

Soil is a Filter

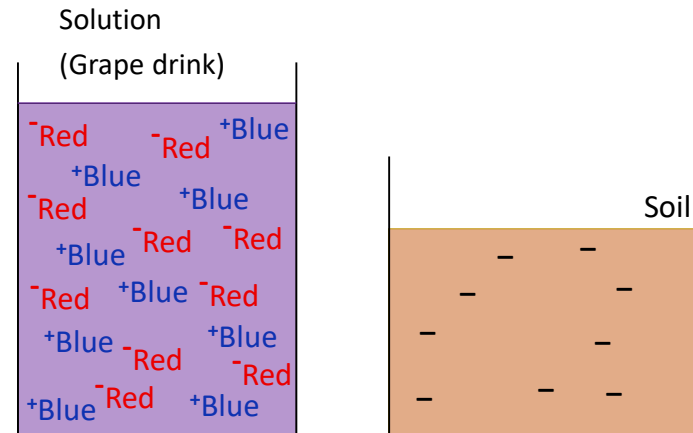
Demonstration with Powdered Grape Drink Mix



1

Figure 1

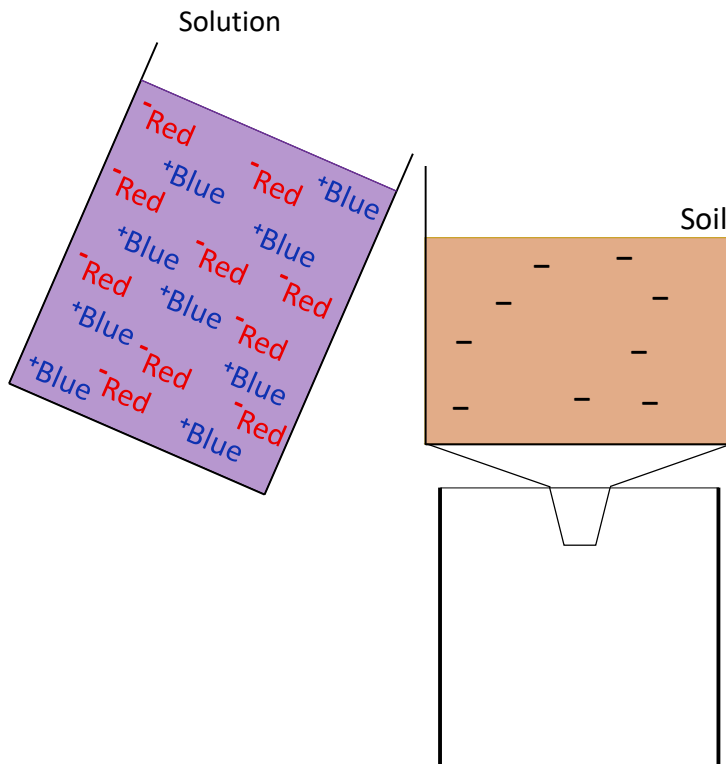
- Grape drink mix is composed of two organic dyes, a blue cation and a red anion; technically it is a salt.
- The dyes are weakly bound and dissolve readily in water, resulting in a purple liquid that actually contains individual red and blue ions dissolved in the water.
- Soils are mixtures of sand (2 to 0.05 mm), silt (0.05 to 0.002 mm), and clay (<0.002 mm) particles. The clays generally have a negative charge, and therefore attract cations (positively charged ions) because opposites attract.



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Figure 2

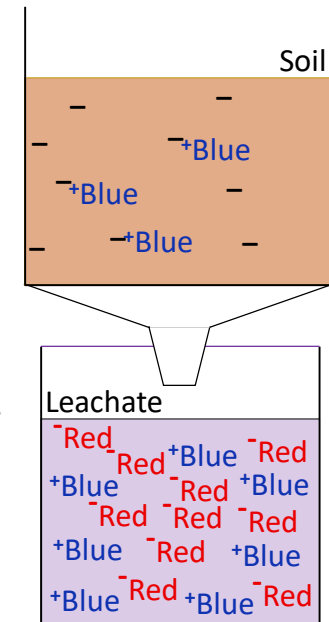
- Slowly pour the grape drink solution through the soil.



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Figure 3a

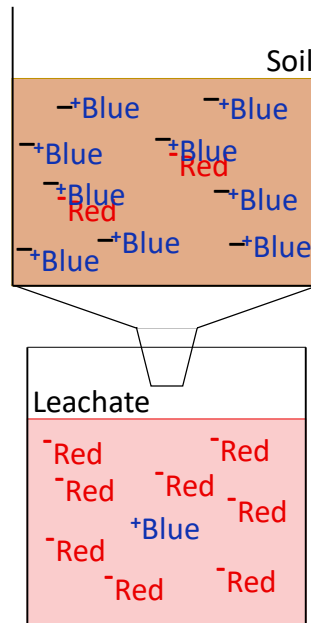
- The cations (blue dye) are retained in the soil, adsorbed to the negatively charged clay particles.
- The anions have the same charge as the clays and are repelled. They leach through the soil, so the leachate often will appear pink or red.
- Sometimes, though there is little color change in the leachate. There are two possible reasons:
 - The soil could be a sand; see Figure 4.
 - If the pores in the soil are large, and the soil relatively dry, the grape drink may flow through the soil too fast for the cations to interact with the charged clay particles.
- In that case, pour the leachate through the soil again.



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Figure 3b

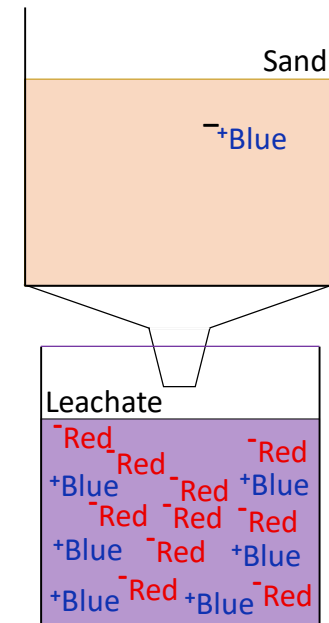
- If the soil is not a sand, when the solution flows through the soil slowly enough for the ions to interact with the soil, the leachate will change color.
- The soil selectively filters the cations from the solution; most of the blue dye is retained in the soil.
- The anions have the same charge as the clays and are repelled. They leach through the soil, so the liquid collected (leachate) often appears pink or red.



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Figure 4

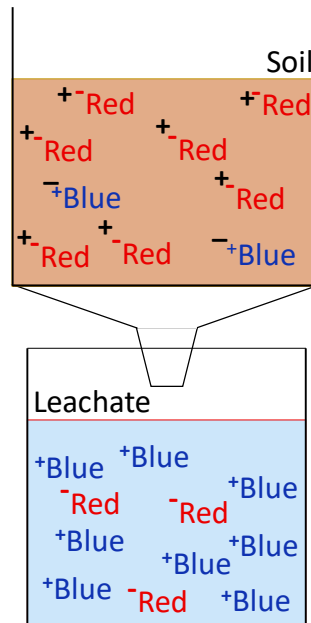
- Pure sands have no charge and are chemically inert – nonreactive. Pure sands are rare – all soils are mixtures of sand, silt, and clay particles – though the percentage of any given particle size may be very small
- Because sands have little charge, they do not filter cations or anions from the solution.
- The leachate contains essentially the same combination of anions and cations as the original solution.
- Because of their shape and size, sands often effectively filter particulates from suspensions, but have little effect on the composition of a solution.



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Figure 5

- In rare cases – most commonly in strongly acidic soils (pH < 5.5) - some clays may develop a positive charge and therefore attract anions.
- In this case, the red anions are held to the positively charged clay particles, and since the blue cations have the same charge as the soil, they flow into the leachate.
- It is important to note a soil can only adsorb as many ions as it has sites to hold them.



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Results

- The purple solution was poured through four soils, from left to right:
 - Neutral pH medium to coarse sand (2 to 0.5 mm particles) purchased at a local store and sieved to remove the smallest particles;
 - Yellow-brown, low-organic matter, neutral pH silt loam from a grassland in Eastern Colorado;
 - Red-brown, low-organic matter, strongly acid fine sandy loam formed in a forested soil in the Ouachita Mountains in Central Arkansas;
 - Black, high-organic matter, slightly acid silt loam formed in a tallgrass prairie in Central Illinois.



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Results

- The original solution is in the bottom center.
- Neutral pH sand - almost no color change in the leachate;
- Yellow-brown, low-organic matter, neutral pH silt loam – red leachate, blue cations remain in soil;
- Red-brown, low-organic matter, strongly acid fine sandy loam – blue leachate, red anions remain in soil;
- Black, high-organic matter, slightly acid silt loam – almost colorless leachate. The blue cations were attached to the clay particles, the red anions were held to the positive charges on organic matter. The organic matter provides a tea-color in the leachate.



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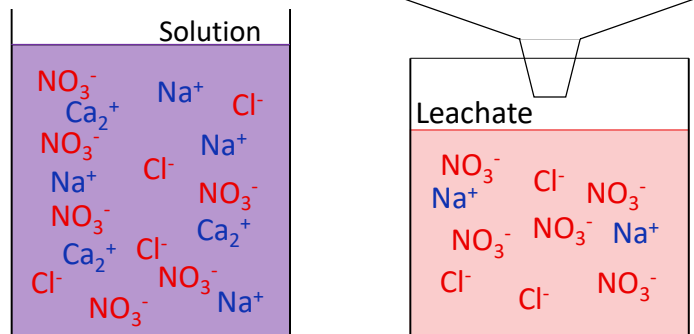
Application

- Soil naturally filters water that falls as rain and goes into rivers.
- Soil is used to filter and purify wastewater that comes from houses, cities, industry, and large animal feeding operations. In this case, microbes in the soil contribute to the filter by decomposing some contaminants.
- A healthy soil is important for good drinking water.
- Salt – Though most people only think of table salt, almost all fertilizers are soluble salts that dissolve when mixing with water in the soil.
- Nitrate is an anion, and so leaches like the red dye. That is why nitrate so often ends up in groundwater, rivers, lakes, and the Gulf of Mexico.
- Calcium and potassium are plant nutrients that are cations, and so usually are held in the soil.
- Heavy metals such as lead and mercury are cations and are held in the soil. This is both good and bad. If they remain in the soil, they do not get into water, but they can be toxic to plants and humans, so people should avoid contact with contaminated soil.

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Figure 6: Application

- Consider adding two soluble fertilizers (salts) to the solution instead of grape drink mix: 3 calcium nitrates, $\text{Ca}(\text{NO}_3)_2$, and 4 sodium chlorides, NaCl .
- Both are composed of a cation (Ca^{2+} and Na^+) and an anion (NO_3^- and Cl^-). Calcium is a divalent cation (2 positive charges) and so joins with 2 nitrate anions.
- With its two charges, calcium takes up two negative charges in the soil.
- This soil holds 8 + charges, but there are 10. Excess cations leach. Calcium (+2) is stronger than sodium (+1), so sodium leaches.



Glossary

- Salt – an acid ion plus a base ion of opposing charges, hence, an ion plus a cation.
 - Salts vary in solubility.
 - People commonly think of table salt, sodium chloride (Na^+Cl^-), but that is only one example. Baking soda, baking powder, gypsum salts, and Epsom salts are other common salts found and used in everyday life in homes around the world.
- Solution – a liquid containing dissolved ions. Dissolution is a chemical process that changes the properties of the constituents; a solution cannot be separated into its component parts (the ingredients used to make it).
- Suspension – a mixture that has other materials floating in the water (though they may be too small to see). The components of a suspension can be physically separated; there are no chemical changes.
- Leachate – the solution that flows through and out of the soil.