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Environmental Conditions of Two Red Sea Coastal Lagoons in Jeddah. 1. Hydrochemistry

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ABSTRACT. Arbaeen (AR) and Reayat Alshabab (RA) are two shallow lagoons in Jeddah lying on the Red Sea coast. Salinity, dissolved oxygen, hydrogen sulphide (H_2S) and Secchi transparency depth as well as bottom topography of the two lagoons are studied. The results reveal that each lagoon is a fjord like estuary hosting a dammed hypolimnitic anoxia and hypersaline water behind the sills covered by a surface brackish water. This water, augmented by entrained water, is freely flowing outside the lagoon and is compensated by a countercurrent of Red Sea water at mid depth (2 m). The brackish water is a seawater mixed with non-saline water discharged from Jeddah sewage treatment plants. Periodic inflow of Red Sea waters into the lagoons frequently occurs but it is not sufficient to replace all the old, dense and euxinic resident waters and to stop the evasion of malodorous H_2S-gas, source of people complaint. The last problem can be partially solved (as short-term solution) by the application of artificial aerations of the hypersaline water layers.

Introduction

Arbaeen (AR) and Reayat Al-Shabab (RA) lagoons (Fig. 1) are two shallow coastal lagoons on the western side of the middle part of Jeddah, on the Red Sea. They had been of great importance as recreational areas and have an even greater potential in this respect. Beside this they were also important for fishing and other water sports. Despite of their importance there is a lack in information about their environmental conditions at least to help in understanding of their present situations and their characteristics. The present work, therefore, is made to investigate the hydrochemical conditions of these lagoons as well as surveying their bottom topography. As the topographical features are also lacking and are required to see if the water exchange process between the lagoons

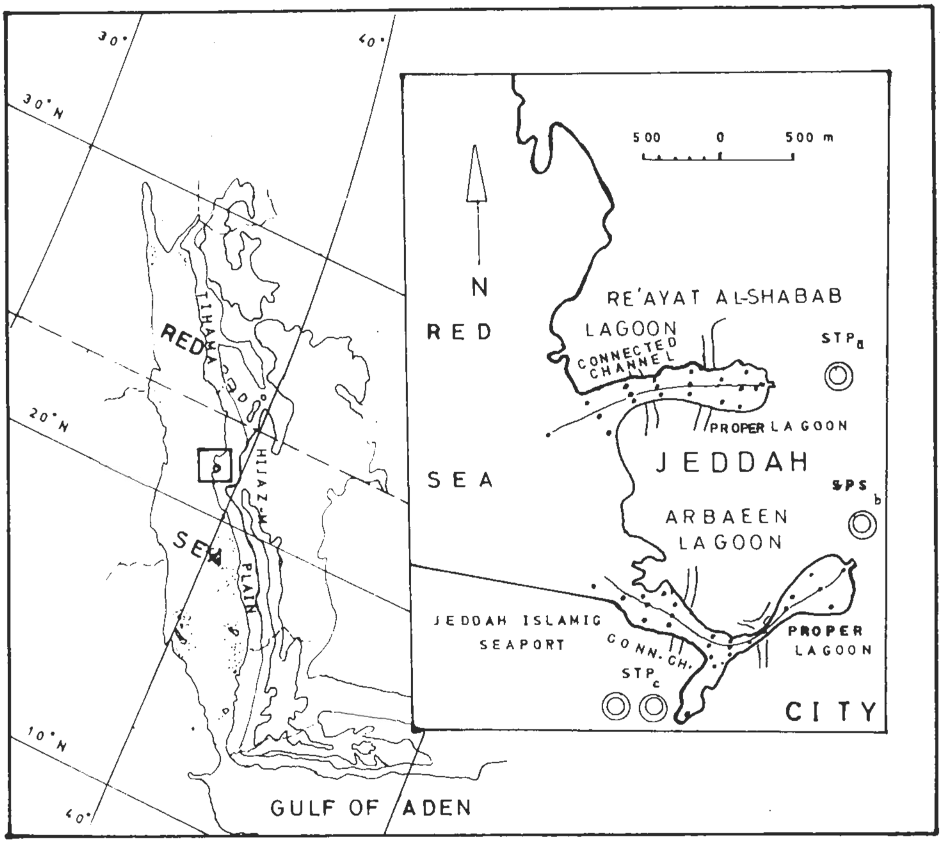

FIG. 1. Map of the Red Sea showing location of Jeddah, the two coastal lagoons, Arbaeen and Reayat Al-Shabab, and Sampling stations.

and the Red Sea waters is free or restricted, *e.g.* due to presence of obstacles or sills at their entrances.

Materials and Methods

Description of the Study Area

The lagoons are shown in Fig. 1 and 2 and some of their morphometric and topographic data are listed in Table 1. Each lagoon is formed from two main parts, a landward Proper Lagoon and a seaward connected channel. The last connects the proper lagoon with the sea. These two parts in case of AR Lagoon form V-shape and at its south tip there is a blind end open drain. At that blind end there is an outfall for wastewater effluent discharges from a nearby sewage treatment plant at site-c (STPc, Fig. 1). Its discharge rate is 68,000 m^3/d (Table 1). Another drain is also there but opens on to the northern broad side of the AR proper lagoon (Fig. 1), it receives wastewater from a by-pass of a sewage pumping station (SPS). The discharge from this source occurs only during storm events. As the pump is actually used to convey raw sewage to the STPc.

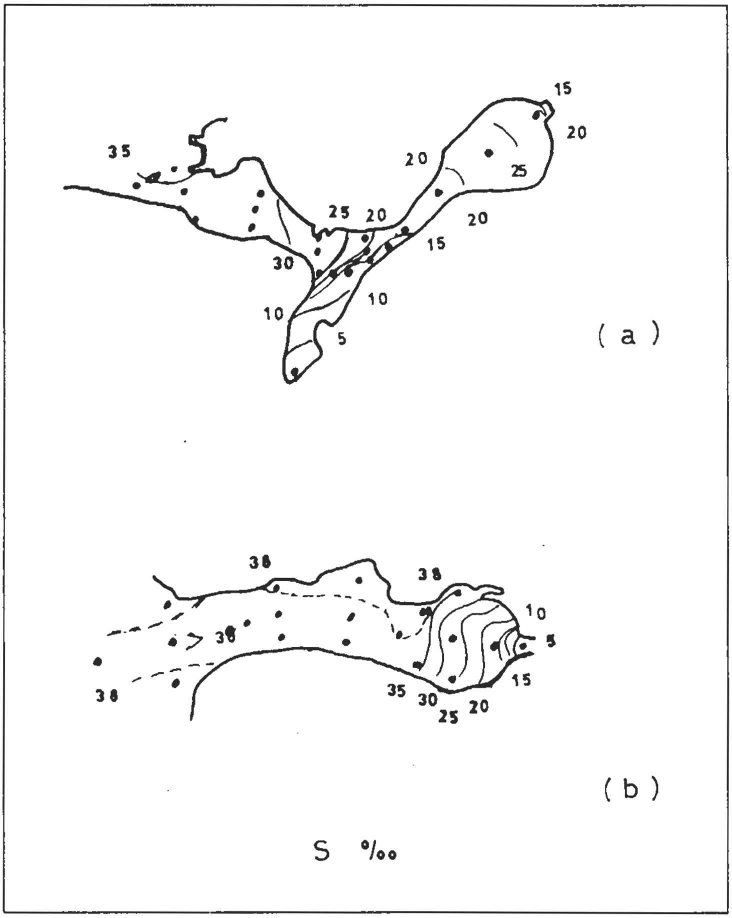

FIG. 2. The water surface horizontal distribution of salinity for (a) Arbaeen and (b) Reayat Al-Shabab lagoons, Jeddah.

In the case of the other lagoon, RA Lagoon, its two parts are lying almost on the same line. Its landward closed end also receives sewage effluents but from another STP at site-a (STPa) at a rate of 35,000 m^3/d. It is worth to mention that both the connected channels of the two lagoons were recently formed after the extension of the land area of Jeddah City more west wards on the account of the sea, in 1985.

Sampling and Analyses

Two types of cruises were carried out in the two lagoons during 1988-1989, one was conducted once in February 1988 for collecting surface water samples from the stations in a sampling grid shown in Fig. 1 and 2, covering different parts of each lagoon. This was to measure their salinity in order to identify if there were other effective landbased non-points inflow of waters to the lagoons. The other type is a monthly cruises (except in July and August) for one year period for sampling of at least nine water columns lying along the longitudinal axis of each lagoon (Fig. 1). The water columns were sam-

TABLE 1. Some morphometric, topographic and other characteristics of the two Jeddah lagoons.

Element	Arbaeen (AR) Lagoon	Reayat Al-Shabab (RA) Lagoon
1. Length (m)	1,500	1,200
2. Maximum width (m)	400	400
3. Surface area (m^2)	253,536	266,073
4. Maximum depth (m)	7	5
5. Volume (m^3)	1,004,142	1,064,290
6. Sill depth (m)	2	2
7. Lagoon width at the outer sill (m)	160	180
8. Volume of the surface 2m water layer (m^3)	507,072	532,146
9. Mean hydraulic residence time for the outflowing upper 1 m layer at steady state (day)	1.45[a]	1.60[a]
10. Wastewater discharge rate from the STP (m^3/d)	68,000[b]	35,000[b]
11. Mean freshwater percentage in the surface water (at the stagnant state)	37[c]	21[c]
12. Mean Secchi Transparency Depth (cm)	40[d]	50[d]

a = Result of division of the freshwater (FW) volume in this layer (= Total volume of the layer * FW %) / the wastewater inflow.

b = After Jeddah STPs, Staff members (Personal comm.).

c = Calculated according to the equation of Ketchum and Keen (1955). FW % = (S_0-S) 100 / S_0, where FW% is the percentage of the non-saline water in the mixed water in the lagoon, S_0 is the proper Red Sea water salinity and S is the salinity of the mixed water.

d = Eutrophic Secchi Transparency average depth in such lagoons is 245 cm (after, Wetzel, 1983) *i.e.* the present lagoons are in highly eutrophic conditions.

pled at discrete depths that can be seen in Fig. 4 and 5. These water samples were used to measure salinity values as well as dissolved oxygen (DO) and hydrogen sulphide (H_2S) contents. Salinity was measured using a Beckman-Bench type (Model RS-7C) salinometer. DO and H_2S were determined with the conventional Winkler's Method and back titration of liberated iodene respectively according to Andersen and Foyen (1969). In the field, sounding of the bottom depths of these lagoons was also made using a graduated rope and lead weight. In addition the Secchi disc transparency depth at each station was measured using the conventional Secchi disc. (Hereafter, the term lagoon will be used to designate both the proper lagoon and its connected channel unless otherwise stated).

Results and Discussion

Topography

Information concerning the soundings of the bottom of both lagoons along their axial lines are summarized in Table 1 and depicted in Fig. 4-6. Generally, each lagoon consists of two basins separated by an intermediate shallow sill, 2 m in depth, and separated from the sea at the entrance by another sill of the same depth. These sills are made of concrete (man-made), to support the piers of two bridges connecting both banks of the channel with each other. As will be seen shortly, these sills separate the subsurface waters deeper than 2 m in the proper lagoon and in the connected channel inhibit their free exchange with the open seawater.

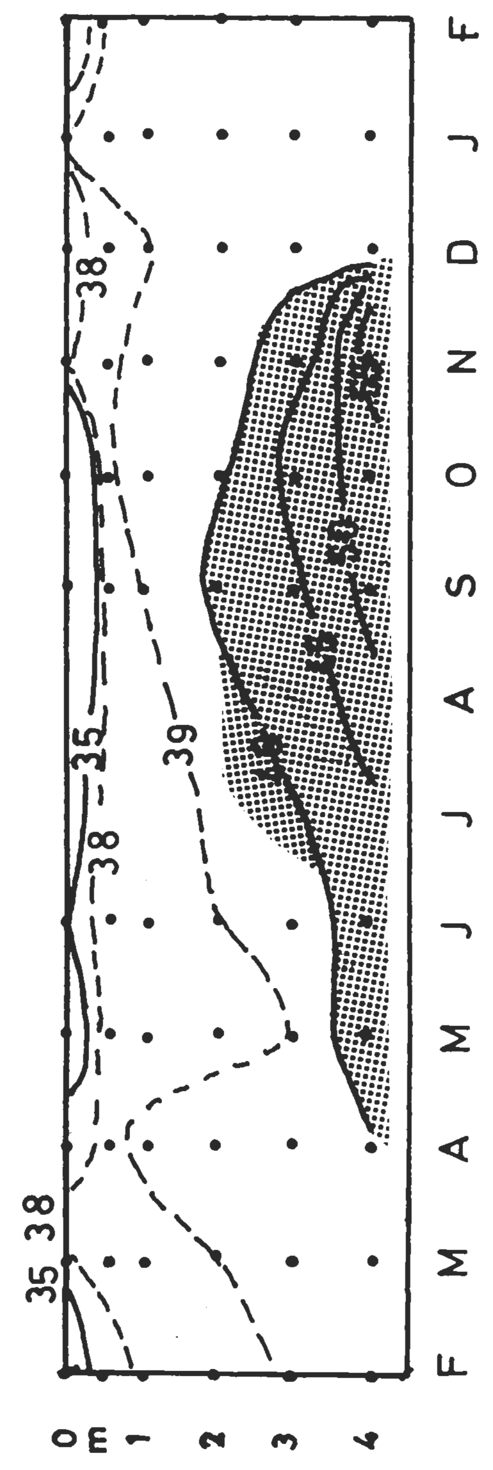

FIG. 3. Monthly variation of vertical distribution of salinity at a station in the connected channel of Reayat Al-Shabab Lagoon.

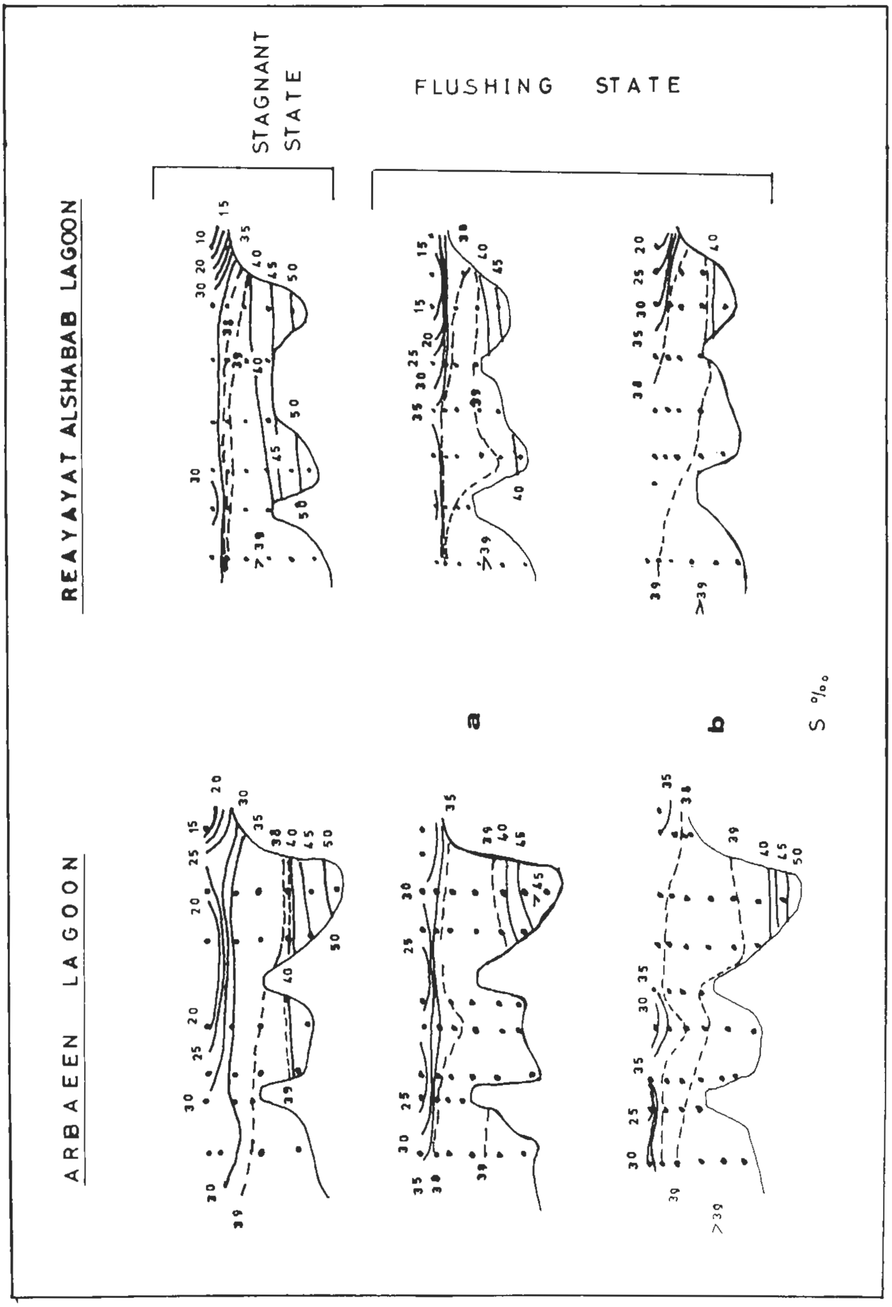

FIG. 4. Vertical distribution of salinity during the two states (a = in late autumn and b = in winter).

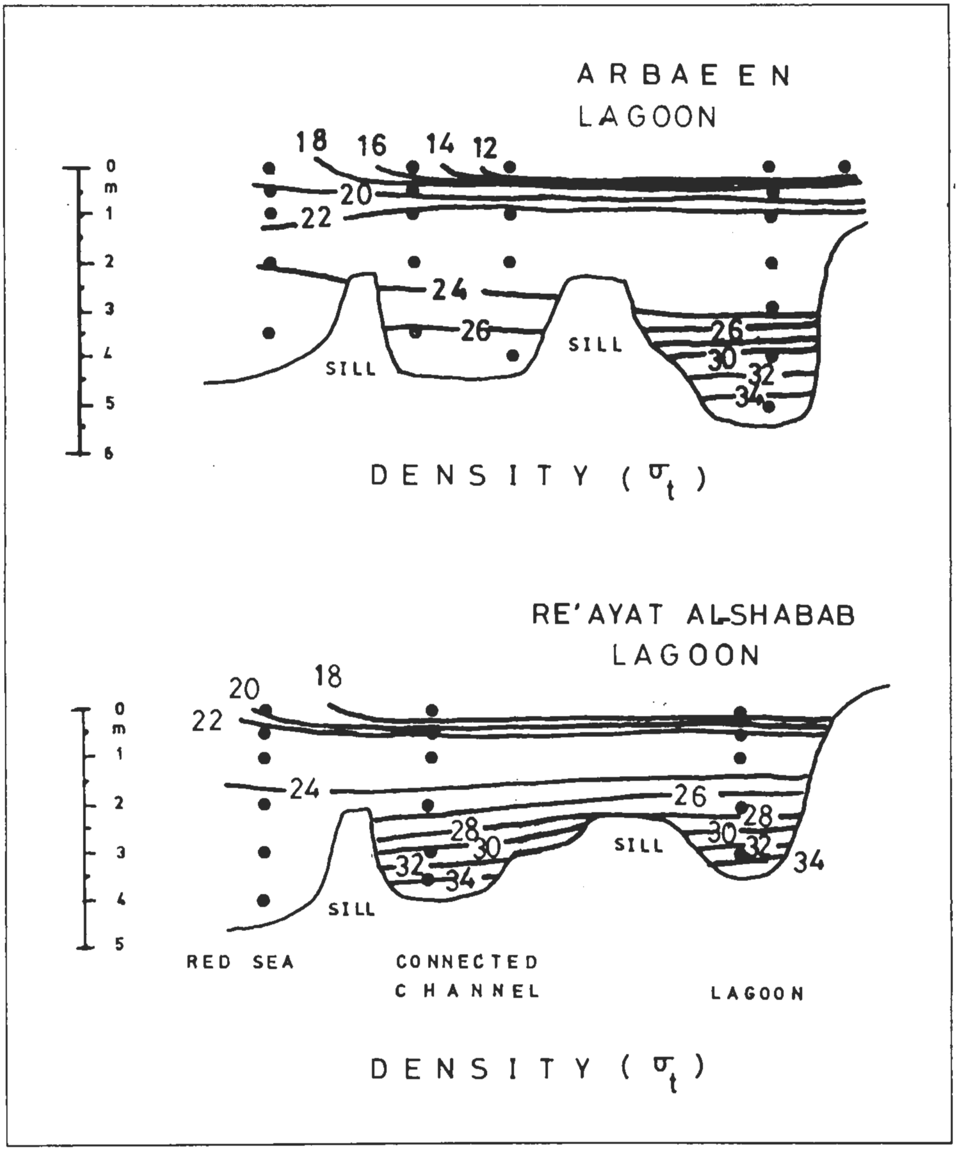

FIG. 5. Vertical distribution of density in the section extending along the longitudinal axis of Arbaeen and Reayat Al-Shabab lagoons, Jeddah, at the Stagnant State.

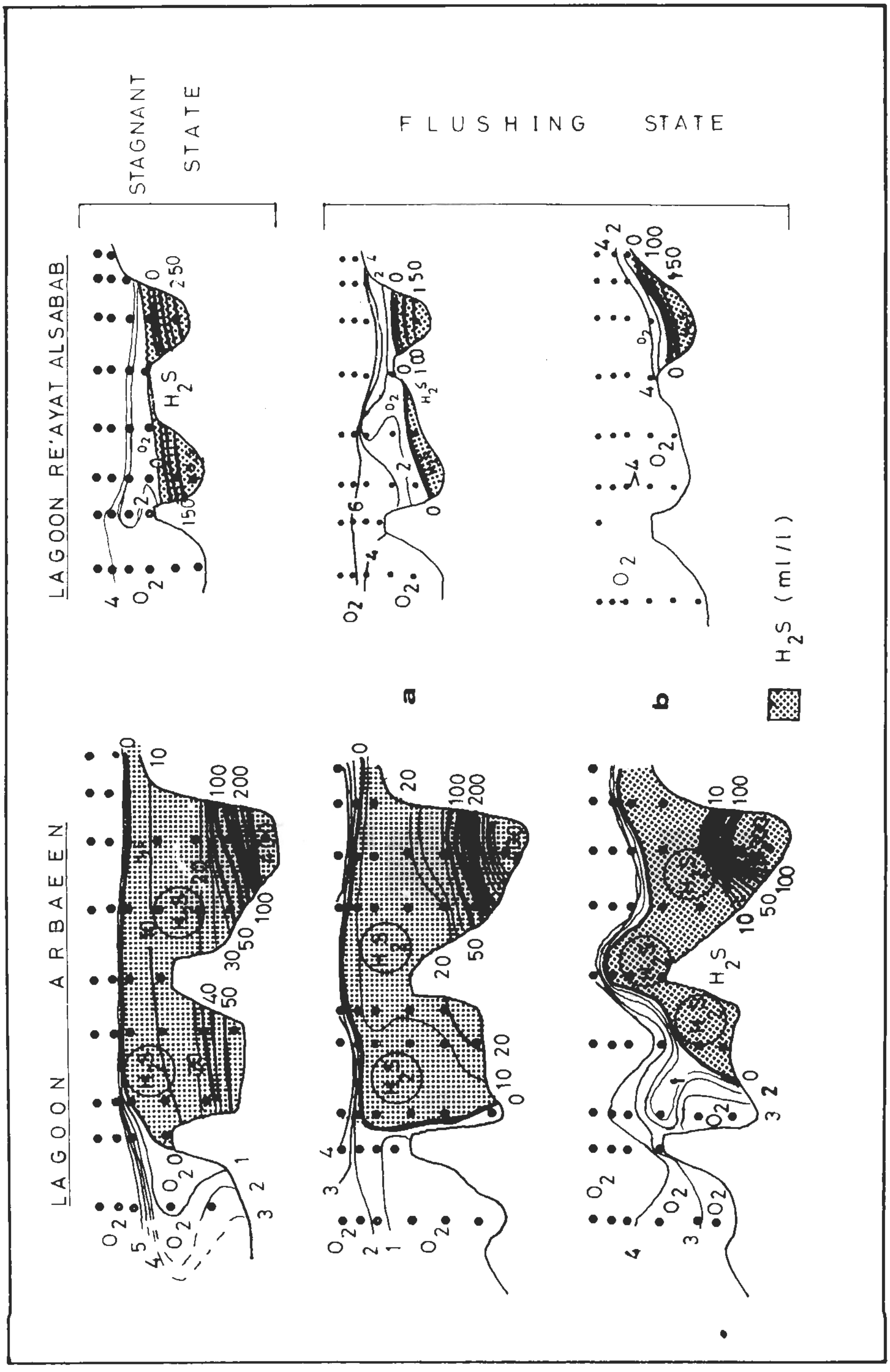

FIG. 6. Vertical distribution of hydrogen sulphide (and dissolved oxygen) in the section extending along the longitudinal axis of Arbaeen and Reayat Al-Shabab lagoons, Jeddah, at Stagnant and Flushing States.

Hydrography

Salinity

1- *The surface distribution*

The distribution of salinity in the surface waters of the lagoons is shown in Fig. 2.

AR Lagoon (Fig. 2a): Salinity of its surface water ranges between 5.0 and 35.2 ppt. The low value is found in the water in vicinity of the discharge site of the STPc effluent, while the high one is observed at the lagoon opening on the sea. The water at the closed end of the proper lagoon, *i.e.* off the SPS at site b, shows salinity values higher than 15 ppt reflecting that the amount of the non-saline water mixed with these waters is considerably low compared with the other waters near the other source STPc, which is consistently disposes effluents at rate 68,000 m^3/d (Table 1). Figure 2 also shows that the non-saline water from the STPc is dispersed not only in the connected channel but also part of it enters the proper lagoon, indicated from the shape of its isohalines particularly those at its southwest end of values < 20 ppt.

RA Lagoon (Fig. 2b): Salinity ranges between 5.0 and 38.0 ppt. The low value is recorded at the closed end of the lagoon near the discharge site of the STPa, whereas the high ones (~ 38.0 ppt) are observed at the open end of the lagoon on the sea. Generally, salinity increases seaward and the gradient in salinity is clearly established in the proper lagoon reflecting the rigorous mixing between the influxed non-saline water of the effluent with the surface waters of this part of the lagoon.

From the above, one can notice that the salinity values at the entrance of RA lagoon is remarkably higher than at the entrance of the other lagoon. Again this is mainly due to the effect of the difference in the amounts of the discharged waters from their land-based sources. Also, the STPs are the main effective sources of the non-saline waters to these lagoons.

2- *Vertical distribution of salinity in the lagoons at the two state*

During the present study for the hydrochemical distributions in both lagoons through the monthly cruises it was found that these lagoons or their hypolimnitic waters dammed behind the sills are passing through two main states. One is stagnant state during, most of the year except in late autumn and winter, which these waters are getting old with time and developed during spring and become well established in summer and part of autumn. The other is the flushing state during which waters from the Red Sea inflow into the lagoons replacing the hypersaline water at least from the connected channels and periodically occurs mostly in late autumn and culminated in winter. These can be seen from examining the monthly variation of vertical distribution of salinity at a station in the connected channel of RA Lagoon (Fig. 3) as an example for the case in both lagoons. Therefore, for the purpose of the present paper the results of three cruises are presented, one in late summer before the inflow representing the stagnant state and the other two are in late autumn and winter representing the flushing state.

The vertical distribution of salinity as well as DO and H_2S along the longitudinal axis of each lagoon at the two states are shown in Fig. 4 and 6. Range and mean values of salinity and H_2S along the water columns of each lagoon's proper lagoon and connected channel and of the Red Sea coast outside the entrance during the two states are listed in Table 2.

a) At the stagnant state (Fig. 4): In each lagoon, the vertical distribution of salinity in the section extending along its longitudinal axis shows the presence of three defined water layers. A surface brackish water layer of 1 cm depth (of salinity values < 35 ppt in the case of AR and < 39 ppt in the case of RA lagoons). This is followed by a sub-surface intermediate water layer, the bottom of which is at a level almost equal to that of the sills (*i.e.* at a depth of 2 m). The salinity values in this layer are less than 40 ppt. Incidentally, they are more of less similar to those of its counterpart in the Red Sea outside the lagoon entrance. The third layer is the bottom water layer with a depth of > 2 m, *i.e.* it is the water layer that lies behind the sills. Its salinity is > 40 ppt, ranging between 40 and >50 ppt. The maximum values (> 50 ppt) are recorded near the bottom. Obviously, the salinity of this layer is much higher than that recorded either in the overlaying layers or even than that at the same level in the Red Sea, *i.e.* it is a hypersaline water layer.

Figure 4 also shows that the depth of the upper layer is generally deeper inside the lagoon than at the entrance. At the entrance it reaches the sea surface. Moreover, the salinity values in this layer increase sharply both seawards and with depth. While in the intermediate layer, the change in salinity is very much less, with a general slight increase seawards.

b) At the flushing or inflowing state (in late autumn and winter) (Fig. 4 and Table 2): In both lagoons, the hypersaline waters in the outer basin (the connected channel) is considerably diluted to reach a salinity level more or less similar to that of the Red Sea water outside the lagoons, while that in the inner part shows a relatively slight decrease in its salinity. At the same time the upper two water layers show an observable increase in both the range and mean salinity (Table 2). The table also shows that there is a general increase in means values of salinity in the lagoons as a whole, despite of the decrease in salinity of the hypersaline waters. This implies displacement of the diluted waters in the lagoons with waters of high salinity mostly from the Red Sea. All these observations indicate that an inflow of Red Sea waters to the lagoons has occurred to replace at least the old resident hypersaline waters in the connected channel and mixing of the upper water layers with the replaced saline waters during its way out to the sea in a water circulation pattern which is schematically represented in Fig. 7. (The mixing process of the upper water layer with the replaced 'old' saline waters during its way out to the sea can be also seen, hereafter, during discussing the distribution of H_2S in these lagoons during the two states). Such water circulation pattern is quite similar to that is usually periodically observed in silled-fjords (El-Rayis, 1977; Farmer and Freeland, 1983).

The above mentioned three water layers that are clearly established in the lagoon during the stagnant state can also be easily seen from studying the distribution of calculated density (σ_t), shown in Fig. 5. Where the outflowing surface brackish water layer has values < 22 and, the intermediate countercurrent Red Sea water layer has values ranging between 22 and 25, while the dammed hypersaline water has values > 25 and reaches values as high as 34 near the bottom of the inner basin or proper lagoon. These observations imply that the bottom water layer is not only saline but also is very dense. Therefore, at the stagnant state, its exchange with the less dense Red Sea waters (σ_t < 25) lying either inside or outside the lagoon is difficult to attain even under the daily tidal range occurring in this region of the Red Sea.

The tidal range of the Jeddah coast is minimum (30 cm) compared to that in the Red Sea either north or south of the Jeddah latitude (Meshal, 1987). Therefore, other factors must be there responsible for occurrence of this periodic inflow in these times of the year. An assessment of these factors, which are mostly tied with the sea level change and general hydrographic characteristics of the Red Sea as a whole, is being made and will be discussed in a subsequent paper.

From the above, we can deduce that: (1) During most of the year, the stagnant period, the non-saline effluent will flow out to the sea as surface brackish water, augmented by entrained water and compensated by a countercurrent from the Red Sea at mid depth. Based on the vertical distribution of salinity, these two water layers together form a positive estuary of Type-C (Pickard, 1975). The presence of the third restricted bottom water layer behind the sills makes the lagoons resemble fjord-type estuaries (Farmer and Freeland, 1983; Wassman *et al.* 1986). According to Bowden (1975), in such estuaries, the volume of the outflowing surface water at any time will be enhanced than that of the discharged effluent to the lagoon by an amount equal to that which is entrained from the deeper waters. Obviously, this process will be in favour of the dilution of a contaminant (discharged with the effluent) in the surface layer particularly when its residence time is relatively short (about 1.6 day, Table 1) and subsequent removal from the lagoon and export to the coastal area. This may lead to a serious impact on some of the important human activities there including fishing and seawater desalination. (2) During the flushing time, an inflow of Red Sea water occurs to replace most of the old resident water of the connected channel (the outer basin) and part of that in the inner basin, the proper lagoon.

It is true that the Jeddah lagoons can be considered as the silled-fjords (*e.g.* like those of the deep fjord in Norway, El-Rayis, 1977) but the lagoons differ in the enrichment of their bottom waters with total dissolved salts (salinity). Where *e.g.* in the Oslofjord, the salinity values of the deep waters that are on the same level on both sides of the (Dröback) sill are almost identical (Grasshoff, 1975; El-Rayis, 1977). This observation makes one believe that the Jeddah lagoons before urbanization were originally hypersaline lagoons, with salt deposits as those lie at the north and south of Jeddah and are far from the Man-Made effects, *e.g.* Hatiba lagoon that lies about 90 km north of the present lagoons where its salinity ranges between 50 and 113 ppt (Meshal, 1987).

H_2S and DO

The distribution of the DO and H_2S in the vertical section extending along the longitudinal axis of the lagoon during the stagnant and flushing states are shown in Fig. 6.

TABLE 2. Range and average values of salinity and hydrogen sulphide (H_2S) in the two Jeddah lagoons at the stagnant (ST) and flushing (FL) states, 1988-1989.

Analyte	State		ARBAEEN LAGOON			REAYAT ALSHABAB LAGOON		
			Proper Lagoon	Connected Channel	Red Sea Outside	Proper Lagoon	Connected Channel	Red Sea Outside
Salinity (ppt)	ST	U	14.3-37.6 29.14	15.1-38.1 32.51	33.0-38.4 34.83	8.2-39.2 32.14	26.5-39.3 36.13	34.2-39.3 37.53
		B	37.3-51.1 41.74	37.3-50.4 40.42	38.4-38.6 38.45	40.4-49.9 44.87	39.2-51.8 43.54	39.3-39.4 39.35
		WWC	14.3-51.1 32.64	15.1-50.4 33.18	33.0-38.6 35.42	8.2-49.9 32.78	26.5-51.8 35.78	34.2-39.4 38.54
	FL (1)	U	27.8-38.5 35.13	22.8-38.9 34.51	28.8-38.9 35.70	16.1-38.6 31.10	29.0-39.1 36.87	34.4-39.1 36.34
		B	38.4-49.0 43.13	38.5-38.9 38.73	38.9-39.2 39.1	38.9-46.0 41.29	39.0-42.1 39.6	39.2-39.3 39.21
		WWC	27.8-49.0 37.55	22.8-38.9 35.68	28.8-39.2 38.05	16.1-46.0 33.27	29.0-42.1 37.88	34.4-39.3 38.69
	(2)	U	33.7-39.1 37.42	22.9-39.2 36.56	30.0-39.2 36.14	18.6-38.6 32.78	38.6-38.8 38.62	38.2-39.3 38.82
		B	38.6-53.0 40.71	38.5-39.2 39.06	39.1-39.4 39.25	38.4-42.4 39.60	39.0-39.2 39.1	39.3 39.3
		WWC	33.7-53.0 38.97	22.9-39.2 37.08	30.0-39.4 38.60	18.6-42.4 34.50	37.8-39.2 38.70	38.2-39.3 39.00
	Seasonal		14.3-53.0 36.39	15.1-39.2 35.31	30.0-39.4 37.36	8.2-49.9 33.52	26.5-51.8 37.45	34.2-39.4 38.74

TABLE 2. (... cont.)

Analyte	State		ARBAEEN LAGOON			REAYAT ALSHABAB LAGOON		
			Proper Lagoon	Connected Channel	Red Sea Outside	Proper Lagoon	Connected Channel	Red Sea Outside
H_2S (ml/l)	ST	U	Nil-12 3	Nil-33 5	Nil-4 1	Nil Nil	Nil Nil	Nil Nil
		B	9-865 20	4053 23	Nil-4 1	21-259 140	Nil-188 70	Nil Nil
		WWC	Nil-865 11	Nil-53 15	Nil-4 1	Nil-259 70	Nil-188 35	Nil Nil
	FL (1)	U	Nil-20 8	Nil-18 4	Nil Nil	Nil Nil	Nil Nil	Nil Nil
		B	10-465 158	Nil-94 15	Nil Nil	Nil-169 56	Nil-10 3	Nil Nil
		WWC	Nil-465 83	Nil-94 9	Nil Nil	Nil-169 28	Nil-10 2	Nil Nil
	(2)	U	Nil-5 1	Nil-5 1	Nil Nil	Nil Nil	Nil Nil	Nil Nil
		B	Nil-355 45	Nil-7 2	Nil Nil	Nil-192 80	Nil Nil	Nil Nil
		WWC	Nil-355 23	Nil-7 1	Nil Nil	Nil-192 40	Nil Nil	Nil Nil
	Seasonal		Nil-865 39	Nil-94 8	Nil-4 Nil	Nil-259 46	Nil-188 12	Nil Nil

U and B are the upper and bottom water layers, respectively. WWC = Whole water column.
Nil = Oxygenated water. (1) and (2) are the flushing state in late autumn and in winter, respectively.

It is easy to notice that H_2S is only detected in the subsurface waters of the lagoons, its depth depends on the time of the day and whether the lagoon is at the stagnant or flushing state. Regarding the time of the day, continuous recording of the DO or H_2S content in the surface water samples collected from the lagoons along twenty-eight hours in both lagoons was conducted. The results reveal that the oxic surface water turns to anoxic water at midnight and stays in the anoxic conditions till 09 O'clock in the morning of the same day, *i.e.* the evasion of the H_2S-gas from the lagoons (that causes people complaints) is expected to be at its maximum rate within the first 9 hours period of the day. This reflects that most of DO produced during the day time in the photic surface layer (its thickness is shown in Table 1) by the indigenous phytoplankton has been consumed during night by both the plankton themselves during respiration process and by that of reduction reaction (Richards, 1965) with the H_2S gas diffused upwards from the subsurface anoxic waters.

At the stagnant state: H_2S is recorded in the subsurface waters deeper than 1 m in AR lagoon while in RA Lagoon it is more deeper at depths > 2 m. The overlying surface water is oxygenated. The interface (thin) water layer or the transition water layer between the oxic and the anoxic layers that is also called the suboxic layer, contains neither oxygen nor H_2S where, at this thin layer, the rate of diffusion of DO downward from the oxic waters and that for H_2S upward from the anoxic waters are normally equal (Richards, 1965). The shallowness of the suboxic water in AR lagoon, therefore, refers to the greater upward diffusion rate of H_2S in this lagoon. Also, it reflects a greater load of oxygen-consuming matter there. In both lagoons, however, values < 200 ml/l H_2S have been recorded in the hypersaline layer of the outer basins and > 200 ml/l in the inner basins or the proper lagoons.

At the flushing period: For AR and RA Lagoons respectively, partial and almost complete removal of H_2S from the bottom water of their outer basins (the connected channels) have occurred, while in their inner basins (the proper lagoons) only partial flush takes place. As in the inner basin an erosion of the isoline 200 ml/l H_2S occurred to become at more deeper level (Fig. 6). In AR Lagoon the suboxic water layer extended upwards to reach a level very close to the sea surface compared to that previously observed (at 1 m depth) during the stagnant state. At the same time, the isolines of H_2S in its outer basin become more vertical with a noticeable dilution in its values seawards. These observations, confirm the inflowing of Red Sea oxygenated water to the lagoons during this state and there it circulates in the pattern earlierly mentioned and depicted in Fig. 7. Obviously, the replaced, old H_2S -bearing and hypersaline waters of the connected channel and those partially flushed from the proper lagoons on its way first towards the blind end of the lagoon and then upward towards the surface, out to the sea, mix with the pre-existing two upper water layers. This has led to (a) the previously mentioned rise in salinity of these upper two water layers and (b) the consumption of their originally present DO to the extent of turning them to waters bearing H_2S (Fig. 6). These steps are also most likely happened in RA Lagoon. The remarkable decrease in the level of concentrations of H_2S in the basins of each lagoon due to the periodic inflow of the Red Sea water is shown in Table 2.

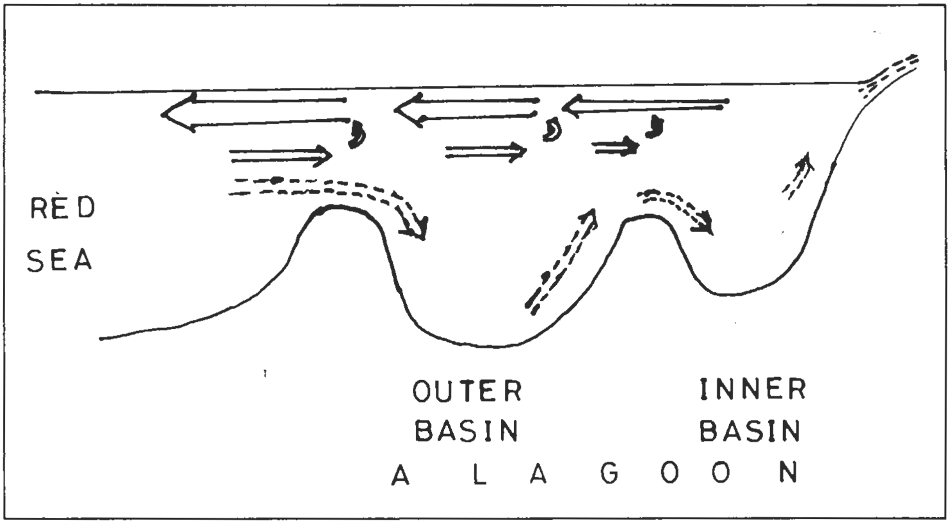

FIG. 7. A schematic representation of the coastal zone of Jeddah from the Red Sea (left) to outer and inner basins of a lagoon. The near surface arrows represent the brackish layer, augmented by entrained water (curved arrows) and compensated by countercurrent at mid depth. The broken arrows indicate the periodic inflow of water replacing old resident water in the lagoon basins.

Generally speaking in most of the anoxic basins and silled-fjords in the world, the H_2S values recorded there usually lie within the range of a few ml to about 70 ml/l (Richards, 1965; Grasshoff, 1975; El-Rayis, 1977; Wassman *et al.*, 1986; Dyrssen and Kremling, 1990). The extremely high values (> 100 ml/l) found in the bottom waters of the Jeddah Lagoons confirm how these lagoons are highly eutrophied and highly loaded with organic matter.

From the above, it is concluded that the periodic flush is temporary and is unable to ventilate all the basins of the lagoons. Solution of this problem (and the problem of the malodorous H_2S-gas evasion from the lagoons) may be attained in either short or long term. The short term solution is the application of an external or artificial aeration to the hypersaline waters of the lagoons. Different artificial aeration techniques for this purpose are compiled and mentioned elsewhere (see *e.g.* Cooke *et al.*, 1986). The long term solution is the diversion of the sources followed by dredging of the (sludgy) surface sediments and frequent aeration of the dammed water layer. The diversion away from these lagoons will certainly reduce the load of organic matter and nutrients that are, directly or indirectly, responsible for the consumption of DO. The nutrients are the sources of secondary organic pollution (Henze, 1978).

Conclusions

Arbaeen and Reayat Al-Shabab Lagoons are two hypereutrophic shallow coastal lagoons on the western side of the middle part of the city of Jeddah. Currently, they are serving as dilution ponds for (inadequate) secondary treated waste waters discharged mainly from the two nearby sewage treatment plants. Each lagoon consists of two basins separated by an intermediate shallow sill, 2 m in depth, and separated from the sea by another sill of the same depth. They are fjord-like lagoons, with a positive estuarine circulation characterizing the top 2 m layer. The deeper waters are dammed behind the sills during most of the year. These are stagnant, old, hypersaline and extremely euxinic waters responsible for the daily (during early morning) frequent H_2S-gas evasion from the lagoons. Periodic inflow of Red Sea water occurs replacing most of the old resident water in the outer basins and part of the inner basins, *i.e.* it fails to completely ventilate all the lagoon basins. Artificial aeration of the bottom water layer is suggested as short-term solution to stop the emanation of the malodorous H_2S-gas.

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الظـــروف البيئيـــة لهـــورين في جـــدة على ساحـــل البحـــر الأحمـــر . ١- هيـدروكيميائيتهما

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المستخلص . الأربعين ورعاية الشباب هما هورين ضحلين في جدة يقعان على شاطئ البحر الأحمر . تم دراسة كل من الملوحة والأكسجين وكبرتيد الهيدروجين الذائبين وكذا عمق الشفافية بالإضافة إلى جس الأعماق في هذين الهورين . واتضح من النتائج أن كل هور ما هو إلا مصب شبيه بالفيورد ذات عوائق مستضيفا لمياه عميقة مملحة آسنة محجوزة خلف العوائق وهذه تكون مغطاة بمياه غير شروب سطحية متدفقة باستمرار وبحرية إلى خارج الهور بعد تزويدها بمياه متصعدة من أسفلها أصلها قادم من البحر نحو الهور عند عمق متوسط (٢ متر) . المياه الغير شروب عبارة عن مياه بحر مختلطة بمياه صرف غير مالحة متدفقة من محطات معالجة الصرف الصحي بجدة . هناك غزو لمياه من البحر الأحمر يحدث على فترات للهورين ولكن ذلك الغزو يكون غير كافيا ليحل محل كل المياه القديمة الثقيلة الآسنة المقيمة هناك والمسؤولة عن توليد ونفاد غاز كبرتيد الهيدروجين الكريه الرائحة منها للهواء مسببًا ازعاج وشكوى مرتادى منطقة الهورين للترويح . مشكلة الازعاج هذه يمكن حلها جزئيًا (على المدى القصير) من خلال عملية تهوية يومية من مصدر خارجي لتلك الطبقة العميقة المملحة .