Soil Organic Matter
Its Characteristics and Roles in Agricultural Environments

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http://timetraveler.html.xdomain.jp

Wise-being in the forest told ….

Homo ab Humo

- Human was born from a rich soil containing large amount of
- **Human – Humus – Humidity**

  There is a profound connection between human, humus, and humidity.

- Sleeping mind of human “Terra as the mother”

Genesis 3.19 – Old Testament

- You were made from soil, and you will become soil again.

Do you feel soil dirty?

Take a clod of soil
into your hand,
watch and smell it.

We will be relieved by such soils:

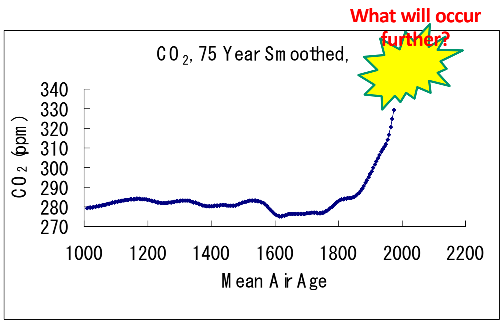
- Black soil
- Soft soil
- Good smelling soil
- Soil in which small worms are living

Such soils contain a suitable amount of organic matter.

Soil breeds life.

Evidence for this fact is

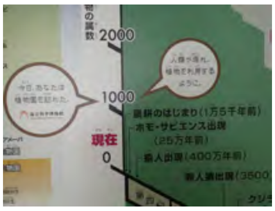
Soil Organic Matter.



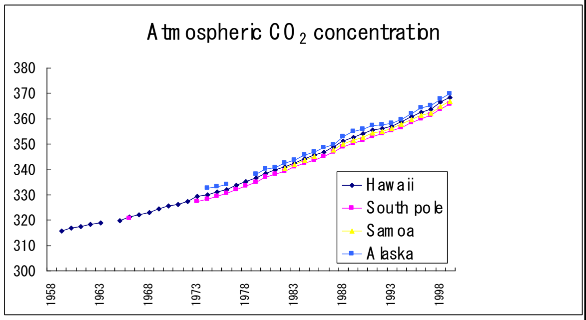
Change in ambient CO_2

(Ice-core data of antarctics)

70% of the biologists consider that the mass extinction is occurring presently.



Increase in atmospheric CO_2 concentration

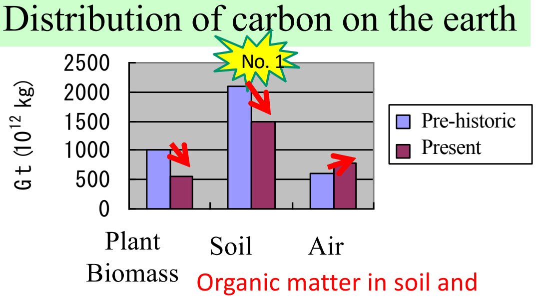


Stocks of carbon on the surface of earth

Stock pools	Stored amount 10^{12} kg
Earth	
Plant biomass	550
Soil humus	1500
Atmosphere 1850 (CO_2 260 ppm)	560
1890 (CO_2 290 ppm)	630
2000 (CO_2 390 ppm)	820
Ocean	38000
Carbonate salts	20×10^6
Dissolved organic matter	600
Solid suspension and sediments	3000
Earth crust (fossil fuel)	4000
Total amount	44800

Hunt(1972), Paul and Clark(1989), Eswaran et al.(1993)
CO_2 concentration was calculated from ice-core data in Law Dome Antarctics.

Distribution of carbon on the earth



Organic matter in soil and vegetaion decreased remarkably due to civilization.

Humic substance is

- The most abundant organic matter on the earth surface. As carbon amount
  1500 Gt (10^9 t, 10^{12} kg)
- 3 times more abundant than plant biomass
- 2 times more abundant than CO_2

2100 Gt of humus carbon in pre-historic age.

Nitrogen on the earth: Location and stock size.

Location of occurrence	10^6 t
Atmosphere	3.9×10^9
Terrestrial Plants	15×10^3
Animals	0.2×10^3
Soil organic matter	150×10^3
Ocean Plants & animals	0.5×10^3
Sea water and sediments	1200×10^3
Nitrate – N in the above	570×10^3

植物栄養学第2版（文永堂）

Phosphorus on the earth: Location and stock size.

Location of occurrence	10^6 t
Terrestrial biota	2.6×10^3
Phosphor mineral	19×10^3
Soil	$96〜160 \times 10^3$
Fresh water	0.090×10^3
Marine Biota	$0.05〜0.12 \times 10^3$
Soluble inorganic P	80×10^3
Sediments	$840{,}000 \times 10^3$

Soil is the largest pool of stocks both for N and P.

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Biomass production and respiration/ combustion on the earth (10^9 t/year)

	Biomass production	CO_2 formation
Plant	500	34.5
Animal	0.5	4.1
Human	0.1	0.7
Microbes	1.0	112
Wild fire		6.9
Volcano		0.15
Factory		15
Total	502	173.5

Emission of CO_2 due to human activity

Factors	Increase rare of CO_2 carbon
	Gt (10^9 t)/year
Fossil fuel combustion	7
Land use change	2.2

Land-use change

Forest clearing
Slush and burn
Grassland to upland field

Large amount of gas is emitted from soil surface

World energy consumption (2003)

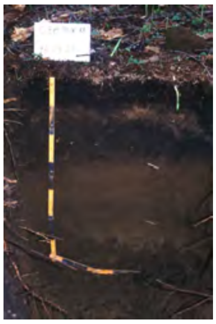
Source	Consumption (petroleum equivalent 10^8 tons)	
Petroleum	36.4	85.5
Natural gas	23.3	
Coal	25.8	
Atomic	6.0	12.0
Hydraulic	6.0	

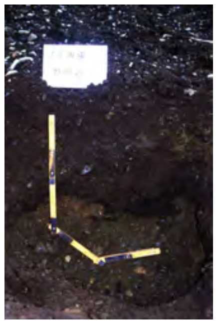
CO_2 emission

heat emission

Energy consumption per capita

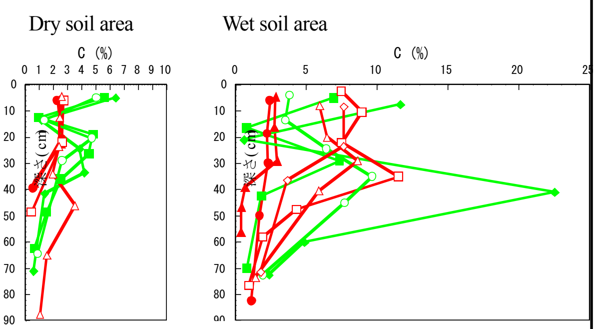
- World 1.7 ton annually (petroleum equivalent)
- Japan 4.1 ton annually
- USA 8.0 ton annually
- Human activity causes the increase in atmospheric CO_2 concentration.
- Plant and soil absorb CO_2.





Wind-break forest soil　　Adjacent upland field soil

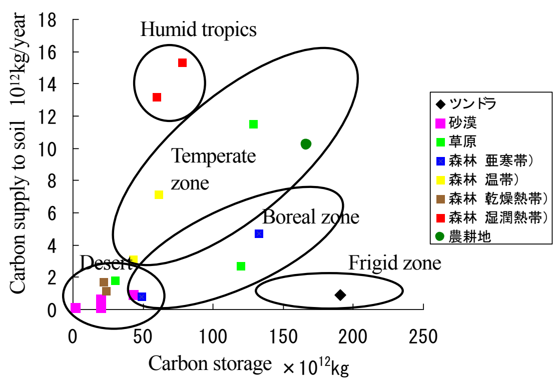
Volcanic ash soil profile in the adjacent forest and upland field.



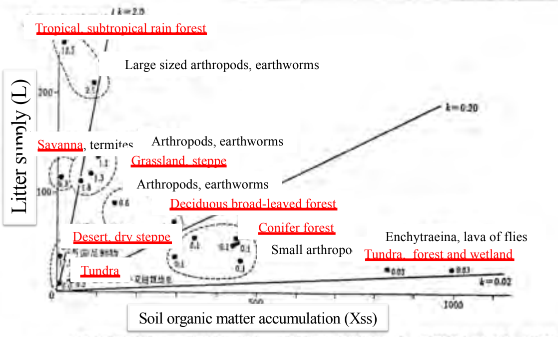
Change in carbon contents of volcanic ash soil profiles in uncultivated and cultivated sites.

uncultivated　cultivated

Supply and storage of carbon in soil



Litter supply and SOM accumulation

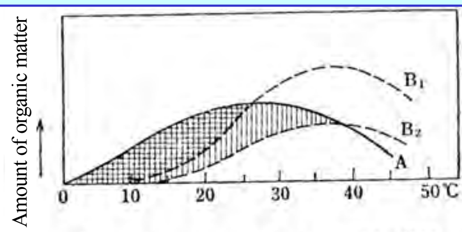


主要な生態系型の落葉供給量（L），土壌有機物の蓄積（Xss），分解率 k=L/Xss および主要な分解動物群　図中の数字はそれぞれの地点での k の値を示す。

Primary forest in Baybay, Leyte

Primary forest soil profile in Baybay, Leyte

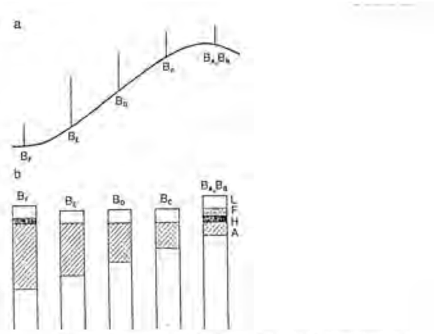
Factors affecting SOM accumulation: temperature and moisture content of soil



Aerobic upland soil
Anaerobic flooded soil
A Organic matter production by plant
B_1 Organic matter decomposition in aerobic soil
B_2 Organic matter decomposition in anaerobic soil

Amounts and Turnover Rates of C and N in the Microbial Biomass for Cultivated Soils for Three Locations

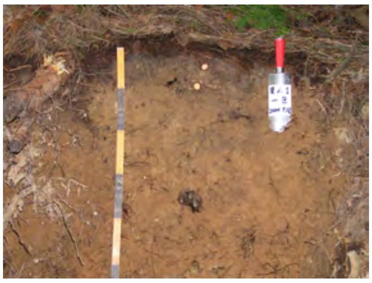
Soil and Locati	Microbial C	Microbial N	C Inputs	Nitrogen Flux through Microbial Biomass	Microbial Turnover Time
	kg/ha	kg/ha	Mg/ha/y	kg/ha/yr	yr
Temperate					
England	570	95	1.2	34	2.5
Canada	1600	300	1.6	53	6.8
Tropical					
Brazil	460	84	13	350	0.24



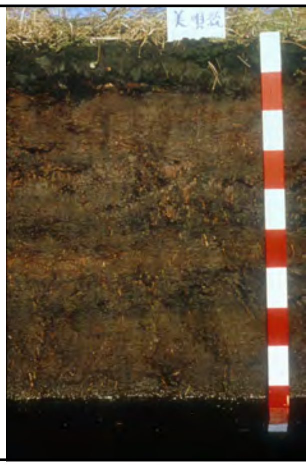
Schematic representation of soil types (B_A—B_F) of Brown forest soil. a: topographic location; b: A_0 and A horizons. Vertical lines indicate growth of the tree.

Red pine forest
(Yaotsu, Gifu prefecture)

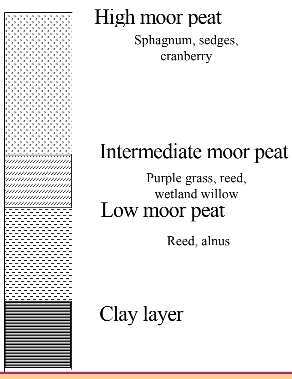
Brown forest soil B_B type (Yaotsu, Gifu)



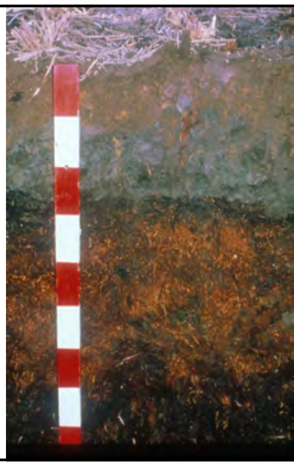
Litter layer of forest soil (O, A_0 layer)



Peat soil in Bibai

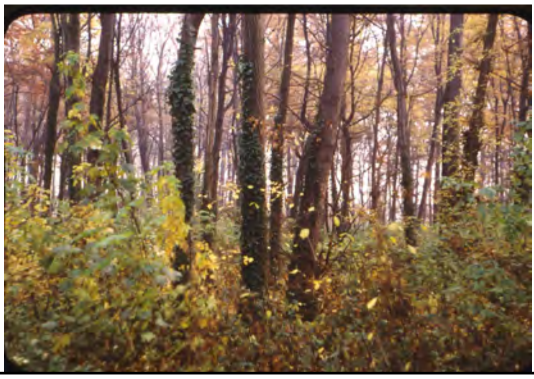


High moor peat soil profile in Bibai



Peat soil with dressed soil
(Nanporo town)

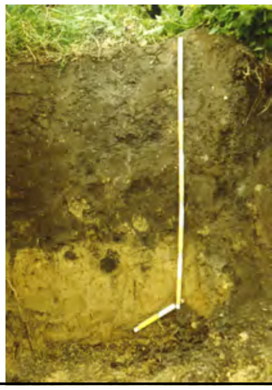
Asel forest near Hildesheim, Germany



Black soil in Asel forest, Germany

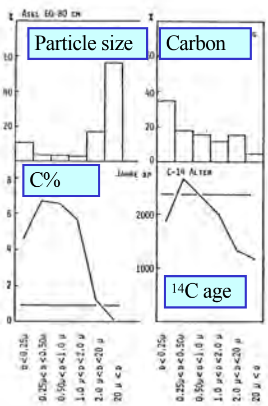
Wheat field in Soellingen/Germany

Black soil in Soellingen upland field



Soil organic matter stabilization on different size of soil particles

Organic matter bound to clay lasts long in soil



Stabilization and abundance of organic matter constituents in soil				
Constituents	Abbreviation	Mean Residence Time	S (kg)	A^0 (kg)
Fresh organic matter (yearly imput)				1000
Decomposable Plant Material	DPM	1	10	10
Refractory Plant Material	RPM	3.9	470	120
Biomass	BIO	25.9	280	10.8
Physically stabilized organic matter	POM	94.8	11.3×10^3	119
Chemically stabilized organic matter	COM	2565	12.2×10^3	4.76
Whole Soil Organic Matter	SOM	1334	24.3×10^3	265

Jenkinson and Rayner, Soil Scinece 123, 6, 1977

S (kg) : Expected accumulation of organic matter after 10000 years when 1000kg ha^{-1} of fresh organic matter is incorporated every year.

A_0 (kg) : Yearly gain of soil organic matter (kg ha^{-1}),

Calculated from S and meanage. A_0 = S/Average Age

Accumulation of organic matter in soil

$$S = (1/\log_e 2) A_0 H$$
$$= 1.44 A_0 H$$

S: Accumulated amount of organic matter after infinite years
A_0: Added amount of organic matter in one year
H: Half life of organic matter
1.44H: Mean residence time

Roles of Soil Organic Matter

Function of humic substance

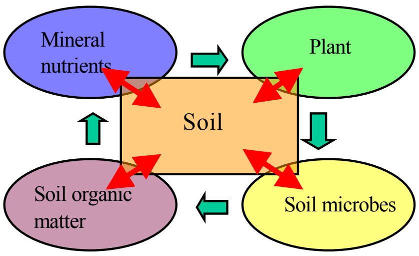
- Largest pool of carbon on the surface of earth
- Repress global warming
- Nutrition supply to plant and microbes
- Hold nutrients and water
- Improve soil physical properties
- Promote plant growth

Humic substance is not almighty, however.

- Humic substance can not support the growth of crops by itself.
- Optimum pH
- Favorable moisture condition
- Sufficient mineral nutrients
- No growth inhibiting substance

should be the background for the effect of humic substances

Role of soil organic matter



Role of Soil Organic Matter

Improvement in

a． Soil Physical properties
b． Chemical & Biological prpperties
c． Plant Growth Promotion Effects

Change in concept of plant nutrition

- J.Tull (early 18th century） Importance of plowing
- A. von Thaer (early 18th century)

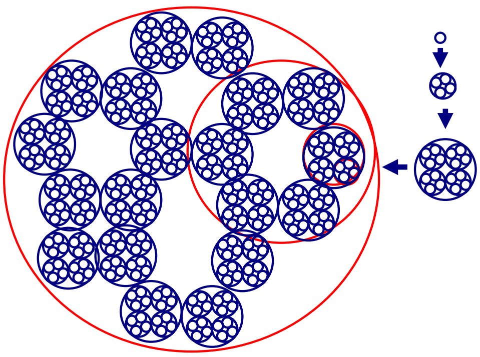
  Theory of humus nutrition
- Theodore de Saussure (early 19th century)

  Importance of mineral nutrition.

  Discovery of photosynthesis
- J.B. Boussingault (1834) Discovery of nitrogen fixation
- J. von Liebig (1840) Mineral nutrition theory

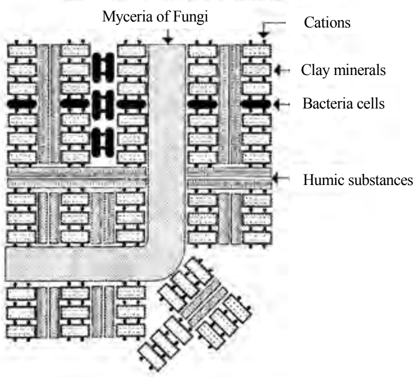
a． Improvement of Soil Physical properties by soil organic matter

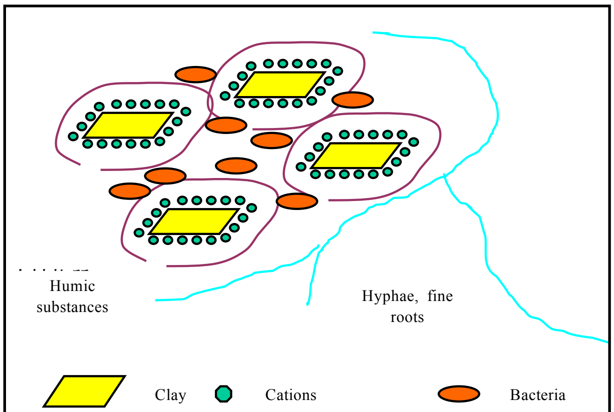
Hyphae of fungi Polysaccharide Humic substance	⇨	Aggregate structure Aeration and Drainage Mitigation of soil erosion Soil water retention Increase in specific heat Increase in soil temperature



Hierarchical structure of soil aggregates

Forming process of soil aggregates





Mechanism of soil aggregate formation

Role of Mycorrhizal fungi

- Promotion of nutrient absorption

  (P absorption)
- Promotion of aggregate formation

  Large sized aggregate

b. Improvements in chemical and biologicalproperties

Retention of cations and anions
Transport and translocation of mineral nutrients
Binding and inactivation of harmful artificial organics
Mitigation of the effect of pollutants
Donor of Proton (H^+)
Physiologically active substances
Nutrient supply in good balance
Source of nutrients for
heterogeneous microbial communities
Competition with pathogenic germs

c. Plant growth promotion effects

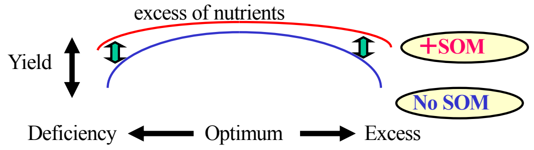
Promotion of germination and root initiation
Promotion of the growth of root and stem
Complex formation with nutrient elements
Promotion of nutrient absorption by plants
Hormone-like activity
Promotion of permeability of cell membrane
Promotion of photosynthesis, respiration,
and enzyme activity
Suppress protein and increase sugar contents in plants
Alleviation of plant growth inhibition under
cold weather and irregular meteorological conditions

Plant growth promotion effects

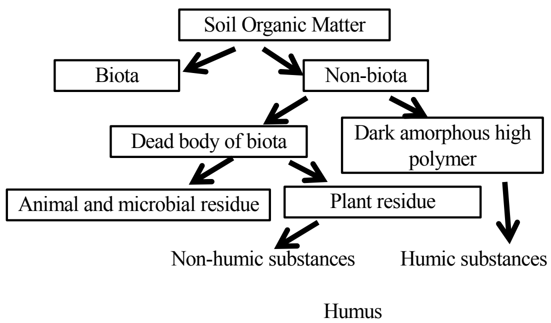
Plant hormone activity

Cold tolerance

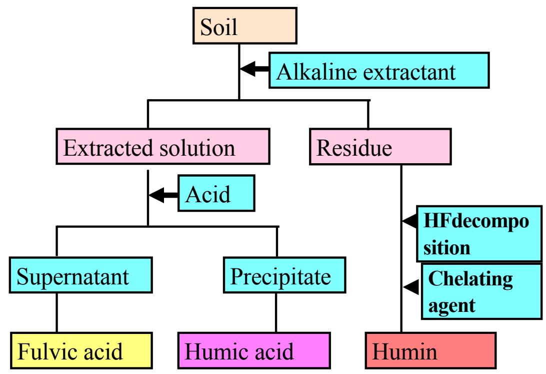
Stable production under deficiency and excess of nutrients



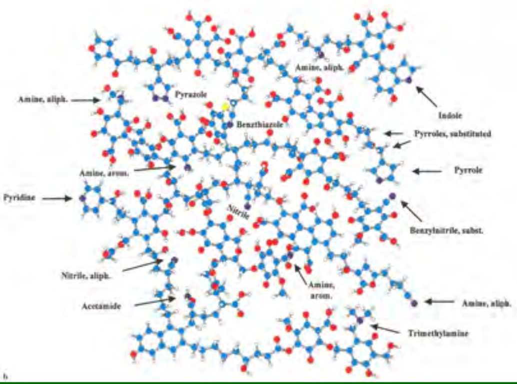
Characterization of soil organic matter



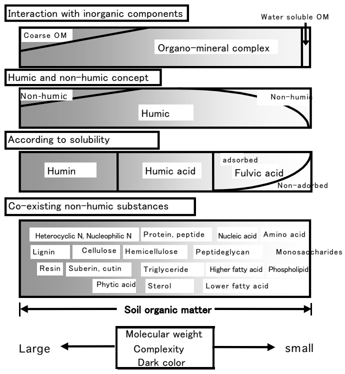
Division of soil organic matter (Takai, 1977)



Fractionation of humic substances



Proposed molecular structure of humic acid



Chemical composition of soil organic matter

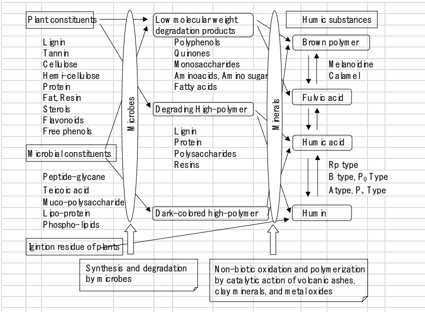
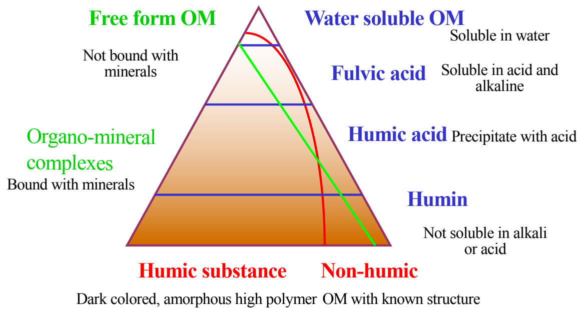
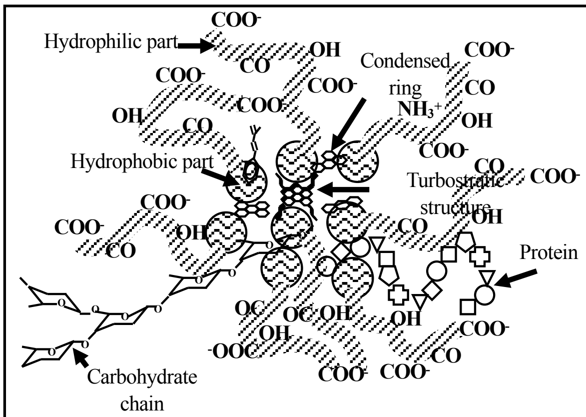


Figure 1. Synthetic pathways of humic substances



Concept on soil organic matter



Structural concept of humic substances

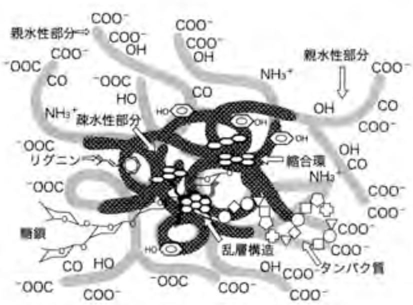


図7-15　腐植物質の構造概念図

Synthetic expression of elementary composition of humic substances

- As indices for expressing elementary composition synthetically, following ratios are calculated. Elementary number is used in the calculation.

Combustion Quotient

- Combustion quotient (CQ) is a theoretical value for respiration quotient as proposed by Tamiya [5)]
- $CQ = 4C / (4C + H - 3N - 2O)$ ------ (1)

Degree of Unsaturation

- Degree of unsaturation (DU) shows the number of unsaturated bonds and ring bonds per 100 carbon atoms.
- $DUH = (2C + N - H) / 2C \times 100$ ------ (2)

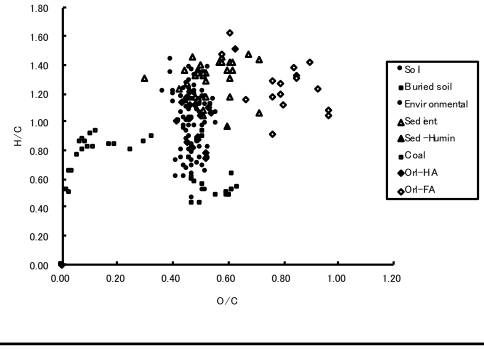
Degree of Oxidation (ω)

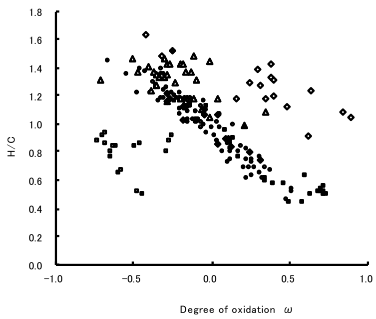
$\omega = (2O - H) / C$ ------ (3)

shows the excess or deficit of oxygen and hydrogen in comparison with $C_n(H_2O)_n$

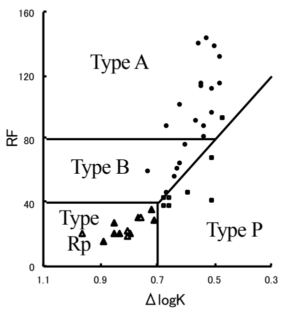
- This value is distributed between -0.8 and $+0.9$ for humic substances.

Elementary composition of humic substances H/C and O/C





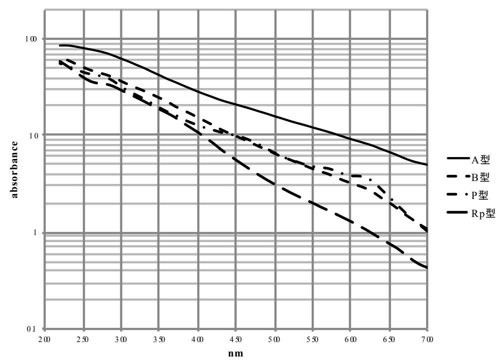
Degree of oxidation(ω) and H/C
● soil humic acids from literature 3 ■ humic acids from buried volcanic ash sois、○ humic asids from literature 7, △ humic acids from sea and lake sediments, ▲ humin from sediments, □ coal, ◆ humic acids from Russian soils in literature 6 ◇fulvic acids from Russian soils.



Classification of humic substances by RF and ΔlogK

● Type A, ○ Type B, ■ Type P with obvious Pg absorption, □ Type P without Pg absorption

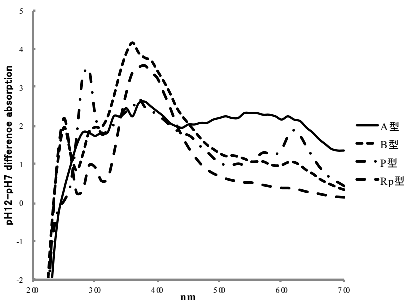
▲ Type Rp from mineral soil, △ Type Rp from O layer



UV-vis. Absorption spectra of humic acis in different types

Type A Inogashira (volcanic ash soil), Type B Higashiyama (brown forest soil), Type P Tsubame (Pg of buried soil), Type Rp Anjo (paddy soil)

Concentrations are adjusted to 1mgC mL^{-1}



pH12-pH7 difference absorption spectra of different types of humic acids.

（Same humic acids as in the previous figure）