CHAPTER 52

RATE OF SEDIMENT MOTION USING FLUORESCENT TRACER

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ABSTRACT

A rational design of coast protection works requires a knowledge of the behaviour of beach under natural conditions. The estimation of the littoral drift rate is thus a necessary preliminary to the analysis of the cause of beach erosion and the evaluation of the effect of projected remedial measures.

This study presents a method for estimating the rate of littoral drift along sandy beaches. The derived method is based on the use of fluorescent tracer, and observing the tracer concentration reaching the different profiles along the study zone, as function of location and time of sampling. Steps followed in estimating the rate of littoral drift, using the derived formula, are included in this paper.

INTRODUCTION

It is a known fact that sand movement along beaches is caused primarily by the action of littoral current systems generated in the swash zone and shoreward of the breaking point by wave breaking at an angle to the beach. Attempts to study beach drifting quantitavely have been relatively few because of the complexity and expense of such study. Studies of this kind required not only the observation of sand movement but also simultaneous recording of the waves, currents and various parameters contributing to the sediment motion. Research and study into problems of sand drifting followed three principle lines :

1. Studies of erosion or accretion in the vicinity of littoral barriers.
2. Model studies of the behaviour of artificial beaches in laboratory wave tanks.
3. Tracer studies of the movement of marked particles on natural boaches.

The first method of using erosion-accretion studies have been the most successful in producing quantitative data in the past. The method necessitates periodical surveying of the area and oontinuous recording of the different wave and current parameters.

Model studies have determined many useful details about the mechanism of sediment transport, but because of the difficulties of assessing the influence of scale effect and of reproducing the complex pattern of waves, currents and sediment particles, this technique can reveal little about the rate of sediment movement at a given area. Studies of sediment transport using fluorescent tracer have been conducted by many investigators (1,2,3,4)(*). Most of these studies are concerned with the attempt to advice a simple, unexpensive technique for marking sand and gravel with fluoresoent dye while very few studies (2) have used tracers in estimating rates of littoral drift.

The present study is an attempt to develop a simple method for estimating the rate of littoral drift along eroding beaches using fluorescent tracer technique. The method was tried for Ras-El-Bar eroding beach along the Northern Coast of Egypt. Both the rate and direction of sediment motion at different points along the beach were estimated.

THEORETICAL CONSIDERATIONS

Consider a mobile bed over which the average intensity of sediment discharge Q, varies from one section to the other along the bed. The value of Q can be determined by injecting a known quantity of tracer sediment, at a reasonable rate, and then observing the surface tracer concentration along different lines normal to the flow direction. Tracer sampling should continue from the time the tracer starts to reach a given sampling line till its complete disappearance from the study reach.

Before dealing with the mathematical derivations of the sediment equation, it may be useful to illustrate the different variables and elements relevant to these derivations, as given in Figure (1), where :

Q = average rate of littoral drift per unit width at any distance X from the injection point.

q = average rate of tracer per unit width reaching any sampling section at any distance X from the injection point.

C = concentration by weight of tracer in the sediment at any sampling point.

dy = length of a typical element of any sampling line.

L = length of any sampling line along which tracer is found.

(*) For referenoes see page 19 please.

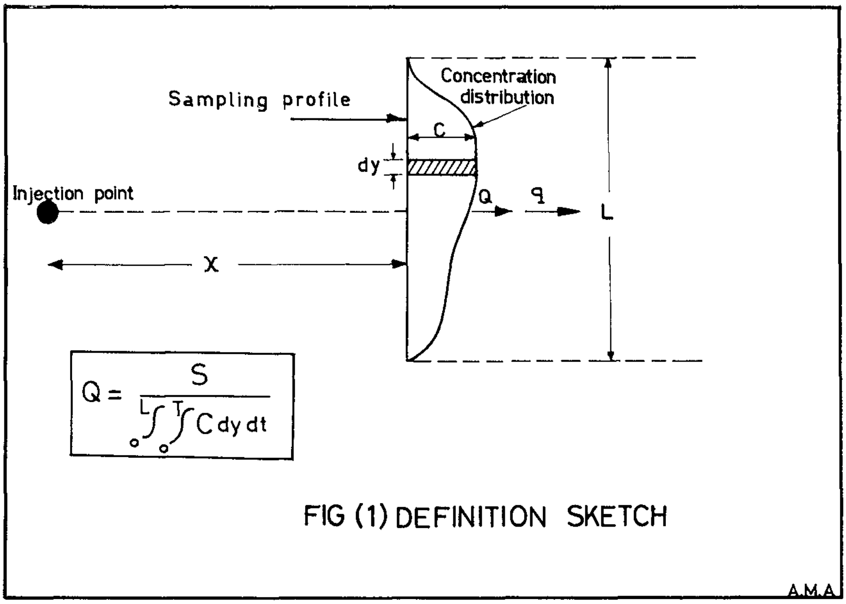


FIG (1) DEFINITION SKETCH

Now, by definition :

$$C = \frac{q}{Q} \quad \ldots\ldots \quad (1)$$

$$\text{or} \quad q = C\,Q \quad \ldots\ldots \quad (2)$$

At any time, t , the amount of tracer, ds , contained in any sampling section may be calculated as follows :

$$ds = \int_0^L q \; dy \quad \ldots\ldots \quad (3)$$

$$\text{or} \quad ds = \int_0^L C\,Q\,dy \quad \ldots\ldots \quad (4)$$

Now, the total amount of tracer S_x , which passes any sampling section during any period, T , may be written as :

$$S_x = \int_0^L \int_0^T C \; Q \; dy \; dt \quad \ldots\ldots \quad (5)$$

where, T is the time between the first arrival of tracer to any sampling section and its complete disappearance.

Equation (5) may be written as :

$$S_x = Q\int_0^L \int_0^T C \; dy \; dt \qquad (6)$$

and hence the average rate of littoral drift Q may be calculated as :

$$Q = \frac{S_x}{\int_0^L \int_0^T C \; dy \; dt} \qquad (7)$$

The use of equation 7 should be governed by the following conditions :

1. If the littoral drift has a unique direction all over the study period, then S_x should equal to the total amount of tracer sand, S, used for injection.

2. If the littoral drift has a minor direction for a small percentage of time, then one gets :

   (a) the value of S_x will be less than S by the amount moved to the opposite direction. Therefore, if one uses $S_x = S$, over estimation of the littoral drift rate will be obtained if one uses equation 7.

   (b) due to the double passage of the tracer sand over any sampling section, the value of $\int_0^L \int_0^T C \; dy \; dt$ in Equation 7 will be increased by the same order of magnitude mentioned before. Therefore, as one uses the measured values of $\int_0^L \int_0^T C \; dy \; dt$ there will be a possibility of underestimating the littoral drift rate by almost the same order of magnitude of the overestimation due to the use of $S = S_x$.

   (c) from (a) and (b) it may be concluded that for beaches where the littoral drift has a major direction, not less than 80% of the time, using $S = S_x$ in Equation 7 will give a reasonable estimate of the littoral drift rate along that beach.

The use of Equation 7 requires the following conditions :

1. Littoral drift should have a major direction.

2. Sampling lines should not be far from injection.

3. Sampling should cover the entire distance from the shore line to any depth seawards where tracer could be found.

4. Sampling should continue till all tracer disappears from the study area.

APPLICATION OF THE DERIVED METHOD FOR THE STUDY OF LITTORAL DRIFT ALONG RAS-EL-BAR, EGYPT.

The field work reported in this paper was carried out[6] at Ras-El-Bar beach, Egypt, and as shown in Figures (2) and (3). This study was made during the period October-February 1969. The beach consists of fine sand, 0.12 mm average grain size, and 1.2 sorting coefficient. Fig.(4) shows the grain size distribution of the beach sand. Wave attacks the study area from the west, NW and NNW directions[5]. The fluoreecent tracer sand used in this etudy is Rhodamine B which gives fluoresce red under ultra-violet light. Fig. (4) shows the mechanical analyeis of the tracer sand used which have almost the same characteristics as the natural sand at Ras-El-Bar.

1. Location of the study area and injection point.

The general location of the study area is usually choeen by some epecific local sediment problems. In Ras-El-Bar case, and from Fig.(3) it can be noticed that erosion predominatee to the western side of the jetty for a distance of 4.00 kilometers, and shoaling inside the Damietta estuary is in progress. Fig.(5) shows the reach of Ras-El-Bar shore line chosen for this study. This reach extends for a distance of 8 kilometers west of the jetty and for more than one kilometer east of Damietta estuary. Injection was made at a point 3.25 kilometers west of the jetty where the shore line is straight and wave disturbance is the least compared with the other parte of the shore line.

2. Injection and Sampling.

Fig.(5) shows the general plan for the injection and sampling locations where the following steps were considered :

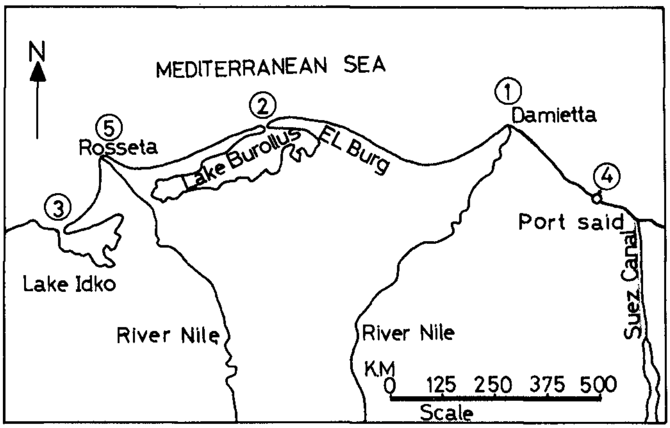
(1) injection point was chosen at a distance of 20 meters from the shore line. It was decided to use injection at a point instead of injection along a line in order to eliminate possible losses of tracer to deeper water.

(2) a total amount of 1050 kilogrammes of tracer were injected at a rate of 50 kilogrammes/2 days.

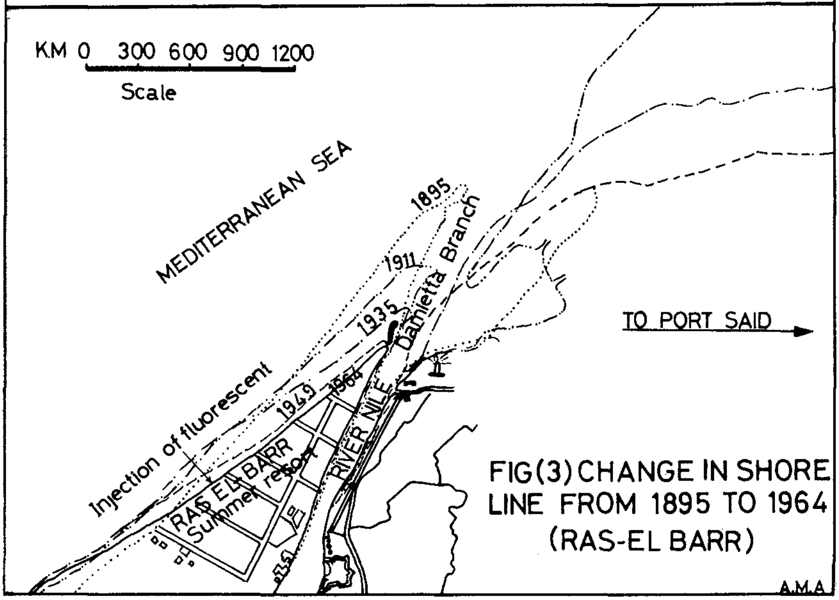
(3) sampling period of 2 daye was chosen and eampling start from the first arrival of tracer to the sampling and continued till all fluorescent particles disappeared from the study area.

(4) sand samples were taken for analyeis from the uppermost two centimeters of the bed with a straight sided can ehape.

(5) each eample was kept inside a nylon eac and was identified by its location and eampling date and was eent to the laboratory for concentration analysis.



FIG(2) GENERAL MAP OF PROBLEM REGIONS ALONG THE EGYPTION COAST



FIG(3) CHANGE IN SHORE LINE FROM 1895 TO 1964 (RAS-EL BARR)

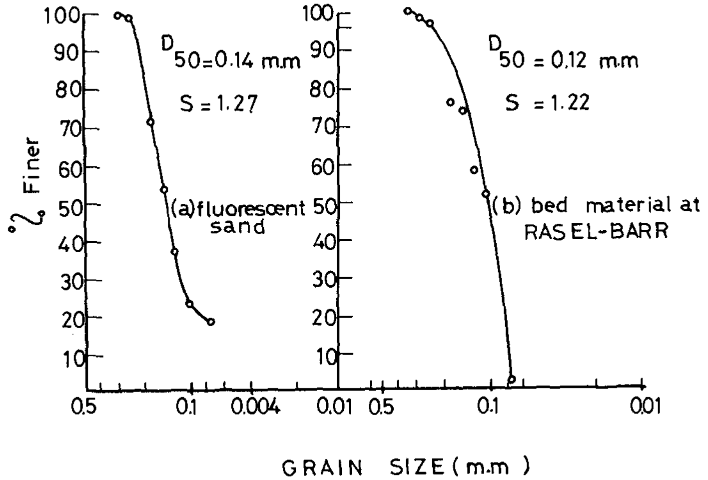


FIG (4) MECHANICAL ANALYSIS FOR BED MATERIAL AND FLUORESCENT SAND.

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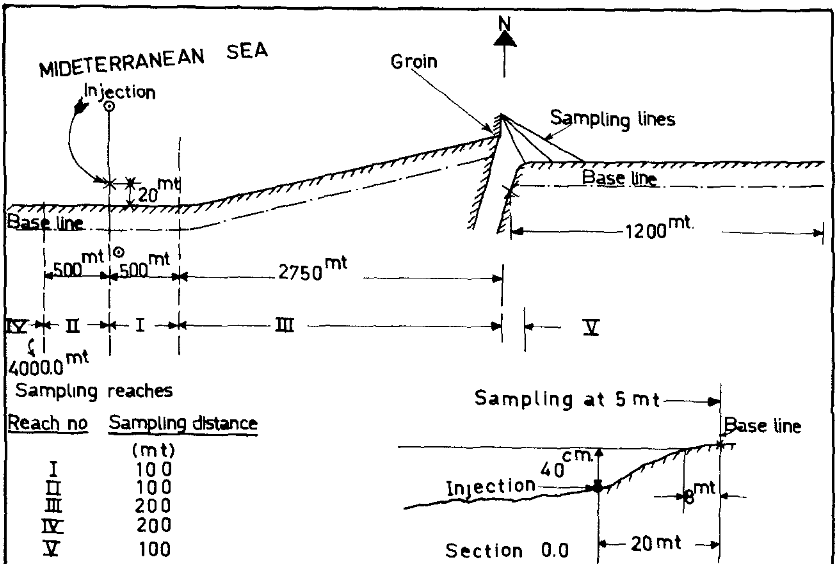

FIG (5) Schematic plan for injection and sampling locations

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3. Methods of fluorescent particles counting and concentration.

A specially designed dark box with two ultra violet lamps was used to measure the tracer concentration in each sample, as follows :

(1) Each sample was spread out in a layer of at least one centimeter thick over a plate 100 cm^2 surface area.

(2) The number of visible tracer particles on the surface of each sample was counted and converted into concentration.

In order to convert figures expressed as number of visible particles per 100 cm^2 into concentration, a calibration experiment was carried out as follows :

(1) Tracer and beach sand were mixed in different known concentrations.

(2) For each concentration, the number of visible particles/100 cm^2 were counted using ultra violet lamp.

(3) Each mixing and counting was carried out fifty times for each concentration, and the counts averaged.

(4) The best straight line through the average points was drawn and represented by the equation :

$$C = n \times 10^{-5} \quad \text{..................................} \quad (8)$$

where, C = tracer concentration by weight and n = number of visible particles/100 cm^2 surface area.

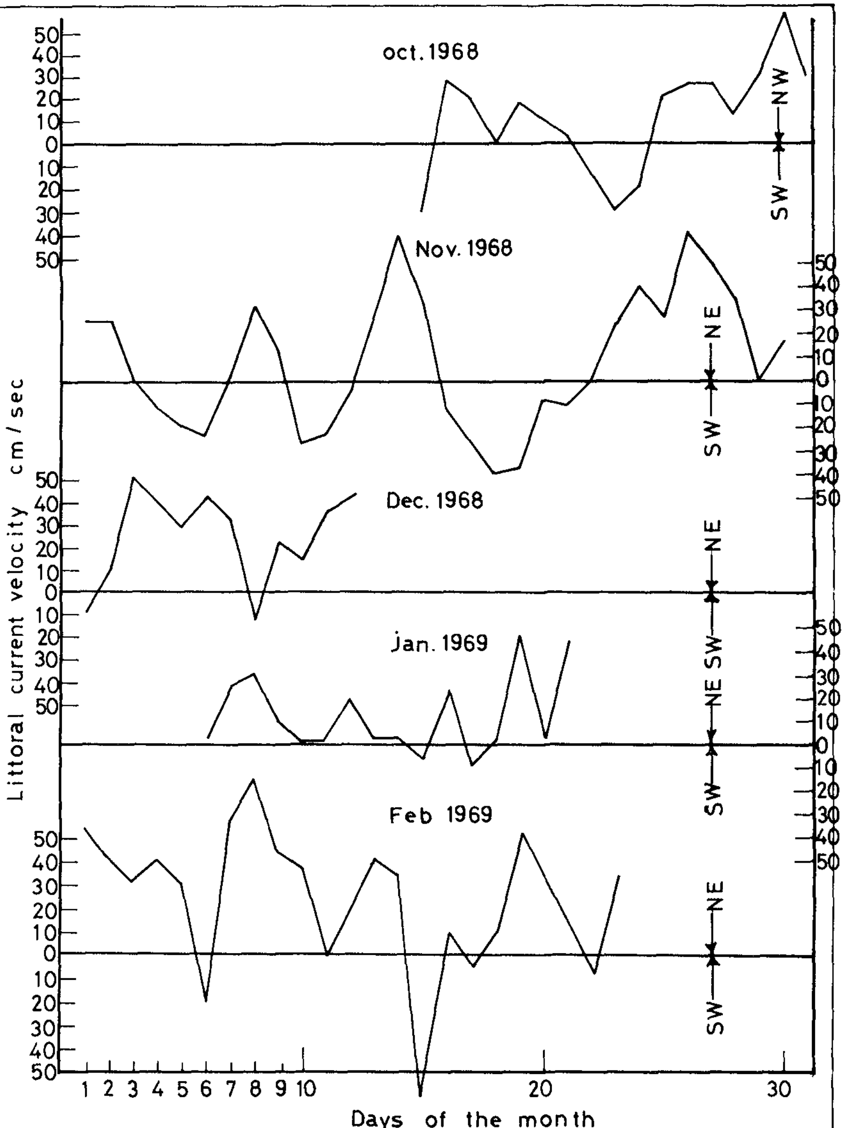
4. Littoral current observation.

Both the direction and intensity of the littoral current were observed at ten different locations along the study area. Figure 6 shows the average results obtained from the littoral current measurements. From Fig. 6 it can be seen that there is a decided majority of currents towards the NE direction with 80% probability of motion towards that direction.

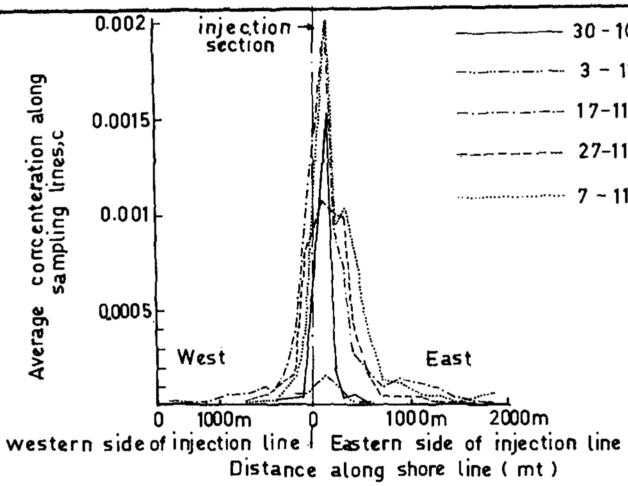
EXPERIMENTAL RESULTS AND ANALYSIS OF DATA

1. Direction of littoral drift.

Before each injection, sampling for tracer concentration was carried out. During the early stages of the study, sampling did not cover the whole area shown in Fig. 5, but starts at small distances from both sides of the injection point and then were increased latter on to cover the whole area, shown in Fig. 5 as the tracer advanced in these areas. Fig. 7 shows the average tracer concentration along the different sampling line and during the injection period. It is clear from Fig. 7 that the majority of tracer moved to the NE direction during the injection period. It should be noticed that, after the last injection was made, sampling continued till all the tracer partioles disappeared from the study area. Fig. 8 shows the distribution of tracer along the



FIG(6) LITTORAL CURRENT ALONG THE STUDY AREA



FIG(7) DISTRIBUTION OF TRACER CONCENTRATION ALONG STUDY AREA (during injection period)

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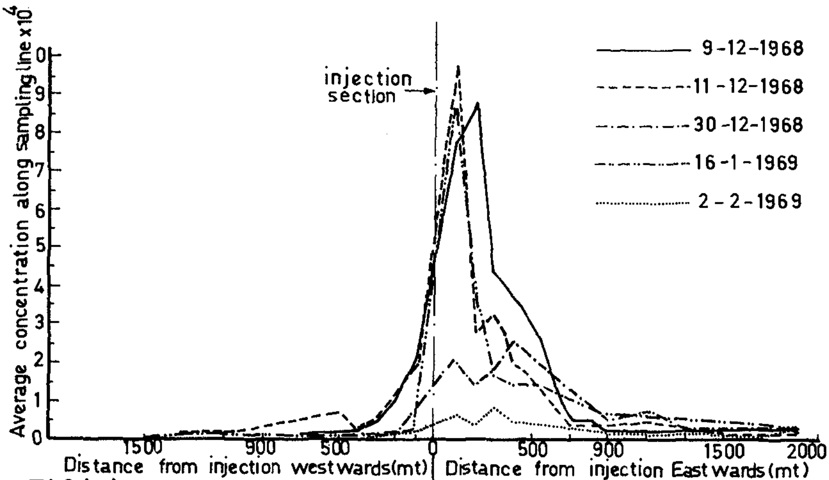
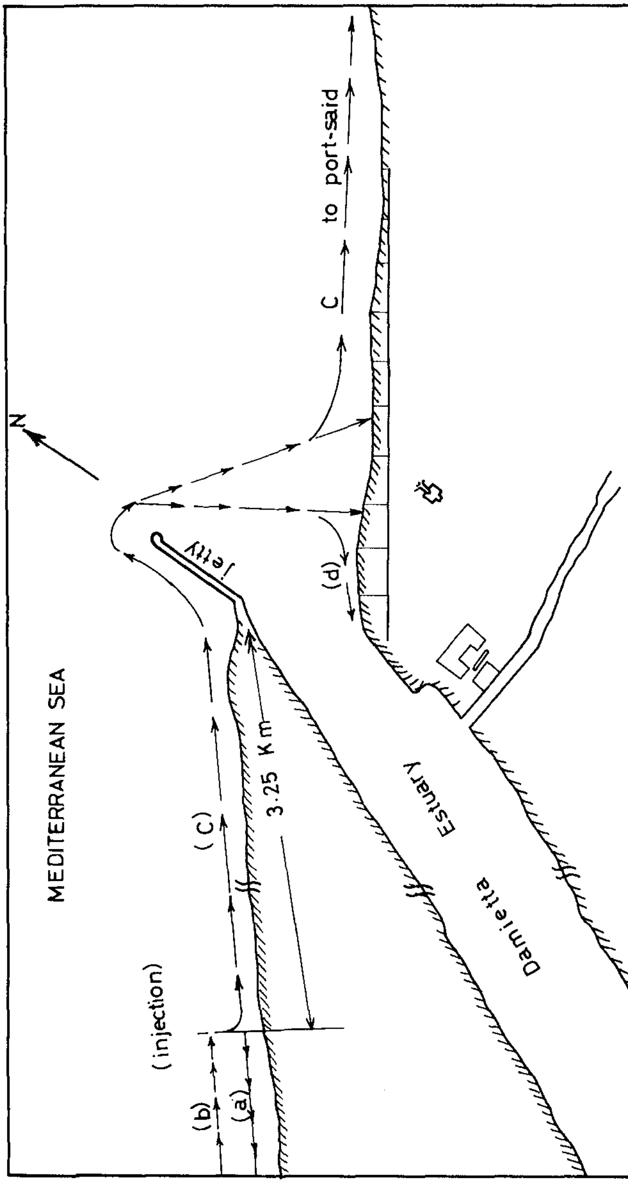


FIG(8) DISTRIBUTION OF TRACER CONCENTRATION ALONG STUDY AREA DURING TRACER DISAPPEARANCE PERIOD.



(a) Irrigular appearance of tracer at different localities.

(b) Continious movement towards the injection point during the decay period.

(c) Regular advance of tracer to the N-E direction.

(d) Advance of tracer inside the inlet.

FIG (9) LITTORAL DRIFT DIRECTION AT RAS-EL BARR BEACH.

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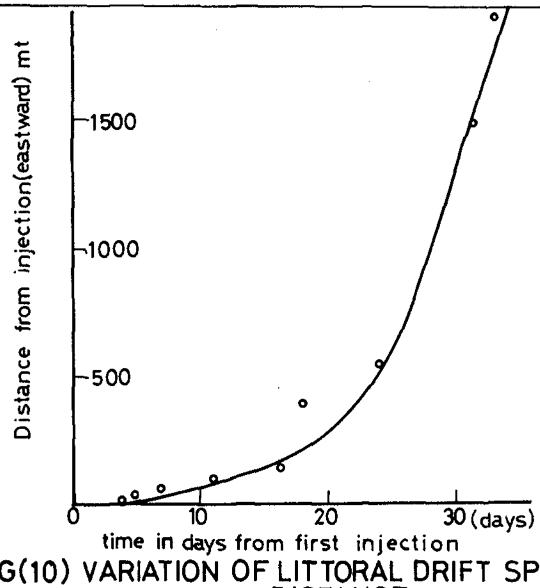
study reach after the last injection was made and during the period which may be called "tracer disappearance period". It is clear from Fig. 8 that the tracer continued to advance to the NE direction with continuous disappearance from the western side of the injection point. Due to the remarked advance of the tracer to the NE direction, sampling was carried out to the eastern side of the Nile exit and inside the inlet, as shown in Fig. 5. Fig. 9 summarizes the main results obtained on the direction of littoral drift motion at the study area, as follows :

(1) The main direction of littoral drift at Ras-El-Bar is from SW to NE direction.

(2) The littoral drift which moves along Ras-El-Bar beach, turns around the jetty by wave diffraction and proceeds to the eastern side of the exit where it partially deposits inside the inlet and partially moves to the NE direction towards Port Said.

2. Speed of littoral drift advance(Pioneer particles).

Pioneer tracer particles advance was followed along the study area. Both the location and the time from the first injection, for the appearance of those particles were recorded at the different points along the beach. Fig.10 shows the plotting of these data where the following may be concluded :



FIG(10) VARIATION OF LITTORAL DRIFT SPEED WITH DISTANCE.

(1) Speed of littoral drift along Ras-El-Bar increases as one moves from the injection point towards the jetty.

(2) For the two kilometers, west of the jetty and where heavy erosion takes place, the littoral drift moves at a speed of about 145 meter/day.

3. <u>Effective zone of littoral movement.</u>

There is no doubt that the movement of beach material takes place largely within the breaker zone, motived by the wave action and littoral current. It is, therefore, believed that once the tracer is injected at a certain point in the breaker zone (as in this study it was), tracer particles will find themselves among the original bed particles and behave in the same manner. It is also known that sediment motion within the breaker zone follows a zig-zag path under the action of the swash and back wash of the waves. Due to this action, tracer particles will behave in that manner and should give an idea about the effective zone of littoral drift motion. Fig. 11 shows the distribution of tracer partcles inside the breaker zone for different sampling sections along the beach. It is clear from Fig. 11 that the effective zone of tracer dispersion took place within fifty meters width of the breaker zone. The same result was obtained for all samples taken all over the study period and specially for the reach 500 meters to both sides of the injeotion point. One may conclude that at least for the mentioned reach, there is no loss of tracer to the off-shore area.

4. <u>Calculation of the littoral drift rate, using Equation 7.</u>

As a result of the present field study, one may observe the following :

a. Littoral drift is directed to the NE direction with probability more than 80%.

b. For the 500 meter reach to the east side of the injection point, tracer losses to the offshore area could be neglected.

From the above and the fact that sampling continued from the moment tracer reaches the given sampling line till its complete disappearance from that section, the main requirements for the application of Equation 7 are fullfilled, and it was used for Ras-El-Bar beach as follows :

(1) Five sampling sections to the eastern side of the injection point where considered for the calculations, namely at 100, 200, 300, 400 and 500 meters from the injection point.

(2) Sampling along these lines continued according to the method given in this paper.

(3) For each sampling section and period, the data were plotted, as shown in Fig. 11. The value of $\int_0^L$ c dy was calculated, where c is the tracer

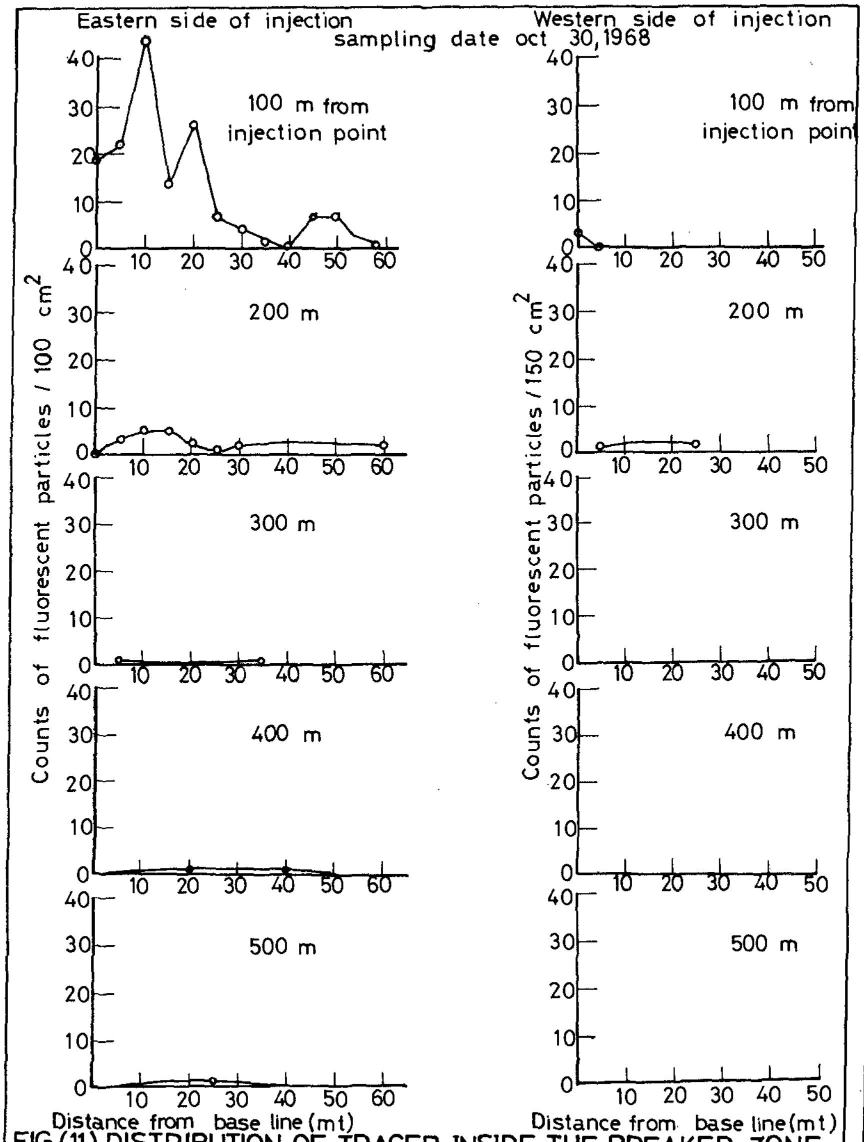


FIG (11) DISTRIBUTION OF TRACER INSIDE THE BREAKER ZONE concentration at any point at distance y from the shore line and L is the effective length of sampling line along which tracer is dispersed.

(4) The values of $\int_0^L C\,dy$ and their corresponding sampling period, t , from the first injection were plotted as shown in Fig. 12.

(5) From Fig. 12 the value $\int_0^L \int_0^T C\,dy\,dt$ was calculated for each sampling section by integrating the area under each $\int_0^L C\,dy$ vs. time curve of Fig. 12.

(6) The estimated rate of littoral drift Q may be calculated using

$$Q = \frac{S_x}{\int_0^L \int_0^T C\;dy\,dt} \quad \text{where ,}$$

S_x = Total amount of tracer injected = 1.05 tons

T = Time, in days, between the first arrival of tracer to any sampling section and its complete disappearance = about 105 days in this study.

(7) The estimated rate of littoral drift is shown in Table (1).

Table (1) - Rate of littoral drift using Equation 7.

Distance from injection (mt)	$\int_0^L \int_0^T C\,dy\,dt$ (mt.day)	Q ton/mt. day	Q m^3/day (*)
100	0.342038	3.08	54.00
200	0.137770	7.60	142.00
300	0.075588	13.90	260.00
400	0.054925	19.00	360.00
500	0.046137	22.00	430.00

(*) Effective width of movement was taken as 50 meters.

Table (1) shows a remarkable eastern increase of the littoral drift rate. This increase is expected due the followings :

a. Increased erosion as one moves from the injection point towards the old Nile exit. This is clear from Fig. 3 where erosion history along that area is shown.

b. Continuous supply of sand to the breaker zone under the action of western and northern waves. This effect was studied(6) using a developed continuity equation for the sediment movement at Ras-El-Bar and introducing all possible factors involved in the supply and loss of sand to a coast as given by J.W. Johnson(7). This study gave an estimated supply of 0.75 m^3/mt of coast to the breaker zone due to the waves attacking the area.

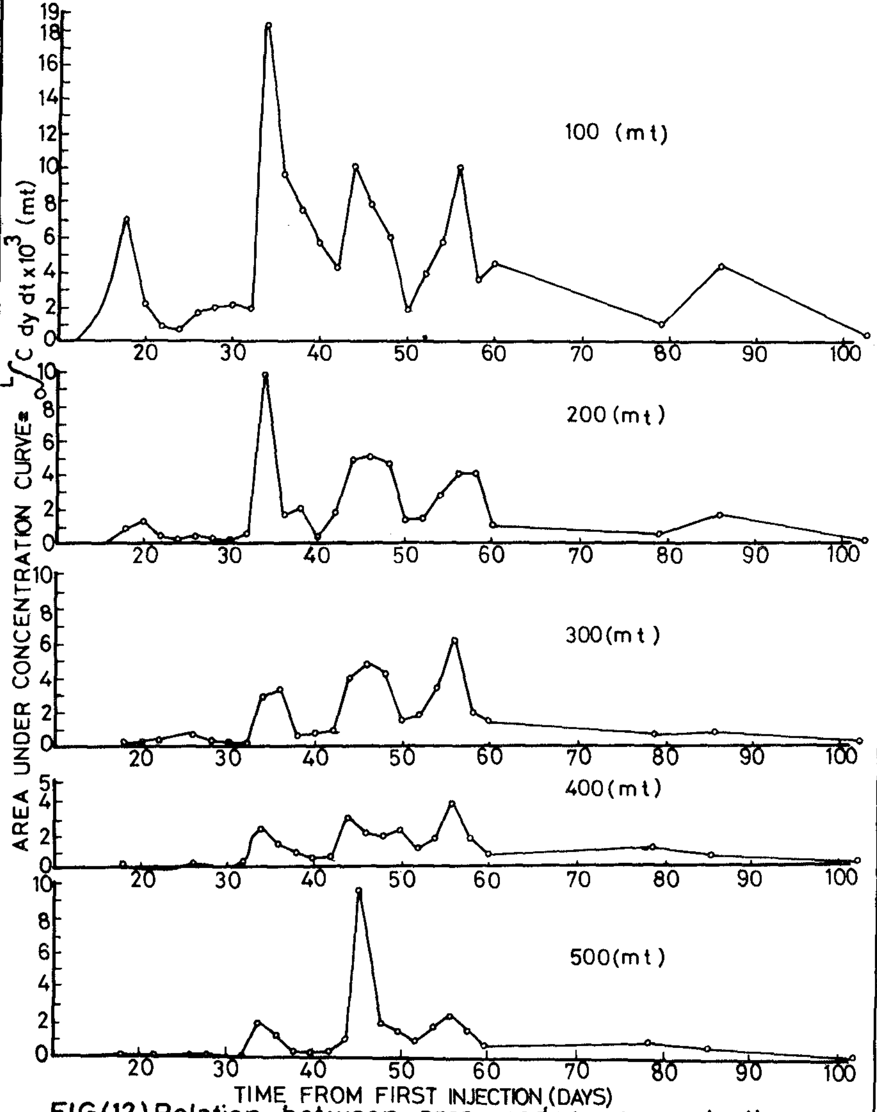


FIG (12) Relation between area under concentration curve and time, along different sampling lines.

5. Thickness of the moving layer.

From Fig. 10, one can estimate the average speed of littoral drift, V_s, at different points along the study area. Table (1) shows the calculations for the littoral drift rate Q at five different locations along the coast. The thickness, δ, of the moving layer of sediment at any locality, may be calculated from the following equation :

$$\delta = \frac{Q}{V_s} \qquad \qquad (9)$$

The thickness of the moving layer at 100, 200, 300, 400 and 500 meters from the injection point is shown in Table (2).

Table (2) - Calculations for the moving layer thickness.

Distance from injection (mt)	Q m^3/mt.day	V_s mt./day	δ (mt.)	δ (cm.)
100	1.08	12.6	0.085	8.5
200	2.85	31.50	0.091	9.1
300	5.20	42.00	0.122	12.2
400	7.20	65.00	0.11	11.0
500	8.60	145.00	0.06	6.0

Σ 46.8

average moving layer thickness δ = 9 cm.

From Table (2), the average thickness of the moving sediment layer, at the breaker zone of Ras-El-Bar, is estimated as 9 centimeters. A formula for relationship between wave height and depth of sand disturbance is given by King[8] ; that for each foot of deep water wave height there is a disturbance to one centimeter. Application of King's formula to Ras-El-Bar coast gives disturbance thickness ranging from 3 to 12 centimeters which is comparable with the thickness of the moving layer calculated. Accordingly, for any future study, collection of sand for either marking or analysis should be taken within this layer.

SUMMARY AND CONCLUSIONS

The present investigation is concerned with the study of sediment movement at Ras-El-Bar coast, using fluorescent tracer technique. A method for calculating the rate of littoral drift was developed. This method is based on the use of tracer and observing the concentration reaching different profiles along the shore line as a function of space and time. The method was used for estimating the rate of drift movement along the eroding beach of Ras-El-Bar. The main findings of this study can be summarized as follows :

(1) The main direction of littoral drift at Ras-El-Bar is from the SW to the NE direction.

(2) Accretion inside the old River Nile exit is partially contributed by erosion from Ras-El-Bar beach.

(3) The average speed of littoral drift along the eroding zone of the beach reaches 145 meters per day.

(4) Reasonable estimate of the littoral drift rate, at a certain point along shore lines, could be obtained using fluorescent tracer and Equation 7, under the following conditions :

a. Littoral drift movement should have a major direction for most of the period.

b. Sampling of tracer along the profile concerned should continue from the moment tracer starts to reach that section till its complete sisappearance from it.

c. Sampling periods of two days interval seems to be reasonable.

d. Sampling should cover any seawards distance wherever tracer may be found.

(5) Littoral drift along Ras-El-Bar is originated from the continuous erosion along the area.

(6) Most of the littoral drift along the breaker zone is supplied by wave action which is originated from erosion in the off shore area.

(7) For the three kilometers coast length, west of the Nile exit, erosion increases as one moves to the N E direction.

(8) For the same reach above littoral drift rate also increases in the same direction. This finding was obtained by Saville(9) who found that greater long shore transport of sand occurred when the beach is eroding than when they were prograting.

(9) The average thickness of the moving sediment layer along the breaker zone, is estimated to be about 9 centimeters.

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