# The sorption of water vapor by windborne plant debris in the Namib Desert

by
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ABSTRACT

The sorption of water vapor by dead plant material under subsaturated conditions was measured as a function of the relative humidity (RH). With prolonged exposure to high RH's, the water content of the material may reach values in excess of 70%. Since the humidity in the Namib Desert, at least near the coast, is almost always very high, the data suggest that absorbed water could be an important water source to debris-eating animals in this region.

## THE SORPTION OF WATER VAPOR BY WINDBORNE PLANT DEBRIS IN THE NAMIB DESERT

The uptake of water vapor and resultant swelling of cellulosic material is a well-known phenomenon to textile and wood-products researchers (e.g., Wahba and Nashed, 1957; Christensen and Kelsey, 1958; Kawai, 1959; Kollman, 1962) and has more recently been related to the flammability of light forest fuels (Blackmarr, 1969). When liquid water is unavailable, it seems possible that such absorbed water could become significant to animals. Although fog has been suggested to be a source of water for animals in the coastal Namib Desert (M. K. Seely, personal communication), there have been no reports to date on the possible similar role of water absorbed in plant fibers from undersaturated air. The low relative humidity in most of the world's deserts would not permit cellulose to be a significant water source in these areas, but the Namib Desert of South West Africa has a high frequency of very humid or foggy days (Logan, 1960; Meigs, 1966; Schulze, 1969) providing conditions resulting in a high water content in cellulosic materials. The present study provides confirmation that under humid conditions, even in the absence of liquid water in the form of fog, dead plant material can serve as a source of a significant amount of water if eaten at certain times of the day.

### Materials and Methods

Dead, dry plant material was collected from the lee side of dunes just south of the Kuiseb River at Gobabeb. It consisted mostly of fragments of the leaves and bracts of the coarse grass *Stipagrostis sabulicola,* as well as lesser amounts of whole leaf sections. A great deal of the material is finely divided and its source is difficult to recognize.

Atmospheres of known relative humidity were generated with sulfuric acid - water mixtures. A ten milliliter sample of each approximate dilution was weighed to the nearest milligram (at 20° C) and the specific gravity calculated. The relative humidity (RH) of air in equilibrium (at 20° C) with each of these solutions was then determined from tables (Handbook of Physics and Chemistry).

The uptake or loss of water was measured by the weight change of a sample of debris suspended in a container over aqueous sulfuric acid of known specific gravity and thus of known RH. The apparatus (Fig. 1) consisted of an analytical balance with the right-hand pan suspended on a fine wire through a hole in the base so that it hung about 30 cm below the balance base inside a bell jar. The wire entered the bell jar through an oil drop in a capillary tube and was thus free to move while still sealed. Access to the jar's interior (i.e. the balance pan with the debris) was provided by an oil-sealed glass plate which closed off the bottom. With this apparatus, the weight of the plant material in a known atmosphere could be conveniently monitored indefinitely. After equilibration at a given RH, the material was dried by removing the glass plate and replacing the petri dish of aqueous sulfuric acid with pure sulfuric acid or anhydrous calcium sulfate. When constant weight was once more attained, these were in turn replaced by the next sulfuric acid dilution. The solutions could be changed very rapidly (approx. 10—12 seconds) and the error introduced from this source is very small.

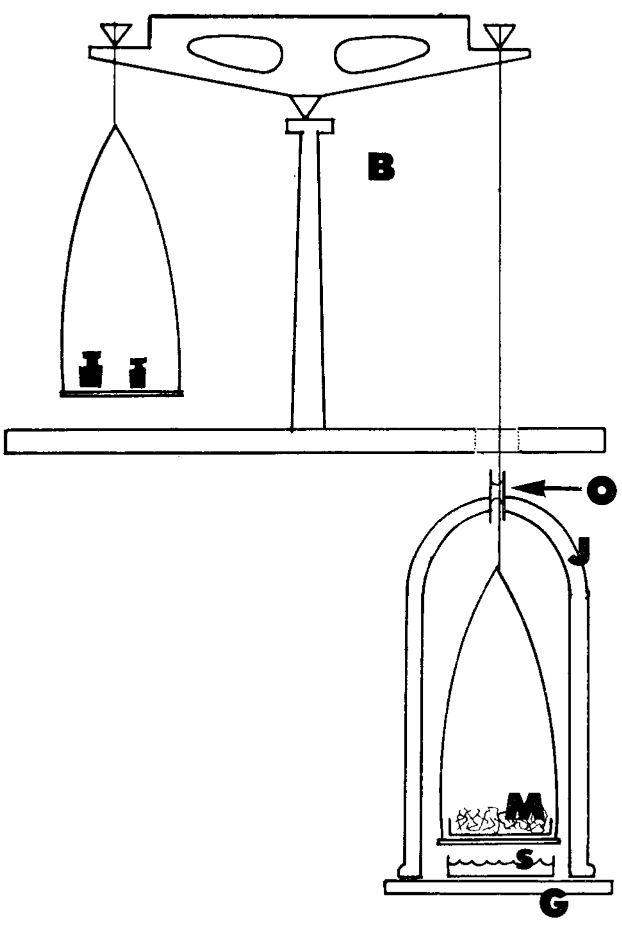


Figure 1. Schematic diagram of the apparatus for determination of the rate of water vapor sorption and the equilibrium moisture content of the plant debris. B = balance; O = oil seal in capillary tube; J = bell jar; M = plant material in petri dish; S = aqueous sulfuric acid in petri dish; G = glass plate sealing bottom of bell jar. The plant material (M) can be continuously weighed while in a sealed atmosphere.

It was important to know how rapidly the standard solutions equilibrated with the atmosphere in the bell jar. For this purpose, two tubes were run through the glass plate: one, carrying oil, fed into a petri dish containing drying agent, the other into (but not touching) an empty petri dish on the balance pan. Thus, when the atmosphere inside the bell jar was thoroughly dry, the drying agent was covered with paraffin oil and the petri dish on the balance received its load of aqueous sulfuric acid. The course of weight loss and the time until weight loss ceased were then determined.

## RESULTS AND DISCUSSION

The equilibrium moisture content (EMC) of the plant material is given in Figure 2 and Table 1. The EMC increases very sharply as 100% RH is approached. Table 1 presents the time required for equilibration of each standard solution with the empty bell jar (column IV) and with the bell jar and plant material (column III). Note that for each RH, the values in III are 11 to 20 times those in IV, indicating that III actually represents the equilibration time of the debris and not the limited evaporation rate of the solutions. These times were graphically determined and are only approximate values. Table 2 gives desorption data for material at EMC dried against calcium sulfate.

The interpretation of water sorption data in light of a possible physiological role is as much dependent upon the rate of sorption as upon the

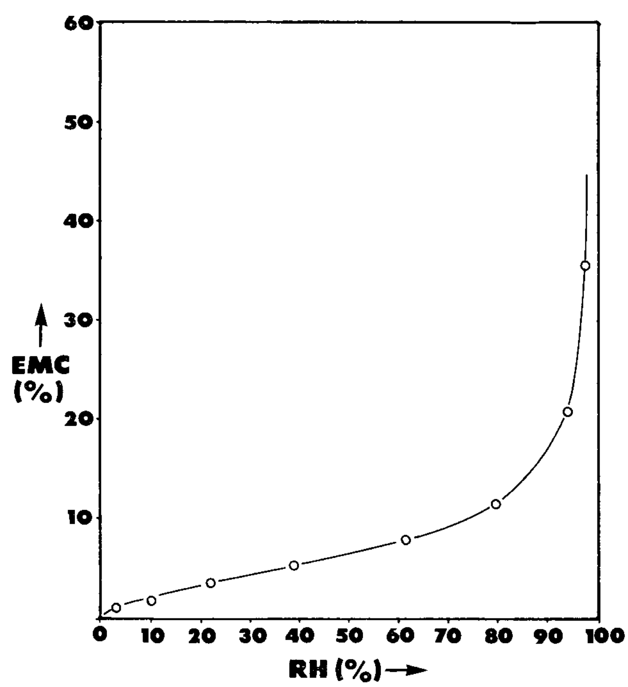


Figure 2. The equilibrium moisture content (EMC) of Namib Desert plant debris as a function of the relative humidity (RH) of the atmosphere.

Table 1. Water absorption by dead plant material: Rate and equilibrium data.

| RH | I | | II | III | IV | V |
|---|---|---|---|---|---|---|
| | Percent water | | EMC (%) | Time to attain EMC (hrs.) | Time to sol'n-atm. equil. (hrs.) | Ratio III/IV |
| | After 5 hrs. | After 10 hrs. | | | | |
| 3,2 | 0,86 | 1,00 | 1,00 | 6 | — | — |
| 10 | 1,60 | 1,89 | 1,89 | 8 | — | — |
| 22 | 3,24 | 3,45 | 3,63 | 11 | — | — |
| 39,4 | 4,97 | 5,19 | 5,21 | 12 | 0,6 | 20 |
| 60,8 | 7,32 | 7,73 | 7,95 | 15 | — | — |
| 79,7 | 9,84 | 10,1 | 11,5 | 22 | 1,5 | 15 |
| 94 | 13,0 | 15,5 | 20,7 | 45 | 2,5 | 18 |
| 97,7 | 14,7 | 18,7 | 35,5 | 160 | 15 | 11 |
| 100 | 15,6 | 19,6 | >67 | >500 | — | — |

EMC. Until EMC is reached, the water content of the material will depend upon the length of exposure. The actual duration of field exposure in the Namib Desert varies with distance from the sea. The frequency and duration of high RH as well as fog increases as the coast is approached. Distant (30 to 80 km) from the coast, high RH usually occurs during the night and may last 5 to 10 hours (Schulze, 1969), an interval too short for EMC to be approached at RH's above about 60%. Table 1 thus also lists the water content after 5 and 10 hours exposure to each RH. For example, under near-saturated conditions (97,7% RH), 10 hours exposure in still air will result in the absorption of about 19% water. At Gobabeb, 50 km inland, longer exposures are not common, but near the coast, the RH is usually at or near saturation for 15 to 18 hours per day or longer and the short periods of lower humidity would then not result in much drying. (See Table 2 for rate of desorption, but note that the RH is 0%, a condition rarely pertaining near the coast.) Under these conditions, it is likely that cellulosic material would be able to approach EMC, and thus contain between 50 and 100% water (depending upon temperature and the nature of the material). Under field conditions, the rate of absorption and desorption will be greatly affected by wind, air temperature and insolation. The data presented here can only give an idea of the order of magnitude of the effects. It should also be pointed out that material equilibrated to intermediate RH's (from 15 to 85%) from the EMC state, that is by desorption, reach on EMC between 2 and 4% higher than samples equilibrated by absorption. This hysteresis has been reported for other cellulosic materials (Wahba and Nashed, 1957).

Table 2. Water content of dead plant material after 5 and 10 hours of drying from the EMC state at RH of approximately 0% (calcium sulfate).

| RH (%) | Percent water | |
|---|---|---|
| | after 5 hrs. | after 10 hrs. |
| 60,8 | 2,8 | 1,5 |
| 79,7 | 3,2 | 1,8 |
| 94 | 5,6 | 2,8 |
| 97,7 | 16 | 5,0 |
| 100 (not at EMC) | 49 | 30 |

The present study suggests that under conditions of sufficiently high RH for sufficiently extended periods, absorbed water in dead plant material can make a substantial contribution to animal water balance. Whether this resource is actually available will require confirmation by determination of water content in field samples. Whether it is actually utilized by animals will require detection of coincidence of their feeding rhythms with periods of high moisture content. A fair proportion of the Namib's animals feed on dead vegetation, most notably many of the tenebrionid beetles. Some larger grazing mammals and birds may feed on it as well. Liquid water may not be readily available to many of these animals, and many of them are geared to efficient conservation of metabolic water. The degree to which water absorbed in the cellulosic diet actually contributes to the animal's water economy is unknown to date, as are the conditions under which such a contribution might be of importance.

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