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Atmospheric Pollution in Dew

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Abstract

AIM: To investigate the difference in the chemistry of rain and dew and to postulate whether the widespread decline in the health and viability of native bush, soils and pastures may be associated with pollutants in the dew.

METHODS: Rain and dew samples were collected and chemical analyses conducted to confirm the presence of certain chemistry that could be associated with the type of degradation and damage observed. Tests for major cations and anions, pH and conductivity were carried out in a laboratory specialising in soils, plants and water chemistry related to agriculture and horticulture. Soil samples were analysed from soils exposed to dew and compared to samples taken from shielded soils.

RESULTS:
There were significant variations in the chemistry of dew compared to rain. Continental dew was higher in Sodium, Chloride and Hydrogen Chloride as opposed to maritime dew.
Chloride levels in dew were up to 270mg/litre while two major cations present were Sodium at 110mg/litre and Hydrogen (as HCl) calculated to be 395mg/litre. Previous tests on rainwater for Chloride were in the range between 0.2mg/litre and as high as 10.0mg/litre.

CONCLUSION:
Dew is a vector that may contain concentrated levels of atmospheric pollutants such as Hydrogen Chloride and Sodium Chloride. The results of this study indicate the need for more research on the composition of dew and the effect of collected dew on a variety of plant species, including pastures in controlled trials. The results of these further studies could impact on many disciplines including agriculture, horticulture, viticulture, forestry, the natural environment, biodiversity and even animal health.

KEY WORDS:
Dew, pollutants, cations, anions, pH, Sodium (Na), Chloride (Cl), Hydrogen Chloride (HCl), salinity, soils, pastures, agriculture, horticulture, viticulture, forestry, biodiversity, the natural environment and animal health.

Contents

Introduction

Since the 1960's Australia has experienced a relatively rapid decline in the health of many of its indigenous trees (Day, 1981; Wylie et al., 1993; Keane et al., 2000). During the mid 1960's an interesting change in pasture plants on our family farm was also observed. This change consisted of yellowing of the plants. These observations later extended to noticing similar changes in other plants, shrubs and native species in our local area. After years of observation, it became apparent that there may be a correlation with certain weather conditions, which caused dew, as opposed to rain, influencing the health of plants.

Dew is a much understudied aspect of precipitation not just in Australia but globally. There is minimal chemical data available on the composition of dew, compared to that which is available for the composition of rain.

Native Vegetation

From observations at the Mumbannar property, it was not only around the house and garden, or the pasture that the yellowing effect was observed, but also in the more heavily vegetated and remnant forest areas. These same characteristics have also been observed in many parts of Southern Australia, including Tasmania and up the east coast to Queensland during the course of travel to these regions. The more plants that were inspected, the more it was evident that the same effect seemed to be happening across the wider landscape (Jurkis, 2005).

In a typical habitat of remnant vegetation, it was observed that the outer canopies would be affected similarly to the pastures. The upper and outer story would show significant signs of stress, yellowing and typical symptoms of 'dieback' (Podger, 1981). This was in great contrast to that of both the mid and under story, where plants would be less affected where they were protected (see Fig. 1 below). Plants of the same species would have a different appearance, depending on if they were shielded by other plants.

Eucalypts have the ability to collect atmospheric moisture and allow it to drip at their root zone as a method of survival in a dry continent. Therefore it could be postulated that concentrations of the precipitants that are found in dew, will be on the soil surface where there is little or no under story present.

Fig. 1. An example of protected (left) and unprotected (right) leaves taken from the same Flowering Gum (*Eucalyptus Ficifolia)*.

Pastures

Signs of these abnormalities were also observed in pastures. Some pasture plants would show yellowing and leaf burn around the margins and continue to show signs of stress (see Fig. 2 below). This abnormality did not seem to be associated with deficiencies or effects of fertilizers, as a range of species showed the same effects with differing variables (ie plant species, soil types, fertilizer history all seemed irrelevant). New pastures that succeeded would often be those that were shielded by surrounding environments (drill rows, bracken fern, etc). Newly germinated seedlings that were exposed to the dew appeared stressed and seemed to have a lower establishment success rate than shielded plants. After the initial yellowing of foliage, plants seemed to be more prone to develop pathogens and fungal conditions. Many growing pastures could be described as having a mosaic pattern consisting of a generally lighter green pasture with darker green patches where cattle have urinated. Urine contains excessive levels of Nitrogen thus meeting the plants requirements for optimum growth. Nitrogen uptake appears to be inhibited during dewy conditions and pastures are responsive to Nitrogen applications after exposure to prolonged periods of dewy conditions (reference).

Fig. 2. An example of the effects of leaf burn on a Phalaris plant.

Dew

After a sequence of dew occurrences, adverse affects would be more apparent. Pastures would be hindered and the typical characteristics of yellowing and bleaching, as mentioned earlier, could be noticed. Plants that were sheltered from the presence of dew did not show any of these symptoms and continued to present healthy characteristics. While the sheltered plants showed a healthy state of natural process the exposed plants seemed to exhibit a reduced ability to photosynthesise. In a number of situations, examples were found where two leaves crossed one another and the protected part of the lower leaf was green and the unprotected surface was Chlorotic and yellow (see Fig. 3 below). The nature of the bleaching on the leaves indicates some form of topical effect on the leaf, not translocation of pollutants from the soil, which would have resulted in bleaching across all the leaf, or along the venation.

A. B.

Fig. 3. Photo A. shows a plant with chlorotic characteristics. Photo B. is of the same plant with two leaves moved aside, displaying the unbleached surface previously protected by the upper leaves.

After periods of dew, Blackwoods (*Acacia melanoxylon*) are a species that show obvious effects of bleaching on their leaves as if bleach has run over the leaf surface (see Fig. 4 below). In some cases, the leaves of the Blackwoods take on an interveinal chlorotic appearance.

Fig. 4. An example of protected (left) and unprotected (right) leaves taken from the same Blackwood plant (*Acacia melanoxylon*).

Other examples of the effects of dew could be seen around the house and garden. Where runoff from a shed spouting flowed on to the ground, the soil failed to support plant life (see Fig. 5 below). There is a relatively small amount of moisture with dew and when it runs out of the down pipe it only travels a short distance before it soaks into the soil. When a rainfall event occurs, there is a greater volume of water flowing out of the down pipe and it travels across the soil surface for a greater distance before it is absorbed.
In some cases outlet pipes would run onto concrete causing an etched effect where the concrete surface was dissolved exposing the harder screenings.

Fig. 5. A down pipe outlet showing a bare area that never supports plant life.

The potential corrosive effect of dew was also noted on various buildings around the farm. For example, on a number of occasions, moisture from the dew would collect on the fly wire screen of windows and run down to the aluminium frame where it effervesced. Eventually this effervescent effect seemed to be associated with severe corrosion of the aluminium window frame. It is possible that dew may contribute to the corrosion of other metals, including galvanized iron shedding.

Another example of the corrosive atmosphere is evident on many old farm sheds where the overlapping galvanized iron sweats and corrodes (see Fig. 6 below). Up until the 1960's galvanized iron sheds and rainwater tanks had a life expectancy far greater than current expectations. In the shed photographed, the dirt floor had a white powder forming between the wet area and the dry area. Because the dry area had not experienced precipitation for approximately one hundred and forty years, it was decided to investigate the soil in the shed to compare the chemistry of both wet and dry areas and to discover the composition of the white precipitate.

A.

B.

Fig. 6. Photo A. shows the corroded section of the corrugated iron roof overlap, on a typical old farm shed allowing dew and rain to leak onto the dirt floor below. Photo B. An aerial view showing the dirt floor below the leaky roof. In the upper area of the photo is the drip zone, the area adjacent and below it is the wet zone, the central white area is a calcium deposit, bordered below by the dry zone.

Rainfall

The affects noted after dew could not be seen after periods of rainfall in the absence of dew conditions. Rainfall without dew, caused plants to develop a green lustre and promote growth. It was as though the dew would contaminate the plants and then the rain would promote new healthy growth, leaving the damaged and bleached foliage inside the canopy.

Outcome

From extended observations and research, it became evident that there might be a correlation with weather conditions and the yellowing, or bleaching, of exposed plant foliage (e.g. White, 1986; Wardlaw, 1990; Auclair, 1993). Symptoms appeared to be worse after significant dew events. It should be noted that once the dew periods finished, generally around November, the plants took on a healthier appearance until dew reoccurrences in the late February early March period. (NB this is not as evident in pastures as their growing season finishes and they become dormant during this time). In contrast to this, signs were alleviated and reversed after rain, indicating that bleaching was not associated with rainfall. It appeared that dew was causing a reduction in productivity of pastures, which lead to the pursuit of this study. If abnormal chemistry is discovered in the dew, it should highlight the possible connection with the reduction of photosynthesis and ill-health of plants as described.

Materials & Methods

To study the chemistry of dew it was necessary to collect dew samples for testing under different meteorological conditions, seasons and from a range of locations. Rain water samples were also tested as a comparison. A method of dew collecting was devised whereby dew was collected on polythene sheeting and stored in sterile glass jars and refrigerated. Various soil samples were also tested to investigate the soil chemistry.
Records were kept of the air mass movement associated with each dew collection to correlate dew chemistry with the direction of the air mass. Air that originates from over a large land mass is called a continental air mass and air that originates over the ocean is called a maritime air mass. It was necessary to determine if the chemistry varied between the dew from the different air movements.

First Dew Collection and Testing
The first of the testing was in 1993, when the Mt Gambier CSIRO was asked to test some locally collected dew samples for pH.

Second Collection and Testing (Rainwater and Dew)
In 2005, more laboratory testing of dew was carried out on samples collected from five different sites from an area covering approximately 120 kms. Dew samples were collected from four main sites in the Millicent (SA), Rennick (Vic), Mumbannar (Vic) and Greenwald (Vic) areas and rain water samples were collected from Mumbannar and Mount Gambier (SA).
Originally, tests were conducted on one rain water and one dew sample from Mumbannar and the results of the Mount Gambier rainwater samples were obtained from the Department of Water, Land and Biodiversity. The three samples of rainwater were tested on a broad spectrum in an attempt to gain a true background level as a reference base for the elements tested and the pH. This allowed a comparison in the chemistry between the dew and the rain.

Four elements were considered as potentially correlated with the plant foliar damage and disorders. These four elemental ions, from the halogen group of elements, were fluoride, iodide, bromide and chloride and it was decided to test the dew samples for these. In addition pH was also tested in each sample to observe if there was a correlation between pH and other elements. The tests were conducted at the Australian Water Quality Centre, Bolivar, SA.

Third Collection and Testing (Rainwater and Dew)
The most recent dew collection and testing was conducted during 2007. The collection was carried out predominantly on one site and was collected on either polythene sheeting or galvanized iron roofing. The weather conditions were recorded for each dew sample.
The tests which were carried out on these samples analysed major cations, anions, conductivity and pH and in particular to search for an associated ion which had not been identified in previous tests. The analyses were conducted by John Ferguson, The Best on Earth, Moorina, Queensland.

Consistency Collection Testing (Dew)

As dew collections were obtained from either polythene sheeting or a galvanised iron roof on a farm shed, a parallel test was carried out to ensure the results were not being influenced by the surface used for collection. Dew was collected for the same period of time, on the same night, at the same location from the two different surfaces.

Series Collection and Testing (Dew)
In 2007, a test was run to establish if collection time played a role in dew chemistry results. The test was carried out over a period of 12 hours, starting at 2000 hours and ending at 0800 hours. The first phase of the series testing was done between 2000 hours to 0200 hours. The second phase of the testing was run between 0200 hours to 0800 hours. Dew collected from both phases remained separated for testing to determine if the time of the precipitation influenced its chemistry.

Soil Testing
Soil samples were tested from the dirt floor of an old shed to compare the wet, exposed soil and the dry protected area and to investigate the composition of the white precipitate that formed between them (**See Fig 6**).

Soil from the gutter outlets of sheds, where the run off from dew concentrated, was tested and adjoining soil a short distance from the run off zone was also tested to compare the soil chemistry.

Two soil samples from under the drip line of naturally occurring Eucalyptus Baxteri were tested for comparison. Both samples were taken from a sandy bank - one sample from where the natural under story and ground cover remained and the other from an adjoining area where there was bare soil and no under story.

All of the soil tests were conducted by John Ferguson, The Best on Earth, Moorina, Queensland, and completed during November 2007.

Results

First Testing (Dew)
The initial tests done in 1993, by the Mt Gambier CSIRO tested some dew samples we had collected from our local area for pH. The results showed a variation of about 2 units in pH but the trial was considered to be inconclusive due to insufficient samples tested.

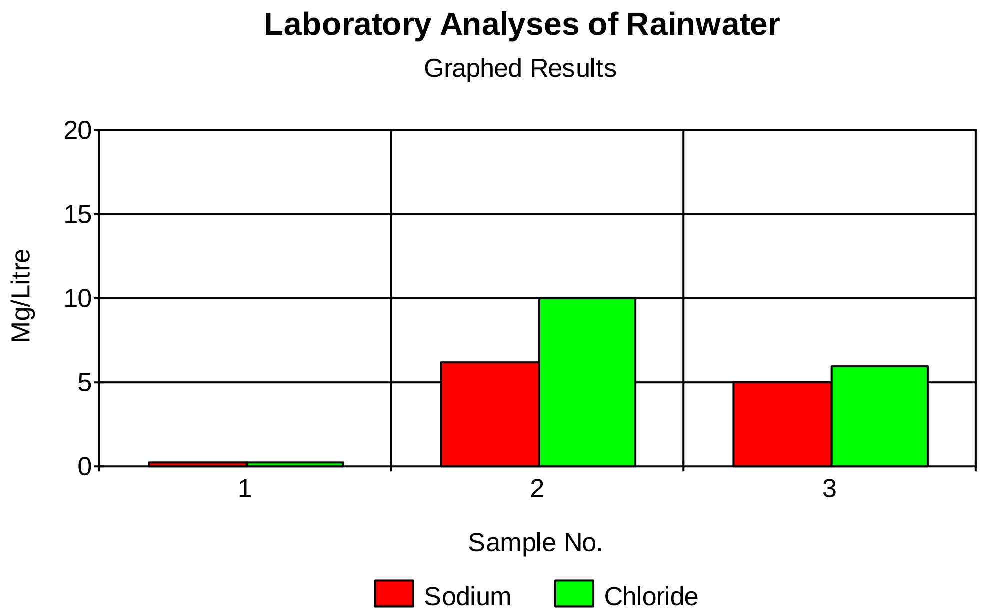
Second Testing (Rainwater and Dew)

RESULTS FROM RAIN WATER TESTING						
Sample No.	F-	Br-	Na	Cl-	pH	Comment
1	<0.05	<0.05	0.2	0.2	5.9	Sample from a single rain event (approx. 06/04)
2	<0.05	<0.05	6.2	10.0	6.7	1.5l of rain collected from 4/11/04 - 30/11/04
3	<0.10	<0.10	5.0	6.0	7.4	Rain samples taken from domestic rainwater tank 5/04

(N.B. Results in Mg/litres.)

Fig. 7_. Test results sample 1 and 2 supplied by the Dept of Water, Land and Biodiversity (Mt Gambier, SA) 2004. Sample 3 tested by Australian Water Quality Centre (Bolivar, SA) & Alternative Health Sciences (Geelong, VIC)- 2005

The sodium and chloride results from rainwater testing Fig 7 shown in graph Fig 8.



TESTS WERE CONDUCTED BY:
Sample No. 1- Department of Water, Land, & Biodiversity (Mt. Gambier, SA) - 2004
Sample No. 2- Department of Water, Land, & Biodiversity (Mt. Gambier, SA) – 2004
Sample No. 3- Australian Water Quality Centre (Bolivar, SA) & Alternative Health Sciences (Geelong, VIC)- 2005

Fig. 8.

Dew samples were tested by Australian Water Quality Centre, Bolivar, SA, July 05.

RESULTS FROM DEW SAMPLE TESTING						
Sample no	Fluoride	Iodide	Bromide	Chloride	Ph	NB
A 5/04	<0.1	<0.05	0.15	49mg/l	6.5	
B 5/04	<0.1	<0.05	0.21	50mg/l	6.8	
C 5/04	<0.1			25mg/l	5.4	
D 5/04	<0.1	<0.05	<0.1	13mg/l	5.5	
E 5/05	0.15	<0.05	<0.10	14mg/l	7.2	
F 5/02	0.14			25mg/l	6.8	Iron roof
G 3/05	0.17			55mg/l	6.9	Iron roof
H 4/02	<0.1			12mg/l	7.1	
I 3/05	<0.1			25mg/l	6.9	Iron roof
J 5/02	0.15			30mg/l	6.9	Iron roof

(N.B. Results are in Mg/litres, except for pH.)

Fig. 9. Test results supplied by Australian Water Quality Centre (Bolivar, SA) 30/06/05.

The levels of chloride in the dew tests were significantly higher than the chloride in the rainwater tests.
From the results of the testing, iodide was the only element that remained low and without change in either dew or rain. The pH range varied 2 units but appeared to have no correlation with the variation of the other elements tested.
Three of the substances tested were present at greater levels in the dew than in the rain with one of those, Chloride, being over 275 times greater than the purest rain sample result. It is noted, however that within the rain samples, from the Mt Gambier Dept of Water, Land and Biodiversity there was a variation of up to 50 times the chloride level.

Third Testing (Rainwater and Dew)

The method used to establish the Laboratory Elemental Readings was the Chromatography method. This method is widely considered as being the most versatile separation method which can be applied to solid, liquid or gaseous mixtures (from a letter written by John Ferguson, The Best On Earth, Moorina ,Queensland, November 2007).

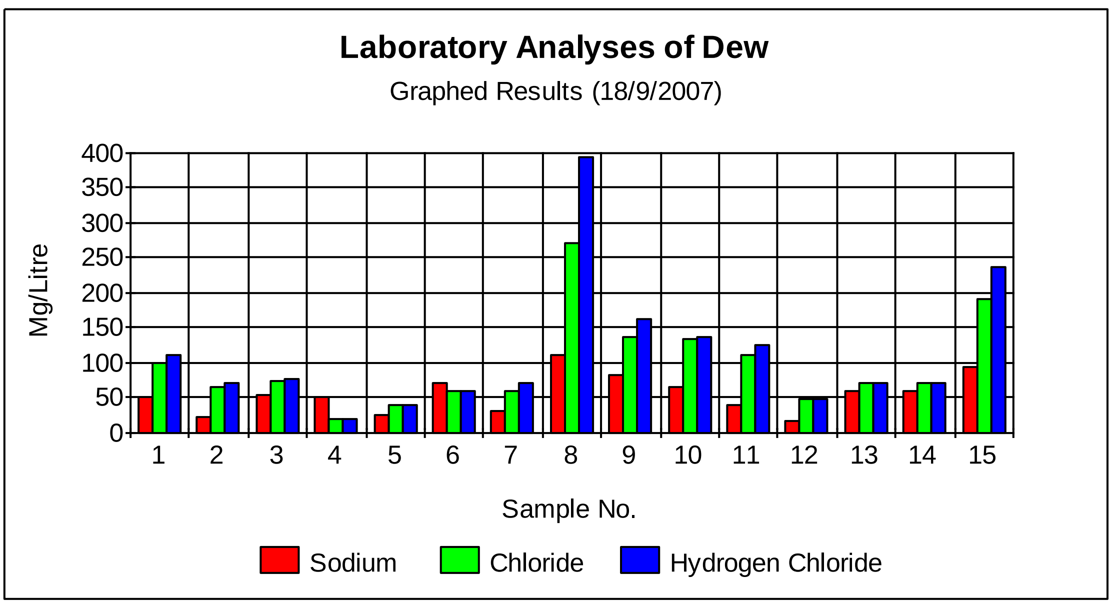


Fig. 10. Tests were conducted by John Ferguson, The Best on Earth (Moorina, QLD).

The higher readings of chloride in the dew occurred when there were clear skies at night under stable high pressure cells. The air mass movement from the north and north east were the coldest and generally returned the higher levels of chloride in the dew.

The test results (**fig 10**) were representative of a range of conditions in which dew was occurring and many samples which have been tested on site (in addition to the laboratory tests) have indicated levels of chloride similar to and greater than the highest level tested in the laboratory (refer to Appendix 1).

The test results of the dew samples appear to be extremely significant and may correlate with the abnormal characteristics and ill health observed in plants. High levels of sodium and chloride present in dew, settling on the leaf surface could have a damaging effect on foliage, in particular the delicate new growth of plants.

Consistency Testing

The results of the parallel testing which were sample 13 (iron roof) and 14 (polythene sheeting) of Laboratory Elemental Readings (**Fig 10** and **Appendix- -**) were almost identical which indicated that the catchment surfaces were not influencing the results.

Series Testing

The series testing results (sample 1 and 2 of Laboratory Elemental readings -**Fig 10**) showed considerable variation in all the elements present. In most cases the higher levels of elements were in the earlier dew test (2000 to 0200hrs).

This concurs with temporal (overnight) dew studies that have found that dew chemistry changed substantially during the course of the night (Foster et al., 1990).

Soil tests

1. **Shed soil tests** The white precipitate was found to be Calcium which was being stripped from the soil with the movement of moisture.

Fig-11 Soil Tests from dirt floor of shed. Summary table of main variables.		
Elements Measured	**Dirt floor under Solid Roof of Shed mg/kg**	**Dirt floor Under Leaky Roof of Shed mg/kg**
Calcium	940	320
Magnesium	380	470
Sodium	57	42
Chloride	26	99
Calcium:Magnesium ratio	2.5:1.0	0.8:1.0
Other Measurements		
Conductivity dS/m	0.08	0.37
Soluble salts mg/Kg	26	44
pH 1:5 water	5.2	5.0
Hydrogen-exchangeable cations	2.4%	7.2%

Tests were conducted by John Ferguson, The Best on Earth (Moorina, QLD).

The high Chloride and Hydrogen level in the soil appear to be directly related to the high levels of both these elements in dew.
The combination of rain and dew draining in on the dirt floor is having a large impact on some of the elements particularly the Calcium which is moving through the soil with the moisture. ie depleting the soil of calcium.

2.<u>Soil Tests from Gutter Outlet</u>

The soil analyses show elevated levels of Sodium, Chloride and soluble salts in the soil influenced by the dew run off. In line with the other soil tests from within the shed, Calcium is decreasing in the soil exposed to the dew runoff.

Fig-12 Soil Tests from Iron Roof Outflow. Summary table of main variables.

Elements Measured	**Soil 1.5 metres away from outflow mg/Kg**	**Soil from base of iron roof outflow mg/Kg**
Calcium	930	720
Magnesium	410	490
Sodium	105	180
Chloride	75	290
Other Measurements		
pH. 1:5 water	5.2	5.0
Soluble salts	80	195
Conductivity dS/m	0.21	0.39
Organic Carbon%	0.9	0.4

Tests were conducted by John Ferguson, The Best on Earth (Moorina, QLD).

After a good rainfall it is possible there could be a degree of flushing from the soil surface of the Sodium and Chloride. This appears to occur because the vegetation around the perimeter of the sterile area around the outlets improves in quality and colour after good rainfall.

3. Soil Tests from under Eucalypts

The variations in the chemical analyses of the soils were dramatic. The samples were taken less than fifteen metres apart. One sample was taken from undisturbed natural bush land and the other was taken from inside a grazed paddock containing only remnant Eucalypts and bare soil.

Fig-13 Soil Tests from under Eucalypts. Summary table of main variables.

Elements Measured	**Soil with natural bush mg/Kg**	**Soil with remnant eucalypts mg/Kg**
Calcium	740	510
Magnesium	320	375
Sodium	108	275
Chloride	88	380
Other Measurements		
pH 1:5 water	5.8	5.4
Soluble salts mg/Kg	61	102
Conductivity dS/m	0.21	0.44
Organic Carbon%	1.7	0.6

Tests were conducted by John Ferguson, The Best on Earth (Moorina, QLD).

The results could be explained by the fact that dew, high in concentrations of Sodium and Chloride, drips from the trees and lands on the foliage of the under story, preventing it from impacting on the soil whereas the non protected soil is being totally exposed to the chemistry of the dew. This could be impacting on the biomass of the soil as the results show the exposed soil contains only 18% of the active bacterial biomass of the protected soil (refer to Appendix 2 & 3).

All the natural bush is under stress but more so in situations where the under story has been depleted.

Overview

In summary, from all the laboratory tests conducted

- It was evident that certain elements, mainly Sodium and Chloride were at much higher levels in the dew than in the rain water samples tested
- Chloride was identified as the major anion that is present at elevated levels.
- Conductivity and pH varies considerably in dew samples tested.
- While testing for the associated cations, it was found that Sodium, Hydrogen and Calcium all play a role, particularly Hydrogen.

Discussion

- Na Cl present in dew could damage plant foliage and may also increase surface soil salinity.
- HCl in dew could damage foliage and increase soil and water acidity. There have been reports that salinity levels are greater around and under some trees than in surrounding soils and our findings are consistent with this. In the case of Eucalypts, they naturally catch atmospheric moisture and drip it at their root zones. This is consistent with the results of the soil tests conducted for this paper where the Sodium and Chloride levels were much higher on exposed soil under Eucalypts.
- The dew results showing high levels of Sodium and Chloride could contribute to dry land salinity. When Sodium and Chloride are settling on the cold landmass on a regular basis over extended periods, the expected cumulative effect of Sodium Chloride would cause an increase in surface salinity. In addition to this, where HCL from the dew is settling on soils with a high Sodium level it could be expected that the Chloride would combine with the Sodium to form Sodium Chloride (NaCl).
- It appears the cocktail of NaCl and HCl present in dew could be interfering with photosynthesis and damaging foliage leaving it open to attack from pathogens. This would reduce the efficiency of plants to utilize water, nutrients and interfere with their health and viability
- Cl is known to inhibit the uptake of N in plants. The only areas where pasture appear to be in optimum health are where excessive amounts of N (eg from animal urine) is present. This is seen as dark green mosaics in pasture. In the case of crops, farmers use additional N to meet the plants requirements so it is not as evident.
- The natural bush has become degraded, unhealthy and under stress since the 1960’s. Even after good rainfall, trees and plants are still showing extreme stress (loss of canopy and epicormic growth etc). Plants are becoming dessicated (with less succulent growth) and this is occurring across wide areas including National Parks. It could be postulated that this could be a result of the constant exposure to the chemicals in the dew.
- While there is a lot of emphasis on excess Carbon in the atmosphere (in relation to Climate Change) there is little evidence in the dew, rain and soil analyses of this study to indicate that the levels of Carbon are as significant as the levels of Sodium, Chloride and Hydrogen Chloride. Chloride is considered to be a far worse Ozone depleting material than Carbon Dioxide. It is well known in the horticultural arena that plants grow better in a Carbon enriched environment.
- Calcium appears to be being stripped from soils. Tests on soils where there has been rain and dew runoff showed decreased amounts of Calcium present in the area exposed to dew compared with identical soil which has been sheltered from the rain and dew for over 100 years.
- Biomatter is less prevalent in exposed soils (refer to Appendix). Soils that had protection of their surface had a much higher biomass. The chemistry in the dew appears inhospitable to the biomass. It is feasible that the exposed soils with higher levels of Sodium, Hydrogen and Chloride would suppress the effectiveness of Rhizobia bacteria .This would reduce the Nitrogen fixation in the soil and greatly reduce plants productivity.

- The occurrence of non-wetting sands seems to be increasing and this may be associated with HCl in dew reacting with silicon in sandy soils.

Bloat and other animal health issues

Livestock ingesting dew may be negatively affected in many ways. Bloat occurs when animals ingest lush legume pastures often during, and after, the occurrence of dew. Excessive amounts of gas are formed (methane $CH4$). Bloat does not seem to occur to the same extent, during periods of rain without dew. Now that the chemistry in the dew has been analysed, the results could explain the overproduction of methane, which is considered to be a major agricultural pollutant and contributor to greenhouse gases. The accelerated production of methane caused by the ingestion of HCl in the dew could be interpreted as a form of secondary pollution.

Other clostridial diseases such as Pulpy Kidney are also associated with lush feed conditions and could possibly be attributed to the pollutants in dew. Calf scours are another animal health problem which seems to be correlated with the weather conditions associated when dew occurs. In addition to these health problems, livestock are becoming increasingly reliant on vitamin and mineral supplements to maintain “normal” health status.

- Corrosion has become a huge cost to many industries, from agriculture through to aviation. Some of this corrosion could be attributed to the chemistry of dew.
- Chloride is known to be associated with the destruction of the ozone layer from the Polar Regions and into the temperate zones around the world.
- Chloride compounds are able to melt ice and lower the freezing point of water.
- With Chloride present in the upper atmosphere at increased rates it seems possible that the water molecules are repelling each other more or reducing the natural attraction.

Possible sources of Chloride pollution

This paper cannot detail the sources of Chloride pollution. However it is commonly accepted that there are many sources of such pollution, including the coal fired power stations that emit pollutants, including Carbon Dioxide and Hydrochloric acid, into the atmosphere (Lightowlers and Cape, 1988; McCulloch et al., 1999). Chloride pollution is also possible from a variety of other sources including plastic manufacturing, domestic and industrial waste incinerations (Shapiro, J.B., Simpson, H.J., et al 2006.), Chloride bleaching pulp mills etc.

It would seem reasonable that this Chloride pollution accumulates in the atmosphere until it settles back on the surface of the earth with atmospheric moisture such as fog, hail, rain, snow and especially dew, because dew is generally derived from stable meteorological conditions from extremely high altitudes.

Why dew and not rain?

A search of the literature and informal discussions with a number of meteorologists suggests that there is very little information about the chemistry of dew. Should rainfall and dew be treated similarly in terms of pollution potential?

In a simple meteorological sense, most precipitation is associated with instability and turbulence in the air mass, causing the moisture laden atmosphere to precipitate as rain, hail or snow. Clear atmospheric conditions, which are occurring more frequently over much of Southern Australia, allow greater radiation cooling of the landmass at night (ie the heat is radiated away from the earth). Dew is formed under stable meteorological conditions when the air mass makes contact with cold surfaces that are at or below the dew point temperature.

Dew derived from continental air mass movements contained considerably higher levels of Sodium Chloride and Hydrogen Chloride when compared to dew formed from maritime air mass movements.

From this investigation it is evident that it is possible that the dew that descends from very high altitudes may contain high amounts of pollutants. The very dry air mass in a high pressure cell gradually descends from extremely high altitudes and condenses on cold surfaces at, or below, the dew point temperature, forming dew. High pressure cells can be very slow moving and can dominate the weather conditions for extended periods and as a result the formation of dew can occur over a number of nights with a cumulative effect.

The pollutants in the upper levels of the atmosphere are likely to be held in suspension for longer than at lower altitudes and they are therefore believed to travel further before being deposited back on earth, making it difficult to determine exactly where the pollution source is.

Rain is characterised by instability, turbulence, and deposition of generally larger quantities of water. Dew is characterised by stability, clear skies (which can be associated with very hot days and very cold nights) and relatively small depositions of moisture.

Frost is simply frozen dew and this leads to the possibility that some of the damaging effects on plants may also be effects of the pollution in the frost, not simply the effect of the low temperature.

Where to from here?

It is evident that more studies need to be done with strict controls and large sample sizes analyzing and comparing the composition of dew and rain. This may lead to the establishment of a standard or range for the composition of dew during various conditions. This information could then be used to produce an ‘artificial’ dew that could then be used in controlled trials of the effect of dew on a variety of plants, pastures, soils, biomass, metals etc, compared to control groups.

The result of this investigation indicates Chloride pollution in dew may be having a negative impact on agricultural, horticultural, viticultural and forestry industries as well as affecting the health and viability of the natural environment and its biodiversity. The issue is large and complex and crosses many disciplines.

Chloride pollution from dew is a phenomenon that needs to be addressed seriously.

The indications may well have a major impact on the direction that the whole debate on Climate Change takes, and the relative impact of Carbon emissions, sequestration and controls might need to be seriously questioned.

The amount of laboratory analyses in this paper has been limited by financial constraints. It is recognized that without some financial support from Meat and Livestock Australia, much of the expensive laboratory testing would not have been possible.

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References

Auclair, A.N.D., 1993. Extreme climatic fluctuations as a cause of forest dieback in the Pacific Rim. Water Air Soil Pollut. 66, 207-229.

Day, M.F., 1981. Forward. In: Old, K.M., Kile, G.A, Ohmart, C.P. (Eds.), Eucalypt Dieback in Forests and Woodlands. CSIRO, Australia, pp. i-ii.

Foster, J.R., Pribush, R.A., Carter, B.H., 1990. The chemistry of dews and frosts in Indianapolis, Indiana. Atmospheric Environment. Part A. General Topics 24(8), 2229-2236.

Jurskis, V., 2005. Eucalypt decline in Australia, and a general concept of tree decline and dieback. Forest Ecology and Management 215, 1-20.

Keane, P.J., Kile, G.A., Podger, F.D., Brown, B.N., 2000. Preface. In: Keane, P.J., Kile, G.A., Podger, F.D., Brown, B.N. (Eds.) Diseases and Pathogens of Eucalypts. CSIRO, Melbourne, pp. xiii-xvi.

Lightowlers, P.J., Cape, J.N., 1988. Sources and fate of atmospheric HCL in the UK and Western-Europe. Atmospheric Environment 22, 7-15.

McCulloch, A., Aucott, M.L., Benkovitz, C.M., Graedel, T.E., Kleiman, G., Midgley, P.M., Li, Y.F., 1999. Global emissions of hydrogen chloride and chloromethane from coal combustion, incineration and industrial activities: Reactive Chlorine Emissions Inventory. Journal of Geophysical Research – Atmospheres 104, 8391-8403.

Podger, F.D., 1981. Some difficulties in the diagnosis of drought as the cause of dieback. In: Old, K.M., Kile, G.A, Ohmart, C.P. (Eds.), Eucalypt Dieback in Forests and Woodlands. CSIRO, Australia, pp. 167-173.

Wardlaw, T., 1990. Changes in forest health associated with short-term climatic fluctuation. Tasforests 2, 107-110.

White, T.C.R., 1986. Weather, *Eucalyptus* dieback in New England, and a general hypothesis of the cause of dieback. Pac. Sci. 40, 58-78.

Wylie, F.R., Johnston, P.J.M., Eismann, R.L., 1993. A survey of native tree dieback in Queensland. Research Paper No. 16. Department of Primary Industries, Queensland.

Shapiro, J.B., Simpson, H.J., Griffin, K.L., Schuster, W.S.F., 2006. Precipitation chloride at West Point, NY: Seasonal patterns and possible contributions from non-seawater sources. Atmospheric Environment 41, 2240-2254.

Appendices

APPENDIX 1

The Best on Earth

John Ferguson
Soil Consultant
Mobile: 0418 989 802

188 Moorina Road, Moorina Qld 4506
Tel: (07) 5496 7037 Fax: (07) 5497 0069

DN McLennan   Investigation Covering Effects of Dew on Agriculture

Laboratory Element Readings Mg/Litre Testing Completed 18-9-2007

Sample No	Laboratory No	Date Sampled	pH Units	Conductivity US/cm	Sodium	Chloride	Hydrogen Chloride
1	6300	16.7.07	6.2	38	50	100	112
2	6301	16.7.07	6.4	15	22	66	72
3	6302	29.7.07	5.7	68	55	75	78
4	6303	13.8.07	7.2	128	50	20	20
5	6304	14.8.07	6.3	65	25	39	40
6	6305	15.8.07	5.7	85	70	60	60
7	6306	17.8.07	6.6	60	30	60	72
8	6307	21.8.07	5.4	95	110	270	395
9	6308	22.8.07	6.0	77	82	137	162
10	6309	23.8.07	5.7	62	66	135	138
11	6310	24.8.07	6.4	49	39	110	127
12	6311	29.8.07	5.7	105	18	48	48
13	6312	30.8.07	6.1	49	60	70	70
14	6313	30.8.07	6.1	47	60	70	70
15	6314	3.9.07	6.2	79	95	190	238

Laboratory Analysis Tested and Reported by John Ferguson

APPENDIX 2
The Best on Earth

John Ferguson
Soil Consultant

188 Moorina Road, Moorina QLD 4506
Tel: (07) 5496 7037 Fax: (07) 5497 0069
Mobile: 0418 989 802

Laboratory Report to: DN McLennan
Location: Mumbannar Victoria
Sample Submitted by: D McLennan
Date Sampled: 15th October 2007
Laboratory No: 6387
Sample Type: Sample B1 – Soil from area of affected Stringybark trees

Organism Biomass Results

Type of Biomass	Reading ug/ml	Desired Range
Active Bacterial Biomass	22	50 – 150
Total Bacterial Biomass	105	150 – 300
Active Fungal Biomass	<0.1	2 – 5
Total Fungal Biomass	0.3	5 – 20

Protozoa	Total No. m/L	Desired Range
Flagellates	600	5 000+
Amoebae	150	5000+
Ciliates	10	20 – 80

Hyphal Diameter (um): <2.0 Total Nematodes: 1.8 (2-10)
Mycorhizal Fungal Colonisation: Nil
Soil Colour (Munsell): Black Type: Silty Sand
Texture and Structure: Fairly Tight

Remarks: Hyphal diameter indicates very limited true fungi, most are antinobacteria species.

APPENDIX 3

The Best on Earth

John Ferguson
Soil Consultant

188 Moorina Road, Moorina QLD 4506
Tel: (07) 5496 7037 Fax: (07) 5497 0069
Mobile: 0418 989 802

Laboratory Report to: DN McLennan
Location: Mumbannar Victoria
Sample Submitted by: D McLennan
Date Sampled: 15th October 2007
Laboratory No: 6388
Sample Type: Sample B2 – Similar Soil Type to B1 but good ground cover

Organism Biomass Results

Type of Biomass	Reading ug/ml	Desired Range
Active Bacterial Biomass	120	50 – 150
Total Bacterial Biomass	320	150 – 300
Active Fungal Biomass	1.2	2 – 5
Total Fungal Biomass	5.6	5 – 20

Protozoa	Total No. m/L	Desired Range
Flagellates	2700	5 000+
Amoebae	3900	5000+
Ciliates	70	20 – 80

Hyphal Diameter (um): 2.2 Total Nematodes: 0.9 (2-10)
Mycorhizal Fungal Colonisation: 5%
Soil Colour (Munsell): Black Type: Silty Sand
Texture and Structure: Fair, but could be improved

Remarks: Hyphal diameter indicates a mixture of antinobacteria and ascomytes species.