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Some Hydrographic Features of Rabigh Lagoon along the Eastern Coast of the Red Sea

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Abstract. According to Presidency of Meteorology and Environment (PME) of Saudi Arabia with the collaboration of International Union for Conservation of Nature and Natural Resources (IUCN), Rabigh Lagoon is classified as environmentally sensitive area. This is a baseline study for Rabigh Lagoon. It is shallow (1.5 m on average), located at the eastern coast of the Red Sea. Water circulation in the lagoon is dominated by the tidal force. Short flushing time scales can maintain a healthy marine environment.

Introduction

Lagoons occupy about 15 % of the earth's coastal zones (Unesco, 1981). Most of the species live in the lagoons; others colonize them temporarily for the purpose of reproduction. Physical properties of the lagoons are important abiotic factors in ecosystem. The lagoons respond rapidly to any changes in temperature and/or salinity of the water because their areas are small with shallow depth (Smith, 1977). Some physical and chemical aspects of the coastal lagoons of the Red Sea have been studied (Meshal 1987 and El-sayed, 1987).

Rabigh Lagoon is located in the central region of the Red Sea along the Saudi coast (22° 51'-22° 59' N), (Fig. 1). The average depth of the lagoon is 1.5 m and the estimated area is approximately 11.7 km^2. The cross-sectional area of the inlet is about 3×10^3 m^2. Rabigh Lagoon is located close to the nodal zone where the tidal range is small, of about 8 cm (Ahmad *et al.,* 1989).

Fig. 1. Rabigh Lagoon showing the location of the hydrographic station.

Materials and Methods

In this study, two stations were selected. One is at the entrance of the lagoon. The second station is at the middle of the lagoon, because there are no significant changes in the hydrographic properties inside the lagoon. Hydrographic variations (temperature, salinity and current velocities) at selected stations were measured. The duration of the measurements is 13 h to ensure the coverage of the semi-diurnal tidal cycle. CTD was used in measuring water temperature and salinity. Water speed and direction were measured by using direct reading current meter. The measurements were collected at the mid depth which varies during the tidal cycle.

Flushing time of the lagoon was calculated using the equation:

$$\text{Flushing Time (unit of time 2T)} = \frac{V}{3/4\,\alpha\,A\,u\,T}$$

where,

V Total volume of water in the lagoon

α the fraction of the introduced volume which is exchanged with seawater during each tidal cycle

A area cross-section

T duration of out or inflow

u current speed

Based on Zimmerman (1981), α for Rabigh Lagoon is taken as 0.4.

Results

Field results obtained during the project are presented (Fig. 2-23). These results contain measurements of sea water temperature, salinity and current meter data. Monthly flushing times are presented in the discussion. These data were collected during the period between April to August over spring-neap tidal cycle.

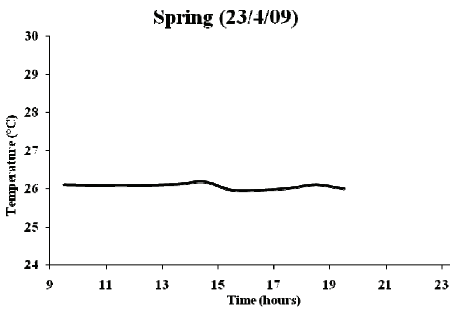

Fig. 2. Temperature variation over a tidal cycle on the 23rd April 2009 at spring tide.

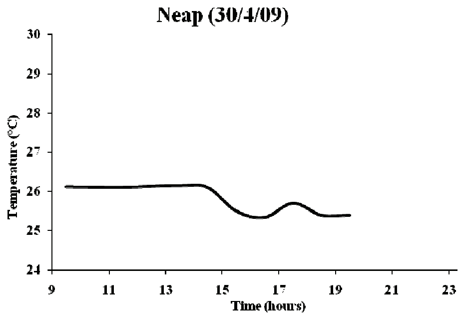

Fig. 3. Temperature variation over a tidal cycle on the 30th April 2009 at neap tide.

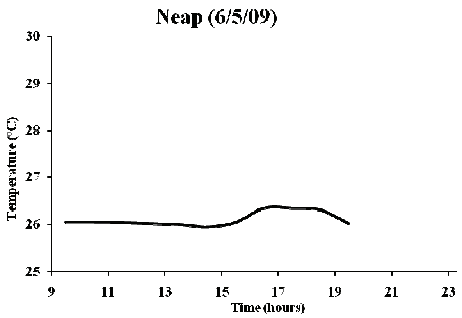

Fig. 4. Temperature variation over a tidal cycle on the 6th May 2009 at neap tide.

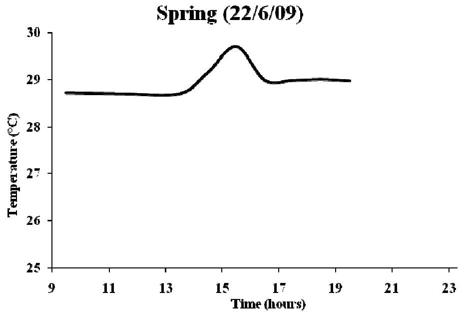

Fig. 5. Temperature variation over a tidal cycle on the 22nd June 2009 at spring tide.

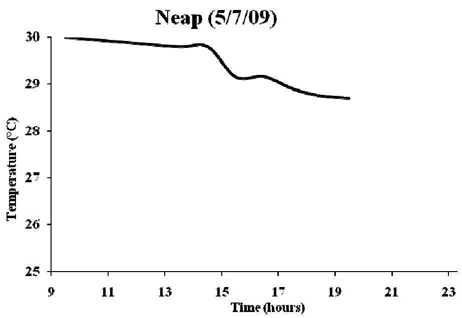

Fig. 6. Temperature variation over a tidal cycle on the 5th July 2009 at neap tide.

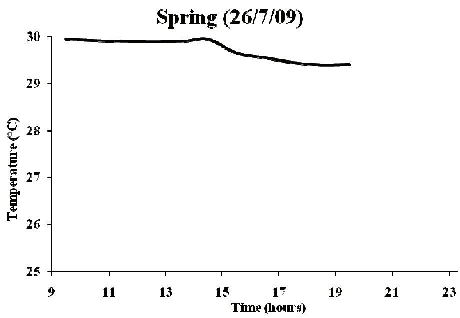

Fig. 7. Temperature variation over a tidal cycle on the 26th July 2009 at spring tide.

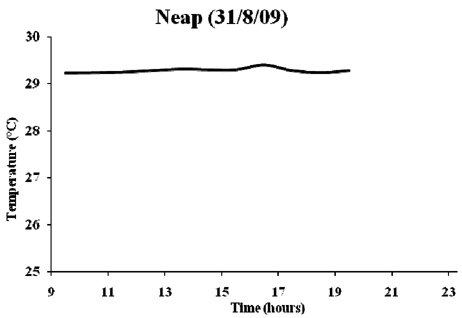

Fig. 8. Temperature variation over a tidal cycle on the 31st August 2009 at neap tide.

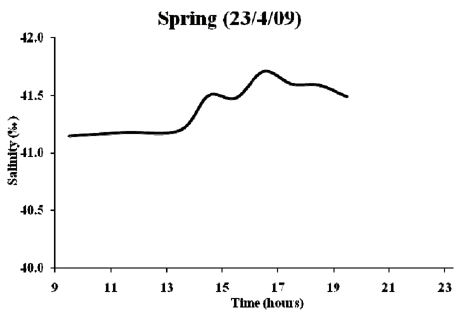

Fig. 9. Salinity variation over a tidal cycle on the 23rd April 2009 at spring tide.

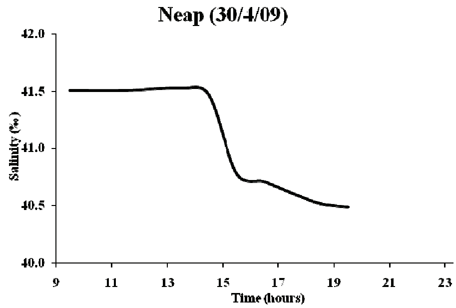

Fig. 10. Salinity variation over a tidal cycle on the 30th April 2009 at neap tide.

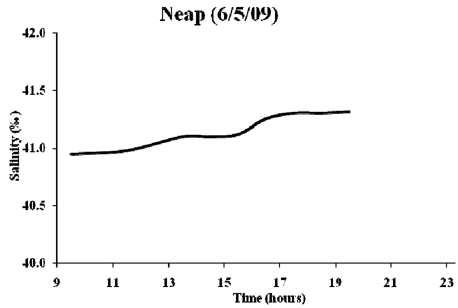

Fig. 11. Salinity variation over a tidal cycle on the 6th May 2009 at neap tide.

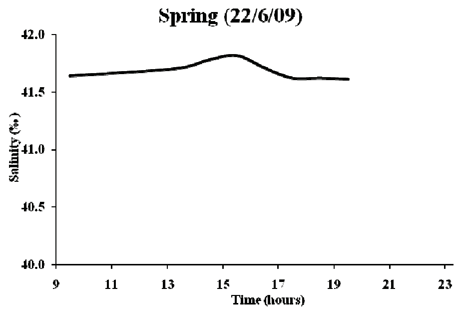

Fig. 12. Salinity variation over a tidal cycle on the 22nd June 2009 at spring tide.

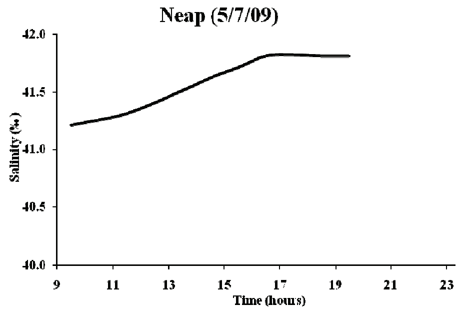

Fig. 13. Salinity variation over a tidal cycle on the 5th July 2006 at neap tide.

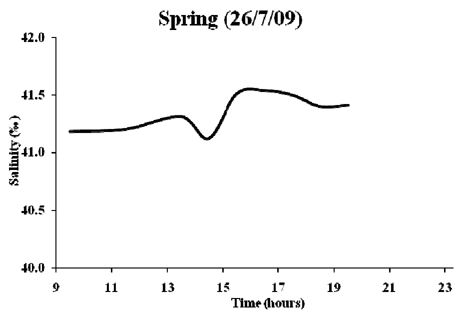

Fig. 14. Salinity variation over a tidal cycle on the 26th July 2009 at spring tide.

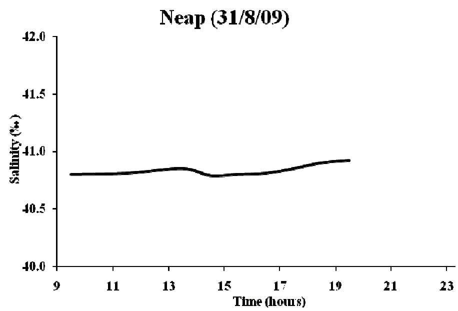

Fig. 15. Salinity variation over a tidal cycle on the 31st August 2009 at neap tide.

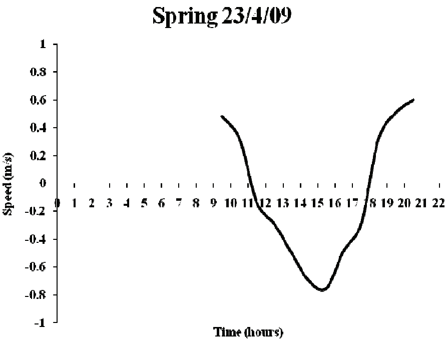

Fig. 16. Current velocity variations over a tidal cycle on the 23rd April 2009 at spring tide.

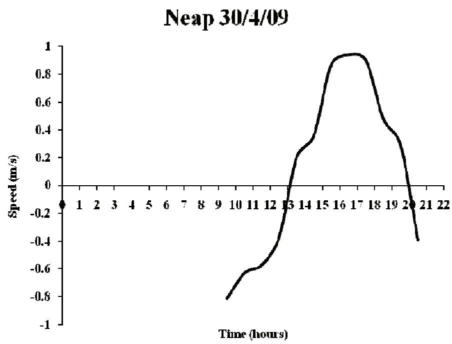

Fig. 17. Current velocity variations over a tidal cycle on the 30th April 2009 at neap tide.

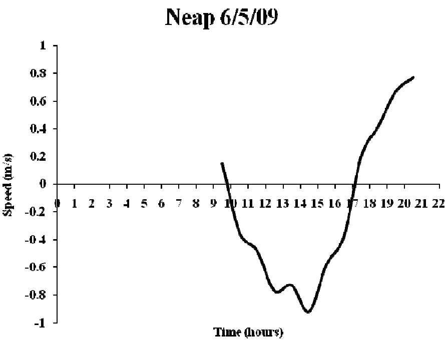

Fig. 18. Current velocity variations over a tidal cycle on the 6th May 2009 at neap tide.

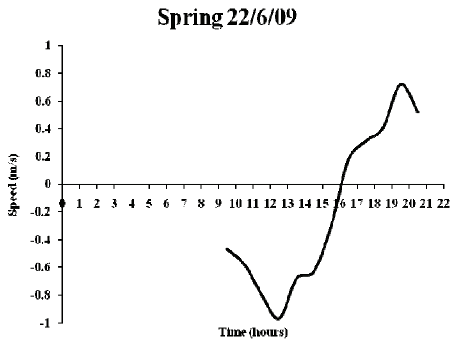

Fig. 19. Current velocity variations over a tidal cycle on the 22nd June 2009 at spring tide.

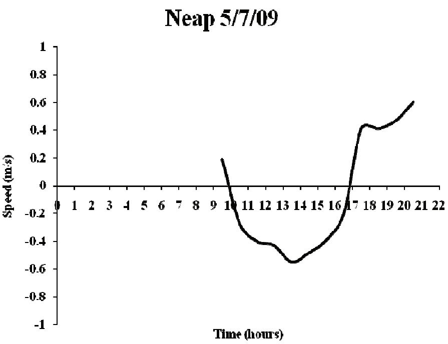

Fig. 20. Current velocity variations over a tidal cycle on the 25th July 2009 at neap tide.

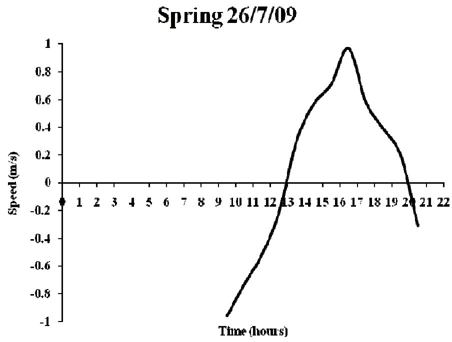

Fig. 21. Current velocity variations over a tidal cycle on the 26th July 2009 at spring tide.

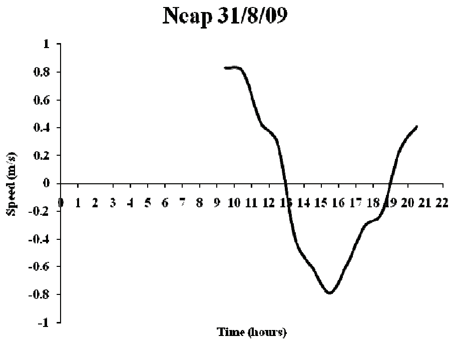

Fig. 22. Current velocity variations over a tidal cycle on the 31st August 2009 at neap tide.

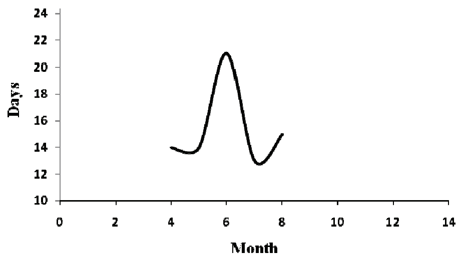

Fig. 23. Flushing Time of Rabigh Lagoon.

Discussion

Temperature variations with time at the mouth of the lagoon are shown in Fig. 2-8. The collected data show that the water temperature varies between a minimum of 25.4°C during April and a maximum of 29.9ºC during July. Salinity variations with time at the mouth of the lagoon are shown in Fig. 9-15. Data were collected during the period between April to August over spring-neap tidal cycle. Water Salinity varies between 40.45 psu in April and 41.82 psu in August.

Tides in the Indian Ocean do not enter the Red Sea directly. Therefore, there is no progressive wave which moves through Bab Al-Mandab and raises and lowers the water level within the Red Sea. Instead there is local oscillatory tide of small amplitude and semi-diurnal period which results in high water at the other end. The time difference between successive high waters or low waters at any location is approximately 12h and 20 min. The Range of the tide is greatest at the two ends averaging about 0.6m near the Gulf of Suez and about 0.9m in the south. There is a difference in the range during spring and neap times. The circulation of a coastal lagoon is highly variable in both space and time. Figures 16-22 show current meter data over one tidal cycle at the lagoon mouth. Positive sign is flood and negative sign is ebb. The current velocity varies between 0.14 $m.s^{-1}$ and 0.97 $m.s^{-1}$ with an average velocity of 0.5 $m.s^{-1}$. The dominant direction is 215º.

The flushing time is defined as the time it takes the water entering the Rabigh Lagoon from the Red Sea to completely flush the lagoon. It is estimated at 14, 14, 21,13 and 15 days in April, May, June, July and August respectively (Fig. 23). The average flushing time is 15.4 days. It was clear that, the flushing time did not depend on the spring-neap cycle of tides. Therefore, the inflow and outflow not only depend on the tide but are also affected by the direction and force of the wind. These non-tidal fluxes do not show any periodicity and may be thought of as a random superposition of oscillating discharges of different periods and amplitudes. Sub-tidal frequencies may play an important role in the displacement spectrum (Smith, 1977, 1978) sometimes having even greater influence than the tides.

Conclusions

The measured data were taken place during spring neap tide and each trip covered one complete semi-diurnal tidal cycle (13 h). Vertical profile of temperature and salinity showed that the water column is well-mixed. Temperature and salinity of the lagoon are relatively high compared to the open sea. The lagoon is dominated by the tidal currents which is controlling the water circulation. Flushing time calculation showed the renewal time scale for the lagoon water is reasonable to keep the rich marine ecosystem in the area.

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دراسة بعض الظواهر الهيدروجرافية لبحيرة رابغ، الساحل الشرقي للبحر الأحمر

علاء البركاني

كلية علوم البحار–جامعة الملك عبدالعزيز–جدة

المملكة العربية السعودية

المستخلص. تعتبر منطقة بحيرة رابغ من المناطق الحساسة بيئيًا، وذلك في تصنيف الرئاسة العامة للأرصاد والبيئة السعودية ومنظمة اليونسكو، لذلك تمت هذه الدراسة والتي أظهرت نتائجها أن حركة المياه في بحيرة رابغ تكون بصفة عامة بسبب قوة المد والجزر، وأن زمن تجدد المياه في البحيرة كافية للحفاظ على التوازن البيئي للمنطقة.