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(03)

selenium. Contamination of the terrestrial food chain has subsequently occurred at this site because of remobilization of selenium (USBR, 1993). In view of the seriousness of selenium biogeochemical cycling (see entry on *Cycles, Geochemical*), exposure potential, including local food market surveys, may be necessary to assess selenium criteria levels since the concentration of selenium in water is not always reflective of the amount of uptake in the food chain (Presser *et al.*, 1994).

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Cross-references

Arsenic Pollution and Toxicity
Cadmium Pollution and Toxicity
Environmental Toxicology
Health Hazards, Environmental
Heavy Metal Pollutants
Lead Poisoning
Mercury in the Environment
Metal Toxicity

SEMI-ARID CLIMATES AND TERRAIN

Semi-arid climates

Differences in the prevailing land use and management of arid and semi-arid areas are determined in part by climate. Arid areas generally receive too little rainfall to support dryland agricultural or domestic livestock grazing. In contrast, in semi-arid areas adequate moisture is usually available at some time during the year to produce forage for livestock, and there are some years when dryland crop production is successful (Heath *et al.*, 1985; Penman, 1963). However, both climates are characterized by extreme variability, with commonly occurring droughts and infrequent periods of above-average rainfall.

Most arid areas of the world occur along two wide belts at approximately 30° latitude north and south of the equator (Lydolph, 1985). In these subtropical belts, the winds generally descend and are dry much of the time. Semi-arid areas associated with the arid deserts generally occur north and/or south of the deserts (in Africa, Asia and Australia) or inland and at slightly higher elevations (in North America, South America, the Middle East, Africa and Asia). On a more localized scale, a combination of terrain and prevailing wind direction can cause 'rain shadow' effects, resulting in arid and semi-arid areas downwind of major mountain features (Oliver and Fairbridge, 1987).

More than a third of the world's land surface is either arid, generally receiving less than 250 mm of annual precipitation, or semi-arid with between 250 mm and 500 mm of annual precipitation. More precise definitions of desert and semi-arid areas are given in climatic classifications based on precipitation, temperature and their seasonal distributions. For example, following Trewartha and Horn (1980), and based on extensive classifications of Köppen (1931), upper and lower mean annual precipitation limits defining semi-arid climates are as follows.

Semi-arid climates, for regions where annual precipitation is not strongly seasonal, are defined by equations linking mean annual values of precipitation, R, in mm, and temperature, T, in degrees C. The upper limit for semi-arid climates, in terms of mean annual precipitation given a specific value of mean annual temperature, is defined by

$$R \leq 20T + 140$$

The corresponding lower limit that separates arid and semi-arid (or alternatively desert and steppe) is defined as half the value of the upper limit from the above equation, or

$$R \geq 10T + 70$$

Temperature and precipitation data from selected locations in arid and semi-arid areas of the world were used to classify climate based on the above criteria and a designation for hot (h, with 8 or more months of the year with average temperature above 10°C) and cold (k, with fewer than 8 months of the year with average temperature above 10°C). The general classification for dry climates is B and the specific classification for semi-arid is S. Thus, BSk represents a cold semi-arid climate and BSh is a hot semi-arid climate. These classifications and

Table S1 Location and summary of climatic classifications for selected locations in arid and semi-arid areas of the world

Location	Latitude (degrees)	Longitude (degrees)	Elevation (m)	Precipitation (mm)	Temperature (°C)	Climate classification[a]	Mean annual precipitation limits (mm) for semi-arid climate classification[b]	
							Upper limit	Lower limit
Yuma, AZ, USA	32.7 N	114.6 W	62	81	22.7	*BWh*	594	297
Khartoum, Sudan	15.6 N	32.6 E	380	162	29.1	*BWh*	722	361
El Paso, TX, USA	31.8 N	106.4 W	1194	221	17.5	*BW*	490	245
Quetta, Pakistan	30.2 N	67.0 E	1673	229	14.9	*BS*	438	219
Alice Springs, Australia	23.8 S	133.9 E	549	275	20.8	*BWh*	556	278
Boise, ID, USA	43.6 N	116.2 W	871	321	11.0	*BSk*	360	180
Tombstone, AZ, USA	31.7 N	110.1 W	1405	357	17.4	*BSh*	488	244
Tashkent, Uzbekistan	41.3 N	69.3 E	428	386	13.6	*BSk*	412	206
Mahalapye, Botswana	23.1 S	26.8 E	1005	485	20.5	*BS*	550	275
Charleville, Australia	26.4 S	146.3 E	304	493	20.5	*BSh*	550	275
Mopti, Mali	14.5 N	4.1 W	272	549	27.9	*BSh*	698	349

[a]Classification notes: *BW*, arid or desert; *BS*, semi-arid or steppe; *h*, hot, 8 months or more with average temperature over 10°C; *k*, cold, fewer than 8 months with average temperature over 10°C.
[b]Precipitation limits calculated as upper limit $= 20T + 140$ and lower limit $= 10T + 70$.

the upper and lower precipitation limits for each location are listed in Table S1.

The occurrence, frequency, and magnitude of precipitation events vary widely in semi-arid areas. Annual potential evapotranspiration significantly exceeds precipitation in such areas and can be accurately predicted with a number of techniques. In contrast, actual evapotranspiration is nearly equal to precipitation and is difficult to calculate under field conditions. Although actual evapotranspiration differs little from precipitation in magnitude on an annual basis, these differences are crucial, as by and large they determine annual soil moisture status, runoff and groundwater recharge.

Vegetation in arid and semi-arid areas is adapted to lack of moisture, extreme variations in precipitation and temperature, and soil characteristics (Hilgard, 1906), as described below. Seasonal distribution of precipitation and temperature also play a dominant role. Three deserts in North America illustrate the interactions of soil–water–plant relationships with climate, soil, and topography (Fuller, 1975). The Mojave Desert is characterized by the dominance of winter precipitation and the absence of precipitation during the hot summer. Vegetation varies strongly with elevation, and thus with temperature and precipitation from the desert to the adjacent semi-arid areas. At higher elevations yucca species are common and Larrea–Franseria associations dominate at lower elevations. The Sonoran Desert is the most floristically diverse of the three deserts with an abundance of cacti, shrubs, riparian trees, and desert to semi-arid grasslands dependent upon elevation, precipitation, and temperature. Precipitation tends to be more bimodal in the Sonoran Desert and thus there are distinct summer vegetative responses usually absent in the Mojave Desert. The Chihuahuan Desert is generally cooler than the Mojave and Sonoran Deserts and is much more dominated by summer rainfall. As a result of the different seasonal variation in precipitation and less variation in elevation, plant communities in the Chihuahuan Desert are less complex than those in the Sonoran Desert.

Terrain

Bedrock geology, describing the form, properties and dimensions of the rock units and how they are locally and regionally related, predetermines the basis of what we see in the landscape. Geologic processes that shape the Earth's surface can be endogenous or exogenous and together they provide the forces shaping the landscape. The existing landscape is also the result of interactions between the atmosphere and the Earth's surface. Because on geologic time scales climate is not constant, paleoclimatology and paleohydrology must be considered in describing the evolution of the landscape.

The terms watershed, catchment and drainage basin (*q.v.*) have similar meanings and definitions. The term watershed means an area above a specified point on a stream channel enclosed by a perimeter. The watershed perimeter defines an area where surface runoff will move into the stream or tributaries above the specified point. In arid and semi-arid regions, vegetative sparseness and normally clear, dry air make these features most evident. Thus a striking feature of arid and semiarid landscapes is the stream channels, and thus watersheds, which combine in complex patterns to produce the channel networks and inter-channel areas. These features in turn control the movement of water and sediment when precipitation causes runoff. The runoff and the associated erosion and sedimentation processes combine with wind erosion and deposition to modify the evolving geomorphic features we see at any particular time (Cooke *et al.*, 1993).

There are direct links between the form and structure (geomorphic features) of the terrain we see in a landscape and the processes that shape them. Geomorphic features influence the movement of wind and water and thus the erosion and sedimentation processes which are in turn modifying the geomorphic features (Doehring, 1977). Key questions in the earth sciences today deal with the interaction and feedback of form and structure with processes at various temporal and spatial scales (Fairbridge, 1968). That these interactions and feedbacks are functions of time, space, and process intensity scales make the 'scale' problem a central focus of much scientific research.

For example, soils in arid and semi-arid regions are notable for their variations with respect to topographic features (Dregne, 1976). Perhaps as striking as their nonhomogeneity in space is their usual close relationship with the parent material due to their thinness, the lack of moisture, and the slowness of the soil-forming processes. The 'better' soils are often formed on alluvial deposits or deposits of loess.

In extensive semi-arid areas, vertical differentiation of soil profiles is lacking, due to weak chemical activity resulting from the dryness. A typical exception to this generalization is the forming of calcrete by deposition and leaching of calcium, in the form of calcium carbonate, and other soluble salts. Variations in soil properties from undifferentiated profiles to calcrete formations have a significant influence on the water balance of semi-arid areas and thus affect hydrologic processes, erosion and sedimentation, biological productivity, and ultimately land use and management (Hudson, 1987).

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Cross-references

Arid Zone Management and Problems
Chaparral (Maquis)
Desertification
Deserts
Drought, Impacts and Management
Ecological Stress
Salinization, Salt Seepage
Soil Erosion
Xerophyte

SEPTIC TANK

A component of an on-lot wastewater treatment system, the septic tank holds all household wastewater for at least 24 hours, allowing for the separation of settleable and floatable solids. Separating the solids from the wastewater prevents clogging of the other components of the treatment system. Up to 50 per cent of the retained solids in the tank decompose. The remaining solids accumulate in the tank. Biological and chemical additives are not needed to aid or accelerate decomposition.

A septic tank is a rectangular or cylindrical watertight container usually ranging in size from 2,000 to 7,500 liters in capacity (Figure S11). It is constructed of sound durable materials that are resistant to corrosion or decay. The most important components of a septic tank are the baffles. The inlet baffle channels wastewater down into the tank, preventing short-circuiting across the top of the tank. The outlet baffle keeps the scum layer from moving out of the tank.

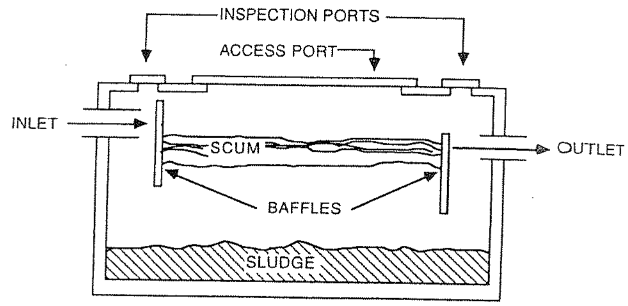

Figure S11 Components of a septic tank.

Septic tank management involves conserving water and limiting food and grease poured down the drain. Septic tanks require periodic pumping, typically every 1 to 5 years, to remove accumulated solids. The baffles should be checked for deterioration and if damaged can be replaced with sanitary tees.

See Burks and Minnis (1994) for further details.

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Cross-references

Bacteria
Pathogen Indicators
Sewage Sludge
Sewage Treatment
Water, Water Quality, Water Supply

SEWAGE SLUDGE

The treatment and purification of raw sewage allows fine-grained particulate material to settle out in the form of sludge and be removed from the bases of separation tanks. Sewage sludge consists of aerated or anaerobically digested slurry and comprises about 10 per cent of municipal waste production (Lottermoser and Morteani, 1993). After collection it is dewatered, stabilized and disposed of in landfills, in municipal dumps, at sea, by high-temperature incineration, or by pyrolysis. Alternatively, it can be used as a high-quality phosphate fertilizer.

Sewage sludge is commonly rich in toxic organic compounds (such as phenols, polychlorinated biphenyls and phthalates), heavy metals (including arsenic, mercury and selenium) and metalloids. In the United States, typical concentrations of