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Periodicity of suspended sediment concentrations in the River Tigris at Baghdad identified using short interval sampling

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Abstract Samples were collected at 2-h intervals from the River Tigris at two stations upstream (Fahama) and downstream (Jadiriyah) of the city of Baghdad for seven days. Suspended sediment concentrations were determined and their periodicity was investigated. Agricultural activity north of Baghdad increased the concentration of suspended sediments causing short periodicity cycles. The deposition of sediment along the reach of the River Tigris within Baghdad city causes a decrease in concentrations and diminishes the short periodicity cycles downstream

La periodicité de la concentration en sédiments suspendus du Tigre à Bagdad déterminée à partir d'échantillonages à court intervalle de temps

Résumé Des échantillons d'eau sont prélevés toutes les deux heures pendant sept jours à deux stations de jaugeage sur le Tigre à Bagdad. La première station est située en amont de la rivière au nord de Bagdad (Fahama), tandis que la deuxième est située en aval (Jadiriyah). Les concentrations des sédiments suspendus sont déterminées et leur periodicité est étudiée. De hautes concentrations sont observées en amont parallèlement à une courte périodicité. Celles-ci sont en rapport avec des activités agricoles importantes. Les conditions sont différentes au sud par suite du dépôt de sédiments à l'intérieur de l'agglomération de Bagdad. La concentration diminue et l'importance des cycles à courte périodicité diminue.

INTRODUCTION

The River Tigris at Baghdad drains an area of 134 000 km^2 and has a mean daily discharge of 1176 $m^3 s^{-1}$. The objective of the research reported here was to investigate the short-term variation of suspended sediment concentrations in the river at Baghdad. Water samples were collected from two stations. The first was situated at Fahama, upstream of Baghdad, while the second was at Jadiriyah within the southern part of Baghdad (see Fig. 1). The sampling programme was carried out for seven days (31 August–6

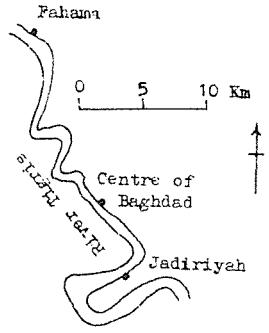

Fig. 1 Location map.

September 1987) and samples were collected at 2-h intervals using an automatic sampler.

ANALYTICAL PROCEDURES

The suspended sediment concentrations of the samples were determined by vacuum filtration. The individual values of concentration (x), mean ($\bar{x}$) and standard deviation (s) were calculated for each station and used in statistical procedures to evaluate their periodicities.

The measure of time dependence of each series was evaluated by an alternative estimate of the autocorrelation function (r_k) where k is the lag ranging from 0 to $N - 1$. Then the correlogram was drawn using r_k *vs.* k with the confidence limits set at the 99% and 95% levels of significance (see Fig. 2).

The periodicity was determined using harmonic analysis and the Fourier coefficients A and B for each harmonic number were therefore calculated to determine the amplitude and phase shift for each harmonic. Finally the percentage contribution of each harmonic to the total variance was found and Fisher's test (1929) was used to detect the significance of the periodicity (including the long term component). The number of harmonics taken was 42 ($N/2$) and the period of each harmonic was found in hours (for the study period $N = 84$).

Power spectral analyses was used as another approach to the investigation of periodicity. The Fourier transform values for each lag were calculated to determine its percentage contribution, and the normal frequencies and the periodicity band corresponding to each lag in hours were then found. The number of lags was limited to 16 so that it would not exceed 20% of the number of observations. For further details of the above statistical procedure the reader is referred to the work of Chow (1964), Yevjevich, (1972), UNESCO-WHO (1978), Langgath & Voight (1980) and Al-Ansari *et al.* (1987).

RESULTS AND DISCUSSION

Upstream of Baghdad at the Fahama station, the suspended sediment concentrations showed a mean value of 182.5 mg l^{-1} and the maximum and

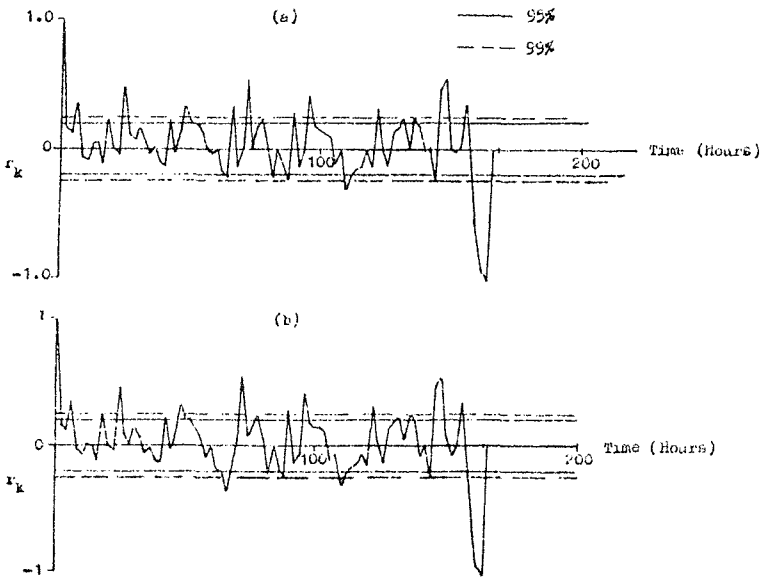

Fig. 2 Correlograms for the Fahama (a) and Jadiriyah (b) stations.

minimum concentrations were 390 and 16.6 mg l^{-1} respectively, and the variance 9751. Lower concentration values were observed downstream at the Jadiriyah station. The mean reached 86.6 mg l^{-1} while the maximum and minimum were 203 and 13.3 mg l^{-1}, with a variance of 1550. Furthermore, the variation of concentrations through time showed a greater fluctuation at Fahama than that at Jadiriyah (see Fig. 3). At both localities, the time trend proved to be insignificant using the *t*-test.

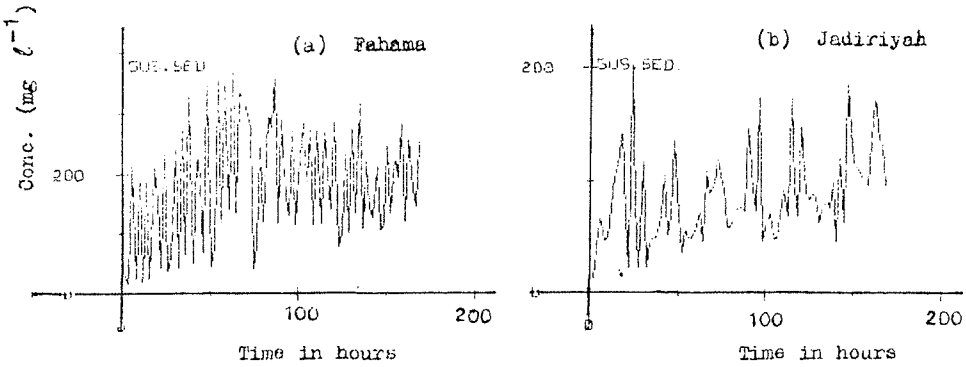

Fig. 3 The variation of suspended sediment concentrations through time at the Fahama (a) and Jadiriyah (b) stations.

The correlograms (Fig. 2) evidenced a uniform short term periodicity at Fahama while a non-uniform periodicity was evident at the Jadiriyah station.

Harmonic analyses at both the 95% and the 99% significance levels for

the Fahama station indicated 4 h and 4.8 h periodicities having percent contributions of 47.9 and 36.1 respectively. Power spectral analyses confirmed the above results, with the 4.2–5.0 and 4.6–5.4 h bands having relatively the maximum percent contribution of 32.9 and 24.9 respectively. Despite the fact that none of the results of the harmonic analyses for the Jadiriyah station showed any significant periodicity, the 24 and 6 h periods showed relatively the highest percent contribution (14.9 and 14.1 respectively). Power spectral analyses also showed that the 5.4–6.6 and 20–60 h bands had relatively the maximum percent contribution of 23.1 and 17.6 respectively (see Table 1 and 2).

Table 1 *Results of harmonic analyses for the Fahama and Jadiriyah stations for cycles having more than 5% contribution*

Fahama station:				*Jadiriyah station:*			
Harmonic no.	*Amplitude**	*Contribution (%)*	*Period (h)*	*Harmonic no.*	*Amplitude**	*Contribution (%)*	*Period (h)*
7	*1107*	*5.67*	*24*	*5*	*169*	*5.45*	*33.6*
28	*2532*	*12.98*	*6*	*7*	*462*	*14.91*	*24*
35	*7054*	*36.17*	*4.8*	*26*	*205*	*6.60*	*6.46*
42	*4678*	*47.97*	*4*	*28*	*437*	*14.1*	*6.0*

**Critical values at confidence levels of 95% = 2953.7 and 469, and at 99% = 3590.8 and 571, for Fahama and Jadiriyah respectively.*

Table 2 *Results of power spectral analyses for the Fahama and Jadiriyah stations for bands having more than 10% contribution*

Fahama station:				*Jadiriyah station:*			
Lag no.	*Contribution (%)*	*Period (h): Nominal*	*Range*	*Lag no.*	*Contribution (%)*	*Period (h): Nominal*	*Range*
10	*17.8*	*6*	*5.4-6.6*	*2*	*17.6*	*30*	*20-60*
12	*24.9*	*5*	*4.6-5.4*	*3*	*12.1*	*20*	*15-30*
13	*32.9*	*4.6*	*4.2-5.0*	*10*	*23.1*	*6*	*5.4-6.6*
14	*12.8*	*4.2*	*4.0-4.6*				
15	*19.4*	*4.0*	*<4-4.2*				

From the above it is clear that the relatively high concentration of suspended sediment in the Tigris water at Fahama is due to the intensive agricultural activity upstream. This fact was confirmed by the statistical cycles of the periodicity analysis, where short range periodicity cycles were more significant due to a continuous supply of sediment from nearby areas which are locally important sources of fine grained sediment (Coleman & Scatena, 1986). It is believed that some of the sediment is deposited on the bed of the river between Fahama and Jadiriyah. This fact is confirmed by the relatively low suspended sediment concentrations at Jadiriyah and the large number of islands within the reach between the two stations. Furthermore,

the statistical results obtained for Jadiriyah failed to show any significant periodicity thereby confirming the above suggestion.

CONCLUSIONS

Intense agricultural activity upstream of the River Tigris at Fahama increases the movement of sediment to the river. This contribution was confirmed by the statistical procedures which identified a short-term periodicity for the station. Deposition of the sediment and bank protection of the river downstream decreased the concentration of sediment and no significant periodicity was identified.

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