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Ultra-violet Absorption Measurement as a Rapid Tool for Tracing Dispersion of Sewage Effluent and for Classification of Water Masses in Two Red Sea Coastal Lagoons, Jeddah

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Abstract

The UV-absorbance was measured in water samples collected during six ssuccessive cruises within one year from two Saudian sewage-affected fjord-like lagoons (Arbaeen and Reayat Al Shabab), Jeddah. The hydrochemical elements, salinity, phosphate and ammonia were also measured. On the surface or on the vertical scales, the distribution pattern of the UV-absorbance and that for the other hydrochemical elements coincided on each other to a great extent. On the surface water scale, it was easy to define the direction of the spreaded discharged wastewater. On the vertical scale, three water layers can be easily ditinguished, surface seawater layer diluted with sewage effluent (contained high values of the UV-absorbance, phosphate and ammonia), intermediate less diluted seawater layer (less polluted) and bottom saline 'old' water layer with exceptional high values of the other three parameters. This situation prevailed for most of the times of the year in the lagoon except during the intermittent flushing periods occured in winter and early spring, where the stratification is disturbed. The UV-absorbance is directly measured in the water samples without any chemical pre-treatments and needs no special trained person.

Introduction

Lagoon Reayat Al Shabab (RA) and Arbaeen (Ar), Jeddah are fjord-like lagoons on the Saudian Red Sea coast (Fig.1). Their surface water salinities are less than those in the adjecent Red Sea water. This is due to the considerable amount of wastewater effluent discharged to each lagoon from the City of Jeddah. Obviously its water exceeds that necessary for evaporation.

Each lagoon is formed from two basins separated from each other and from the sea by two shallow sills (Fig. 4 and 5). Both lagoons intermittently produce malodorous hydrogen sulphide gas and the colour of their waters turned to yellow - brown. The last indicates presence of yellow substance (sometimes called Gelbstoff or Gilven, Kalle, 1966; Kirk, 1983).

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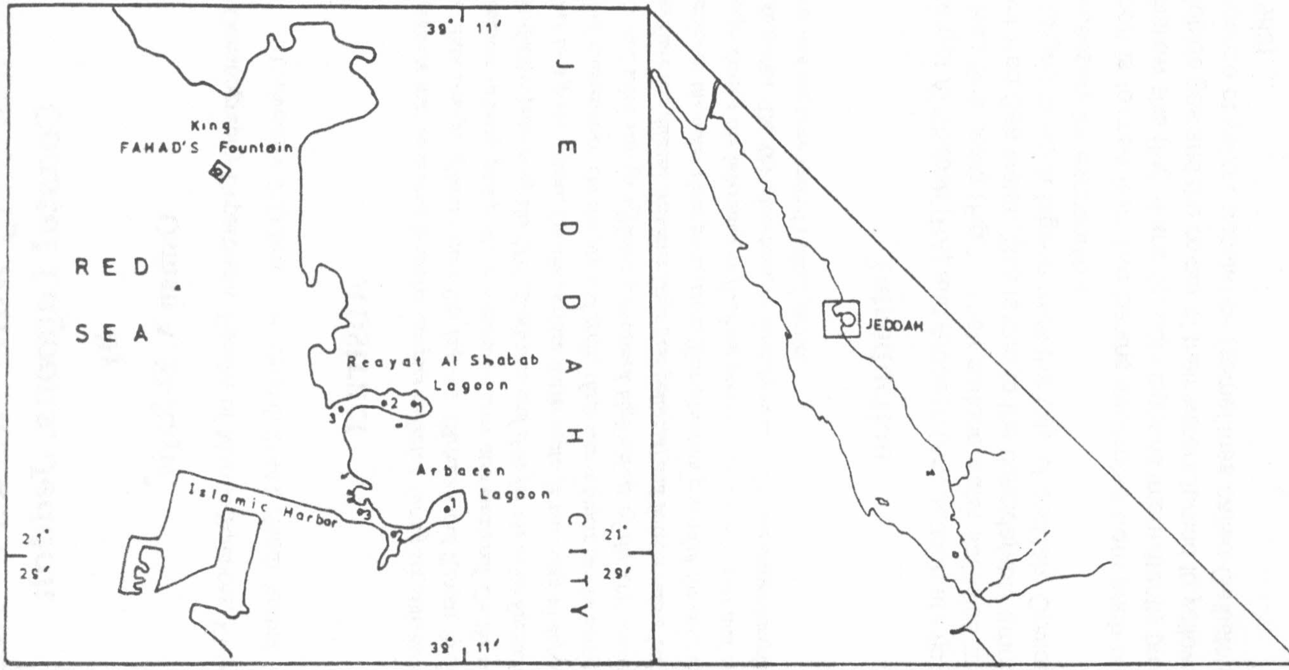

Fig. (1)

Map of the Red Sea coast in front of Jeddah, showing the positions of lagoons Reayat Al Shabab and Arbaeen.

These lagoons are two of the important recreational areas present in Jeddah City. Therfore, a study and monitoring for their environmental conditions are necessary. This in order to evaluate the quality of the water, to see if these lagoons are naturally flushed with water from the sea and the role played by the subsurface sills. In addition to see the way of the dispersion of the effluent in the surface water layer and the role of the wind on the dispersion.

Further more, if there is a simple and reliable technique for surveillence for both, the way of the dispersion of the wastes in the surface layer and for identification and monitoring the water layers that may present in these lagoons.

The present work is dealing with the last part (finding a reliable and rapid technique for monitoring the dispersion of the sewage effluents and for water layers). The first parts of requirements had been made and mentioned elsewhere by El-Rayis (1988 and 1989). The most important conlusion from these works was that measurements of phosphate and ammonia concentrations in the lagoon water can be used as good tracers for the dispersion of the effluent in the surface layer (better than salinity) and also for identification of the different water masses in these lagoons. Also showed that the dispersion of the effluent in the surface layer was controlled mainly by the surface wind. In addition, on the vertical scale, there were three distinct water layers, which were stand during most of the times of the year, except during winter and early spring, as the bottom one disappeared. Or in another words, each lagoon was passing by two states one was the stagnation or (stratification), its duration from spring to the end of autumn. During this period the third layer (bottom anoxic layer) appears. The other was the flushing period where the bottom anoxic water layer disappears, at least from the outer basin of the lagoon, due to its exchanges with sea water from the sea.

The thinking of using the UV-absorbance measurement; in the present paper; as the promising technique was due first to the presence of the yellow substance in the water of the lagoon. Secondly, its measurement is direct, easy and needs no trained person.

According to Bricaud et al. (1981) the yellow substance is the only important absorbing constituent of most natural waters and in those sewage affected water bodies (Lara et aal. 1985), over much of the wave lengths of the visible-UV spectrum between 700 and 240 nm, and is monotonically increasing absorption with decreasing wave length (Kalle, 11966: Jerlov, 1976; Carder et al., 1989). Generally, the absorption measurements were prefered to the UV part of the spectrum for the following reasons: (1) the absorption is much higher than in the visible part, Carder et al., 1989; (2) at the UV-wave lengths, interference from colloidal scattering is less significant and absorption coefficients are higher than in the visible (one can obtain acceptable precision by using a cuvette, its light path greater than 1 cm, Bricaud 1981; Davis-Colly and Vant, 1987); and finally (3) it shows closely relation to values of dissolved organic matter, DOM, in the water samples especially those collected from a very limited geographic region, where the nature of the DOM is supposed not to change markedly as the decomposition processes of DOM are generally slower at high salinities, Lara et al. (1985).

The UV-absorbance at wave length 281 nm was used (Krom and Sholmoviz, 1977: Malcolm, 1985).

Material and Methods

Surface and subsurface water samples were collected during six successive cruises within one year from the lagoons RA and Ar from stations and depths shown in Fig S.2, 3, 4 and 5.

The UV-absorbance at the 281 nm was adopted and measured with Pye Unicam Spectrophotometer (Model 6700) and were recorded as the instrument readings of extinction values (Armstrong and Boalch, 1961; Carder et al., 11989). A 5 cm cuvette with silica windows was used and to avoid doubts as the purity and consistency of a liquid medium, all measurements were made with air as the reference path. The UV-absorbance was made on, Whattman GF//C glass fiber filter, filtered water samples. The filter was previously rinsed with the same sample.

In the sametime, sub-water samples were used for determination of the other hydrochemical elements, salinity, reactive phosphate and ammonia (according to Parsons et al., 1984). The salinity was measured by an inductive salinometer-Bench type.

Results and Discussion

For the purpose of the present paper two sets of data for each lagoon are choosed. One during the stagnant period and the other during the flushing period.

The results of the UV-absorbance and also for the other studied elements (salinity, ammonia and phosphate) are presented here as distributions, horizontally in the surface water and vertically in a section extending along the longitudinal axis of each of the two lagoons.

The horizontal distributions for the four elements studied in the surface water of the lagoons RA and Ar during two different prevailed wind directions cruises are shown in Figs. 2 and 3, respectively. From these figures, the most important feature is, for each lagoon and for each cruise, the common distrbution pattern and coincidence of that for the UV-absorbance with that for the other hydrochemical parameters. But the pattern, however, was not the same for both cruses. Eventually, this is due to the effect of the different wind directions that were prevailing during each of these cruises. For example, Fig. 2a the wind prevailed was mainly northerly whereas that in the Fig. 2b, was coming mainly from the southeast.

Although of the coincidence of the distribution pattern for the four studied elements for each cruise, but there was an inversion in the relation between the UV-absorbance and salinity and direct relation with each of the other two elements. The strength of these relationships is, expressed by the value of the correlation coefficient (r), shown in table 1. The inverse relationship with salinity, however, refers to the fact that origin of most of the dissolved organic matter in the surface layer is mainly from the sewage effluent.

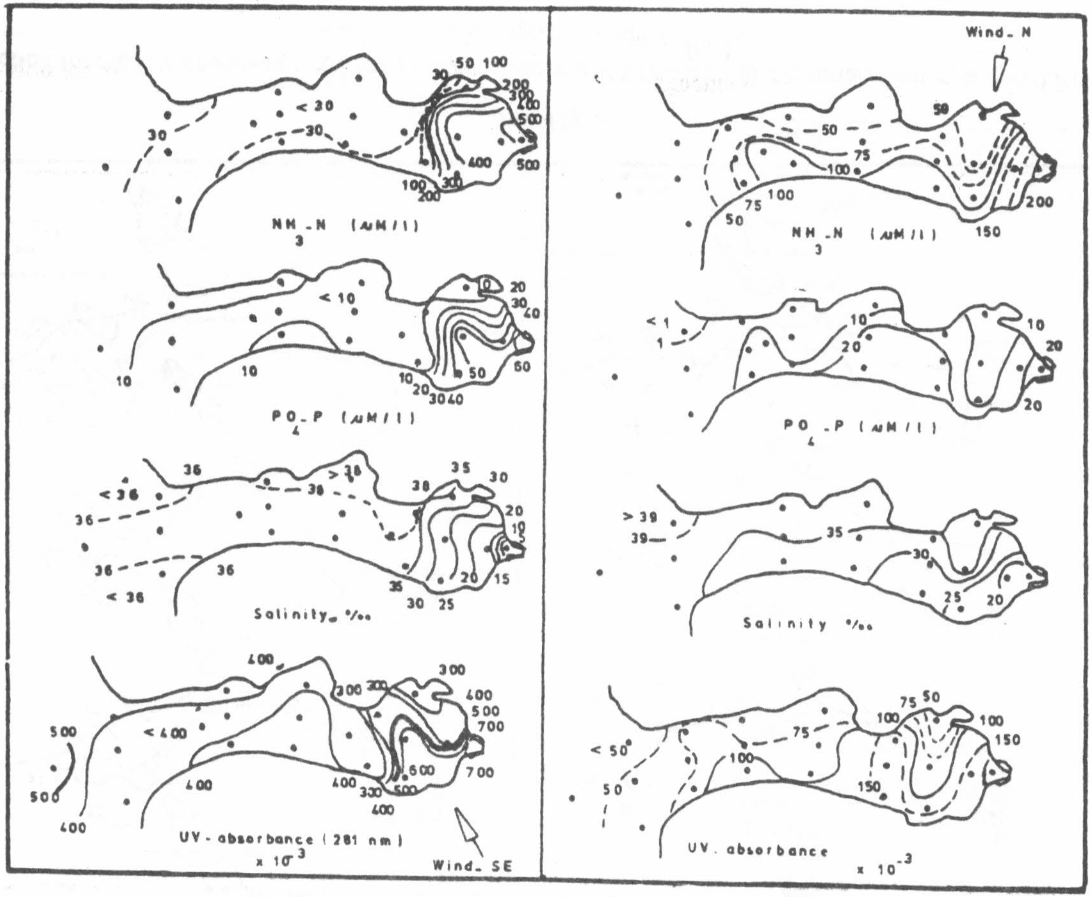

Fig. (2)

The horizontal distribution for the UV-absorbance and for the other three studied elements in the surface water, at two different direction prevailed winds, of lagoon Reayat Al Shabab, Jeddah

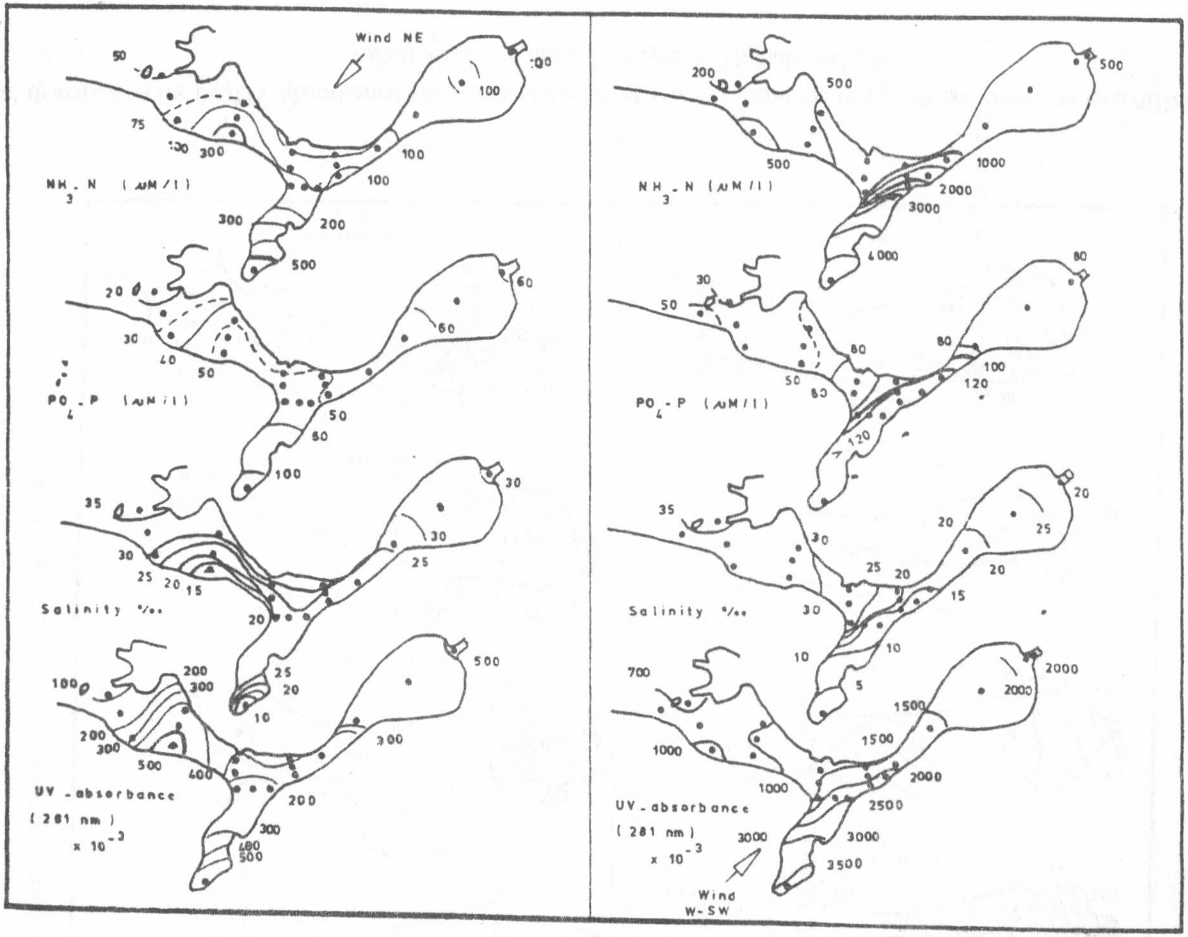

Fig. (3)

Horizonatal distribution for the UV-absorbance and for the other three studied elements in the surface water, at two different directions prevailed winds, of lagoon Arbaeen, Jeddah.

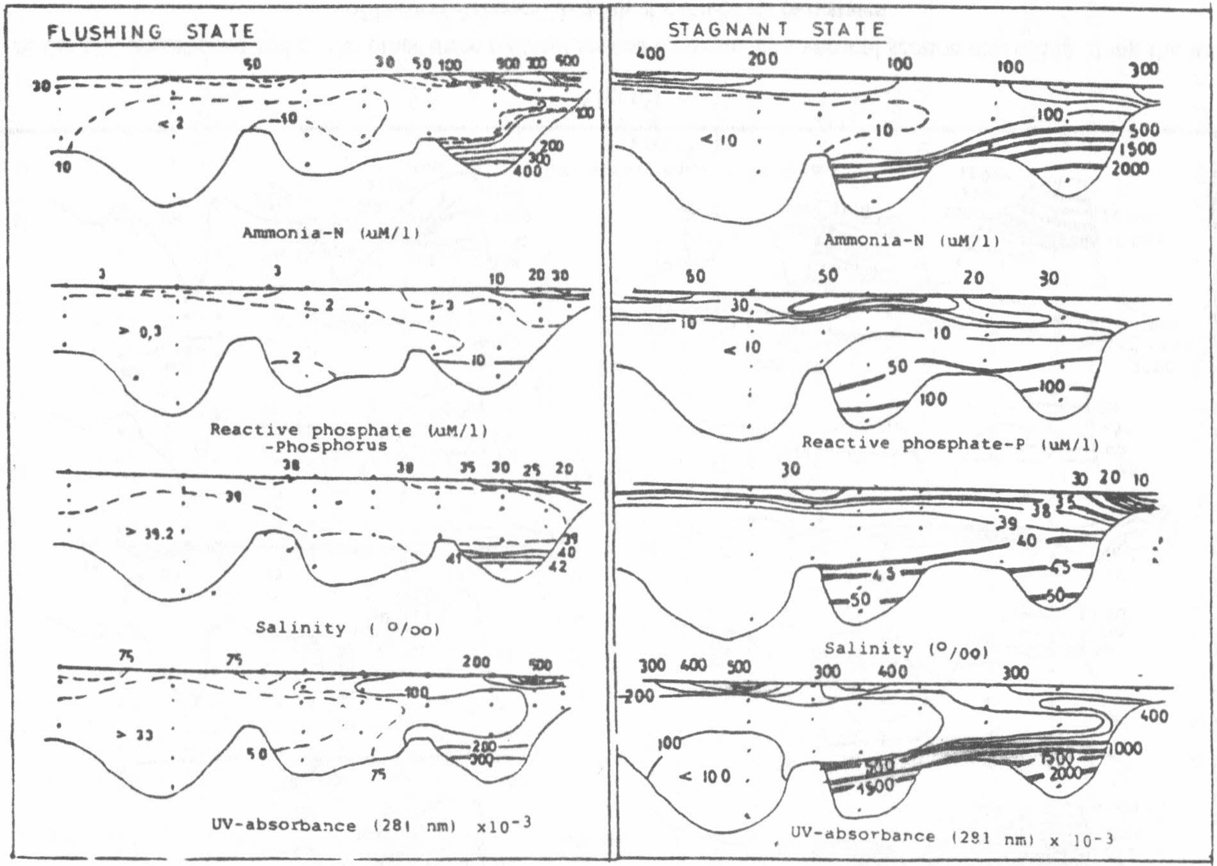

Fig. (4)

Distribution of the UV-absorbance and of the other three hydrochemical elements in a vertical section etending along the longitudinal axis of lagoon Reayat Al Shabab, Jeddah, at each of its two states.

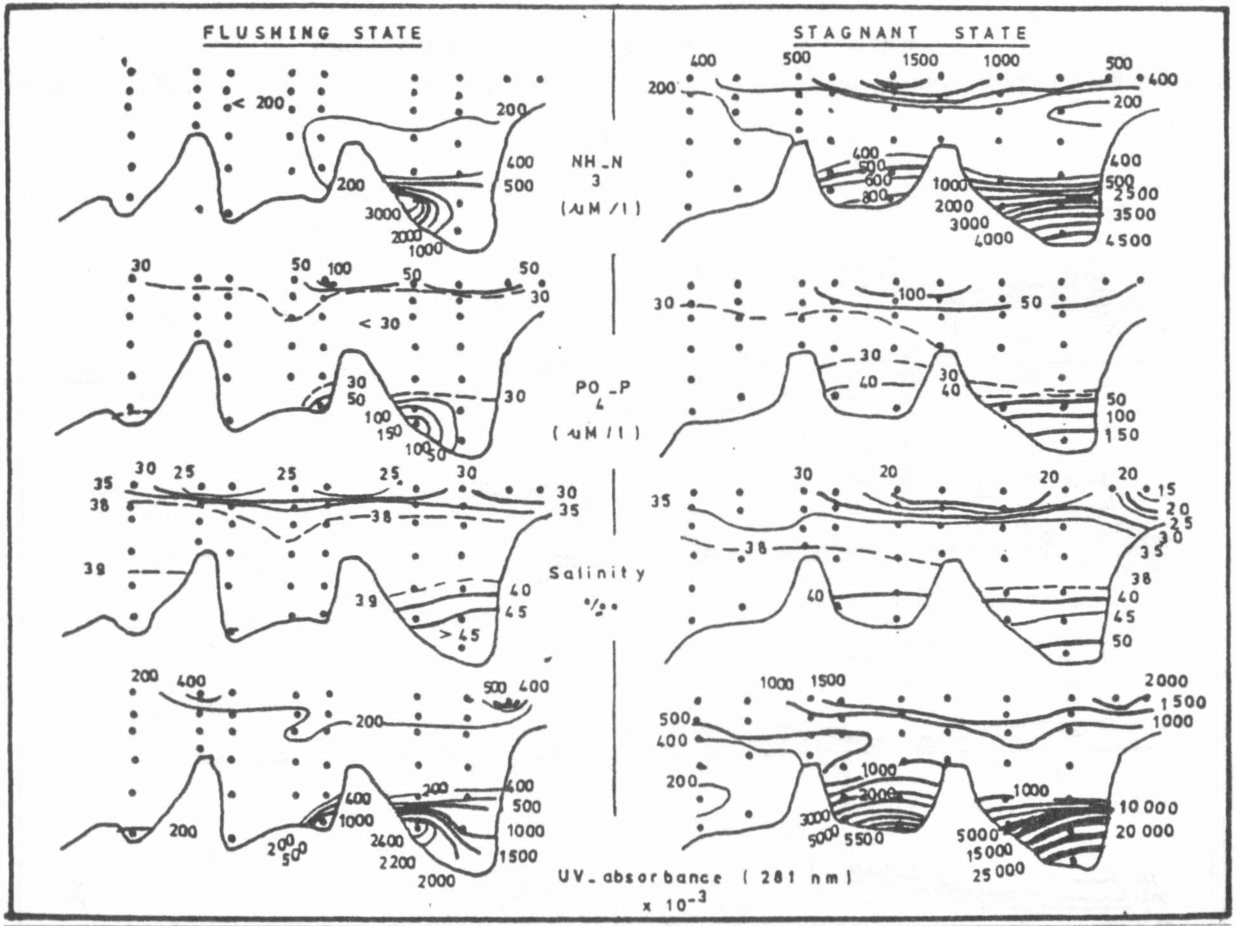

Fig. (5)

Distribution of the UV-absorbance and of the other three hydrochemical elements in a vertical section extending along the longitudinal axis of lagoon Arbaeen, Jeddah at each of its two states.

The vertical distribution for the UV-absorbance and for the other hydrchemical elements in the vertical section extending along the axis of each of the lagoons RA and Ar are shown in Figs. 4 and 5, respectively. Also the vertical distribution for the four studied parameters, during the two states of the lagoons water columns representing the inner and outer basins and in the sea outside the lagoon; at stations 1, 2 and 3, respectively; are shown in Figs. 6 and 7.

Figs. 4a and 5a represent the lagoons RA and Ar, respectively during the stagnant state, where the three distinct water layers were clearly seen. The first, is surface seawater layer diluted with wastewater indicated from the high values of the UV-absorbance; its salinity was less than 35% and contains high values of the phosphate and ammonia. Followed by an intermediate one, which is less diluted with efluent and therfore, is less polluted. It has lower values of the UV-absorbance. The salinity in this water layer ranged between 35 and 40%. The third layer, is the bottom one, which is present only during the stagnant period and disappears at least from the outer basin of the lagoon (Figs. 4b and 5b) during the flushing period in winter. The water in the bottom layer is charactarized by having exceptionally high values not only for the UV-absorbance but also for the other three elements including salinity. Within this layer there was a sharp increase in the value of each parameter with depth (Figs. 4a, 5a, 6a and 7a). The salinity relations with the other elements in this layer contradict those noticed in the upper two layers, where the salinity was inversely related with the other three parameters including the UV-absorbance.

The bottom layer, as can be seen from figures 4 and 5, is the one that lies behind the subsurface shallow sills and eventually will be the layer which is restricted or less exchangeable with the outer seawater, especially during the stagnant period. Actually, this water layer works as a good nutrient trap. As the regenerated nutrient elements like phosphate will be accumulated there after their release during the oxidation processes for the detrital that rains from the upper two layers. The salinity in the bottom layer, however, is greater than 40%, it reach values up to 56% in the water near the surface sediments. These values are considered abnormal as the maximum salinity value ever recorded in the Red Sea water outside the lagoon never exceeds 39.9%. Therefore the source (s) of this saline water is questionable and needs further investigation.

The relationships between the UV-absorbance and each of the other elements in the waters (when the bottom water is not included or included) of the two water colums of the lagoon and for that in the sea outside during the two states are shown in table 2. In general the inverse relation with salinity in the upper two layers was clear and when the bottom water becomes included the relation becomes direct, indicated from the positive sign of (r).

From above, the coincidence between the distribution pattern of the UV-absorbance with those sewage indicating elements, makes one to draw a conclusion that the UV-absorbance itself is also a sewage indicating element. As the UV-absorbance measurement is simpler and more rapid relative to the other chemical elements (phosphate and ammonia) so one will prefere using it for monitoring the dispersion of the waste effluent in the surface water. Not only that but also for the physical classification of the water layers present in these lagoons. Due to these advantages, one can also use this simple technique for determination the exact time for the occurrence of the flushing of the lagoon, through contineous measurement of the UV-absorbance of a water column in its outer basin. This technique, however, in addition to its simplicity is also less costly as it does not need any chemicals for pre-treatment of the water samples before measurement.

Table (1): The relationships (and the correlation coefficient, r) between the UV-absorbance and each of the salinity, phosphate and ammonia in the surface water, at two different wind conditions, for each of the two lagoons Arbaeen and Reayat Al Shabab, Jeddah.

UV-Salinity*	UV-Phosphate	UV-Ammonia	Wind condition
	Lagoon Arbaeen		
n = 24			
A = 40.5	15.7	824	
B = - 10.7	38.4	1256	W-SW wind
r = - 0.85	0.81	0.90	
n = 20			
A = 27.2	17.0	62	
B = - 5.7	77.5	148	NE wind
r = - 0.91	0.85	0.95	
	Lagoon Reayat Al Shabab		
n = 19			
A = 41.4	- 1.8	- 4	
B = - 49.0	61.8	890	N wind
r = - 0.90	0.93	0.83	
n = 19			
A = 43.5	- 23.0	- 197	
B = - 23.2	96.6	730	SE wind
r = - 0.89	0.80	0.91	

* Salinity = UV. B ± A.

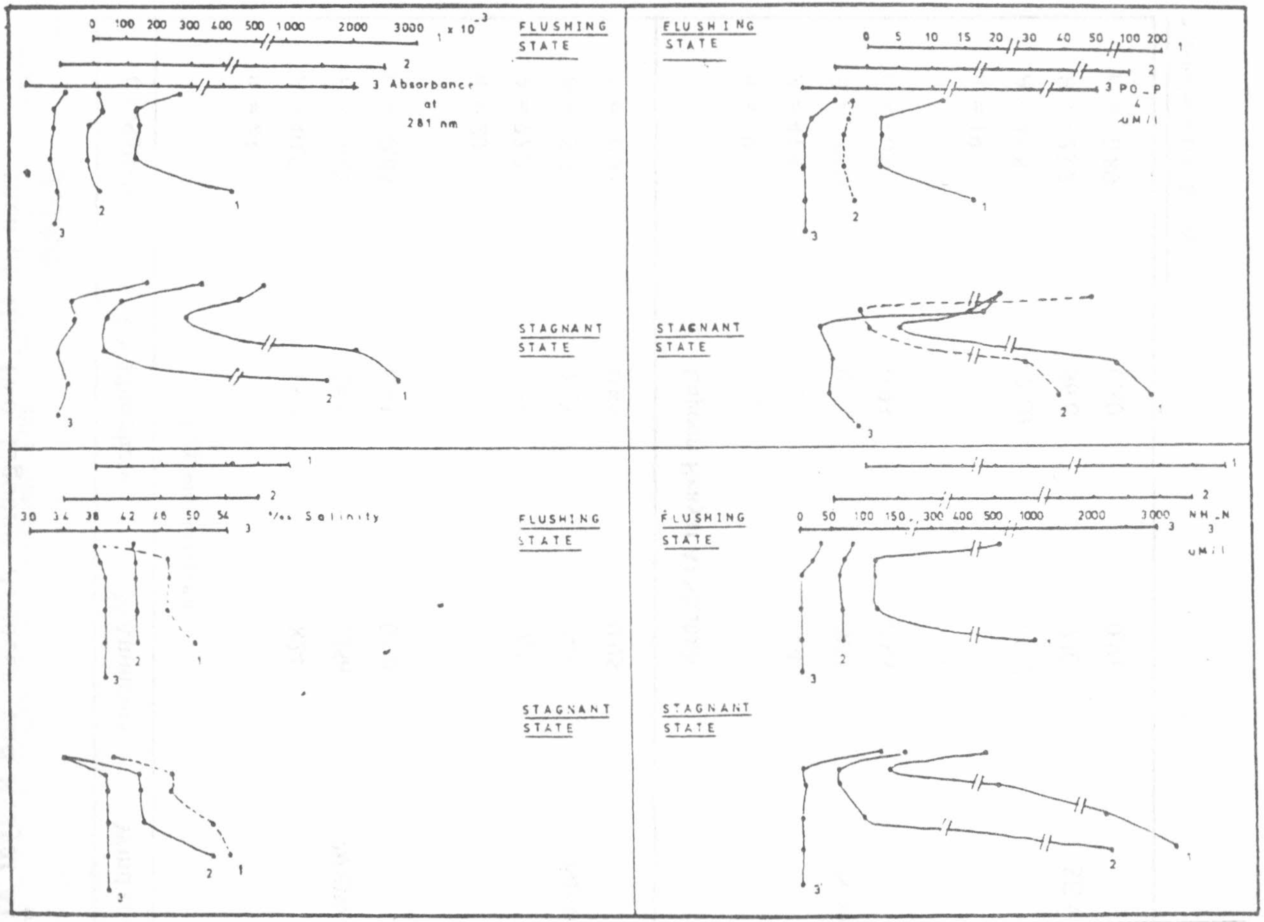

Fig. (6)

Vertical distribution of the UV-absorbance and of the other three hydrochemical elements along the water columns of stations 1, 2 and 3 representing the inner and outer basins and in the sea outsidde the lagoon Reayat Al Shabab, Jaddah.

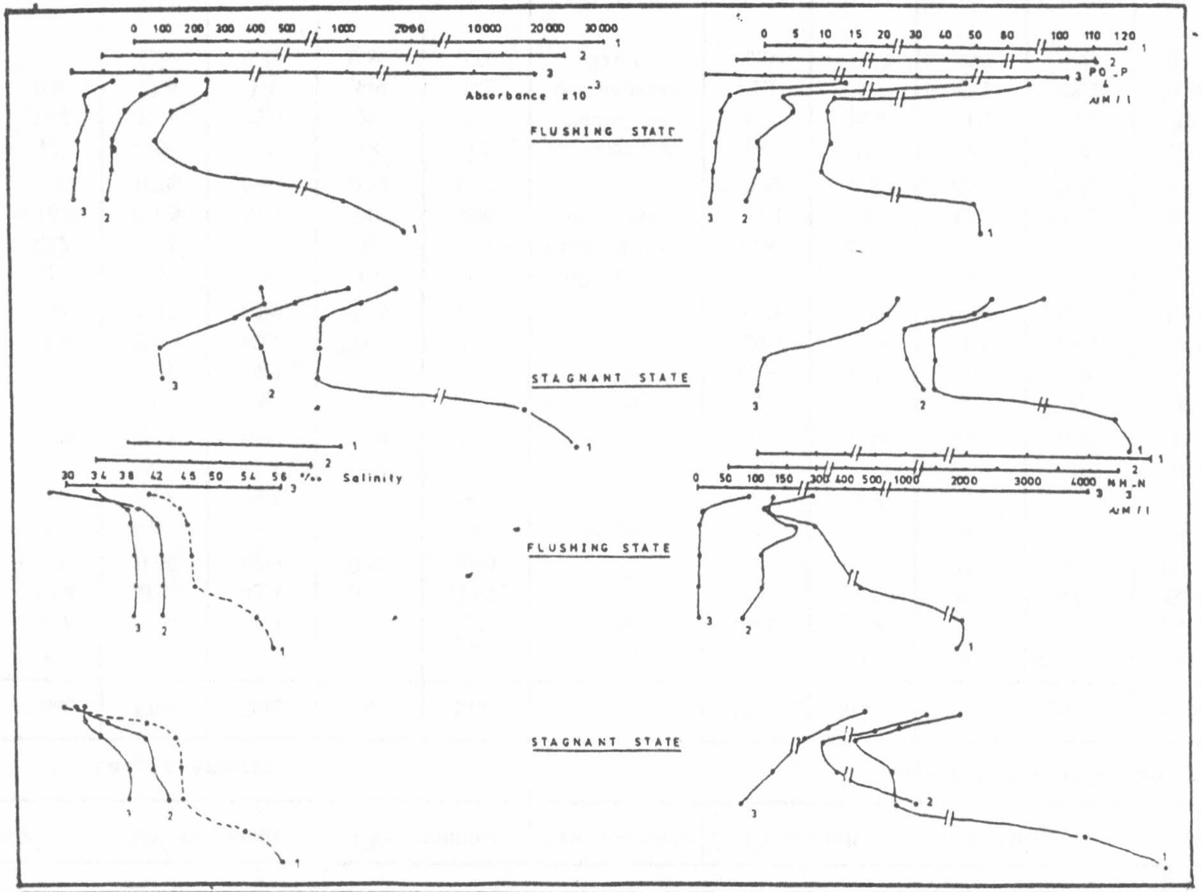

Fig. (7)

Vertical distribution of the UV-absorbance and of the other three hydrochemical elements along the water columns of stations 1, 2 and 3 representing the inner and outer basins and in the sea outsidde the lagoon Reayat Al Shabab, Jaddah.

Table (2): The relationships (and the correlation coefficient, r) between the UV-absorbance and each of the salinity, phosphate and ammonia along the water columns, at the flushing and stagnant states, for each of the lagoons Arbaeen and Reayat Al Shabab, Jeddah.

	UV- Saalinity*		UV- Phosphate		UV- Ammonia		Water column (s)	UV- Salinity		UV- Phosphate		UV- Ammonia	
	Laagoon Arbaeen							Laagoon Reayat Al Shabab					
	Flus.	Stag.	Flus.	Stag.	Flus.	Stag.		Flus.	Stag.	Flus.	Stag.	Flus.	Stag.
n =	4	5	4	5	4	5	Inner basin	4	3	4	3	4	3
A =	40.6	49.7	- 7.9	- 1.7	71	- 211		46.8	38.8	- 6.9	- 13.2	- 622	- 798
B =	- 24.4	- 15.4	202.1	43.4	517	615		- 64.4	- 0.0	70.5	63.9	2316	1870
r =	- 0.77	- 0.99	0.60	0.99	0.85	0.94		- 0.99	- 0.99	0.99	0.99	0.99	0.99
n =	6	5	6	5	6	5	Middle basin	5	3	5	3	5	3
A =	41.3	42.8	- 4.8	13.5	59	86		39.3	44.4	- 0.2	- 52.0	- 1	- 33
B =	- 65.7	- 9.6	230.1	34.8	133	432		- 4.1	- 31.7	21.9	339.7	166	300
r =	- 0.95	- 0.94	0.95	0.93	0.59	0.75		- 0.53	- 0.99	0.82	0.99	0.63	0.96
n =	6	5	6	5	6	5	Outer basin	6	6	6	6	6	6
A =	39.8	41.5	- 2.5	- 9.7	- 9	- 55		41.6	40.6	- 7.9	2.9	56	- 25
B =	- 40.8	- 9.6	208.9	63.1	752	529		- 29.5	- 10.9	104	69.4	747	257
r =	- 0.98	- 0.99	0.97	0.99	0.95	0.93		- 0.78	- 0.99	0.90	0.74	0.81	0.99
n =	16	15	16	15	16	15	All lagoon except the bottom water layer	15	13	16	13	16	12
A =	40.0	43.2	- 2.3	3.7	30	- 24		43.6	41.2	- 3.0	3.8	- 126	- 44
B =	- 35.3	- 10.2	171.5	41.5	246	490		- 47.1	- 14.1	47.1	91.3	345	1
r =	- 0.76	- 0.92	0.76	0.94	0.52	0.85		- 0.93	- 0.80	0.97	0.70	0.97	0.87
n =	20	17	20	17	18	17	All lagoon including the bottom water layer	16	16	16	16	16	16
A =	36.7	34.4	11.1	35.3	26	262		38.7	36.6	- 3.0	11.1	- 126	- 218
B =	6.1	0.6	27.9	3.4	549	142		- 1.1	- 5.1	47.1	38.2	1408	1218
r =	0.55	0.71	0.59	0.85	0.89	0.99		- 0.04	- 0.67	0.97	0.73	0.97	0.96

* Salinity = UV. B ± A.

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