler in 1828.

See also

- Biofact (biology)
- Biomass
- Detritus
- Humus
- Organic geochemistry
- Sedimentary organic matter
- Total organic carbon

Compare with:

- Biological tissue
- Biomolecule
- Biotic material
- Cellular component
- Organic production

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