The concentration of ammonia and nitrate in rain water over Israel in relation to environmental factors

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ABSTRACT

Ammonia in monthly composite rain water samples from seven stations in Israel shows marked dependence of concentration on soil temperature. The mean concentration during the cool winter months is 0.17 e.p.m. NH_4^+, while in spring it rises to at least four times higher. Release of pedogenic ammonia from calcareous soils, which becomes accelerated at the beginning of the warm spring, is considered to be the major source of the ammonia. Losses from fertilization with ammonium containing fertilizers may be a contributing factor.

Nitrate concentration is less variable and averages 0.04 e.p.m. NO_3^- during the winter months.

Total seasonal washout by rain ranged from about 4 to over 20 kg NH_4-N per hectare depending on precipitation or on the average 40 g NH_4-N per hectare for each mm rain.

Introduction

A network of rain water collecting stations has been operating in Israel since 1960/61 (YAALON & KATZ, 1961). Nitrogen compounds were not originally included in the sampling program, but in the course of our study it was found that anions always exceeded the sum of cations Na, K, Ca and Mg, sometimes by up to 20 %. It was thought that the missing cation could only be NH_4^+. During the rainy season 1962/63 ammonia and nitrate was therefore included in the determinations at seven representative stations, which confirmed the presence of ammonia in all samples, together with much smaller amounts of nitrates. The seven stations selected represent a rather dense network around the E 35° longitude and N 32° latitude, over a distance from North to South of less than 140 km, but covering a wide range of climatic conditions—from the subtropic Upper Jordan Valley situated below mean sea level, via the subhumid Mediterranean coastal plain, to the mild semiarid climate of the Northern Negev (Fig. 1).

The rainy season of 1962/63 started late and slowly. Only in December was the precipitation considerably in excess of normal. During the following months it was somewhat below normal, resulting in a total precipitation distribution which was close to normal in the North, but decreased progressively to 50 per cent below normal in the South, with severe drought in the Negev (Meteorological Service, 1962/63).

In the following the analytical data are reported and correlated with some environmental factors.

Methods

The precipitation was collected from standard rain gauges of the Meteorological Service and kept in polyethylene bottles. The samples contain also all dry fallout and dust settling on the rain gauges and occasionally become contaminated by bird droppings. In the laboratory they were filtered through Whatman 40 filter paper.

Ammonia was distilled off and measured by nesslerization of the distillate using a Spectronic 20 spectrophotometer at 410 mμ. Nitrate was determined in a similar way after its reduction by Devarda's alloy. Half of the ammonia analyses were performed in duplicate. Nitrate was not determined in all samples or was often below sensitivity of the method. During certain months the amount of precipitation collected did not suffice for all the analyses.

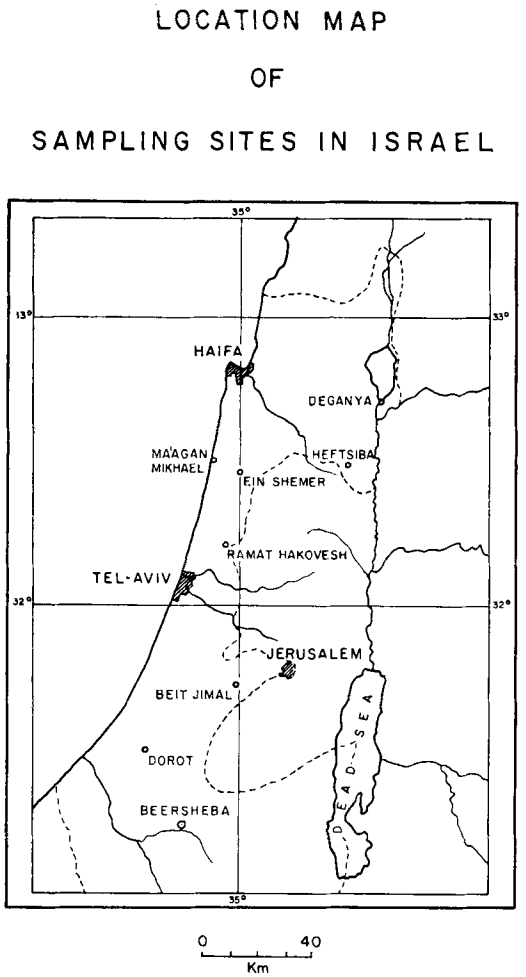

FIG. 1. Location map of sampling sites in Israel.

Results and discussion

SEASONAL VARIATION

In Table 1 the ammonia concentrations of the composite monthly samples are tabulated. The concentration varies from a minimum of 0.03 e.p.m. to 1.6 e.p.m. NH_4^+ (0.4 to 22 mg/l NH_4-N). During mid-winter the most common values range between 0.1 to 0.2 e.p.m. NH_4^+ but later in spring they practically all are in excess of 0.6 e.p.m. NH_4^+. The variation from month to month at any one station is larger than the variation between monthly values of all stations. The average monthly values and mean deviation are listed in the bottom line of the table. They have been plotted in Fig. 2 and suggest a strong dependence on temperature. There is no correlation with distance from the sea or other climatic factors as found for chlorine and like oceanogenic constituents. A terrestrial source must therefore be sought.

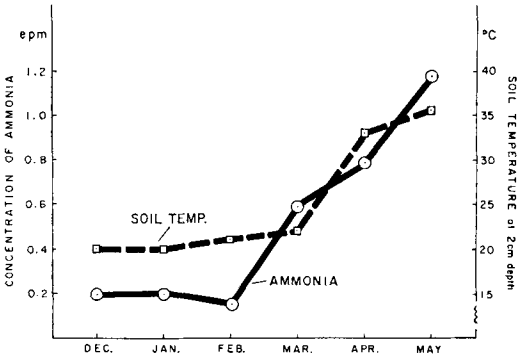

FIG. 2. Average monthly concentration of ammonia in precipitation in relation to mean soil temperature at 2 cm depth, 1962/63.

CORRELATION WITH SOIL BIOLOGICAL ACTIVITY

In Fig. 2 the ammonia concentration is compared with the mean monthly soil temperature as measured at a depth of 2 cm at 14 hours local time. Seven stations with a similar geographic regional distribution as the rain collecting stations were selected and the average calculated from the data of the Meteorological Service, Agro-Meteorological Bulletin (1962/63). The low figure for March is somewhat misleading as the average temperature for the second half of March exceeded by 7°C that of the first half. There was no such large temperature shift in any of the other months. Rain fell mainly in the middle of March. Air temperature shows a more gradual and somewhat later rise and hence is less strongly correlated with the ammonia values.

From the three possible sources of ammonia usually considered in similar investigations—fossil fuels (ERIKSSON, 1952), ocean (WILSON, 1959), and soils (VIRTANEN, 1952)—it appears that in the present case the amount of ammonia unloaded by precipitation over Israel is controlled by its rate of release from the soil by biological activity during decomposition of soil organic matter, as evidenced by the high concentration during the warm and still somewhat wet spring. There has been increasing evidence that semiarid soils display a marked microbiological activity during the drying season.

TABLE 1. *Ammonia and nitrate in precipitation over Israel, 1962/1963.*

Station	Precipitation mm	Ammonia Dec.	Jan.	Feb.	Mar.	Apr.	May	NH_4–N 1962/63 kg/ha	Nitrate Dec.	Jan.	Feb.
		e.p.m. NH_4^+							e.p.m. NO_3^-		
Deganya	358	0.28	—	0.42	0.54	0.61	0.93	18	0.086	—	0.041
Heftsibah	365	0.20	—	0.07	0.63	—	1.58	22	—	—	0.022
Maagan Mikhael	402	0.11	0.32	0.24	0.61	—	—	16	0.043	—	0.024
Ein Shemer	548	0.27	0.18	0.03	—	0.75	1.00	22	0.043	—	—
Ramat Hakovesh	438	0.16	0.09	0.13	—	—	—	12	0.049	0.043	—
Beit Jimal	203	0.12	—	0.10	—	—	—	7	0.048	—	0.022
Dorot	159	—	—	0.06	—	—	—	4	—	—	—
Average and mean derivation		0.19 ± 0.06	0.20 ± 0.08	0.15 ± 0.11	0.59 ± 0.07	0.68 ± 0.07	1.17 ± 0.28		Av. of all		0.042 ± 0.012
Precipitation monthly range		30 to 269	2 to 130	59 to 97	16 to 44	1 to 40	6 to 76				

Thus JONES (1957) observed a rapid loss of organic nitrogen from the Sudan Gezira soil during the hot dry season from February to May. Under Israel conditions the release is further enhanced by the slightly alkaline reaction of the largely calcareous soils (YAALON *et al.*, 1962). The ammonia in the air is no doubt also supplemented by losses from fertilization with ammonium containing fertilizers, but according to information obtained at the respective stations nitrogen fertilization is actually more common during the beginning of the rainy season. Some of the extreme high values might be due to the use of ammonium fertilizers in the neighbourhood of the gauges or possibly contamination from bird droppings.

Nitrate concentrations are less variable and often below the limit of detection (Table 1). The average of the ten determinations in which nitrates have been found is 0.042 e.p.m. NO_3^- or only $\frac{1}{4}$ of the amount of ammonia during the winter months.

CORRELATION WITH PRECIPITATION

The total amount of ammonia nitrogen brought down during the rainy season depends on the amount of precipitation (Fig. 3). The amount of NH_4–N per hectare has been calculated from the sum of the monthly values and by extrapolation of the missing values using the appropriate average concentrations for the month in question and checked by reference to the difference between sum of anions and all the other cations as mentioned previously. The trend obtained is sufficiently significant so that this correction by extrapolation, which affects only months with little rain, does not change the results by more than the total uncertainty inherent in the monthly values themselves.

The calculated regression coefficient of 0.04 is significant, with a correlation coefficient equal to 0.70. It follows that the mean annual deposition of ammonia is 40 g NH_4–N per hectare for each mm of precipitation. A similar calculation for data obtained by MENCHIKOVSKY (1925) at Tel-Aviv gives only 1.5 g N/ha per mm rain.

COMPARISON WITH PREVIOUS DATA

The present data are much higher than the only previously made analyses in Israel by MENCHIKOVSKY (1925) in Tel-Aviv for 1922/23 and 1923/24, yet he obtained a similar seasonal variation. It is tempting to suggest that the reason for the present values being at least one

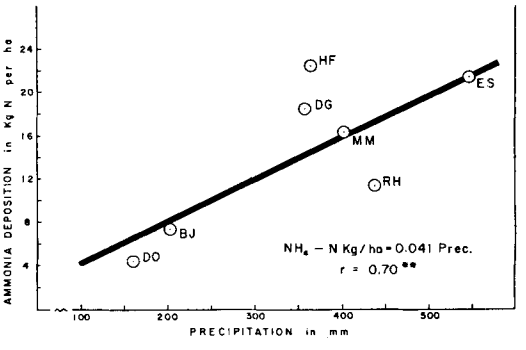

FIG. 3. Total ammonia nitrogen deposition for the rainy season in relation to total precipitation, 1962/63.

magnitude higher may be sought in the increased microbiological activity brought about by the spread of intensive agriculture and heavy fertilization during the last 40 years. Though the present figures are relatively high also in relation to other data (ERIKSSON, 1952) their magnitude is amply confirmed by checking against the other constituents in the samples.

If we consider that the observed higher content of ammonia in the air is due to the more rapid decomposition and release of organically bound pedogenic nitrogen, triggered by men's interference in the established balance, then the phenomenon also points to the obstacles encountered in the warm Mediterranean and semiarid climate when attempting to raise the organic matter content of the soil by heavy manuring. This is in good agreement with observations of JONES (1957) that the organic nitrogen content of the Sudan Gezira soil did not increase beyond an equilibrium value as determined by the environment.

COMPARISON WITH OTHER DATA

Though the first nitrogen analyses in rain water have been made over a hundred years ago and a great many of them have been published since (ERIKSSON, 1952), there are few determinations from the Mediterranean or semiarid environment suitable for comparison with the Israel data. Data from Europe and U.S.A. or humid tropical areas with acid soils indicate that nitrate is under these conditions often as common as ammonia. Only KUDRIN (1948) reports from the loessial serozem area of Central Asia that ammonia represents 90 % of all nitrogen brought down. He attributes this however to the continental position of Tashkent rather than to the effect of the calcareous soils. The low average content (0.6 mg N/l) seems to be in agreement with the low soil biological activity in this semiarid zone.

That soils may serve as the major source of ammonia has already been suggested by RUSSEL and RICHARDS (1919) on the basis of analyses from Rothamsted in England. A plausible correlation with the nature of soils was also obtained by JUNGE (1958) in the U.S.A. network, showing higher concentrations over regions with calcareous soils.

Seasonal variations in nitrogen concentrations have been reported in several studies. Though ERIKSSON (1952) in his analysis of the monthly variations of several stations statistically isolated the effect of temperature for Ottawa, Canada, he does not consider the soil to be the major source of ammonia. Two peak concentrations are often observed. Maximum concentration during winter are usually explained by the increased combustion of fuels, a factor which is of course insignificant in Israel. JUNGE (1963) reports that spring and summer rains contain more nitrogen than fall and winter rains. But a close correlation with soil temperature does not seem to have been reported before, though many of the previously published data could no doubt be interpreted in this way. The smaller variation in nitrate is in agreement with other data.

SOME REMARKS ON THE NITROGEN BALANCE

The ammonia content in the rain of Israel represents about 10 % and occasionally up to 20 % of the total cationic constituents in the precipitation. This quantity is in the same range as potassium, whose source is also largely terrestrial. It is much smaller than the accretion of Na, Ca or Mg (data to be published). While small, the quantity is not insignificant for agriculture. Based on the average precipitation for the whole country the total deposition is at least 20,000 tons of N annually, or about equal to the annual consumption of chemical fertilizers (22,000 tons N in 1962). It should however be remembered that the data indicate that the nitrogen brought down by the rain is not necessarily a net gain to the soil, but mainly represents a segment in the local geochemical cycle of nitrogen compounds. Preliminary calculations indicate that presently the nitrogen balance is positive, i.e. the amount of nitrogen removed by agricultural produce is smaller than the amount of fertilizer used. If this surplus nitrogen cannot be permanently fixed in the soil organic matter, the ammonia and nitrate content in the air and rain is likely to remain high or even increase, which in turn must be beneficial to surrounding unfertilized areas such as forests and pasture land.

Acknowledgement

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