
610-280 Environmental Chemistry

Rachel Caruso

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Soil: Composition

- Stoke's Law, surface area calculations
 - Metal oxides
- Organic component
 - Water and gas
 - Plant nutrients

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References

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Stoke's law

- Sedimentation – particle size

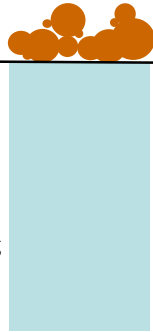
r – radius of particle
 η – viscosity of solution
 v – velocity
 ρ_p – density of particle
 ρ_s – density of solution
 g – acceleration due to gravity

$$F_r = 6\pi r \eta v$$

$$F_g = m \times g$$

$$F_g = \frac{4}{3} \pi r^3 (\rho_p - \rho_s) \times g$$

$$r = \sqrt{\frac{9\eta v}{2g(\rho_p - \rho_s)}}$$



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Surface area

Surface area of a spherical particle

$$SA = 4\pi r^2$$



Total surface area of particles per unit mass

$$SA_T = (\text{no. of particles}) \times 4\pi r^2$$

$$\text{no. of particles} = \frac{1 \text{ g}}{m_p} \quad m_p = \frac{4}{3} \pi r^3 \times \rho$$

$$SA_T = \frac{3}{4} \frac{4\pi r^2}{\pi r^3 \rho} = \frac{3}{r\rho}$$

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Metal oxides

- Non-silicate minerals:
 - eg. Fe, Mn, Al oxides.
- Three most common crystalline oxides in soil are gibbsite $\text{Al}(\text{OH})_3$, goethite FeOOH and hematite Fe_2O_3 .
- Not inclined to develop structural charge as a result of isomorphous substitution – low CEC even with high SA. Do develop limited surface charge – dependent on pH.
- Do have considerable capacity to chemisorb metal ions, inorganic and organic anions.
- Present in soil as free oxides, clay mineral coatings, clay edges.

http://www.soils.wisc.edu/virtual_museum/gibbsite/index.html
http://www.soils.wisc.edu/virtual_museum/hematite/index.html

Organic matter

- Organic matter along with clay minerals has an extremely important influence on the chemical and physical properties of soils.
- Comprised of 2 major groups
 - Nonnitrogenous compounds (mainly carbohydrates):
 - Saccharides
 - uronides
 - Nitrogenous compounds (derived from proteins):
 - Amino sugars
 - Amino acids
 - Amides
 - Heterocyclic amino acid

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Plant decomposition

- Plant cell polysaccharides
 - Cellulose
 - Hemicellulose
 - Lignin
- C and N
 - used by microorganisms
 - escape as gas
 - transformed into other substances
- Plant material takes on black coloration due to oxidation of sugars forming quinones
- Volume decrease
- Final product is “humus”



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Wikipedia

Humic substances

- Amorphous
- Dark coloured
- Hydrophilic
- Wide range MW
- Large number of functional groups
- Three main fractions
 - Humic acid
 - Fulvic acid
 - Humin

http://www.soils.wisc.edu/virtual_museum/som/index.html

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Functions of organic matter

- Maintain good pore structure
- Improve water retention
- Retain nutrients (eg. Ca^{2+} , K^+)
- Release N, P, S and trace elements by mineralisation
- Adsorption of toxic organics

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Humus – Clay interaction

Most of humic material is bound to clays through

- the sharing of polyvalent cations
 R-COO-Ca-Clay
- interaction of the negatively charged humus colloids with positively charged surface of hydrated oxides
 $\text{Humus}^- \text{ } ^+\text{Clay}$
- hydrogen bonding to siloxane or gibbsite sheet
- van der Waals forces

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Water in soil

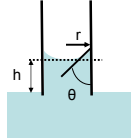
- Found in pores between soil particles
- Associated with mineral clays and humus material
- Transport medium
- Solution constituents commonly encountered in soils: K^+ , Na^+ , Ca^{2+} , Mg^{2+} , HCO_3^- , CO_3^{2-} , HSO_4^- , SO_4^{2-} , Cl^- , F^-

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Capillary action

- Surface tension, γ , draws liquid up a thin tube.

$$h = \frac{2\gamma \cos \theta}{\rho g r}$$



- Q: Given that the surface tension of water is 0.0728 Jm^{-2} , density is 1000 kgm^{-3} , gravitation is 9.8 ms^{-2} , θ is 20° , calculate radius required to obtain water heights of 0.001 m , 0.01 m and 0.10 m .

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Gas in soil

- Found in pores between particles
- Decay of organic matter increases CO_2 content, decreases O_2 content compared to atmospheric air

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Essential plant nutrients

Macronutrients

- From atmosphere and water
 - **Carbon, hydrogen and oxygen**
- From soil
 - **Phosphorus, potassium, nitrogen**, sulphur, calcium, magnesium

Micronutrients required in much smaller quantities: Fe, Mn, B, Mo, Cu, Zn, Cl

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Potassium

- Most absorbed mineral element except N
- Functions for
 - building protein,
 - photosynthesis,
 - fruit quality and
 - reduction of diseases
- Supplied to plants from
 - Soil minerals
 - Organic material
 - fertilizer

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Phosphorus

- Essential part of photosynthesis process
- Supplied to plants from
 - Fertilizer, phosphates (mineral), nucleic acids
- Functions in the
 - formation of oils, sugars, starches,...
 - photosynthesis
 - plant growth

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In summary

Soil: Composition

- Discussed Stoke's Law, surface area, capillary action calculations
- Studied metal oxides, organic, water, gas component of soil
 - Plant nutrients and their source in soil

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