SPORE CONTENT OF AIR OVER THE MEDITERRANEAN SEA*

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INTRODUCTION

PRESENCE of characteristic spore and pollen population in the air over inland agricultural and industrial areas has long been recognised. The recent work of Pady and Kelly (1953) and Pady and Kapika (1955) using aeroplanes proved the existence of fungus spores in the upper layers of air over the Arctic and the Atlantic Oceans. Miquel (1876) was the first to investigate whether or not micro-organisms are found in the lower layers of the sea air. Using an aspirator worked by suction off condensor of the engine of the ship, he took samples at a level of 10 metres above the floating line of the ship, during a voyage to Canaries from Paris. He found that sea rapidly purified contaminated air and wind at a distance beyond 100 Km. from the shore was almost perfectly pure. These results led him to the conclusion that large bodies of water become an absolute obstacle to the spread of infectious diseases through air. The quantitative data collected by Hesselman (1919) indicate how with the increase in distance from the land, decrease in the number of pollen grains of certain pines is brought about. Erdtman (1937) trapped pollen grains by means of vacuum cleaners during a voyage from Gothenburg to New York. His results showed that pollen grains per 100 cubic metres of air declined from 18·0 in North Sea to 0·7 in mid-ocean and rose to 6·0 off New Foundland, fell to 3·5 south of Nova Scotia and finally rose to 15·0 off the coast of New England, while his records for experiments conducted on the top of a water tower in Vasteras about 110 Km. west of Stockholm showed an average of 18,000 pollen grains per 100 $m.^3$ of air. The results obtained by Bisby (1935) using Petri-dishes as spore traps in a voyage from Montreal to London, convinced him that micro-organisms are so scarce over the oceans as to necessitate special arrangements for long exposure of plates and slides. The introduction of volumetric suction air sampling methods (Hirst, 1952; Gregory, 1954) have now made it possible to get a quantitatively and qualitatively complete picture of the spore content of air at any locality and it is considered worthwhile to sample air over oceans employing a volumetric suction trap to gather more information on the spore content of the sea air.

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Methods

With the kind permission of the Penninsular and Oriental Steam Navigation Company, Ltd., London, and the co-operation of the Commander and the officers of the ship, arrangements were made on the Passenger ship S. S. STRATHMORE for running a spore trap during a voyage from London to Bombay scheduled to go through the Suez Canal during October-November 1956. Due to the 'Suez crisis' the route of the ship was changed when she was in the Mediterranean Sea. From there she was diverted to Malta and after a stay of nearly two days in the Malta Harbour, she was taken back to Gibralter and reached Bombay *via* Cape of Good Hope. During this journey air was sampled from Gibralter to Malta, Malta to Gibralter and Gibralter to Las Palmas. On the 'bridge' of the ship at a height of 70 ft. above the sea-level, air was sampled at a rate of 10 litres per minute using the 'Impactor unit' of Gregory's (1954) Portable Volumetric Spore Trap. The 'Impactor unit' was connected to the suction port of an 'Edwards R. B. 4 pump and compressor' run with a D.C. motor. The flow rate was regulated by the use of an 'Orifice-plate' with a narrow bore, the size of which was adjusted to allow a flow rate of 10 1./min. which was placed in the rubber tubing connecting the 'Compressor' and the 'Impactor unit'. The slides which were prepared according to the method described by Gregory (1954) were changed often and were mounted in 'Solvar'. Due to the presence of less number of spores on the trace, the entire trace was examined under the oil immersion objective to count the number of each 'Spore type' caught on the slide. The number counted was then converted into an estimated number of spores per cubic metre of air. Identification of spores was based on the spore morphology alone and the categories of the 'spore types' chosen are 'form groups' devised (as was done by Hirst, 1953; Gregory and Hirst, 1957; Gregory and Sreeramulu, 1958 and Sreeramulu, 1956) after comparison with many reference slides of carefully identified spores. Those not included in any named group were counted under one group: 'Unclassified'.

Results

The slides were changed often to see whether there is any relation between the time of the day and the number and the types of spore population present in the air. In Table I the serial numbers of the slides along with the dates and the times at which they were changed are given in columns 1, 2 and 3. In the other columns data showing the position of the ship at the beginning and the end of exposure of each slide, the distance travelled during the time of exposure, distance to the nearest land, wind direction and speed, and the wet and dry bulb readings taken from the ship's records are presented. In Table II the estimated number per cubic metre of air for the spore types included in this study are given along with the volume of air sampled with each slide. To get a comparative idea about the changes, the time of the day, distance to the nearest land and wind direction are also included in the table.

TABLE I

Data giving the position of the ship, time of air sampling, wind and other factors prevailing during the period of exposure of each slide in the trap

Slide No.	Date	Time of exposure		Position of the ship		Distance travelled (miles)	Distance from the nearest land (miles)	Wind		Onshore or Offshore	Dry bulb	Wet bulb	Remarks
		Time on	Time off	At on	At off			Velocity (knots)	Direction				
1	October 29	4-30 P.M.	5-30 P.M.	36 08 N 04 48 W	36 10 N 04 25 E	..	20—21	18	..	Offshore	63	56	
2	30	10-40 A.M.	12-40 P.M.	36 45 N 02 00 E	36 47 N 02 24 E	..	10	7	..	Parallel to shore	68	59	
3	30	12-40 P.M.	3-05 P.M.	36 50 N 02 45 E	36 30 N 03 45 E	42	7—4	9	NW	Onshore	67	60	
4	30—31	9-05 P.M.	6-45 A.M.	37 11 N 05 57 E	37 30 N 09 45 E	190	12—25	5	W	Parallel to shore	64	59	
5	31	7-35 A.M.	12-00 Noon	37 19 N 10 39 E	36 50 N 12 00 E	87	4—16	13	S	Offshore	67	60	
6	31	12-05 P.M.	6-30 P.M.	36 50 N 12 00 E	36 10 N 14 00 E	115	4—8	11	SE	Offshore	72	60	
7	31	6-45 P.M.	? (Before 8 P.M.)	36 50 N 12 05 E	..	30	5	2	Var.	Variable	71	76	
											at Noon		
8	November 1	8-30 A.M.	4-35 P.M.	..	..	..	..	2	Var.	Variable	81	75	Ship moored in the Malta Harbour
9	1	4-40 P.M.	5-50 P.M.	..	..	..	..	5	SW	..	75	72	,,
10	1—2	8-55 P.M.	7-45 A.M.	..	..	..	..	13	S	..	72	66	,,

11	2	7-50 A.M.	10-30 A.M.	36 00 N 14 40 E	36 00 N 14 15 E	48	1—20	13	S	Offshore	68	62	Leaving Malta Harbour
12	2	10-30 A.M.	2-35 P.M.	36 00 N 14 15 E	36 50 N 12 20 E	76	15	13	NWN	Offshore	66	62	
13	2	2-35 P.M.	4-35 P.M.	36 50 N 12 20 E	36 55 N 11 30 E	38	20	13	WNW	Offshore	65	62	
14	2	4-35 P.M.	10-55 P.M.	36 55 N 11 30 E	37 22 N 09 22 E	120	5	30	WNW	Offshore	64	58	
15	2—3	11-00 P.M.	8-20 A.M.	36 50 N 01 00 E	37 13 N 05 58 E	171	5—30	30	W	Parallel to shore	60	56	
16	3	8-25 A.M.	11-00 A.M.	37 13 N 05 58 E	37 10 N 04 30 E	45	20—10	21	W	..	59	57	Rain
17	3	3-00 P.M.	11-00 P.M.	36 55 N 03 04 E	36 40 N 00 20 E	152	8—5	18	W	Parallel to shore	62	56	Rain
18	3—4	11-00 P.M.	11-00 A.M.	36 40 N 00 20 E	36 16 N 04 50 W	238	20—50	7	W	..	64	58	
19	4	11-05 A.M.	9-00 P.M.	36 16 N 04 50 W	35 43 N 06 07 W	65	5—0·5	5	W	Offshore	62	57	Reached Gibralter and inside the harbour
20	4—5	9-05 P.M.	9-45 A.M.	35 43 N 06 07 W	32 59 N 09 34 W	228	10—30	4	NE	Offshore	64	58	Left Gibralter Harbour
21	5	9-50 A.M.	9-15 P.M.	32 59 N 09 34 W	30 13 N 13 10 W	230	50	3	NE	Offshore	69	63	
22	5—6	9-20 P.M.	? (About 5-30 A.M.)	30 13 N 13 10 W	31 50 N 16 00 W	171	30—1	4	NE	Offshore	67	62	Reached Las Palmas Harbour
23	6	7-30 A.M.	..	..	..	..	..	4	NE	Onshore	69	64	Inside Las Palmas Harbour

TABLE

Estimated number per cubic metre of air of the

Slide No.	Date	Time of exposure		Volume of air sampled (cubic meters)	Distance to the nearest land (miles)	Wind direction (onshore or offshore)
		Time on	Time off			
	October					
*1	29	4-30 P.M.	5-30 P.M.	0·60	20—21	Off.
2	30	10-40 A.M.	12-40 P.M.	1·20	10	Parallel
3	30	12-40 P.M.	3-05 P.M.	1·45	7—4	On.
4	30—31	9-05 P.M.	6-45 A.M.	5·80	12—25	Parallel
5	31	7-35 A.M.	12-00 Noon	2·65	4—16	Off.
6	31	12-05 P.M.	6-30 P.M.	3·85	4—8	Off.
7	31	6-45 P.M.	? (About 7-45 P.M.)	? 0·60	5	Var.
8	November 1	8-30 A.M.	4-35 P.M.	4·85	Inside Malta Harbour	Var.
9	1	4-40 P.M.	5-50 P.M.	0·70	do.	..
10	1—2	8-55 P.M.	7-45 A.M.	6·50	do.	..
11	2	7-50 A.M.	10-30 A.M.	1·60	Leaving Malta Harbour	Off.
12	2	10-30 A.M.	2-35 P.M.	2·45	15	Off.
13	2	2-35 P.M.	4-35 P.M.	1·20	20	Off.
14	2	4-35 P.M.	10-55 P.M.	3·80	5	Off.
15	2—3	11-00 P.M.	8-20 A.M.	5·60	5—30	Parallel
16	3	8-25 A.M.	11-00 A.M.	1·55	20—10	..
*17	3	3-00 P.M.	11-00 P.M.	4·80	8—5	Parallel
*18	3—4	11-00 P.M.	11-00 A.M.	7·20	20—50	..
19	4	11-05 A.M.	9-00 P.M.	5·95	5—0·5	Off.
20	4—5	9-05 P.M.	9-45 A.M.	7·60	10—30	Off.
21	5	9-50 A.M.	9-15 P.M.	6·85	50	Off.
22	5—6	9-20 P.M.	? (About 5-30 A.M.)	? 4·90	30—1	Off.
*23	6	7-30 A.M.	..	..	Inside Las Palmas Harbour	..

* Counts not taken as the trace on the slide is damaged during the transit.

II

various spore types together with some relevant data

Estimated number per cubic metre of air of the various spore types																	Totals		
Cladosporium	Smuts	Red-brown basidiospores	Yellow basidiospores	*Alternaria*	*Stemphylium*	*Epicoccum*	*Periconia*	*Helminthosporium*	Coloured bicelled spores	'*Fumago*' type	Septate fusiform spores	*Torula herbarum*	*Nigrospora*	Uredospores	*Curvularia*	Unclassified	Fungus spores	Pollens	Hyphal fragments
34·2	5·9	12·5	0·8	4·2	..	..	0·8	..	7·5	..	5·0	2·5	0·8	0·8	..	18·4	95·0	3·3	3·3
1·6	25·2	4·2	1·4	6·3	1·4	0·7	0·7	..	2·1	7·0	0·7	..	..	..	..	18·0	83·5	0·7	7·6
12·9	6·7	5·4	1·6	0·7	0·3	0·2	..	0·3	2·1	1·2	0·5	0·2	0·7	..	..	3·1	35·5	0·2	0·9
12·1	4·2	15·0	2·3	6·4	1·5	0·8	..	..	6·4	..	..	1·9	..	..	..	23·8	74·5	2·6	3·4
10·4	2·6	6·3	1·1	5·7	0·8	..	..	..	5·2	0·5	..	..	0·3	0·3	..	10·0	44·0	0·3	4·4
15·1	1·7	10·0	1·7	1·7	1·7	..	..	1·7	8·4	..	..	..	..	..	..	10·0	53·5	1·7	..
2·1	17·7	12·2	2·1	9·3	8·2	..	1·7	2·1	..	2·3	..	0·1	..	..	0·8	15·7	91·0	16·6	?
28·6	18·5	50·0	12·9	7·1	8·5	1·4	..	..	..	..	5·7	..	..	..	1·4	7·4	222·0	7·1	?
3·7	2·3	14·8	1·2	7·7	2·3	..	..	0·8	6·2	3·1	0·6	0·5	0·6	..	0·5	10·0	62·0	6·5	?
25·3	3·8	9·4	1·3	12·5	2·5	..	..	5·0	..	1·3	1·3	1·3	..	..	..	27·2	109·0	16·9	?
21·6	3·7	4·5	2·9	0·4	..	0·4	..	0·4	..	..	0·8	0·8	..	..	0·4	4·9	43·5	2·9	2·9
19·2	4·2	1·7	3·3	0·8	0·8	0·8	..	..	0·8	..	0·8	..	1·7	..	..	6·7	40·7	1·7	2·5
17·1	..	2·4	1·9	0·8	..	..	1·5	..	..	..	..	0·5	..	..		15·3	41·0	0·3	1·6
3·6	0·4	0·7	0·4	0·2	..	..	..	..	..	0·4	..	..	0·2	..	..	3·6	9·3	0·5	0·7
11·0	..	1·9	1·9	..	..	..	..	..	..	..	..	..	..	..	..	12·9	27·4	..	2·5
35·4	1·6	5·9	1·4	4·6	1·5	0·8	2·4	0·8	0·7	1·5	0·8	0·7	1·7	..	..	21·7	106·0	4·1	10·2
45·0	12·2	4·8	1·7	6·9	0·5	1·1	0·8	0·4	4·4	0·5	0·5	0·7	6·9	0·8	0·1	28·3	138·0	1·6	8·0
4·3	1·3	1·3	0·3	0·4	0·3	..	..	..	0·3	0·5	..	..	..	..	..	5·4	14·3	2·5	0·3
3·5	11·6	0·8	2·0	0·2	0·6	..	0·6	..	1·2	0·2	0·6	..	..	..	..	3·7	29·0	0·4	2·7

Discussion

The results presented in Table II confirm the presence of a variety of fungus spores and pollen grains in the lower layers of the sea air upto a distance of about 50 miles away from the coastline, the quantities of each spore type varying with the distance to the nearest land. When the ship was moored inside the harbours of Malta and Gibralter concentrations of about 200/m.³ were observed, but when she was travelling at about a distance of 50 miles from the shore concentrations of about 14/m.³ were noticed. As was recorded by Rittenberg (1939) for air over a portion of the Pacific Ocean, here also a gradual decrease in the concentration of the various spore types was noticed with increase in distance from the nearest land.

Of the many types of spores and pollen grains caught from the sea air, spores of the *Cladosporium* type and the coloured basidiospores occurred in comparatively higher numbers than those of many crop pathogens. (Highest concentrations recorded during the entire period: Coloured basidiospores—62/m.³; *Cladosporium* type—45/m.³; *Ustilago* type—25/m.³; *Alternaria* type—12/m.³ and *Helminthosporium* type—5/m.³) Pollens were present throughout the whole period in very low concentrations with an average value of about 4/m.³ while the corresponding value for the total number of fungus spores was about 70/m.³

The use of the Automatic Volumetric Spore Trap (Hirst, 1952) has revealed (Hirst, 1953; Gregory and Sreeramulu, 1958) the existence of different characteristic spore loads during day and night times in inland temperate areas. To find out whether the spore types occurring in the sea air also exhibit any such periodicity, slides were changed often. Spore types which are known to exhibit their peak concentrations during the daytime on land (*Cladosporium* type, *Alternaria* type, etc.) were observed to occur in higher concentrations during daytimes than during night times in the sea air, but basidiospores and the like which are known to occur in higher concentrations during the night times on land, were not found in significantly higher numbers during night times in the sea air. As atmospheric turbulence is a major factor responsible for the dispersal of spores in the air, probably the absence of higher concentrations of the spore types which are known to possess distinct nocturnal spore discharging habit, might be due to the low state of turbulence in the air at the time of their discharge on land. After dawn on land atmospheric turbulence begins to increase and reaches a maximum by about noon when buoyancy effects also are known to predominate. Under these conditions rapid spread of the spores in the air takes place. This explains why *Cladosporium* type and the like occurred in sea air in higher concentrations during daytime while basidiospores which are usually found in higher numbers during the night time on land when turbulence is very low, did not show considerable increase in their numbers during night time.

Comparison of the spore content of the sea and land air shows that plant spores occur in very low concentrations in sea air and that almost all the spores caught from the atmosphere above the sea are of terrestrial origin. The observed gradual decrease in concentration of these spores with increase in distance from the shore indicates that oceans of large size like the Pacific, the Atlantic and the Indian Oceans probably serve as effective barriers for the long distance dissemination of air-borne spores.

SUMMARY

Pollen and fungus spore content of the air 70 ft. above the sea-level, over a part of the Mediterranean Sea was studied employing a suction trap during a voyage in October-November 1956. A variety of fungus spores and pollen grains of terrestrial origin showing a gradual decrease in their concentrations with increase in distance upto 50 miles from the shore were found. The changes in concentrations of 18 spore types were recorded. The significance of the data was discussed.

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* Originals not seen.