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BACTERIOLOGICAL INVESTIGATIONS IN THE NORTHERN GULF OF OMAN*

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ABSTRACT

During the cruise of *R. V.* '*METEOR*' in the northern Gulf of Oman from 25 to 30 March and from 14 to 16 April 1965, plate counts on ZoBell's Medium 2216 E were received from 95 water samples of 15 stations to study the distribution of saprophytic bacteria in this part of the Arabian Sea and their correlation with salinity, temperature, turbidity and oxygen concentration.

The highest bacterial numbers were usually found just above the thermocline in 20-30 m depth. The counts were significantly greater along the Arabian coast than on the Iranian side of the gulf. In the samples of the Persian Gulf higher bacterial numbers were present than in the surrounding Indian Ocean water of lower salinity. This may be explained by higher nutrient concentrations of the water coming from the Persian Gulf.

Five to 20 per cent of the bacteria growing on ZoBell's Medium 2216 E were luminescent forms. However, only less than 5% produced pigments. Most of the isolated strains are motile gram negative rods, and strongly proteolytic.

INTRODUCTION

DURING the cruise of *R. V.* '*METEOR*' in the northern Gulf of Oman in 1965 (part of the I.I.O.E.), bacteriological investigations were performed from March 25th through 30th and from April 14th through 16th. Ninety-five water samples were taken from 15 stations in the area south of the Straits of Hormus to about 25° northern latitude (Fig. 1a). The water depth in this area ranges from 60 to 700 metres. For practical reasons, only a restricted number of samples could be investigated bacteriologically. Mainly stations with depths between 100 m and 400 m were chosen, for they offered the best chance to study the influence of outstreaming currents from the Persian Gulf on the bacterial distribution in the Gulf of Oman.

So far no bacteriological data have been reported from this part of the sea. Therefore, so-called total counts were taken by the plate-method in order to get a survey of the bacterial distribution and the correlation with a variety of chemical and oceanographical data. The present study reports the results. Furthermore different saprophytic bacteria were isolated from the plates and maintained.

METHODS

The water samples were taken aseptically with samplers after ZoBell (ZoBell 1946). To a depth of 200 metres autoclaved beerbottles of 300 ml volume could be used, below this sterilized rubber balls. The samplers were included in the oceano-

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graphical series, each of the bacteriological samplers being placed 2 metres under a Meteor-sampler. Thus time could be saved. Moreover, the comparison with chemical data from an oceanographical sample taken 2 metres above seemed to be preferable to data from a separate series, as it is difficult for the ship to hold the exact position for a longer time. In order to cover every individual water body of a vertical profile (especially the outstreaming currents from the Persian Gulf), the bacteriological samplers were distributed according to the results of continuous recordings of temperature and transparency (Ziegenbein, 1966). The water samples were handled within 30 minutes. The bacterial counts were performed on ZoBell's sea water agar formula 2216 E :

5 g peptone (Difco)

1 g yeast extract (Difco)

0.01 g ferric phosphate

15 g agar (Difco)

750 ml aged sea water

250 ml dist. water

pH 7.6-7.8

This medium supports growth of a representative number of saprophytic bacteria, which will be termed total count.

One ml of the sea water sample or of the 1:10 dilution respectively (in autoclaved water mixture of 3 parts sea water and 1 part dist. water) were plated with 10 ml agar of 40-42°C. An incubator installed in the refrigerator provided an incubating temperature of 18°C with an extreme variation of 2 degrees to either side due to the movement of the ship. Colonies were counted after a fortnight with a counting device. The slight temperature fluctuations largely equalized during the relatively long incubation time and could be neglected. When counting, the occurrence of luminous bacteria and coloured colonies were noted separately. Each water sample was plated four times in parallel, twice without dilution and twice diluted 1 : 10.

Results

The number of bacteria growing on the yeast-extract-peptone medium of ZoBell (formula 2216 E) ranged from 8 to 470 per millilitre. With most stations the highest counts were obtained in the range of the thermocline, located at 20-30 m depth, and in the overlaying water. The counts were lowest below 200 m. As for the local distribution, the bacterial amount in the south-west part of the Gulf of Oman, that is along the Arabian seaboard, exceeded that of the north-east part along the Iranian coast. Figs. 1b to 2b show the bacterial distribution at 22 m, 62 m, 102 m and 192-202 m depth, respectively. Above the thermocline at a depth of 22 m (Fig. 1b) an increase in bacterial numbers from north-east to south-west can be observed. Thus the counts of the three stations next to the Iranian coast ranged from 72 to 94 and those of the three corresponding stations near the Arabian coast from 113 to 298. As can be seen from Fig. 1c, below the thermocline, in the 60 m range, the bacterial counts of both areas mentioned exceed those of the central part of the Gulf. The same is true for the 100 m (Fig. 2a) and the 200 m level (Fig. 2b). Again in these depths, the increase towards the Arabian board surmounts that towards the Iranian board.

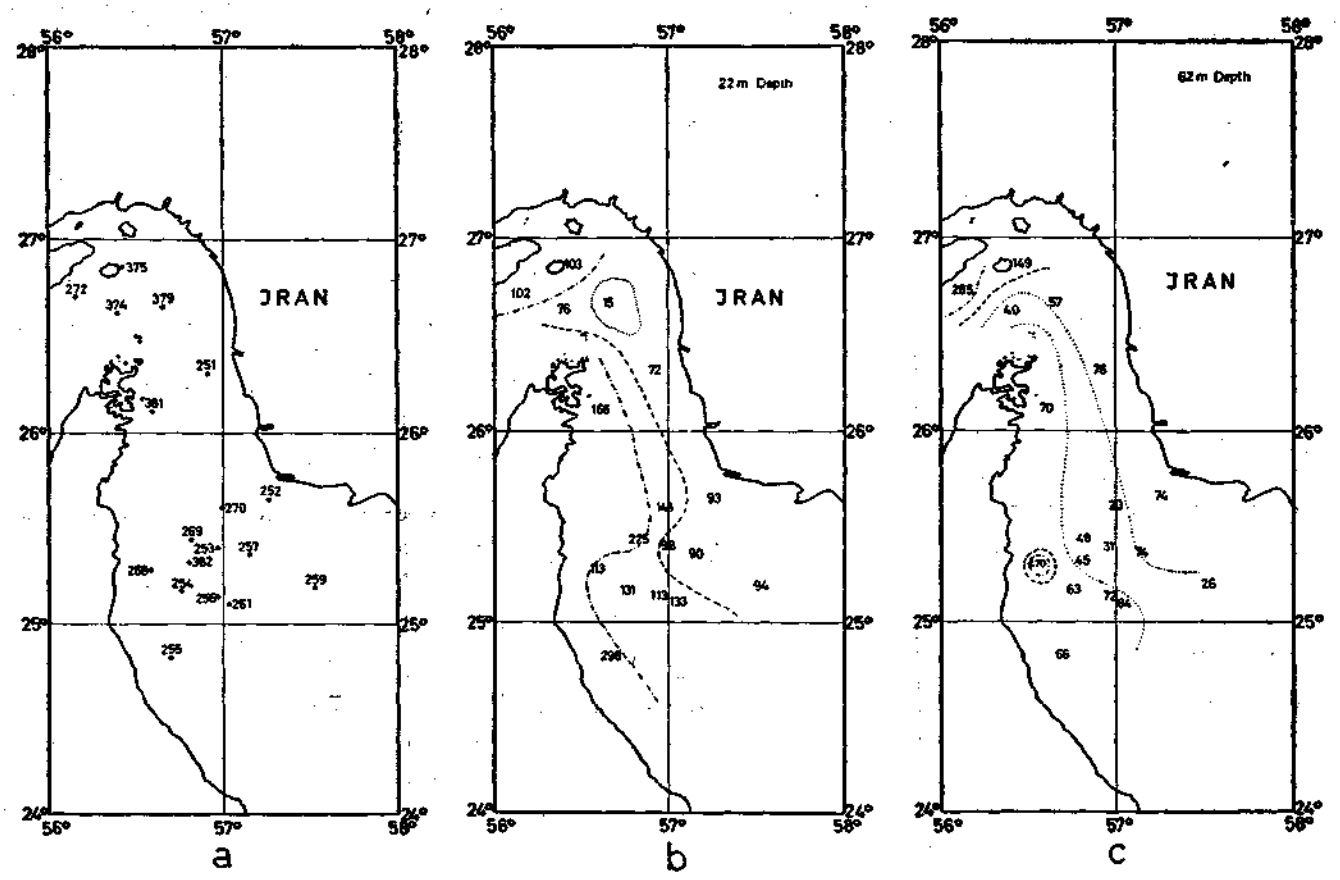

Fig. 1 a. Position of the stations in the Gulf of Oman in the Straits of Hormus, where bacteriological investigations were performed; b. Bacterial distribution in the waters of the northern Gulf of Oman at a depth of 22 m; and c. same at a depth of 62 m.

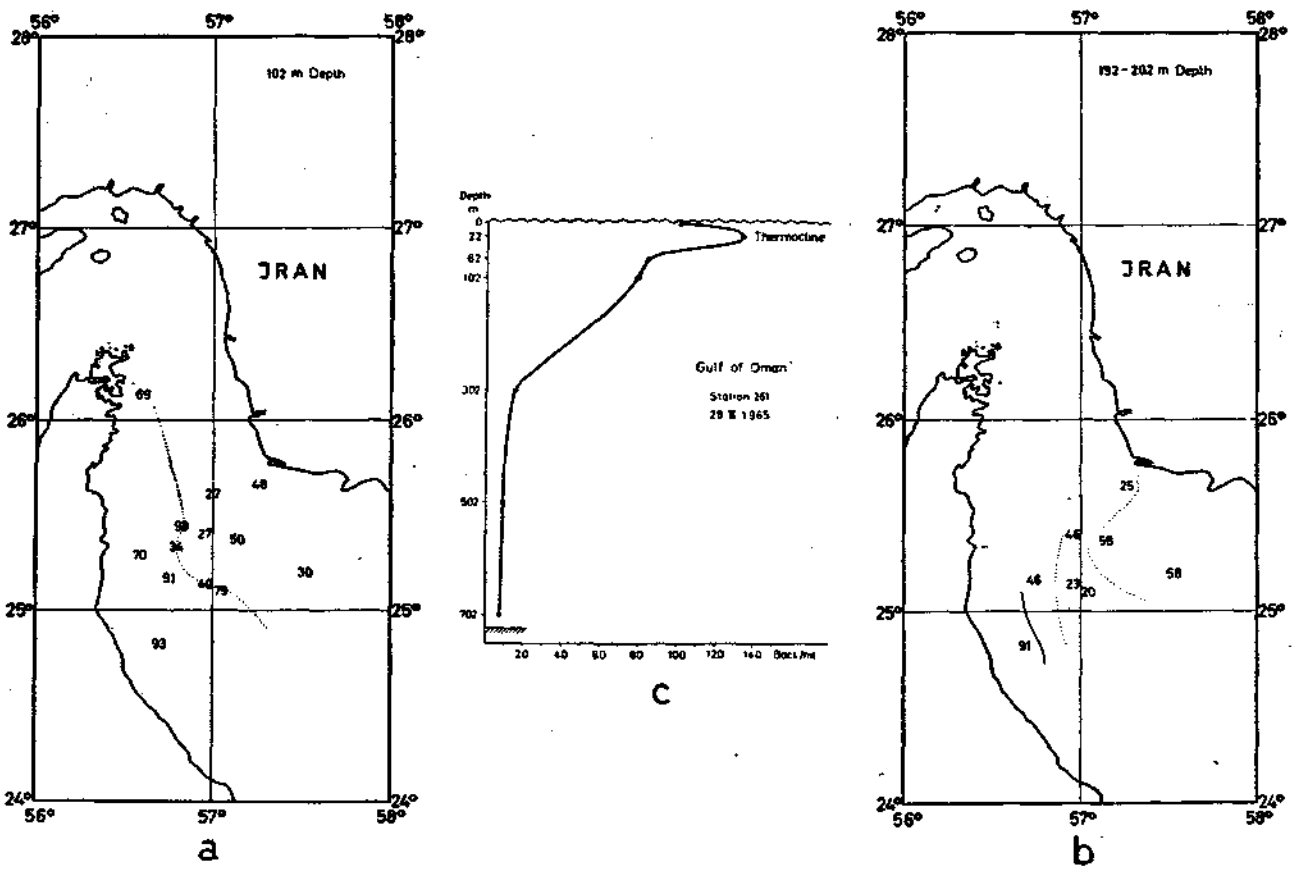

Fig. 2 a. Bacterial distribution in the water of the northern Gulf of Oman at a depth of 102 m ; b. same at a depth of 192-202 m ; and c. Vertical distribution of bacteria at station 261 in the centre of the northern Gulf of Oman on 28 March, 1965.

The bacterial counts show a striking correlation with the salinity of the water. The top layer consists of Indian Ocean water with a salinity range of 36·4-36·6‰ (which is quite similar to that of the northern Arabian sea). Below this a current from the Persian Gulf, consisting of water of higher salinity, moves from the Straits of Hormus south-east (Brettschneider *et al.*, 1970). At station 381 this current is located below 50 m, at stations 268 and 269 between 100 and 120 m, at stations 253 and 284 between 180 and 200 m, at 256 from 250 to 400 m and at station 261 between 290 and 330 m depth. Here the salinity ranges from 39·8 to 37·1‰. Regarding the bacterial counts of this water body, the values decrease from the Straits of Hormus south-east. The following table illustrates salinities and bacterial counts as well as the corresponding water temperatures and oxygen saturations of the stations mentioned :

position (station)	381	269	268	253	254	256	261
depth m	77	102	122	192	192	402	302
bacteria/ml	67	93	99	46	46	43	15
salinity ‰	39·7	39·1	38·4	37·8	37·1	37·5	37·5
temperature °C		21·2	21·5	20·8	19·8	18·9	20·5
% oxygen saturation	76	70	73	61	57	43	50

In the time scale the salinity of this water body as well as the bacterial counts decreased with increasing distance from the Straits of Hormus. It can be concluded, that the bacterial amount approaches that of the Arabian Sea due to the continued mixing of Gulf and Indian Ocean water. Below 200 metres the bacterial amount has apparently adjusted to that of the Arabian Sea (Fig. 2b). At a depth of 100 m, however, marked differences in bacterial numbers can be observed. For instance, at station 269 in the middle of the northern Gulf of Oman the bacterial count of 93 per millilitre at a salinity of 39·1‰ exceeds that of the neighbouring stations 253, 270 and 382, where at the same depth Indian Ocean water with a salinity of 36·4‰ was found (Fig. 2a). The coastal area makes an exception. Along the Arabian coast increased bacterial counts were determined even at salinities similar to Indian Ocean water. This increase of bacterial counts near the coast is quite common (Gunkel, 1965 ; Rheinheimer and Gunkel, in preparation), so that these values are not comparable with those from the central part of the area.

Like salinity, the oxygen saturation of the outstreaming Gulf water exceeds that of Indian Ocean water of the same depth (Grasshoff, p.c.), and decreases at increasing distances from the Straits of Hormus. The raised bacterial content of the Gulf water will contribute to the decrease of oxygen saturation, but the primary cause for this will be the mixing with Indian Ocean water of low oxygen content. There does not seem to exist a direct influence of the degree of oxygen saturation on the bacterial amount. The higher counts of the outstreaming Gulf water are due solely to the increased content of organic material.

Following the depth, the temperature of the water streaming from the Persian Gulf to the Gulf of Oman drops. In the area of investigation the slight decrease in temperature of this water body is of no influence on the distribution of bacteria and the composition of their populations.

The vertical bacterial distribution of the Gulf of Oman is by and large characterised by the profile of station 261 (Fig. 2c), which clearly shows the fall in bacterial numbers below the thermocline. At a depth of 300 metres a rise of salinity to

37·5‰ marks the outstreaming water of the Persian Gulf. The corresponding bacterial content, however, has already adjusted to that of the surrounding Indian Ocean water. There is often a rise in bacterial numbers to be observed right above the bottom (*e.g.*, stations 253, 286, 257, 259, 268 and 269). At station 268, the bacterial count makes up 470 cfu/ml at a depth of 62 metres. This was the highest value found in all samples from this part of the sea. The high microbial content of an individual sample might be due to a dead organism in the sample, but in this case the rise in bacterial number coincides with an increase in turbidity, through a minor one, and a thermocline (Ziegenbein, personal communication). In the Straits of Hormus three vertical profiles with samples from 4, 20, 40 and 60 m depths were taken on 25 March at anchor station 251. At 8.30 a.m. there was a strong outstream of Persian Gulf water. The bacterial counts showed slight variations between 60 and 85 cfu/ml. At 2.45 p.m. the outstream was reduced, and the bacterial counts showed a stronger variation, ranging from 46 to 100 cfu/ml. At 8.15 p.m. however, at nearly stagnant water, there were hardly any differences in bacterial counts to be observed, the values ranging from 73 to 84 cfu/ml. The average counts of the individual series (for all depths regarded), showed little variation with the time, the values being 69, 75 and 76, respectively. As all samples had salinities between 36·5 and 36·6‰, it can be concluded, that station 251 was surrounded by well mixed Indian Ocean water streaming back, with a bacterial content corresponding to the average of the upper layers in the eastern Gulf of Oman. On April 15th and 16th on anchor station 382 was occupied in the northern part of the Gulf of Oman. Here also the values of two series of samples, taken at an interval of 21 hours, differed only slightly. Apparently the bacterial content in the area of investigations does not show short-term fluctuations, anyhow not in springtime.

The high amount of luminous bacteria was striking. They occurred in nearly all samples between the surface and 600 metres depth. Their percentage of the total count on ZoBell's agar (2216 E) ranged from 5 to 20, with an average of at least 10 per cent. The colonies emitted an intense greenish or bluish-green light. Eight strains have been isolated, falling into two groups. Both are halophile and do not develop in fresh water media. The members of group I (6 strains) are gramnegative rods, often slightly curved, and violently motile by one polar flagellum. Young cells, grown on ZoBell's medium, measure 0·6 to 1·3 μ in width and 1·2 to 3·2 μ in length. Growth and luminescence are most intense at salinities between 30 and 50‰. The members of group II (2 strains) grow in gramnegative short rods. They grow best at 20‰ salinity. The following table illustrates the main differences between both groups:

	Optimal salinity	Optimal temperature	Minimal temperature	Indole	Nitrate reduction
group I	40‰	15°C	5°C	–	+
group II	20‰	30°C	10°C	+	–

After the seventh edition of Bergey's Manual (Breed *et al.*, 1957) both groups belong to the genus *Photobacterium*, while Spencer (1956) includes group I within Vibrio and group II within Aeromonas. Group I might comprise free-living luminous bacteria, group II possibly symbiontic inhabitants of the luminescent apparatus of marine animals. The differing salinity and temperature dependences support this assumption.

The percentage of pigmented bacteria was relatively low. Yellow, orange, brown, rose and red colonies have been observed on the counting plates. In most samples their percentage of the total count was less than 5 per cent, while in the Persian Gulf they often made up 10% or more (upto 50%).

Bacteria growing in star-shaped aggregates (Ahrens and Rheinheimer, 1967) were not found.

Most of the isolations are motile gramnegative rods. Proteolytic forms with only minor saccharolytic activity predominate by far.

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