Introduction to Environmental Geology, 5e

Chapter 17

Soils and Environment

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Chapter 17: Overview

- Understand soil terminology and the processes responsible for the development of soils
- Understand soil fertility and the interactions of water in soil processes
- Become familiar with soil classification
- Know primary engineering properties of soils
- Know relationships between land use and soils
- Know sediment pollution and management
- Understand how soils affect land-use planning, and how we can sustain soil resources

Case History: Times Beach, MO

- River town with pop. 2400, west of St. Louis
- In 1983, the town evacuated and purchased by government for $36 million
- Entire town contaminated with dioxin from the oil sprayed on the road to control dust
- Dioxin: Composed of oxygen, hydrogen, carbon, and chlorine, extremely toxic to mammals and a carcinogen in humans; about 75 types of dioxin
- Controversy concerning the effects of human exposure to dioxin, the evacuation an overreaction?

Soil

- Supporting rooted plant life: Solid Earth materials altered by physical, chemical, and biological processes
- Land-use planning: Soil suitability is large part of land capability
- Waste disposal: Soil properties are critical
- Impact of natural hazards: Affected by soil properties
- Climatic signal: clues to the past climate

Soil

Soil profiles:

- Weathering
- Physical and chemical breakdown of rocks
- Residual soil
- Transported soil
- Soils are open systems

Soil horizons:

- Movement of materials in soil creates distinct horizons parallel to the land surface
- Soil profile consists of soil horizons:
  - O horizon
  - A horizon
  - E horizon
  - B horizon
  - C horizon
  - R horizon

Soil Profile

Soil horizon: distinct layers roughly parallel to the surface as soil develops over time

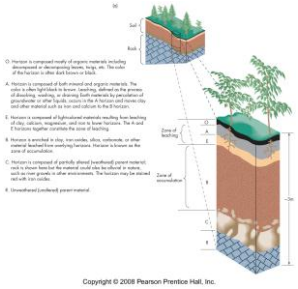

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Figure 17.3 A

Soil's General Properties

- Color: Depending on the amount of organic matter, iron oxides, and soil water retention
- Texture: Relative proportions of sand, silt, and clay-sized particles affect soil's strength and ability to retain water and nutrients
- Structure:
  - Aggregates of soil as *peds*
  - The more developed with time, the more complex a soil's structure, from granular to blocky to prismatic

Soil Texture

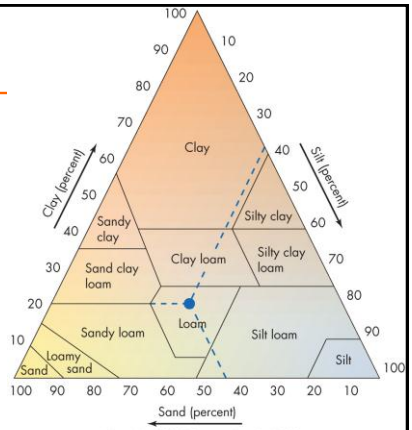


Figure 17.4

Soil Structure

Types of peds	Typical size range	Horizon usually found in	Comments
Granular	1–10 mm	*A*	Can also be found in *B* and *C* horizons
Blocky	5–50 mm	B_t	Are usually designated as angular or subangular
Prismatic	10–100 mm	B_t	If columns have rounded tops, structure is called columnar
Platy	1–10 mm	*E*	May also occur in some *B* horizons

Soil Fertility

- Soil's capability to supply nutrients needed for plant growth, such as N, P, K
- A complex ecosystem in itself, containing millions of living things in a single cubic meter
- Fertility changes:
  - Increase: Applying fertilizers or mixing materials to improve soil texture
  - Decrease: Leaching or soil erosion

Soil Water

- Soil pores filled with air or liquid (water)
- Soil in saturated condition, if filled with water; otherwise unsaturated
- The saturation level of soil water changes with climate (hardly saturated in arid climate) and seasons (deficit vs. surplus conditions)
- Movement of water: important in pollution monitoring and management

Soil Classification

- Soil classification based on physical and chemical properties of the soil profile
- Unified soil classification system: widely used in engineering practice, based on particle size, abundance of organic material, and odor
- Useful for agricultural, environmental engineering, and land use planning *(see Table 17.1 for properties of soil order)*

TABLE 17.2 Unified Soil Classification System Used by Engineers

	Major Division		Group Symbol	Soil Group Name
COARSE-GRAINED SOILS (more than half of material larger than 0.074 mm) — GRAVELS	Clean gravels	Less than 5% fines	GW	Well-graded gravel
			GP	Poorly graded gravel
	Dirty gravels	More than 12% fines	GM	Silty gravel
			GC	Clayey gravel
SANDS	Clean sands	Less than 5% fines	SW	Well-graded sand
			SP	Poorly graded sand
	Dirty sands	More than 12% fines	SM	Silty sand
			SC	Clayey sand
FINE-GRAINED SOILS (more than half of material smaller than 0.074 mm) — SILTS, NONPLASTIC			ML	Silt
			MH	Micaceous silt
			OL	Organic silt
CLAYS, PLASTIC			CL	Silty clay
			CH	High plastic clay
			OH	Organic clay
Predominantly organics			PT	Peat and muck

Note: The value 0.074 mm is the boundary between sand and silt that engineers use. Geologists use 0.063 mm for the same boundary.

TABLE 17.3 Generalized Sizes, Descriptions, and Properties of Soils

Soil	Soil Component	Symbol	Grain Size Range and Description	Significant Properties
Coarse-grained components	Boulder	None	Rounded to angular, bulky, hard, rock particle; average diameter more than 25.6 cm.	Boulders and cobbles are very stable components used for fills, ballast, and riprap. Because of size and weight, their occurrence in natural deposits tends to improve the stability of foundations. Angularity of particles increases stability.
	Cobble	None	Rounded to angular, bulky, hard, rock particle; average diameter 6.5–25.6 cm.	
	Gravel	G	Rounded to angular, bulky, hard, rock particles greater than 2 mm in diameter.	Gravel and sand have essentially the same engineering properties, differing mainly in degree. They are easy to compact, little affected by moisture, and not subject to frost action. Gravels are generally more pervious and more stable and resistant to erosion and pipping than are sands. The well-graded sands and gravels are generally less pervious and more stable than those that are poorly graded and of uniform gradation.
	Sand	S	Rounded to angular, bulky, hard, rock particles 0.074–2 mm in diameter.	
Fine-grained components	Silt	M	Particles 0.004–0.074 mm in diameter; slightly plastic or nonplastic regardless of moisture; exhibits little or no strength when air dried.	Silt is inherently unstable, particularly with increased moisture, and has a tendency to become quick when saturated. It is relatively impervious, difficult to compact, highly susceptible to frost heave, easily erodible, and subject to pipping and boiling. Bulky grains reduce compressibility, whereas flaky grains (such as mical increase compressibility, producing an elastic silt.
	Clay	C	Particles smaller than 0.004 mm in diameter; exhibits plastic properties within a certain range of moisture; exhibits considerable strength when air dried.	The distinguishing characteristic of clay is cohesion or cohesive strength, which increases with decreasing moisture. The permeability of clay is very low; it is difficult to compact when wet and impossible to drain by ordinary means; when compacted, is resistant to erosion and piping; not susceptible to frost heave; and subject to expansion and shrinkage with changes in moisture. The properties are influenced not only by the size and shape (flat or platelike) but also by their mineral composition. In general, the montmorillonite clay mineral has the greatest and kaolinite the least adverse effect on the properties.
	Organic matter	O	Organic matter in various sizes and stages of decomposition.	Organic matter present even in moderate amounts increases the compressibility and reduces the stability of the fine-grained components. It may decay, causing voids, or change the properties of a soil by chemical alterations; hence, organic soils are not desirable for engineering purposes.

Table 17.3a

Engineering Properties of Soils

- Strength: Soil's ability to resist deformation, function of cohesive and frictional forces between soil particles
- Sensitivity: Measuring the changes in soil strength from disturbances
- Compressibility: Soil's tendency to consolidate or decrease in volume

Strength and Compressibility

Figure 17.8 and 17.10

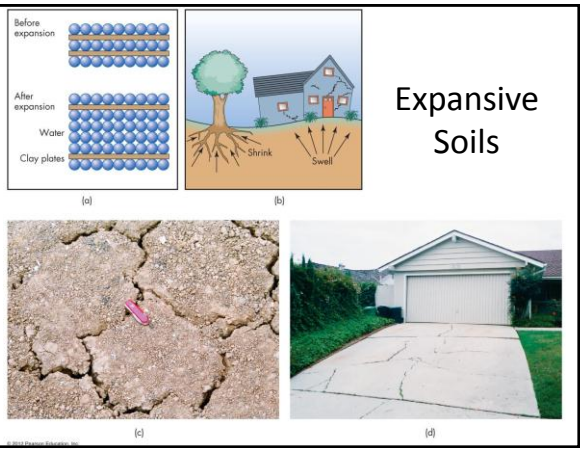
Engineering Properties of Soils

- Erodibility: The ease with which soil is removed by wind or water
- Hydraulic conductivity: The ease of soil to allow water to move through
- Corrosion potential: Depending on the chemistry of soil, soil-water content, and type of buried materials in the soil

Engineering Properties of Soils

- Ease of excavation: The degree of ease to remove soil using certain equipment during construction
- Shrink-swell potential: Soil's tendency to gain or lose water -
  - Expansive soils: Causing significant environmental problems in the U.S.
  - Changes in moisture content
  - Topography and drainage also significant

Expansive Soils



Soil Strength

- Soil strength: The ability of a soil to resist deformation
- Function of cohesive and frictional forces
- Cohesion due to surface tension caused by the attraction of water molecules to each other at the surface or between soil grain
- The total frictional force is a function of the density, size, and shape of the soil particles and of the weight of overlying particles that force the grains together, usually the result of both cohesion and internal friction and vegetation

Rates of Soil Erosion

- **Volume, mass, or weight of soil removed from a specific area during a specific period of time, kilograms per year per hectare**
- The Universal Soil Loss Equation: A = RKLSCP
  - A: Long-term average annual soil loss for the site
  - R: Long-term rainfall runoff erosion factor
  - K: Soil erodibility index factor
  - L: Hillslope/length factor
  - S: Hillslope/gradient factor
  - C: Soil cover factor
  - P: Soil erosion-control practice factor

Soil Erosion

- Urbanization: Rapid development and construction
- Desertification: Overgrazed or disturbed
- Deforestation: Forest over-logged or burned
- Surface mining: in 2000, 65% coal produced from surface mining
- Soil erosion and deposition: by natural hazards, such as floods

Sediment Pollution

One of greatest pollutants…

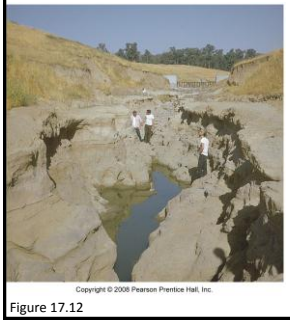
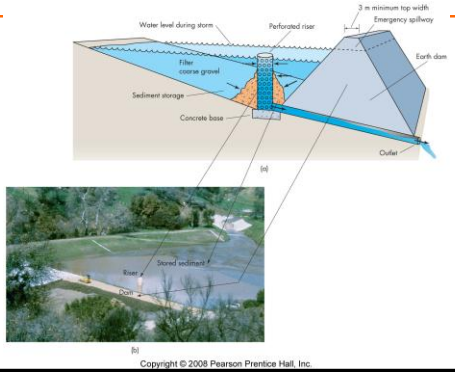


Figure 17.12

- Chokes streams
- Fills lakes, reservoirs, river channels, etc.
- Buries vegetation
- Creates nuisance that is difficult to remove

Need better land-use and urban development planning and sediment control basins to prevent excess pollution.

Sediment Control Basin



Land-Use and Soil Problems

- Influencing the pattern, amount, and intensity of surface-water runoff, erosion, and sedimentation
- Agriculture: Estimated 10% of the world has best agricultural land damaged due to soil erosion and overuse during the last 50 years
- Better practice to sustain soils:
  - Contour plowing
  - No-till agriculture (no plowing)
  - Terracing slopes, retaining walls
  - Planting more than one crop, particularly in tropical areas or crop rotation.

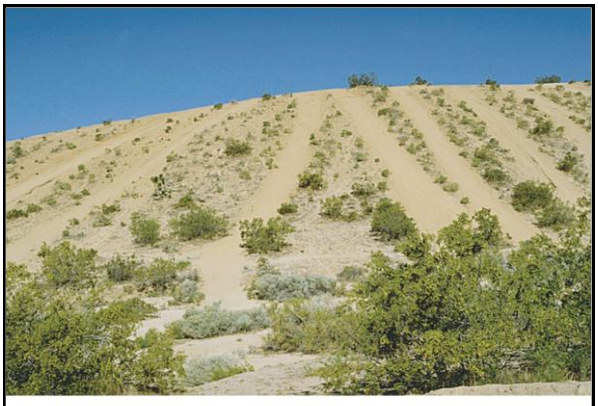
Figure 17.17 and 17.18

Land-Use and Soil Problems

- Urbanization: Conversion of agricultural, forest, and rural lands
- Soil scraped off and lost
- Changes of soil properties
- Soil pollution: Use of chemicals
- Changes of surface runoff, sediment yield, and stream dynamics affecting soil and soil erosion

Land-Use and Soil Problems

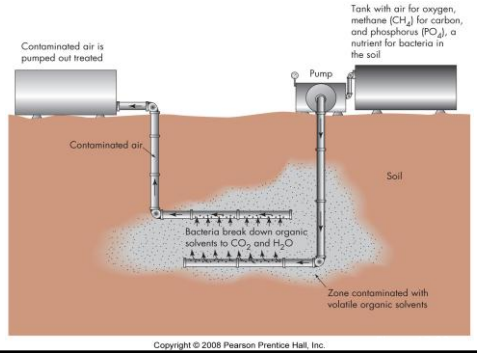
- Off-road vehicles: recreation, tourism, etc.
- In deserts, coastal dunes, forested mountains, lake-side, etc.
- Cause changes in rates of soil erosion, hydrology, habitats of plants and animals
- Impacts from the increased number of mountain bikes in parks, national forests, etc.


(a)

Soil Pollution

- Soil pollution: By any materials detrimental to human and other living organisms, such as organic chemicals, inorganic chemicals, toxic substances
- Intentionally or accidentally applied to soils
- Inappropriate disposal of waste materials
- Treatment: Excavation, disposal, incineration, and bioremediation

Bioremediation of Polluted Soil



Soil Survey and Land-Use Planning

- Soil survey: Providing important information about soils
- Soil properties: Critical for the best use of land; specific soils suitable for certain land use
- Soil's engineering properties: Necessary info for identifying potential problems before construction
- Detailed soil maps: Helpful and important in land use planning

Critical Thinking Topics

- Defend the statement that soil erosion is an environmental problem that could seriously damage, or even cause the collapse of, our civilization.
- What are things an individual citizen can do to prevent soil erosion?
- Does the impact of soil erosion go beyond where it occurs? Explain your answer
- Are the soil problems more severe in developed countries or developing countries?