RAINFALL SALT LOADS IN SOUTHERN QUEENSLAND, AUSTRALIA

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Abstract
Two east-west transects were established in southern Queensland to quantify atmospheric inputs of chloride and associated ions. Electrical conductivity and major ions were measured in rainfall at nine sites within the Queensland Murray-Darling Basin and one site to the east. Chloride deposition trends followed those established by other authors in Australia i.e. decreasing with distance inland from the coast. A power function was fitted to allow prediction at any point between 100 km and 680 km from the coast. The resultant equation developed for the Queensland Murray-Darling Basin will be useful in improving the quality of both point based and catchment scale salt mass balance calculations within the area.

Additional Keywords: chloride, salinity

Introduction
Atmospheric accessions of salts have long been identified as an important contribution to regolith salt stores in Australia (Isbell *et al*., 1983; Simpson and Herczeg 1994; Keywood *et al*. 1997). Atmospheric accessions are typically comprised of salts within rainfall, sea spray and dust. Data concerning salt mass in rainfall are deemed essential for both point scale and basin scale salinity modelling, and calculations of salt mass balances within catchments e.g. Tolmie *et al*. (2003), Jolly *et al*. (2001). The lack of sufficient data for the Queensland Murray-Darling Basin (QMDB) in southern Queensland was identified as part of regional salinity investigations and modelling exercises in the area (Biggs and Power 2003). The QMDB is comprised of seven major catchments, the majority of which have been targeted for activities under the National Action Plan for Salinity and Water Quality.

A number of those authors listed above described a range of algorithms for southern and western Australia to model the general trend of declining rainfall chloride with distance inland. Such algorithms are frequently used in regional or Basin scale modelling of salt balances. The data of Blackburn and McLeod (1983) has been used for Basin scale salinity calculations in the QMDB but it had on only one data point within the Queensland. The intention of my work was therefore to increase the number of data points within the QMDB for which rainfall chloride data is available, and to verify whether the algorithms suggested by other authors do in fact accurately predict rainfall chloride within the Basin.

Methods
Two transects (Figure 1) were established to quantify rainfall chemistry in the southern and northern QMDB (including one site east of the QMDB). The ten sites were part of the Bureau of Meteorology (BoM) rainfall measurement network. The transects represent a significant topographical cross-section, as well as a substantial rainfall gradient (Table 1). A general trend of declining rainfall to the west exists, and the Great Dividing Range plays a significant local climatic role. Rainfall is summer dominant. Storms typically move from west to east, associated with cold fronts moving in that direction intercepting moist air blown in from the coastal zones. Cyclones from the north can periodically exert a significant influence on the local weather.

The sites were established to utilise the existing BoM network, and hence made use of standard rainfall collection facilities at those sites. Bulk precipitation samples were collected on a monthly basis from each site i.e. all rainfall from a rain gauge during a particular month was collected as a bulk sample. Gauges were either standard BoM gauges (measuring 203mm in diameter) or conventional plastic gauges, and were assumed to be kept clean according to BoM standards. Sampling occurred from Jan 2002 to March 2003. Occurrence of a number of significant storm events enabled some single events to be captured.

Bulk samples for each month were collected, filtered using a 0.45µm membrane and analysed for electrical conductivity (EC) using direct determination, for major cations using ICP AES and for major anions using ion chromatography in a NATA accredited laboratory.

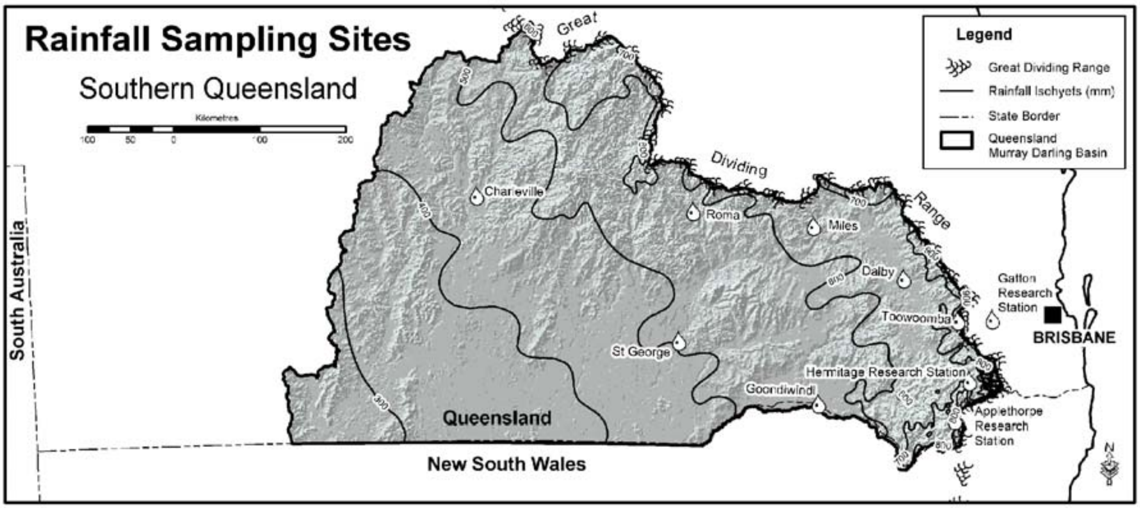

Figure 1. Location of sampling sites

Calculations

Analytical data were checked for consistency using a similar method to that of Blackburn and McLeod (1983). Raw data was initially converted from mg/kg to mmole$_c$/litre and then the sum of anions (Cl, SO_4, NO_3) was subtracted from the sum of cations (Ca, Mg, Na, K). Minor differences in values were expected due to quantification limits of analytes. As suggested by Blackburn and McLeod, a positive difference i.e. excess of cations, was assumed to estimate the quantity of bicarbonate (HCO_3) present.

Table 1. Site attributes

Site	Latitude	Longitude	Elevation (m)	Ann. avge rainfall (mm)	Avge no. rain days	Dist. to coast (km)
Northern transect						
Gatton R.S	-27.5483	152.3312	93	816	98	100
Toowoomba	-27.5817	151.9268	675	955	106	135
Dalby	-27.1641	151.2665	344	676	71	180
Miles	-26.6592	150.1870	305	657	68	290
Roma	-26.5438	148.7791	299	600	57	430
Charleville	-26.4107	146.2579	293	499	51	680
Southern transect						
Applethorpe R.S	-28.6180	151.9536	872	784	111	160
Goondiwindi	-28.5208	150.3261	217	621	69	320
St George	-27.9071	148.6487	201	517	55	480
Hermitage R.S	-28.2069	152.1017	475	670	78	140

Results

A total of 132 samples were received for the sampling period, with the most (24) samples collected in Toowoomba, and the least (6) at Roma.

Data validation

Validation of data through ion summation and ion ratio comparison resolved most, but not all anomalous sample results. This suggests that there may be multiple causes for such apparent anomalies. Twenty samples with anomalous data were discarded from data analysis.

EC and Cl

Electrical conductivity and chloride (Cl) varied both at each site and between sites (Table 2), but were typically related ($r^2 = 0.64$ for a linear relationship), although as EC increased, the strength of the relationship decreased. A general declining trend in both EC and Cl was observed from east to west. Interestingly, the decline is related to an absence of high values in the west, as eastern sites recorded both high and low values. Standard deviations for both EC and Cl were generally lower in western sites than eastern sites. Goondiwindi consistently recorded higher EC:Cl ratios than other sites with the exception of Miles which periodically recorded similar values. Eastern sites often possessed lower EC:Cl ratios than western sites, but a clear geographic trend could not be defined.

Mean Cl concentration values arrange the sites in descending order of Gatton, Applethorpe, Dalby, Hermitage, Toowoomba, St George, Goondiwindi, Miles, Charleville, Roma. Gatton recorded the highest standard deviation, and Roma the lowest. When Cl concentration was translated to chloride mass deposition (kg/ha/yr), a clear geographic trend of declining deposition with distance inland became obvious. This is in accordance with results observed elsewhere in Australia and is related to declining rainfall with distance inland.

Table 2. Mean EC and Cl

Site	Mean EC (μS/cm)	s.d	Mean Cl (mg/kg)	s.d	Mean Cl (kg/ha/yr)	n
Northern transect						
Gatton R.S	37.98	23.61	4.76	3.49	38.9	11
Toowoomba	22.88	10.52	2.20	1.39	21.0	22
Dalby	23.00	20.62	2.82	3.09	19.1	14
Miles	21.91	9.90	1.40	0.81	9.2	12
Roma	14.13	5.61	0.94	0.76	5.7	4
Charleville	13.59	9.81	1.37	1.14	6.8	12
Southern transect						
Applethorpe R.S	22.50	20.96	3.92	3.08	30.7	5
Goondiwindi	32.00	24.21	1.41	1.27	8.7	9
St George	20.16	8.82	1.78	0.99	9.2	9
Hermitage R.S	25.82	11.21	2.40	1.78	16.1	14

Discussion

Results obtained were comparable with those derived from similar studies elsewhere in Australia. Variability was a cause of concern at some sites, and warrants further discussion. Comparison of the algorithm derived from the chloride deposition data with other such equations derived around Australia, and the implications of the data are worth considering.

Variability

The high degree of variability encountered at some sites was expected in part, due to the sample collection method. Unlike studies conducted by authors such as Blackburn and McLeod (1983) and others, no dedicated sample collection devices were utilised in this study. Sample collection relied upon existing infrastructure, and the presumption that it was maintained according to required standards. As such, there was certainly possibility of contamination and error during the sample collection process. The presence of some SO_4 rich samples in western stations suggests the likelihood of dust contamination. Analytical error within the laboratory, and subtle methodological differences between the two laboratories employed was also a possible source of error. Climatic variability contributes an unknown degree of deviation in results when considering long-term averages. The sampling period was during an El Niņo phase, towards the end of a prolonged drought. It is unclear as to whether the data gathered would be significantly different from that found during normal or La Niña phases.

EC, Cl

The results illustrate the expected general trend of declining EC and Cl concentration with distance inland. Chloride concentrations were similar to those recorded elsewhere in Australia by authors such as Blackburn and McLeod (1983) and Hingston and Gailitis (1976). While EC values followed a declining trend with distance inland, much greater variation in values occurred than in chloride, confirming the assumption that salts other than NaCl were contributing to EC at times.

No obvious seasonal variation in EC or Cl concentration was obvious for any site, although consideration of all data together does suggest some weak evidence of a decrease in Cl concentration during summer months. This is in contrast with other authors such as Hutton and Leslie (1958) who noted considerable difference in rainfall Cl concentration between summer and winter, and the data of Blackburn and McLeod (1983) for Charleville. For that site, they suggested minimum Cl concentrations were found in winter. Hutton and Leslie (1958) also found Cl concentrations were usually higher in smaller rainfall events. For the duration of my study, there was only a weak relationship indicating decreasing Cl concentration with increasing rainfall event size.

Cl mass

As summarised by Isbell (1983), previous authors generally describe decreasing chloride mass deposition with distance inland. The mean value obtained in my study for Charleville (6.8 kg/ha/yr) at 680 km to the coast, is greater than the values recorded by Keywood *et al*. (1997) for similar distances inland in their two transects in western Australia and the Northern Territory. Those authors reported figures of 1.0 and 0.8 kg/ha/yr at 615 km and

780 km respectively in their west-east array, and 1.0 and 0.9 kg/ha/yr at 550 km and 850 km respectively in their north-south array.

Most previous authors have derived equations from their data to predict chloride concentration or chloride mass deposition (kg/ha/yr) with distance inland. My data would suggest a better correlation exists for chloride mass rather than concentration (r^2 = 0.82 *cf* 0.66 for power functions fitted). Figure 2 illustrates chloride mass *vs* distance to coast for my mean data, in conjunction with the data of Blackburn and McLeod (1983), and a data derived using the equation of Keywood *et al*. (1997).

Values currently being used in either point based or catchment scale chloride mass calculations for the region are similar to those derived from my study, but in many cases, a single value has been applied across all geographic areas. The data I have collected suggests that chloride mass deposition values can vary considerably in the short term, and single values should not be applied across large geographic areas unless the intended use is insensitive to the degree of variation found in southern Queensland.

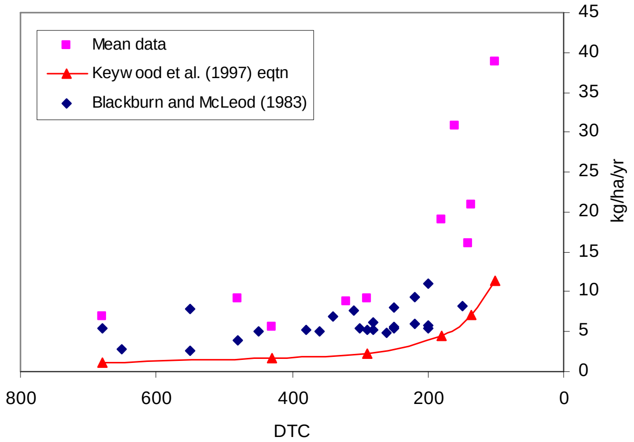

Figure 2 Chloride mass deposition *vs* distance to coast

Conclusions

Chloride mass deposition was proven to follow similar trends to those found elsewhere in Australia. A power function was fitted to the data, to allow prediction of chloride mass up to 680 km inland from the coast of south-eastern Queensland. Contamination of samples by dust and other sources was a problem, but sufficient data was gathered to establish the mass deposition relationship was in accordance with expected values.

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