

Short Communication

Computation of diffusion coefficients for waters of Gauthami Godavari estuary using one-dimensional advection-diffusion model

D Jyothi, T V Ramana Murty, V V Sarma & D P Rao

National Institute of Oceanography, Regional Centre, 176, Lawson's Bay Colony, Visakhapatnam 530 017, A P, India

Received 20 October 1998, revised 17 April 2000

An analysis of salinity, salt budget and diffusion coefficients based on the salinity data of Gauthami Godavari estuary for three different months (Nov. '95 Jan. '96, April '96) representing different seasons has been carried out. Diffusion coefficients vary quite randomly with distance between 90 - 4050 m²/s for consecutive months during Nov. '95 - Jan. '96 and between 10 - 869 m²/s for Jan. '96 - April. '96. The mean values of diffusion coefficients are found to be 1510 m²/s for consecutive months during Nov. '95 - Jan. '96, 174 m²/s for Jan. '96 - April '96 and are attributed to the river run-off. The undulations in diffusion coefficients reflect the topographic features. The estuarine salt budget shows an increase of salt content by 62% from Nov. '95 - Jan. '96 and 32% from Jan. '96 - April. '96

Pollutants cause serious concern to the near-shore and estuarine environment under certain flow conditions. As the pollutant load on the estuary increases, the water quality may deteriorate rapidly and therefore the scientific interests are centered on the analysis of water quality. The pollutants will be subjected to a number of physical, chemical and biological processes in the estuary ultimately resulting in their dilution and dispersion. This process can be mathematically modelled to fulfill the pre-operational evaluation of discharge pollutants or conducting continuous field experiments. As a case study we have applied one-dimensional advection-diffusion model for the waters of Gauthami Godavari estuary to determine the axial diffusion coefficients and thereby to predict the impact assessment.

The study area (Fig. 1) is the lower most 32 km stretch of Gauthami Godavari and the downstream point (Fig. 1) is Bhairavapalem where this debouches into the Bay of Bengal. Water samples were collected at 21 stations using Niskin bottles along the axis of the estuary for the months Nov. '95, Jan. '96 and April '96. Salinity was estimated using Kundsens titration method¹ with an accuracy of $\pm 0.01 \times 10^{-3}$. Depth at the stations was measured using a portable echo sounder. The average depth along the 32 km stretch varied from 12 m at the mouth to 2 m at the head of estuary. The tidal range in the estuary² is about 1.5 m. The rainfall shows marked time variability corresponding to the onset and retrieval of the monsoon^{3,4}. Freshwater discharge data were taken

from Godavari Head Water Division, Dowalaswaram, Andhra Pradesh. The runoff into the estuary was 600 m³/s for Nov '95, 40 m³/s for Jan'96 and 20 m³/s for April '96.

The axial variation of the salinity in the estuary has a wide range in the present study. Higher salinity (up to 23×10^{-3}) was noticed at the mouth and decreased sharply to $0.1-1.12 \times 10^{-3}$ at the head of the estuary during the entire study period. The variation of the salinity along the axis of the estuary during different months is shown in (Fig. 2). Vertical salinity gradients were slightly higher (15×10^{-3}) at the mouth of the estuary during November when compared to that of Jan. '96 (14×10^{-3}) and April '96 (12×10^{-3}). The

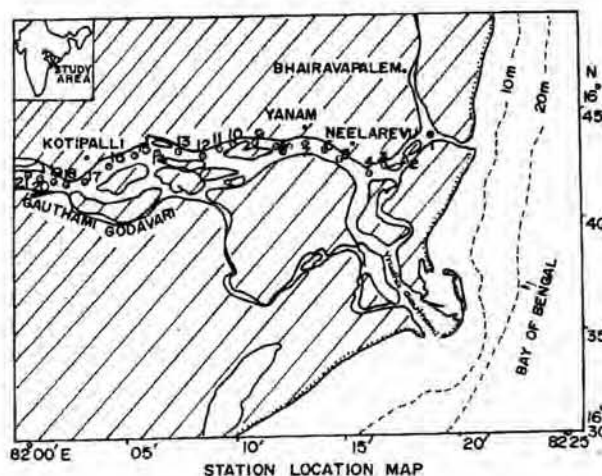


Fig. 1—Station location map.

salinity of the estuary changes from month to month depending on river runoff conditions. According to the salinity structure, the estuary is well-stratified (less mixing) during Jan '96, partially stratified (up to 20 km from mouth) during Nov. '95 and vertically well mixed during April '96. The intertidal volume of the estuary depends on the phase of the tide i.e., varies from spring to neap tide.

Salt budget i.e. the total salt in the estuary, (S_{tot}), is given by

$$S_{tot} = \int_x^{\infty} S(x) A(x) dx$$

where A is the cross-sectional area. The upper limit of the integral is far upstream end where salinity

$[S(x)]$ vanishes. The seasonal variation of total salinity S_{tot} at each station from mouth to head of the estuary is given in Fig. 3. The total salinity content decreases from mouth to head of the estuary during three seasons. Comparatively very less salt content observed in all the seasons from 20 km to 32 km from mouth of the estuary for the above seasons. The seasonwise total salt content for the whole estuary increases from Jan. '96 ($1.9 \times 10^9 / m^3$) to Nov. '95 ($3.1 \times 10^9 / m^3$) and to April '96 ($4.1 \times 10^9 / m^3$). Thus an increase of 63% salt content from Jan. '96 to Nov. '95 and 32% from Nov. '95 to April '96 is noticed in the present observation.

For estimation of the horizontal diffusion coefficient along the channel axis (x), the following equation was adopted⁵

$$\partial/\partial t \int_x^{\infty} S(x) A(x) dx = K A \partial S/\partial x + RS$$

where K , R , t , A are the axial diffusion coefficient, river runoff, time period and cross sectional areas respectively. Here, assumption has been made that the observation time is much greater than the mixing time⁶. In view of this, one can easily adopt the one-dimensional advection diffusion model. Averages of $\partial S/\partial x$, R , S , are also used as input parameters in the above one-dimensional advection-diffusion model. The above input parameters are seasonally integrated⁷ for the 90 days period starting from Nov. '95.

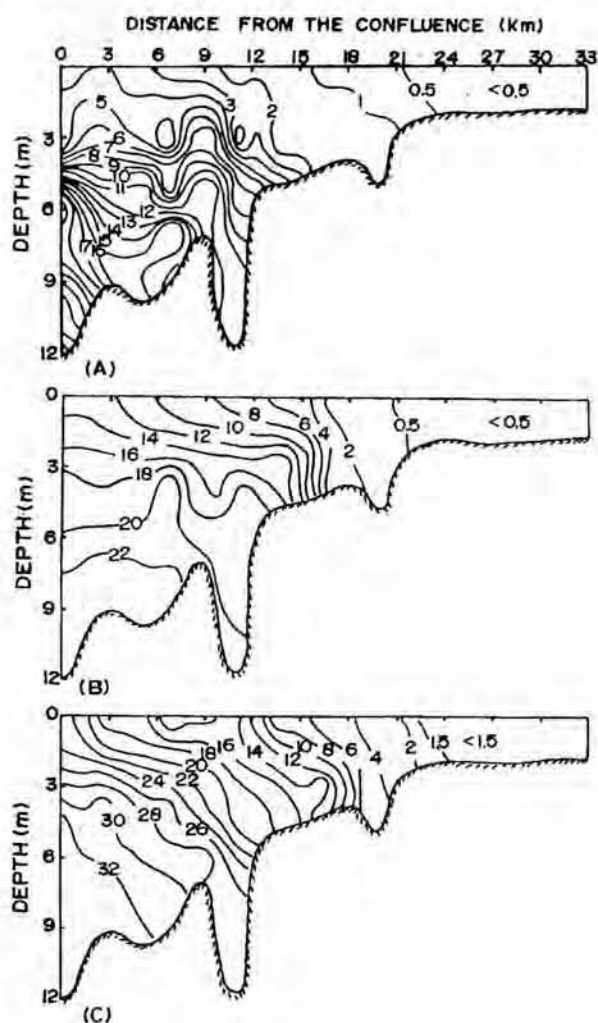


Fig. 2—Variation of salinity along the longitudinal stretch of Gauthami Godavari estuary during different seasons. A) Nov. '95 B) Jan. '96, c) April '96

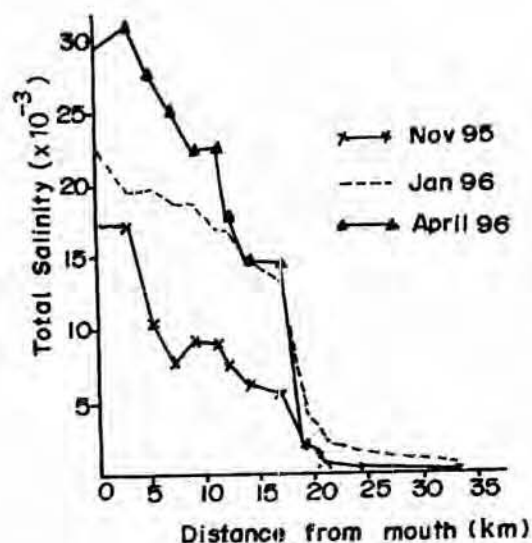


Fig. 3—Seasonal variation of the total salt in the estuary

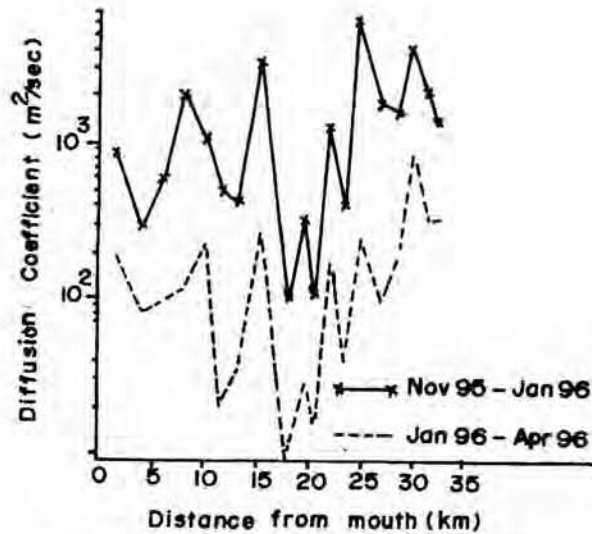


Fig. 4—Horizontal diffusion coefficient K (m^2/s).

Diffusion coefficient vary, quite randomly with range between 90-4050 m^2/s for consecutive months of Jan. - Nov. and between 10-869 m^2/s for Nov. - April. (Fig. 4). The mean value of these coefficients are found to be 1510 m^2/s and 174 m^2/s for consecutive months of Nov. '95 - Jan. '96 and Jan. '96 - April. '96 respectively. Undulations in diffusion coefficients reflect the bottom topography.

Regression equations for the above two consecutive seasons have been established for diffusion coefficients, where Y_i is the function of distance from the mouth. These equations are given below.

$$Y_1(x) = 62.7073 x + 352.741 \text{ (Nov. - Jan.)}$$

$$Y_2(x) = 8.55283 x + 17.5469 \text{ (Jan. - April)}$$

These equations would be more useful to get diffusion coefficients for any point along the channel axis, which in turn, helps to compute the concentration of pollutant along the axis of estuary. Thus these studies will help to predict the impact assessment.

One of the authors (DJ) thanks the Department of Ocean Development for the award of fellowship. Authors are thankful to Dr. E.Desai and Dr.K.S.R.Murthy, for giving constant encouragement throughout the work.

References

- 1 Grasshoff K, Ehrhardt M & Kremling K, *Methods of seawater analysis*, (Verlag Chemie, Weinheim, Germany) 1983, pp. 250.
- 2 Reddy B S R & Ranga Rao V, Flushing and dispersion characteristics of Godavari estuary under different river discharge conditions *Indian J Mar Sci*, 22 (1993) 111-114.
- 3 Ranga Rao V, Ramana Y V & Reddy B S R, Salinity and current distribution in the Godavari estuary, east coast of India, *Indian J Mar Sci*, 17 (1988) 14-18.
- 4 Rama Sarma D V, *Hydrography of the Godavari estuary*, Ph.D thesis, Andhra University, India, 1965.
- 5 Shetye S R & Murty C S, Seasonal variation of the salinity in Zuari estuary, Goa, India, *Proc Indian Acad Sci (Earth Planet Sci)*, 96 (1987) 249-257.
- 6 Fischer H B, John List E, Koh R C Y, Imberger J & Brooks N H, *Mixing in inland and coastal waters* (Academic Press, Inc Orlands, Florida) 1979, pp 483.
- 7 Ralson A & Wilf H S, Spline functions, interpolation and numerical quadrature, in *mathematical methods for digital computers*, edited by T N E Greiville (John Wiley, New York), 1966, pp 153-293.