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# The Chemistry of Namib Desert Fog in Comparison with Coastal Desert Fog of Chile and Oman 187-190

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Abstract: This paper documents the ion concentrations and ion enrichment relative to sea water, in Namib Desert fog water, with the purpose of establishing its suitability for future Namibian fogwater collection schemes, while also examining claims that Namib Desert fog water carries exceptionally high concentrations of sulphate, which may be responsible for the formation of gypsum deposits in the desert. The work suggests that Namibian fog water is at least as clean as has been reported from other coastal deserts in South America and Arabia, and provides a source of very clean water for the coastal desert region of south-western Africa. It does not appear that fog is an efficient sulphur source for the formation of the gypsum deposits, unless rare events with high concentrations of marine sulphur compounds occur.

## 1. **INTRODUCTION**

Fogwater utilisation is currently being evaluated in the Central Namib Desert, where small Topnaar settlements along the lower course of the Kuiseb River seek an alternative water source. Results published so far were obtained from unconventional sample devices, such as rooftops and raingauges and suggest very high dissolved loads (Besler 1972, Goudie 1972).

The chemical composition of Namib Desert fog water is also of geological relevance as it has long been considered to be a significant pathway of decompositional marine biogenic sulphur (H2S) from off-shore sediment gas eruptions into the Namib Desert (Martin 1963). Sulphur tends to be the limiting element in the formation of gypsum (CaSO4.2H2O) a common desert evaporite. Due to the absence of significant sulphate sources within the underlying regional geology, fog deposition has long been considered to promote the formation of Southern Africa's most extensive accumulation of superficial, pedogenic gypsum minerals. A which will be examined in this study.

By implementing the same sampling and analysis procedure as has been used in Chile (Schemenauer and Cereceda 1992a) and Oman (Schemenauer and Cereceda 1992b), the results in this study will be directly comparable with the chemistry of coastal desert fog elsewhere and should establish the usefulness of fog water for human consumption as well as detennine its significance as a pathway of marine biogenic sulphur in the fonnation of pedogenic desert sulphate minerals. The main fog sampling site in this study was at the Desert Ecological Research Unit on the banks of the Kuiseb at Gobabeb (150 53' 10" E, 22044' 19" S), 420 m above sea level and 55 km from the South Atlantic Ocean.

### 1.1 **Methods**

Fog water was sampled using two identical, Canadian built (Atmospheric Environment Service, AES), passive samplers similar to the collector used by Mohnen and Kadlecek (1989), which in turn was a modified version of that of Falconer and Falconer (1980) (Atmospheric Sciences Research Center, ASRC). All samples were collected following detailed procedures given in the Operator's Manual for the Chemistry of High Elevation Fog (CHEF 1987) Program of Canada and analysed at Les Laboratoires Savoie-Dufresne Inc. in Montreal, Canada.

Analyses for Na, K, NH4, CI, N03, Ca, Mg and S04 were performed with a Waters Ion Chromatograph. Enrichment factors relative to CI were calculated, using the method outlined in Schemenauer and Cereceda (1992a) based on elemental seawater ratios by (Kennish 1989).

### 1.2 **Results**

Between April 1994 and October 1995, 7 samples from 6 distinct fog events were obtained from a variety of locations within the Central Namib Desert (Table 1).

In contrast to previous results, this data suggests Namib fog to be very clean. Furthermore, the total ion concentrations (mean 14.5 ppm) as well as S04 levels measured (mean 3.2 ppm) for Namib fogwater samples are lower than AES samples obtained from Chile and Oman (Schemenauer and Cereceda 1992 a,b) (Table 2 ) and are amongst the cleanest samples ever collected with the AES/ASRC collector.

Enrichment factors for Namibian fogwater S04 (Table 3) show appreciable levels of enrichment (mean value 5.8) relative to seawater and are indicative of organic marine compounds and remobilised terrestrial gypsum (Annegam et al. 1983). High enrichment factors are associated with Ca (mean value 17.3), suggesting considerable terrestrial aerosol contributions from calcareous bedrock exposures in the area. These exposures could also account for the slightly enriched presence of K (mean value 2.3) in the fog samples, though the values are so near to those for

seawater that the contribution may not be great. Enrichment factors for Na (mean value 1.2) and Mg (mean value 1.1) are even more conservative and remarkably consistent for all Namib AES/ASRC samples, suggesting that these ions are predominantly of seawater origin.
Namibian Enrichment Levels are similar to fogwater samples from the coastal deserts of Oman and Chile, with the conservative nature of Na and Mg also being evident in samples from these countries. Enrichment levels for K in the other deserts are also moderate, while the general presence of Ca rich terrestrial nuclei is evident in all samples. Enrichment of S04 is most noticeable in Chile (mean 10.1), which is thought to be caused by marine biogenic DMS production associated with the cold Humboldt current (Schemenauer and Cereceda I 992a). Analogue oceanic conditions generated by the Benguela current produce similar levels of S04 enrichment in Namibia (mean 5.8). There is no comparable cold current along the coast of Oman, though there may be some cool upwellings, and the S04 enrichment factor is considerably lower (0.5).

### 1.3 **Conclusion**

It is apparent that Namib Desert fog is extremely clean and potable, with levels of enrichment and ion concentrations comparable to those measured in the coastal deserts of Oman and Chile.
Given these data, Namibian fog is unlikely to be a significant player in the regional biogeochemical cycle and unlikely to contribute directly to gypsum accumulation. These results do not however preclude the occurrence of much higher atmospheric sulphur loads in conjunction with sporadic and major biogenic H2S emissions from the Benguela sediments. That such events do occur is supported by anecdotal evidence from the people living along the coast of Namibia. Definitive answers can only come from long term monitoring of gas, particulate and fog chemistry.

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Table 1. Concentration of major ions (ppm) in fogwater samples obtained with the AES/ASRC fog collector in the Central Namib Desert, Namibia in 1994 and 1995. TIC is the total ion concentration

| Sample no. | pH | TIC | $SO_4$ | $NO_3$ | Cl | Na (ppm) | K | Ca | Mg | $HCO_3$ | $NH_4$ | Date/Time |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1003 | 6.5 | 3.3 | 0.58 | 0.22 | 0.38 | 0.36 | 0 | 0.3 | 0.03 | 0.63 | 0.81 | 19 April 1994/ 0330-0900 |
| 1005 | 6.4 | 9.7 | 2.23 | 0.27 | 2.79 | 1.59 | 0.2 | 1.08 | 0.18 | 0.49 | 0.92 | 23-24 July 1994/ 2200-0630 |
| 1007 | 6.6 | 9.4 | 1.86 | 0.32 | 2.55 | 1.41 | 0.18 | 1.27 | 0.17 | 0.75 | 0.93 | 23-24 July 1994/ 2200-0630 |
| 1009 | 6.2 | 16.4 | 4.99 | 0.72 | 4.4 | 2.57 | 0.33 | 1.76 | 0.31 | 0.31 | 1.05 | 18 October 1994/ 0600-0930 |
| 1012 | 5.9 | 27.9 | 6.71 | 0.44 | 10.0 | 6.11 | 0.5 | 2.48 | 0.65 | 1.86 | 0.84 | 12 Sept. 1995/ 0340-0540 |
| 1023 | 5.6 | 20.4 | 3.77 | 0.58 | 8.33 | 4.98 | 0.12 | 0.69 | 0.98 | 0.07 | 0.85 | 11 October 1995/ 0340-0710 |
| 1025 | 6.4 | 13.7 | 2.21 | 0.28 | 5.31 | 3.1 | 0.28 | 0.72 | 0.38 | 0.44 | 0.98 | 16 October 1995/ 0245-0805 |

Table 2. A comparison of major ions (ppm) in fogwater samples from the coastal deserts of Chile, Oman and Namibia. The maximum allowable World Health Organisation (WHO) drinking water concentrationsare also shown

| Location | type | n | pH | TIC | $SO_4$ | $NO_3$ | Cl | Na (ppm) | K | Ca | Mg | $HCO_3$ | $NH_4$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chile[1] | fog | 7 | 4.7 | 31.5 | 12.3 | 1.6 | 8.7 | 5.4 | 0.5 | 1.0 | 0.7 | 0.00 | 1.4 |
| Oman[2] | fog | 7 | 7.4 | 103.8 | 3.4 | 4.7 | 44.1 | 24.1 | 1.1 | 15.1 | 2.9 | 10.7 | 0.2 |
| Namibia | fog | 7 | 6.2 | 14.5 | 3.2 | 3.4 | 4.8 | 2.9 | 0.2 | 1.2 | 0.4 | 0.7 | 0.9 |
| WHO | | | 6-8.5 | | 250 | 45 | 250 | | | 200 | 125 | | |

([1]Schemenauer and Cereceda 1992a, [2]Schemenauer Cereceda 1992b)

Table 3. Enrichment factors relative to chlorine in fogwater samples from this study and the mean values from the coastal deserts of Chile, Oman and Namibia

| Location | | EFCa | $EFSO_4$ | EFK | EFMg | EFNa |
|---|---|---|---|---|---|---|
| Chile[1] | fog | 5.3 | 10.1 | 2.6 | 1.3 | 1.1 |
| Oman[2] | fog | 16.3 | 0.5 | 1.2 | 1.0 | 1.0 |
| Namibia | fog | 17.3 | 5.8 | 2.3 | 1.1 | 1.2 |

([1]Schemenauer and Cereceda 1992a, [2]Schemenauer Cereceda 1992b)