Impacts of salt on water resources

ASSIGN BUSTER

Introduction.

Salinity, one of the major water crises occurring around the globe, is the high concentration of total dissolved solids (TDS), such as sodium and chlorine, in soils and water (Rose, 2004). Salinity is a critical and prevalent problem affecting Australia, threatening the Australian natural environment and the sustainability of productive agricultural areas (Bridgman, Dragovish, & Dodson, 2008; McDowell, 2008). This can be attributed to naturally high saline levels in the soils (McDowell, 2008; Pannell, 2001). Across the globe, in countries such as in America, Iran, Pakistan, India and China, large concentrations of salt have accumulated over time due to rainfall, rock weathering, sea water intrusion and aerosol deposits (Table 1) (Beresford et al., 2001; Hülsebusch et al., 2007). Dryland salinity, a form of secondary salinity, has particularly become a major problem worldwide (Beresford et al., 2001). Annually, approximately four million hectares of global farmland is abandoned due to excessive salt (Beresford et al., 2001). Salinity is a widespread problem with numerous major social, economic and environmental consequences (Beresford et al., 2001).

Outline

This paper will consider the occurrence and impacts of primary and secondary salinity on water resources. The discussion will commence by focusing on primary salinity, its occurrence and associated impacts using an example from the Lake Eyre Basin, Australia. The next part of the essay will discuss secondary salinity, its occurrence and impacts using examples from Katanning Western Australia (WA) and Turkey. Iran and Pakistan will then be examined as examples showing the occurrence and impacts of both primary and secondary salinity. Finally the impacts of salinity will be identified and the main arguments of this account summarised.

Discussion

Primary Salinity

Primary salinity is a natural process that affects soils and waters and occurs generally in regions of the world where rainfall is insufficient to leach salts from the soil and evaporation or transpiration is high (McDowell, 2008). In episodes of high evaporation, transpiration and reduced rainfall, salinity becomes a problem as the volume of water decreases while salt concentrations increase (Bridgman, Dragovish, & Dodson, 2008). Approximately 1000 million hectares, which corresponds to seven per cent of the world's total land area, is affected to some extent by salt (Rose, 2004). The majority of the globe's saline affected land is influence by primary salinity resulting from natural soil evolution (Hülsebusch et al., 2007). Arid tropical areas, in particular, are subject to potential evaporation that is higher than rainfall, which leads to the rising of water to the topsoil where solutes accumulate and salinity can occur naturally (Hülsebusch et al., 2007). Australia's arid and semi-arid areas usually have salt present in the groundwater (Table 2) (Bridgman, Dragovish, & Dodson, 2008). For example, the River Darling becomes saline during harsh drought periods and salinity concentrations increase in the Hunter Valley when flow diminishes (Bridgman, Dragovish, & Dodson, 2008).

Lake Eyre Basin, South Australia

The Lake Eyre Basin (LEB), in central Australia, is a largely flat area dominated by semi-arid to arid environmental conditions (Figure 1)

(McMahon et al., 2008). The area encounters high evaporation rates and spatially and temporally highly variable rainfall (Kingsford & Porter, 1993). Year round, potential evaporation is usually greater than actual evaporation with average yearly Class A pan evaporation rates of 3300 millimetres (mm) (Costelloe et al., 2008). Average yearly rainfall in the LEB ranges from less than 200mm in some areas, up to 700mm in others, with an annual coefficient of variability spanning from 0. 2 to 0. 7 (McMahon et al., 2008). Hydrological conditions in the LEB can vary between prolonged periods of 18 to24 months of no flow, to shorter phases where inundation of slow-moving floods can occur (Costelloe et al., 2008). The portioning of the stable isotopes of water such as d16O/ d18O can be utilised to determine whether evaporation (enriching/fractionation occurs) or transpiration (no fractionation) occurs (Costelloe et al., 2008). In Lake Eyre, the water is sodium and chlorine ion dominated with salinity varying from approximately 25 300 mg L-1 and 272 800 mg L-1 (Kingsford & Porter, 1993). The absence of invertebrates and waterbirds in Lake Eyre is thought to be due to salinity from increased evaporation during the dry months (Kingsford & Porter, 1993). This salinity is also said to be responsible for massive fish kills that occur as the lake dries after a flood period (Kingsford & Porter, 1993). Samples taken in the LEB showed that there was greater enrichment of the isotopic signatures of the surface water than the groundwater samples, a product of high rates of evaporation (Costelloe et al., 2008). The Diamantina River catchment, a major contributor of streamflow to Lake Eyre, was found to have hypersaline, 85, 000 mg L-1 [Cl], residual pools in the channel, with a highly enriched isotopic signature, indicating evaporation (Costelloe et al., 2008). The Neales River catchment in the LEB demonstrated extremely saline groundwater (71, 000 mg L-1 [Cl]) and hypersaline residual pools of 130, 000-150, 000 mg L-1 [Cl] (Costelloe et al., 2008).

Secondary Salinity

Secondary salinity is caused by man made changes to the hydrological cycle either through the replacement of native vegetation with shallow-rooted vegetation or through the excessive use or inefficient distribution of water in irrigation for agriculture (Beresford et al., 2001; Rose, 2004). Modern anthropogenic land-use practices are increasing the area of salt-affected land, which is a major environmental issue (Bridgman, Dragovish, & Dodson, 2008). Estimates of secondary salinity affecting the globe are suggested at around 74 million hectares, with 43 million hectares of that land occurring on irrigated land and the remaining area on non-irrigated land (Rose, 2004). In Australia, areas of the Murray Basin and the Mallee region in Victoria (VIC) and New South Wales (NSW) are affected by dryland and irrigation salinity, while irrigation salinity impacts the Riverina Plain in VIC and NSW and the Riverland Region in South Australia (Beresford et al., 2001).

Dryland Salinity

Dryland salinity is the resultant change in subsurface hydrology in which native vegetation with deeper roots are replaced by shallow-rooted vegetation, such as agricultural crops (Rose, 2004). This process causes a decrease in annual evaporation and an increase in the amount of water reaching the water table (Bridgman, Dragovish, & Dodson, 2008). The proceeding rise in the amount of water available can then lead to saline water reaching the soil surface and vegetation (Rose, 2004). When this saline water intersects or reaches the surface, waterlogging and salinization of the surface soil can occur due to the accumulation of salts (Rose, 2004). There is an estimated lag time of 30 to 50 years between vegetation clearance and the emergence of salinity (Bridgman, Dragovish, & Dodson, 2008). Around a third of the areas in Australia that are susceptible to dryland salinity are expected to become saline (Figure 2) (Rose, 2004). Dryland salinity has impacted North and South Dakota in Northern America and the Canadian Western Prairies due to large scale wheat farming in which there is now increasing loss of productivity and rising death rates in a variety of wildlife (Beresford et al., 2001). India, Thailand, Argentina, and South Africa are some of the other countries that experience problems with dryland salinity (Pannell & Ewing, 2006).

Katanning District, WA

In the Katanning district, extensive clearing of native vegetation has lead to the area being reported as having one of the worst salinity problems in WA (Beresford et al., 2001). The town is located in a low, flat part of the landscape, and is agriculturally centred on crops, such as wheat and canola, and sheep (Figure 3) (Beresford et al., 2001). The initial perennial vegetation, mainly of Mallee associations, has been removed and replaced with the aforementioned crops (Bridgman, Dragovish, & Dodson, 2008). Following 1891, there was increased wheat cultivation in the district and land clearing (Beresford et al., 2001). In the early 1900s, the increase of salt in nearby natural water sources was quickly linked to the clearing of native vegetation (Beresford et al., 2001). In 2000, records of the Katanning Creek Catchment showed that only 1000 hectares of remnant vegetation remained translating to less than 10 per cent of the catchment being covered

(Beresford et al., 2001). It was also discovered in 2000 that 125 hectares of land neighbouring the town boundary was salt affected, the water table was less than one metre from the surface in some areas and older infrastructure were showing evidence of salt-induced decay (Beresford et al., 2001). Groundwater under the township is influenced by the subsurface flow from catchments where extensive land clearing has occurred (Beresford et al., 2001). Dryland salinity in Australia will continue to increase unless farming systems are dramatically altered on a large scale (Rose, 2004).

Irrigation Salinity

The application of irrigation can increase salinity levels in soil water, surface water systems and/or aquifers (Van Weert, Van der Gun, & Reckman, 2009). Irrigation can also raise water tables, lead to waterlogging, and cause evaporation directly from the water table, increasing solute concentration in the soil (Van Weert, Van der Gun, & Reckman, 2009). Around the world, the greater part of anthropogenic salinity is associated with irrigated rather than non-irrigated land (Bridgman, Dragovish, & Dodson, 2008). A higher amount of land in Australia that is non-irrigated, rather than irrigated, however, is salt-affected (Pannell & Ewing, 2006). Bridgman, Dragovish, & Dodson (2008) stated that irrigated areas that have their water table within two metres of the soil surface are salinized. Agriculture, in which irrigation systems are utilized, is especially prone to salinization with approximately half of the irrigation systems globally affected by salinization, alkalization or waterlogging (Munns, 2002). Countries particularly affected by irrigation salinity include Egypt, China, Pakistan, Iran, India, and Argentina (Hülsebusch et al., 2007).

Sanliurfa-Harran Plain – Turkey

Turkey faces salinity problems due to large-scale and intensive irrigation, such as in the Harran Plain (Van Weert, Van der Gun, & Reckman, 2009). Only 25 percent, or 19. 3 million hectares, of Turkey’s land surface is usable for agricultural practices, three percent of which is affected by salinity (Atis, 2006). The main source of soil salinity has resulted from the adverse effects of irrigation water, leading to the formation of high water tables resulting in decreased agricultural productivity and income (Atis, 2006). The Sanliurfa-Harran Plain region is located in an arid and semi-arid climate (Kendirli, Cakmak, & Ucar, 2005). In this area, high levels of total dissolved solids have emerged in the shallow groundwater due to excessive and uncontrolled irrigation, waterlogging, rising water tables, and drainage problems (Van Weert, Van der Gun, & Reckman, 2009). Prior to the implementation of irrigation in the central and southern parts of the Harran Plain, salinity and drainage problems already existed, which were then exacerbated when irrigation was applied (Table 3) (Kendirli, Cakmak, & Ucar, 2005). It was estimated over fifty percent of productive agricultural land in the Akcakale Groundwater Irrigations area of the Harran Plain was becoming saline after irrigation, some 5000 hectares (Kendirli, Cakmak, & Ucar, 2005). In the towns of Harran and Akcakale, within the Sanliurfa-Harran Plain, increased salinity problems and high saline and sodium soils were attributed to public irrigation (Kendirli, Cakmak, & Ucar, 2005). Within the Sanliurfa-Harran Plain, over 29 percent of soils examined were becoming saline following irrigation (Kendirli, Cakmak, & Ucar, 2005).

Combined Salinity

In Iran and Pakistan, the salinization of land resources is a major problem due to a combination of primary salinity and secondary salinity (Kahlown et al., 2003; Qadir, Qureshi, & Cheraghi, 2008). Thirty per cent of Iran's irrigated area and 26. 2 per cent of Pakistan's are severely affected by irrigation salinity, much of which may need abandoning (Kendirli, Cakmak, & Ucar, 2005; Hülsebusch et al., 2007). Iran and Pakistan mainly endure arid and semi-arid environmental conditions (Kahlown et al., 2003; Qadir, Qureshi, & Cheraghi, 2008). Annually, rainfall nationally averages 250mm in Iran, while average yearly potential evaporation is extremely high, varying from 700mm to over 4000mm (Qadir, Qureshi, & Cheraghi, 2008). Approximately 34 million hectares in Iran are salt-affected (Qadir, Qureshi, & Cheraghi, 2008). In the northern area of Iran, slight to moderate salt-affected soils exist, where as highly saline soils are present in the central areas (Figure 4) (Qadir, Qureshi, & Cheraghi, 2008). Primary salinity in Iran is a result of a combination of factors including: the geological composition of the soil's parent material, such as halite and gypsum, natural salinization of surface waters due to stream salinity, salinity and the expansion of salinity from wind-borne origins, seawater intrusion, low rainfall and high potential evapotranspiration (Qadir, Qureshi, & Cheraghi, 2008). Secondary salinity has been a result of: irrigation with saline waters, deficient drainage, unsustainable groundwater pumping, saline aquifer over-exploitation, excessive irrigation and overgrazing (Qadir, Qureshi, & Cheraghi, 2008). Some 4. 2 million hectares in Pakistan are severely affected by irrigation salinity (Hülsebusch et al., 2007). Salinization of soils and water in Pakistan are a result of: natural climatic characteristics, such as high evaporation, geological conditions and the dissolution of salt bearing strata, waterlogging, intensive irrigation, poor drainage, salinity ingress, inefficient irrigation and inappropriate use of low quality groundwater (Kahlown et al., 2003; Van Weert, Van der Gun, & Reckman, 2009). Widespread soil and water salinization in Iran and Pakistan has occurred due to varied combinations of these factors (Kahlown et al., 2003; Qadir, Qureshi, & Cheraghi, 2008).

Impacts

Salinity can cause tree die back, changes in ecosystems, loss of productive lands, salt bush growth, erosion, saline groundwater discharge and saline surface water (Beresford et al., 2001; Bridgman, Dragovish, & Dodson, 2008). The groundwater that rises as a result of dryland salinity can contain relatively high amounts of salts which results in saline seepages emerging where the water table intersects the ground surface (Bridgman, Dragovish, & Dodson, 2008). If concentrations of sodium ions are high enough, the physical structure of soils may be completely degraded from salinity (McDowell, 2008). This is due to the collapse of soil aggregates and deflocculation of clay particles; compaction then occurs and causes decreased permeability and porosity which restricts water storage as well as slowing internal drainage (McDowell, 2008). Salinity can result in the deterioration of river and stream quality, for example, in the Murray Darling River system in SA, the town of Morgan’s water quality is expected to exceed the desirable drinking limit of 500 mg L – 1 total soluble salts within the next ninety years (Pannell & Ewing, 2006). Concentrated salt-affected water can move to surface water systems, infiltrate below the root zone or may reach an aquifer and contribute to a progressive increase in salinity of groundwater, decreasing the water quality (Van Weert, Van der Gun, & Reckman, 2009). There can be a greater risk of large-scale water quality problems due to an increase in leakage of saline waters from the impacted region (McDowell, 2008). Increased flood risks have also been identified as an impact of dryland salinity as a result of shallower water tables which can lead to at least a two-fold increase in flood flows (Pannell & Ewing, 2006).

Conclusions

Salinity is a major problem throughout the world, particularly in arid and semi-arid environmental climates. Primary salinity is a natural phenomenon that affects soils and waters in periods of high evaporation, transpiration, and low rainfall. This process occurs notably in Australia, as well as many other countries, such as Iran and Pakistan. Secondary salinity is human induced from either land clearing or irrigation. Numerous countries experience dryland salinity, such as North America, India, Canada, Thailand, Argentina, and South Africa, as well as Australia. Countries that are affected by irrigation salinity include Egypt, Australia, China, Pakistan, Iran, Turkey, India, and Argentina. Generally, salinity causes a decrease in the quality of water resources and can lead to a decrease in quantity, if the water table has risen substantially as a result, and increased evaporation occurs.

References

Atis, E 2006, Economic impacts on cotton production due to land degradation in the Gediz Delta, Turkey, Land Use Policy, 26, pp. 181 – 186.

Beresford, Q, Bekle, H, Phillips, H, & Mulcock, J 2001, The Salinity Crisis: Landscapes, Communities and Politics, University of Western Australia Press, Crawley.

Bridgman, H, Dragovish, D, & Dodson, J 2008, The Australian Physical Environment, Oxford University Press, USA.

Costelloe, JF, Payne, E, Woodrow, IE, Irvine, EC, Western, AW, & Leaney, FW 2008, Water sources accessed by arid zone riparian trees in highly saline environments, Australia, Oecologia, 156, pp. 43 – 52.

Hülsebusch, C, Wichern, F, Hemann, H, & Wolff, P (eds.) 2007, Organic agriculture in the Tropics and Subtropics Current status and perspectives Supplement No. 9 to the Journal of Agriculture and Rural Development in the Tropics and Subtropics, Kassel University Press, Germany.

Kahlown, MA, Chang, MC, Ashraf, M, Hassan, MS 2003, Salt Affected Soils and their Reclamation: Research Report 4, Pakistan Council of Research in Water Resources, Islamabad.

Kendirli, B, Cakmak, B, & Ucar, Y 2005, Salinity in the Southeastern Anatolia Project (Gap), Turkey: Issues and Options, Irrigation and Drainage, 54, pp. 115 – 122.

Kingsford, RT, & Porter, JL 1993, Waterbirds of Lake Eyre, Australia, Biological Conservation, 65, pp. 141 – 151.

McDowell, RW (ed.) 2008, Environmental Impacts of Pasture-Based Farming, CAB International, Oxfordshire.

McMahon, TA, Murphy, RE, Peel, MC, Costelloe, JF, & Chiew, FHS 2008, Understanding the surface hydrology of the Lake Eyre Basin: Part 1-Rainfall, Journal of Arid Environments, 72, 1853 -1868.

Munns, R 2002, Comparative physiology of salt and water stress, Plant, Cell and Environment, 25, pp. 239 – 250.

Pannell, DJ, & Ewing, MA 2006, Managing Secondary Dryland Salinity: Options and Challenges, Agricultural Water Management, 80, pp. 41 – 56.

Qadir, M, Qureshi, AS, & Cheraghi, SAM 2008, Extent and Characterisation of Salt-Affected Soils in Iran and Strategies for their Amelioration and Management, Land Degradation & Development, 19, pp. 214 – 227.

Rose, C 2004, An Introduction to the Environmental Physics of Soil, Water and Watersheds, Cambridge University Press, Cambridge.

Van Weert, F, Van der Gun, J, & Reckman, J 2009, Global Overview of Saline Groundwater Occurrence and Genesis, International Groundwater Resources Assessment Centre, Utrecht.