Best Practice Treatment Designs and Installations for Sodic Soils

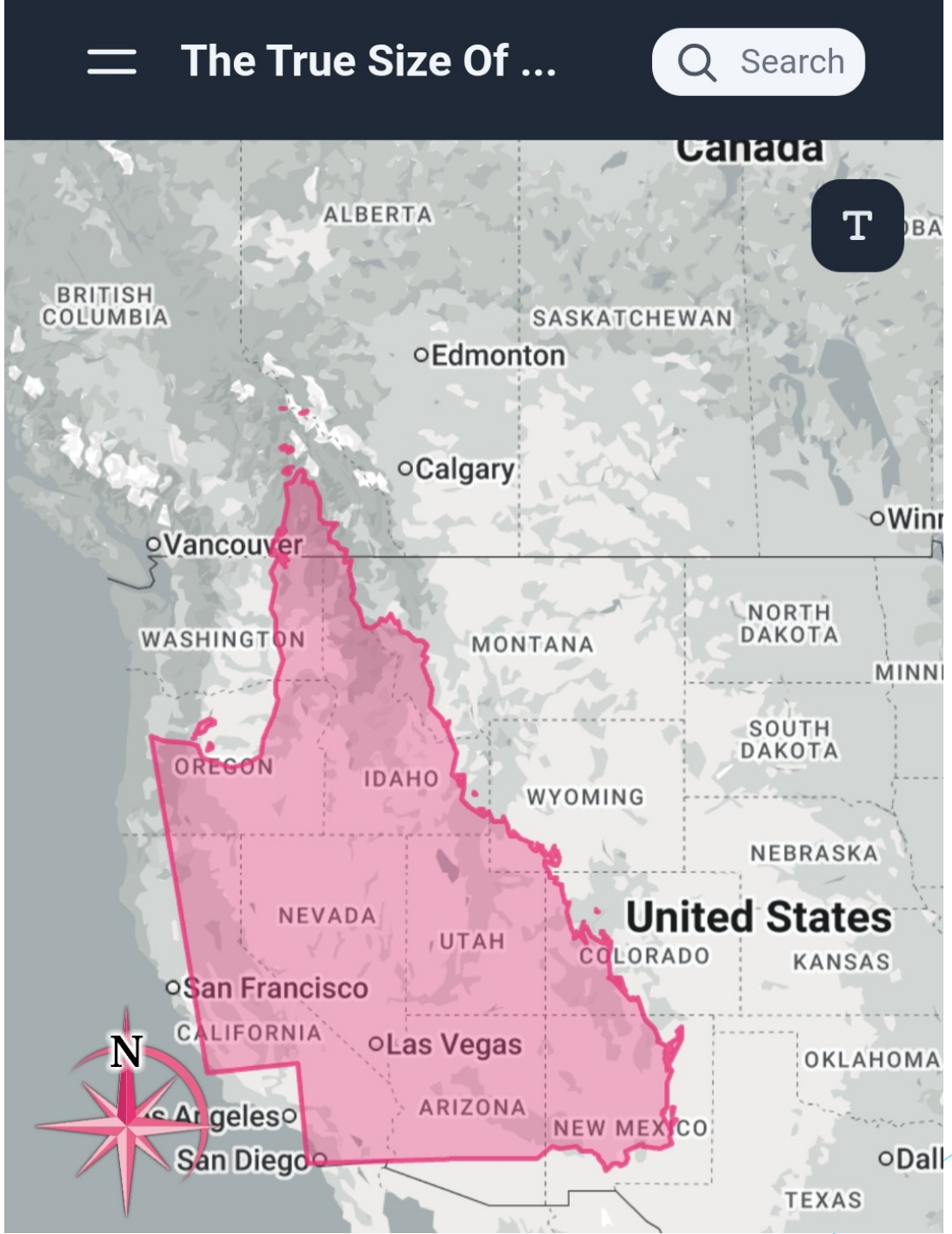
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water treatment & technology

Ben Kele: Managing Director of Arris Pty Ltd

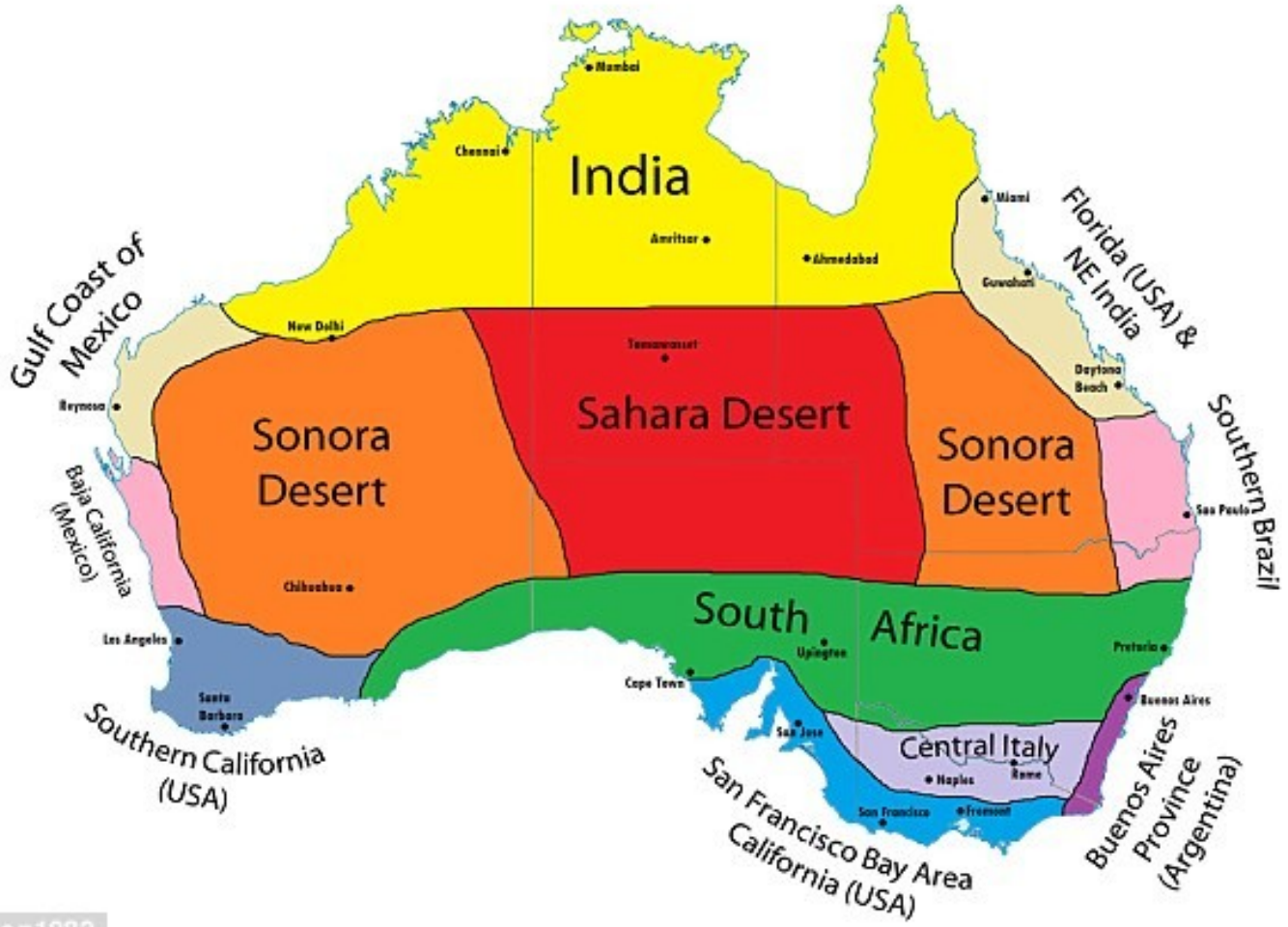
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Australia/North America Comparison




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Climate Map of Australia



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Sodic Soils in the US

- Total Affected Area: Roughly 38% of the contiguous US land area has some level of salt or sodium impact in the 0–100 cm (0-40 inch) depth range
- Cropland Impact: About 64 million hectares (158 million acres) of these affected soils are classified as cropland.
  - Regional Hotspots: The Northern Great Plains—including states like South Dakota, North Dakota, Montana, and Wyoming—contain over 10 million hectares affected specifically by saline-sodic conditions.
- Classification Definition: A soil is considered sodic when its exchangeable sodium percentage (ESP) is 15% or higher, or its sodium adsorption ratio (SAR) exceeds 13
- Salinity and sodicity are not the same

Salinity

- Risk to the environment and responsible for a loss in agricultural productivity
- Often described as solely the impact of sodium chloride, but this is incorrect
- Salts are inherent in water from the leaching of salts from rocks
  - Also present in rainwater from atmospheric particles

Salinity

- Salts can be defined as compounds that disassociate in water to form negative ions (anions) and positive ions (cations) (Patterson, 2007).
- Chemically a salt is the result of a neutralisation reaction between an acid and a base (Lambert and Turner, 2000).
- A salt is an ionic compound that can be either an organic or inorganic chemical (Lambert and Turner, 2000).
- The concentration of all salts present in a soil or water is the definition of salinity (VanDeGraaff and Patterson, 2001).

Salinity

- Another common misconception is that all salts, and therefore all salinity, are harmful to soils (Patterson, 2007). A beneficial agricultural salt is calcium carbonate ($CaCO_3$)
- This salt dissociates into calcium cations (Ca^{2+}) and carbonate anions (CO_3^{2-}); where the calcium ions can improve soil structure and plant nutrition and the carbonate ions increase the mineralised carbon levels in the soil (Bertrand et al., 2007, Patterson, 2007).

Types of Salinity

Salinity Type	Symbol	Definition
Water salinity	EC_w	Electrical conductivity of water
Irrigation water salinity	EC_{iw}	Electrical conductivity of water applied for irrigation
Soil salinity	EC_e	Electrical conductivity of water contained in the soil sample and extracted for measurement. Also called the electrical conductivity of saturation extract
Soil water salinity	EC_{sw}	Electrical conductivity of the soil water. It is difficult to measure soil water salinity, EC_e, is usually measured. Generally EC_e is approximately half of the soil water salinity, EC_{sw}
Drainage water salinity	EC_{dw}	Electrical conductivity of water drained from the root zone or a defined layer where percolated water is drained from the soil
Threshold Electrolyte Concentration	TEC	Electrical conductivity related to the first discernible effect on soil structure; also known as the threshold concentration or C_{TH}
Turbidity Electrolyte Concentration	TUEC	Electrical conductivity at which the dismantling of the soil microstructure is indicated by the appearance of dispersed particles in the percolate—this occurs when the electrolyte concentration is about one-quarter of the threshold concentration. Also known as the turbidity concentration or C_{TU}

Salinity

- The removal of salts from recycled water is considered to be both difficult and costly (Shuval 1991)
  - The only thing that takes salt out of water is money
- High Solubility
- Salts based upon sodium and the associated sodicity are major concerns when irrigating with recycled water (Graaff and Patterson 2001)

Sodicity

- Sodium is present in most types of water and soil
- The sodium absorption ratio (SAR) is the comparison of the relative preponderance of dissolved sodium (Na) ions in water in contrast to the concentrations of dissolved calcium (Ca) and magnesium (Mg)

Sodicity

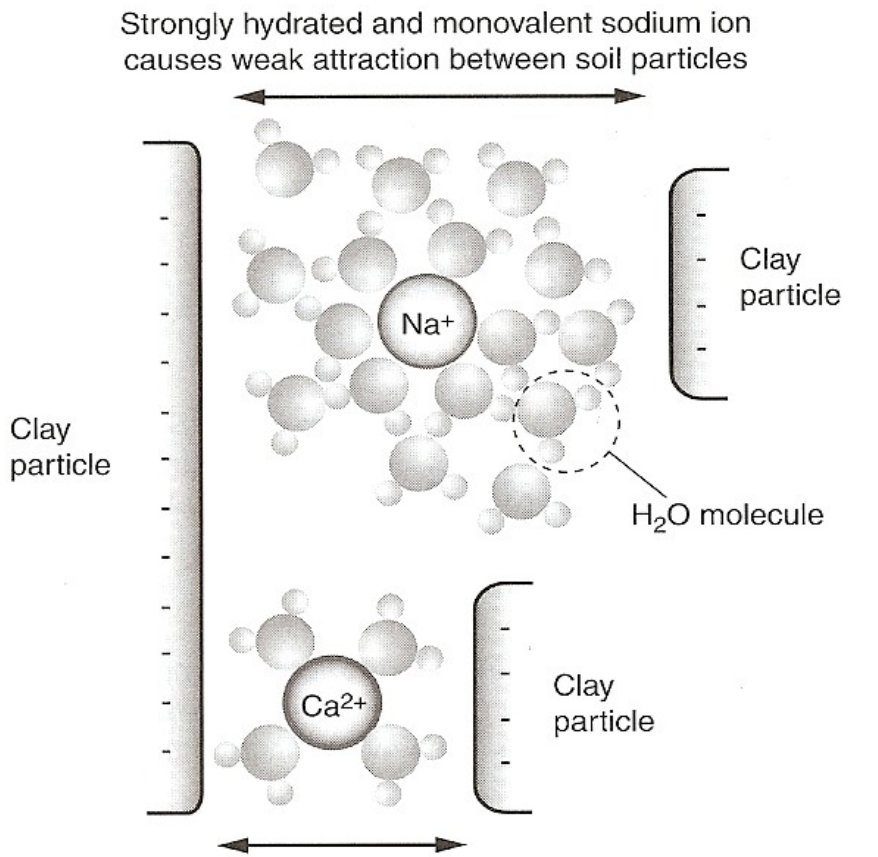
- SAR = $Na/\sqrt{(Ca + Mg)/2}$
- Where: Concentrations are in centimoles (+) per litre (Van de Graaff and Patterson 2001)

- What impact the SAR has when applied to a soil is greatly depended on the soil structural components (sand, silt, clay), the cation exchange capacity (CEC) and the exchangeable sodium percentage (ESP) of the soil.

Sodicity Relationship with 3 Soils

	Soil A	Soil B	Soil C
Texture	Loam	Humus-rich Loam	Sand
Clay mineral type	Kaolinite	Montmorillonite	No clay
CEC cmol(+) L^{-1}	5	25	0
Amount of Na mg/kg	690	690	690
ESP% of CEC	60	12	No exchangeable Na All Na as free salt
Sodicity	Very high	Low	Nil
Indicative dispersion	Maybe severe	Insignificant	Nil

Sodicity

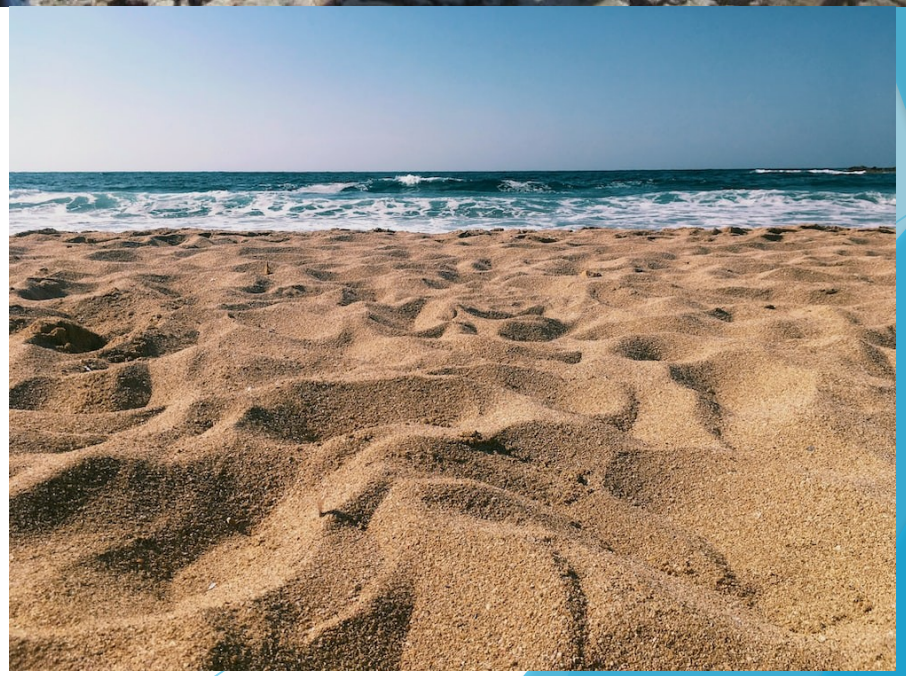


The effect of calcium and sodium ions on soil particles (Asano et al., 2007)

Sodium Adsorption Ratio (SAR)

- The sodium absorption ratio (SAR) is the comparison of the relative preponderance of dissolved sodium (Na^{+}) ions in water to the concentrations of dissolved calcium (Ca^{2+}) and magnesium (Mg^{2+})
- The soil type in the proposed irrigation area is also very important.
  - Sodicity has the most impact on heavy clay soils and the least effect on sands



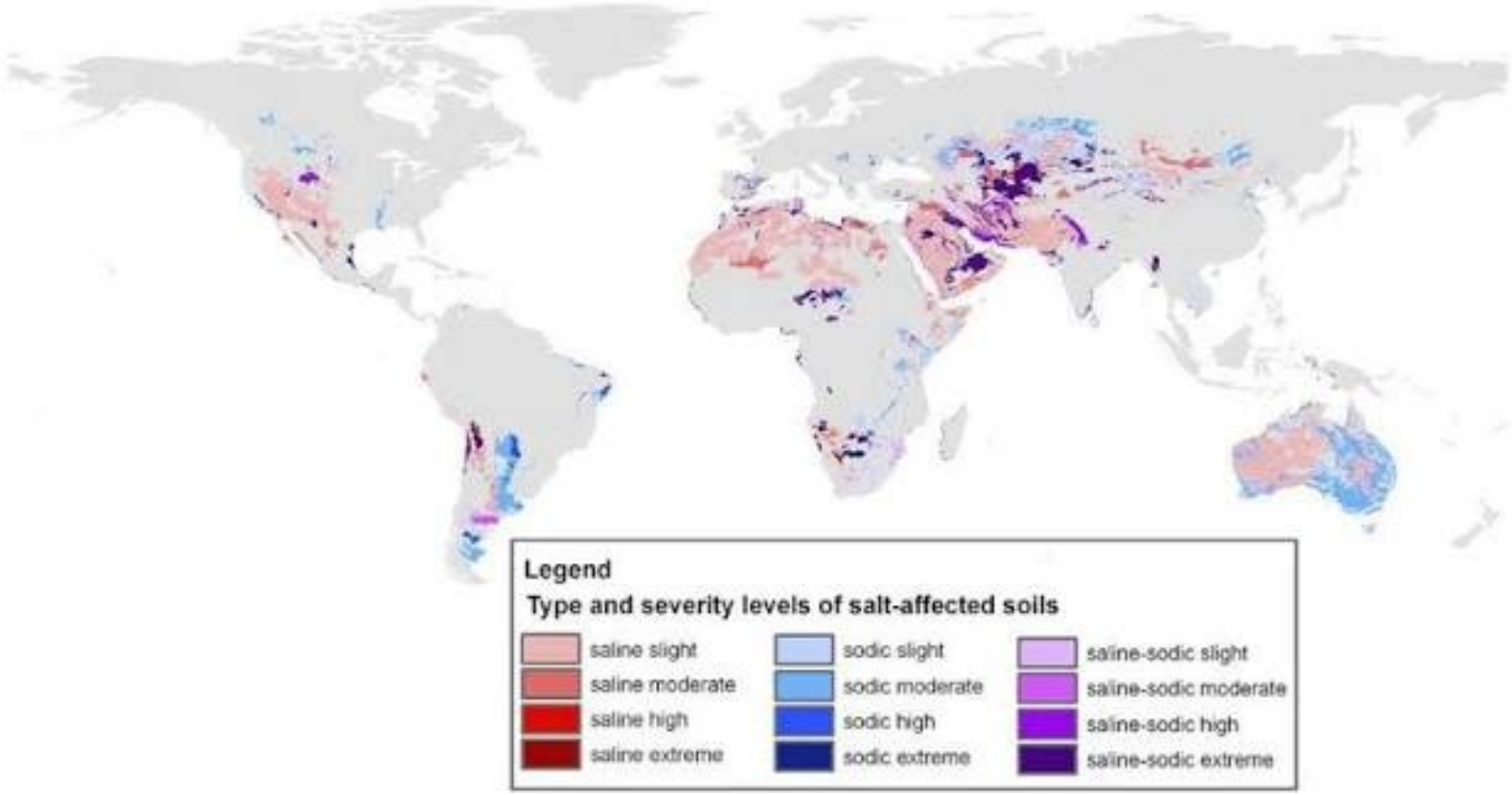


Impact of Sodic Soils on On-site Systems

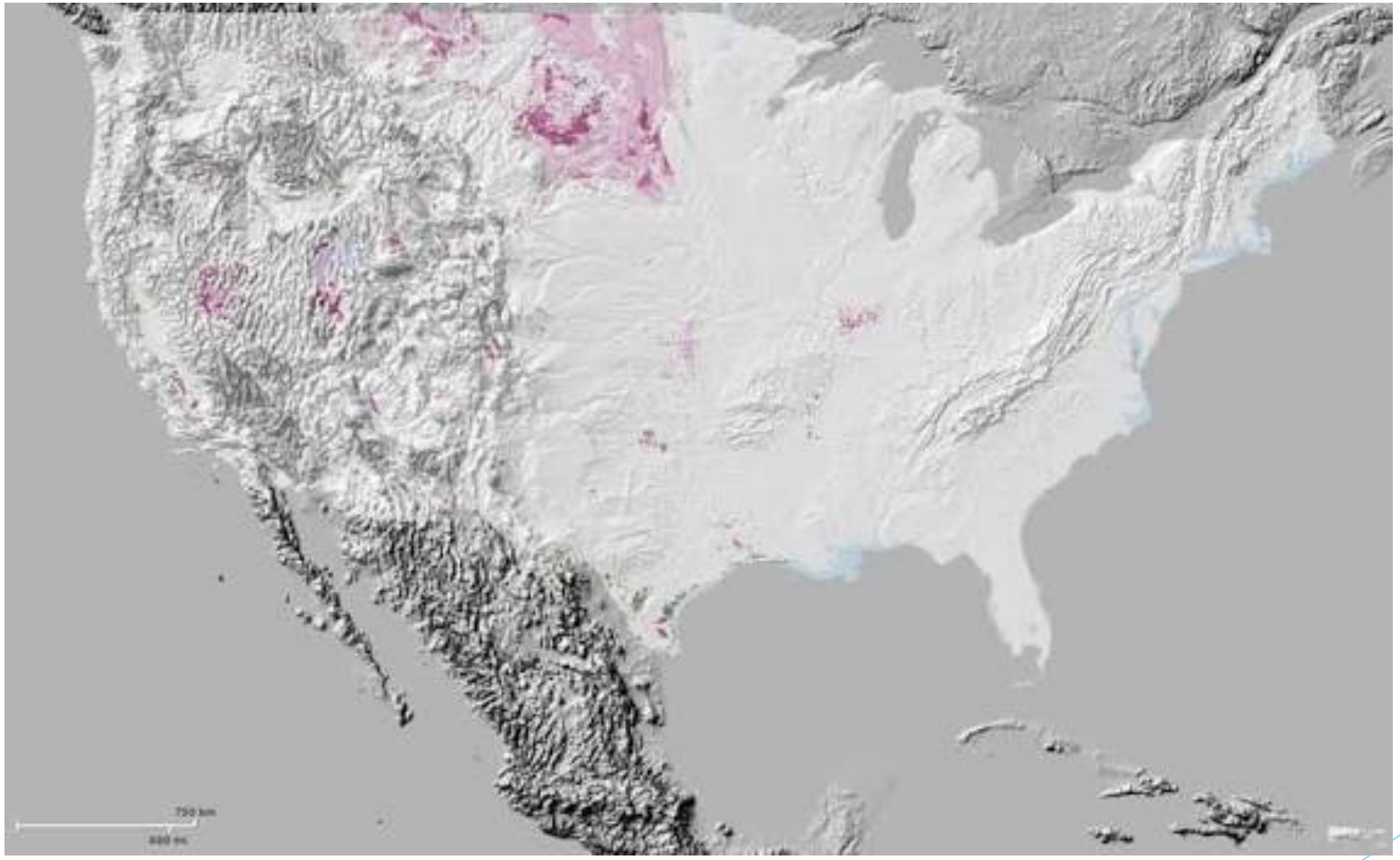




World-Wide Sodic Soils



Sodic Soils in the US



Where Does the Sodium Salt Originate?



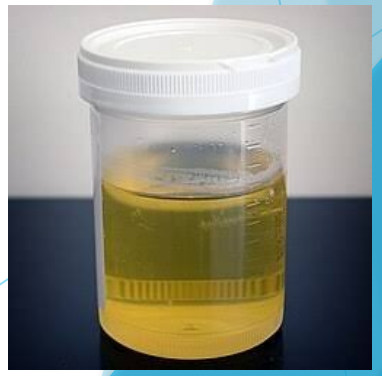












On-site Wastewater & Sodic Soils

- Colorado has updated their State Regulations to cover sodic soils
- Because sodic soils disperse when wet, they block the pores required for filtration, thus traditional gravel trenches or deep absorption beds are generally restricted.
- Counties dealing with high-sodium geology (such as parts of Western Colorado) enforce specific engineering guidelines:
  - Pressure distribution systems are strictly required instead of gravity-fed lines. Effluent must be spread out evenly across the zone using timed, multiple doses throughout the day to prevent over-saturation
  - Elevated sewage treatment mounds or at-grade systems are preferred. These place the infiltrative surface at or above the natural grade to avoid heavy sodic subsoils
  - Advanced Treatment Proprietary higher-level treatment technologies (e.g., aerobic treatment units) are often combined with a sand bed lining. This reduces swelling in the underlying soil substrate, boosts evaporation, and promotes oxygenation.

Sodium Salt Treatment Methods

- The only thing that takes sodium salt out of water is money…
- Very few water treatment techniques remove sodium salts
  - Typically, very expensive to install and run
  - Need somewhere for the accumulated salt brine to go
- Most cost-effective treatment method is not to put the excess sodium into the wastewater system in the 1st place
  - Don't use detergents with sodium bulk fillers
  - Don't use sodium salt-based water softeners
  - Don't put RO brine into the on-site wastewater system
- Some on-site wastewater techniques can offset the adverse impacts of sodicity
  - Ion exchange media
  - Woodchip filters (denitrifying woodchip bioreactors)

Woodchip Filters

- Primarily used for denitrifying
- The organic matter in the woodchips is very good at offsetting the SAR/ESP impacts in sodic soils
  - Also releases calcium and magnesium into the water
  - Relatively little sodium
- Improves soil structure and water flow
- Replacing the woodchip is a major maintenance step

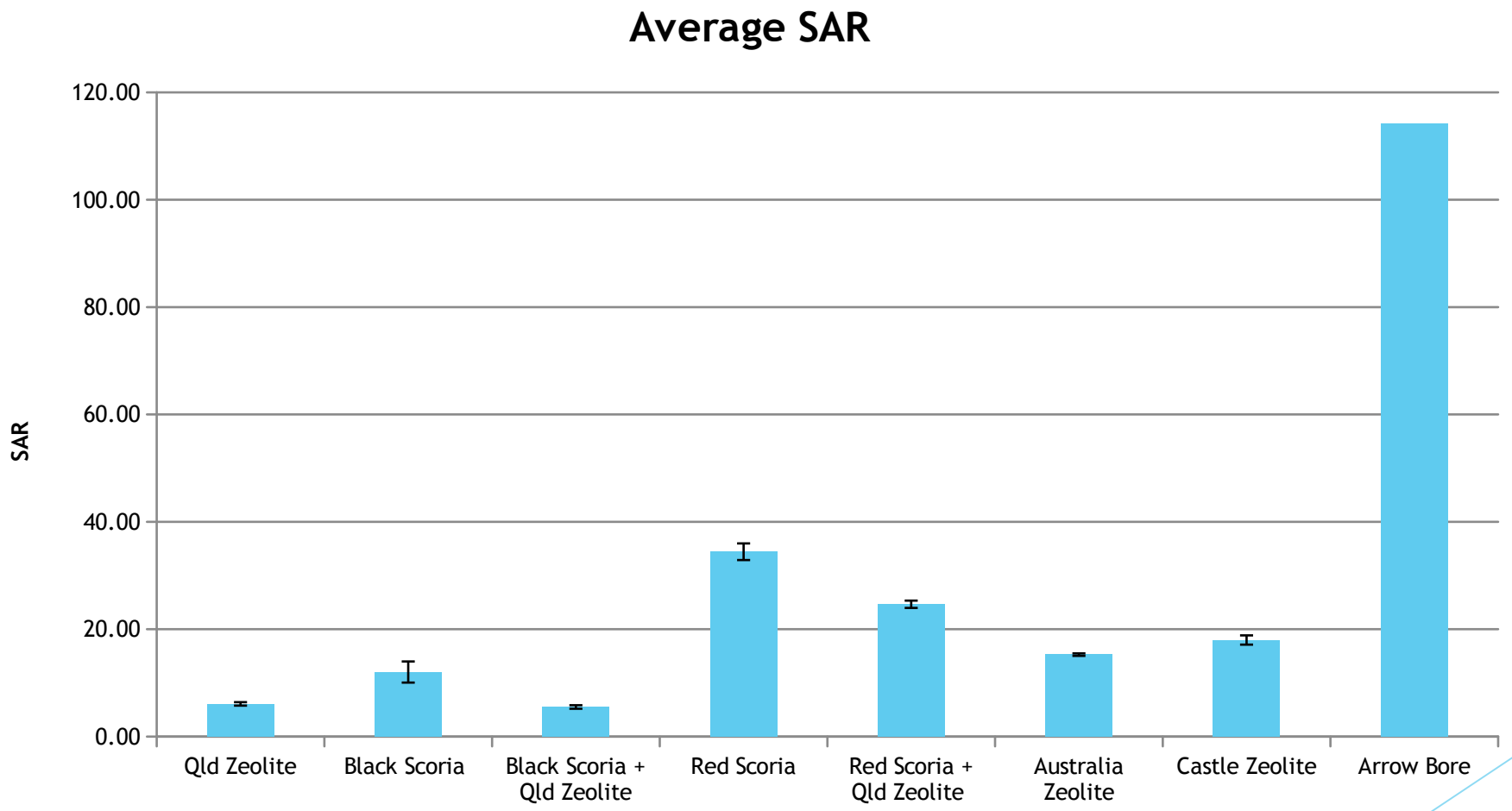


Ion Exchange Media

- Ion exchange sodium out of solution and replace it with either calcium or magnesium
- Reduces the SAR of the water
- Have a limited life span
  - Can have other treatment benefits
- Very difficult and costly to replace at the end of their effective life
- Will extend the life of the soil and can be used with other options such as soil amendments



Mixed Media Results





Soil Amendments & Repair

- Application rate
  - Even distribution
  - Intermittent dosing (sequencing valve)
  - Pump controller with small doses; rather than floats which send a relatively large volume of the tank
- Basic good gardening advice
  - Gypsum and organic carbon (compost)
  - This can be counter-intuitive, as compost has a high BOD5/COD
  - Difference between applying to soil and disposing to water
  - Gypsum repairs soil from the adverse impacts of sodicity

Soil Amendment: Gypsum





Conclusion

- Sodic soils should be identified during the initial site inspection and/or design process
- Education about the reduction of sodium salts should occur with the home owner
- Fit-for-purpose on-site treatment and dispersal systems should be installed
- Soil amendments should be considered as part of the installation and maintenance regime