IMPROVING FACULTATIVE PONDS HYDRAULICS WITH BAFFLES

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ABSTRACT:

Influence of baffles on hydraulic properties of stabilization ponds was studied using tracer test. From this test, the dispersion number index, d, was evaluated for each of the five 125 L ponds at an average hydraulic loading of 8.333 L/day. The results show that for good efficiency, the actual mean detention time, t_g must be greater than or at least equal to the nominal detention time, t_n. Generally, excessive short-circuitings are reduced by some baffle arrangements in the ponds. The results indicate that baffled points have low values of dispersion index, d, and exhibit flow patterns nearer to a plug flow. The overall performance is thus improved by increasing the number of baffles. The lowest value of d, of 0.030 was given by the tank with 15 baffles, the highest value of 0.151 was given by the unbaffled (plain) tank while tanks with 6, 9 and 12 baffles gave d values of 0.0114, 0.100 and 0.060 respectively. Baffled tanks (ponds) are analogue to ponds in series or a stream. Other characteristics examined are the standard detention time, t_s the percentage difference of nominal detention time (t_n) and actual detention time, ψ the percentage dead space, δ; index of dead space, α_d and index of short circuiting, α_s. The method adopted in evaluating most of these parameters seems simpler and more reliable than any other previous methods.

1.0 INTRODUCTION:

Suppose the residence time of fluid elements in a reactor is t, then the function, F(t) is the fraction of the elements in the effluent stream having residence times less than t. This implies that, $F(0) = F(\infty) = 1$, indicating that none of the fluid can pass through the vessel in zero time and all will eventually come out. Another function is the point distribution function or E - curve. This is the residence time distribution (RTD) function of the fluid. It is related to the F - curve by;

$$E(t) = F(t)/dt \quad (1)$$

Hence, E(t) is the function of the effluent that has residence times between t and t + dt. The area under the E - curve, equation (2) is unity.

$$E(t)dt = \int_0^\infty E(t)dt = 1 \quad (2)$$

While the fraction of the fluid element that has residence time less than t_o is given by

$$F(t) = \int_{t_o} E(t)dt \quad (3)$$

The total reaction time of the tracer introduced can be estimated with Simpson's rule as suggested by Grady and Lim (1980).

The flow through curve (C - curve) for real tank is shown in figure 1 with dimensionless co-ordinates C_e/C_i and t_g/t_n i.e (Thirumurthi, 1969) where;

C_e = tracer concentration at the effluent after time t

C_i or C_o = total weight of tracer added at the influent divided by the volume of the tank, that is the concentration if the dose is dispersed instantaneously throughout the tank volume,

t_g = actual mean detention time

t_n = nominal (theoretical) detention time i.e. volume, V per flow rate, Q.

$\Theta_p f$ = dimensionless time deviation from plug flow

D/UL = dispersion number index, d

This plot is independent of the detention time and the amount of tracer used. For a stable flow and without dead spaces, the value of t_g/t_n to the center of gravity will be unity, Unstable condition would give unreproducible curve shapes whereas a stable flow pattern is indicated when the same curve can be reproduced with fair precision. Moreover, unstable condition will yield undependable short circuiting study results and erratic suspended solids (SS) removal permonance.

Previous work have shown that stabilisation ponds behave as dispersed flow reactor which is characterized by the combination of influence of detention time, dead spaces, short circuiting, standard detention time efficiency and lateral disper-

sion (Kilani and Ogunrombi, 1984 and Thirumurthi, 1967). The more the deviation from an ideal plug flow, the lower the efficiency of the pond systems. Results from this study clearly support this concept.

The effective retention period will be less than the true retention period and the relative time to the center of gravity, of the dispersion curve, t_g/t_n will be less than unity. If there is any interchange between dead spaces and the main body of the liquid, there will be flow through the dead spaces, but the resulting tail of the dispersion curves may be so long with so small ordinates that the end of the tail will be lost and as apparent, value of t_g/t_n less than unity will result.

If there are dead spaces, the recorded values of C_e/C_i will be greater then the effective values and all ordinates of the dispersion curve will be increased in proportion to the decrease in t_g/t_n such that the area will remain unity. Since the relative time to the center of gravity is unity except for tanks with dead spaces, t_g/t_n is an indicator of amount of the dead space, and for tanks with dead space, it is sometimes analogous to index of short circuiting. The relative time to the center of area, t_g/t_n is usually less than unity and the smaller its value the worse the short circuiting.

According to Thirumurthi (1969), dropping C_i and t_n in the co-ordinates, the C - curve (Figure 1), becomes a dimensional dispersion curve (Figure 2) in which the variables are defined as follows:

t_i = time interval; for the initial indication of the tracer in the effluent;

t_p = time for effluent tracer to reach peak concentration t_{10}, t_{50}, t_{90} = time for 10%, 50% and 90% of the tracer to be observed at the effluent respectively t_a = t_{50} = median time or time at which 50% of the tracer is observed at the effluent.

$t_g = \frac{\sum C_i}{\sum C}$ = time to reach the centroid of the curve, or actual mean detention time. C is the tracer concentration at time t.

The percentage dead space parameter, δ can be derived as

$$\delta = 1 - t_g/t_n \quad (4)$$

or

$$\delta = 1 - \theta \quad (5)$$

It is a measure of the amount of the reactor volume where mixing is less than desirable. Dead space has an obvious effect on the conversion. As percentage dead space, δ increases the effective flow area decreases which results in a decreased detention time of the wastewater and poorer reactor performance. Since half the particle of fluid pass in less time, t_a is the "probable flowing-through time" of the fluid. The dispersion of fluid is measured approximately by the time of initial appearance, t_i of the changein the effluent. The smaller the relative time, t_i / t_a the more rapid the dispersion. Small values of ti/tn and ta/tn indicate serious short circuiting.

Another good parameter for evaluating mixing pattern in the tank is the Morril Index (MI). As the MI approaches 1.0, the flow through the tank, approacher ideal plug flow. MI is equal to t90/t10.

The ideal situation for flow through a reactor is typified by plug flow. If the influent waste mixes vertically and then moves through the reactor as a slug, the optimum condition, called plug flow, has been realized. That is, all the fluid will have remained in the pond long enough for treatment and none will have remained longer than necessary. This condition leads to pond of minimum volume for a given waste load and thus minimum cost (Olanrewaju, - 1986).

The deviation of a given flow from plug can therefore, be considered a measure of pond efficiency. It is the waste that leaves the pond before one detention time that contributes to poor reactor efficiency. Furthermore it is not only the amount of waste leaving too soon, but the amount of time it lacks in remaining in the reactor one detention time that is important. As such the deviation from plug flow regime, Θpf can be expressed by dispersion index, d, or the distance from the line $\Theta = 1$ to the centroid of the area under the C - curve (Figure 1) for $0 < \Theta < 1$.

$$\theta_{pf} = \frac{\int_0^1 (1-\theta)\frac{C_e}{C_i}d\theta}{\int_0^1 \frac{C_e}{C_i}d\theta} \quad (6)$$

Out of all parameters, the dispersion index, d, seems to be the most quantitative and qualitative parameter (Thirumurthi, 1967; Levenspiel, 1962; Thirumurthi, 1969; Mangelson and Watters, 1972, and Olanrewaju, 1986).

The value of the dispersion index, d is obtained from equation 7 as:

$$d = \frac{1}{3}\left((3\sigma^2 + 1)^{1/2} - 1\right) \quad (7)$$

$$\sigma^2 = t^2/t_g^2 \quad (8)$$

$$\sigma^2 = \frac{\sum t^2 C}{\sum C} - \frac{(\sum tC)^2}{(\sum C)} \quad (9)$$

$$\sigma^2 = \beta - t^2. \quad (10)$$

Where

σ_t^2 is the variance of C - curve in "time squared" units;

σ^2 variance of C - curve, dimensionless; t, time, C the tracer concentration (mg/L) and $\beta = \sum \lambda / \sum \gamma$}

This index has the strongest statistical probability of describing the hydraulic performance of ponds. Its derivation involves important parameters such as the time and concentration in the tracer study. The larger the number of points on the C - curve (flow-through curve) which are included in the calculations of the index, the smaller is the relative error in the measurement, Thirumurthi (1969). As d tends to zero, the reactor tends to plug flow system and hence becomes more efficient.

2.0 MATERIAL AND METHOD

2.1 Material

Five rectangular galvanized steel tanks were used as laboratory model ponds, each having a working capacity of 125 litres. The ponds differed only in the number of baffles. Pond A hand no baffle and served as the control model, pond B had

6 baffles, pond C and 9 baffles, pond D had 12 baffles while pond E had 15 baffles. These are round-the-end baffle configurations which force the water to follow a snake-like path in the horizontal plane through the ponds.

2.2 Experimental Method

The tanks (ponds) were filled with tap water and the desired flow rate of 8.33 L/d was maintained by pumping tap water from a reservoir using peristatic pumps. (Figures 3-8). The selection of hydraulic loading of 8.33 L/d and 15 baffles being optimum was based on previous studies (Olanrewaju, 1986). After the pumps had maintained steady state flow, 25 mL of Indigo Carmine solution of known concentration was added to the inlet of each pond. Samples were collected from the outlet of the ponds daily and analysed for the concentration of the dye. This was accomplished by measuring the transmittance of the samples using a Spectronic 20 model and obtaining the corresponding concentrations from the calibration curve which was initially prepared. The tracer recovery curves were prepared by plotting concentrations against time (Figure 3). From these curves and using methods suggested by Kilani and Ogunrombi (1984) and Olanrewaju (1986) the hydraulic characteristics of the ponds were estimated. These include the dispersion index (d), index of short circuiting (α_s), index of dead volume (α_d), and actual mean detention time (t_g).

2.3 Analytical Procedure: (Table 1)

In column I, list the sampling time, t with the corresponding sampling time increment in column 2. In column 3, list the tracer concentration, C corresponding to the time in column 1 with its concentration increment, ΔC in column 4, ΔC would change sign from positive to negative whenever the concentration falls. In the fifth column list the values of Y - function, $(C - 1/2\,\Delta C)\,\Delta t$ while in the sixth and seventh columns list the Z - function, $(Y/t - 1/2\,\Delta t)$ and W - function, (Y^2/Z) calculated values respectively. Under columns eight and thirteen, list the calculated values of, λ, (Wt) and β, $(\Sigma\, Wt / \Sigma\, Y)$ respectively. In columns nine, ten, eleven and twelve list the summations of Y, Z, W and λ, respectively.

3.0 RESULTS:

Figures 9 shows the tracer recovery curves at 15 day nominal detention time. Using table 1 presented, tracer test data for each tank are given in tables 2 through 6 while the summary of the tracer test derived data is given in table 7.

4.0 DISCUSSION OF RESULTS:

From the effluents 100 percent tracer concentration recoveries were obtained in all the tanks even though less percentage has been observed when the flow rate is very small (Olanrewaju, 1986). A curve which is high and narrow and attains its peak close to the theoretical detention time indicates a high efficiency. Both tanks D and E were found to meet these criteria with peaks at 14 days and 16 days respectively. Tank A without baffle seems to be relatively very poor with a peak flow at 6 days. The efficiency in terms of these criteria improves as the number of baffles increases (Figure 3).

The actual mean detention time, t_g, is approximately.

$$\frac{\sum_{0}^{\infty} (C - \tfrac{1}{2}\Delta C)(t - \tfrac{1}{2}\Delta t)\,\Delta t}{\sum_{0}^{\infty} (C - \tfrac{1}{2}\Delta C)\,\Delta t} \qquad (11)$$

$$t_g = \sum t\,C / \sum C \qquad (12)$$

The actual detention time, t_g is generally smaller than the nominal (theoretical) detention time, t_n and t_g increases/from 8.53 to 19.79 days as the number of baffles increases from zero to 15 baffles (Figure 10). When t_g/t_n is unity, then ideally such hydraulic loading with the corresponding number of baffles would give the optimum efficiency. This is for 100 percent efficient reactor. However, since attainment of 100 percent efficient system may be technologically hard, more input in terms of increase actual detention time is required to obtain near 100 percent efficiency. Thus, the percentage deviation of t_g from t_n, (ψ) was observed to decrease from 55 to - 28 with increasing number of baffles (Figure 10). This is given by equation 13.

$$\psi = 2\,\frac{t_o - t_g}{t_o + t_g} \qquad (13)$$

This is in agreement with the views of previous investigators (Kilani and Ogunrombi, 1984). The lower the value of, ψ the better the performance of the ponds in terms of mixing characteristics. In this study the lowest value of ψ (-28) was obtained when 15 baffles pond was used. Effective detention time, t_e which is the time during which both batch and continuous feed operation concentrations are equal is given by equation (14).

$$t_e = \frac{(C - \tfrac{1}{2}\Delta C)\,\Delta t}{t - \tfrac{1}{2}\Delta t} \qquad (14)$$

or, upon simplifying,

$$t_e = \sum \gamma / \sum Z = t_s \qquad (15)$$

Due to simplifying assumptions especially its validity for only second order reaction flocculation thereby imposing some further limitations on its validity, t_e may be called standard detention time, t_s rather than effective detention time, t_g. If we divide t_s by the nominal detention time, t_n one obtains the standard detention time efficiency which is a good measure of the detention effectiveness of the reactor, that is,

$$t_n = t_s/t_n$$

This ratio, t_n is very useful in describing the detention time effectiveness of a reactor. High value of t_n may be associated with good reactor performance (Fiedler and Fitch, 1959). t_n increases with the number of baffles (Figures 11). t_n for tanks A, B, C, D and E were 39, 51, 60, 85 and 102 per cent respectively (Table 7). The percentage dead space, δ as given in equations (4) or (5) decreases from 43 to -32% with increases in the number of baffles (Figure 11). This trend is desirable since as δ increases, the reactor efficiency decreases. This also implies that the index of dead space, α_d increases with the efficiency of the reactor; whereas, the index of short circuiting, α_s decreases from 0.297 to 0.040 as the number of baffles or the efficiency increases (Figures 12). Hence both the percentage dead space given as:

$$\alpha_d = 1 - \delta \qquad (17)$$

and index of short circuiting, α_s given by:

$$\alpha_s = t_l/t_n = (t_g - t_p)/t_n \quad (18)$$

follow the same trend (Figures 11 and 12).

The values of d decrease with increase in the number of baffles (Figures 13). That is the difference in mixing efficiency becomes progressively pronounced with increase number of baffles. Since d = D/uL, the longer the path length, L, the smaller the value of d. Among the objectives of introducing baffles is to increase the length of travel. The 15-baffle tank gave the lowest value of d of 0.030. The plain pond gave d value of 0.151 while ponds B, C and D gave values of 0.114, 0.100 and 0.060 respectively. Relatively, the 15-baffle tank is closer to plug flow than any other tank and hence is the most efficient reactor. Baffles increase the L/W ratio. The ratios are 2:1, 6:1, 9:1, 12:1 and 15:1 for tanks having 0, 6, 9, 12 and 15 baffles respectively. As the L/W ratio increases, the hydraulic efficiency also increases. There was a marked increase in the actual detention time and a significant decrease in dead space and plug flow deviation parameter, Θ_{pf} in baffled tanks. This is obvious since as the L/W ratio increases, the conditions for plug or one dimensional flow are almost satisfied. The number of baffles coincides with the ratio except in the tank with zero baffles that has a 2:1 ratio.

In order to apply the concepts described in this study in the design of a full scale wastewater treatment reactor where proper mixing is desirable, a knowledge of the dispersion index number, d is needed. The dispersion index number for a full scale prototype reactor ($d_{prototype}$) can be obtained from that of a laboratory scale study (d_{model}) using equation 19 fully developed elsewhere (Olanrewaju 1986).

$$d_{prototype} = \frac{1}{\beta^2} d_{modal} \quad (19)$$

where

β = scale factor = $L_{model}/L_{prototype}$

The relationship as given by equation 19 is based on fundamental laws of hydraulic modelling namely the laws of geometric, kinematic and dynamic similarities (Olanrewaju, 1986). The relationship was tested and found to satisfy all the laws.

The optimum space time was given by Tank E with 15 baffles. Since this implies that more volume could be handled per unit time (space velocity), for a fixed flow this is desirable. In order to avoid sedimentation and in view of both normal channel friction and velocity gradients in the main channel and the baffle slots, there is an optimum flow under which these problems would not have much impact on the system hydraulics. In this study, the assumption is that necessary velocities must be redeveloped at each change in direction of flow hence the velocities were not measured, implying that the head loss is assumed to be the same throughout the reactor.

If the L:W ratio is too high, the velocity gradients which are purposely intensified by induced changes in the flow direction may not be possible. Excessive headloss may also result. Unlike raw water, there are considerable amounts of solids in wastewater, excessive number of baffles would make the reactor behave like filters and maintenance such as desludging may be impossible. The above statements have underscored the benefit of more surface areas in terms of number of baffles that would be provided for the microorganisms to cling to and oxidise the waste materials.

The selection of 15 days nominal detention time and maximum number of 15 baffles is thus based on the reasons advanced above to reconfirm findings from previous studies (Olanrewaju, 1986).

5.0 CONCLUSION:

Tracer test is useful in assessing the hydraulic characteristics of a reactor such as a stabilization pond. This study presented indicates that the dispersed plug model adequately describes the longitudinal mixing conditions in a reactor. Although literature indicate that this model cannot satisfactorily characterize flow patterns which deviate greatly from plug flow, the experimental data verifies the use of the modified method for analysing the hydraulic property of a reactor.

The more the deviation of a real tank from the ideal plug flow regime, the lower the efficiency. Increase in the tank length brings the reactor performance closer to plug flow. The effects of changing the tank length - to - width ratio, L/W also has very great influence on the overall efficiency of the reactor. High L/W ratios due to baffles are the most desirable for optimum hydraulic performance.

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TABLE 1: ESTIMATION OF TRACER TEST PARAMETERS

t (day)	∆t (day)	C Tracer concentration (mg/L)	∆C (mg/L)	Y (C-½∆C)∆t	Z Y/(t-½∆t)	W Y^2/Z	∆ Wt	ΣY	ΣZ	ΣW	Σ∆	ΣY/Σ ∆
1	2	3	4	5	6	7	8	9	10	11	12	13
t_1	t^1	C_1	ΔC_1	Y_1	Z_1	W_1	Δ_1					
t_2	t_2-t_1	C_2	C_2-C_1	Y_2	Z_2	W_2	Δ_2					
t_3	t_3-t_2	C_3	C_3-C_2	Y_3	Z_3	W_3	Δ_3					
=	=	=	=	=	=	=	=					
t_n	t_n-t_{n-1}	C_n	C_n-C_{n-1}	Y_n	Z_n	W_n	Δ_n					

TABLE 2: TRACER TEST DATA (TANK A 15 DAYS)

t (d)	t (d)	C Tracer Conc. (mg/L)	C (mg/L)	Y Function	Z Function	W Function	∆	ß
1	1.0	1.00	1.00	0.50	1.00	0.25	0.25	
2	1.0	1.8	0.8	1.4	0.67	2.93	5.85	
3	1.0	4.5	2.7	3.15	1.25	7.94	23.81	
4	1.0	6.5	2.00	5.5	1.57	19.27	77.07	
5	1.0	7.4	0.9	6.95	1.54	31.37	156.83	
6	1.0	8.0	0.6	7.7	1.40	42.35	245.1	
7	1.0	7.5	-0.5	7.75	1.19	50.47	353.31	
8	1.0	6.3	-1.2	6.9	0.92	51.75	414.0	
9	1.0	5.2	-1.1	5.75	0.68	48.62	437.59	
10	1.0	4.4	-0.8	4.8	0.51	45.18	451.76	
12	2.0	3.0	-1.4	7.4	0.67	81.75	980.78	
14	2.0	2.1	-0.9	5.1	0.39	66.69	933.69	
16	2.0	1.7	-0.4	3.8	0.25	57.76	924.16	
18	2.0	1.1	-0.6	2.8	0.16	49.00	982.0	
20	2.0	0.8	-0.2	1.8	0.09	36.0	720.0	
22	2.0	0.5	-0.3	1.3	0.06	28.17	619.67	

TABLE 3: TRACER TEST DATA (TANK B 15 DAYS)

t (d)	t (d)	C Tracer conc. (mg/L)	C (mg/L)	Y Function	Z Function	W Function	A	B
2	1.0	1.50	1.50	1.50	1.50	1.50	3.0	
3	1.0	2.10	0.60	1.80	0.72	4.50	13.50	
4	1.0	3.10	1.00	2.60	0.74	9.14	36.54	
5	1.0	4.90	1.80	4.00	0.89	17.98	89.89	
6	1.0	6.30	1.40	5.60	1.02	30.75	184.47	
7	1.0	7.3	1.00	6.80	1.05	44.04	308.27	
8	1.0	8.0	0.70	7.65	1.02	57.38	459.0	
9	1.0	7.0	-1.00	7.50	0.88	63.13	631.30	
10	1.0	6.2	-0.8	6.60	0.69	63.13	631.30	
11	1.0	5.4	-0.8	5.8	0.55	61.16	672.8	
12	1.0	4.8	-0.6	5.1	0.44	59.11	709.36	124
14	2.0	3.5	-1.3	8.30	0.64	107.64	1506.97	
16	2.0	2.6	-0.9	6.10	0.41	90.76	1452.1	
18	2.0	1.6	-1.0	4.20	0.25	70.56	1270.08	
20	2.0	0.9	-0.7	2.50	0.13	48.08	961.54	
22	2.0	0.4	-0.5	1.30	0.06	28.71	619.677	

TABLE 4: TRACER TEST DATA (TANK C 15 DAYS)

t (d)	t (d)	C Tracer Conc. (mg/L)	C (mg/L)	Y Function	Z Function	W Function	A	B
2	2.0	0.5	0.5	0.5	0.5	0.5	1.00	
4	1.0	2.0	1.5	2.5	0.83	7.53	30.12	
6	1.0	3.5	1.5	5.5	1.10	27.5	165.00	
8	1.0	6.0	1.5	9.5	1.36	66.36	530.88	
10	1.0	8.0	2.0	14.00	1.56	125.64	1256.4	
12	1.0	6.5	-1.5	14.50	1.32	159.28	1911.36	156
14	1.0	5.5	-1.0	12.00	0.92	156.52	2191.28	
16	1.0	3.8	-1.7	9.30	0.62	139.50	2232.0	
18	1.0	2.3	-1.5	6.10	0.36	103.36	1860.48	
20	1.0	1.2	-1.1	3.50	0.18	68.06	1361.2	
22	1.0	0.5	-0.7	1.7	0.08	36.13	794.86	

TABLE 5: TRACER TEST DATA (TANK D 15 DAYS)

t (d)	t (d)	C Tracer Conc. (mg/L)	C (mg/L)	Y Function	Z Function	W Function	⅄	ß
2	2.0	0.3	0.3	0.3	0.3	0.3	0.6	
4	1.0	1.0	0.7	1.30	0.43	3.93	15.72	
6	1.0	2.0	1.0	3.00	0.60	15.00	90.00	
8	1.0	3.3	1.3	5.30	0.76	36.96	295.68	
10	1.0	5.0	1.7	8.30	0.92	74.88	748.80	
12	1.0	6.6	1.6	11.60	1.05	128.15	1537.80	
14	1.0	8.0	1.4	14.60	1.12	190.32	2664.48	
16	1.0	7.1	-0.9	13.30	0.89	198.75	3180.04	290.00
18	1.0	6.8	-0.3	13.90	0.82	236.30	4253.40	
20	1.0	5.4	-1.4	12.20	0.64	232.56	4651.20	
22	1.0	3.8	-1.6	9.20	0.44	192.36	4231.92	
24	1.0	2.9	-0.9	6.70	0.29	154.79	3714.96	
26	1.0	2.0	-0.9	4.90	0.20	120.05	3121.30	
28	1.0	1.3	-0.7	3.30	0.12	90.75	2541.00	
30	1.0	0.7	-0.6	2.00	0.07	57.14	1714.20	
32	1.0	0.1	-0.6	1.60	0.05	51.20	1638.40	

TABLE 6: TRACER TEST DATA (TANK E 15 DAYS)

t (d)	t (d)	C Tracer Conc. (mg/L)	C (mg/L)	Y Function	Z Function	W Function	⅄	ß
4	4.0	0.2	0.2	0.40	0.20	0.80	3.20	
6	2.0	0.5	0.2	0.70	0.14	3.50	21.00	
8	2.0	1.2	0.3	1.70	0.24	12.04	96.32	
10	2.0	3.0	0.7	4.20	0.47	37.53	375.32	
12	2.0	4.8	1.8	7.80	0.71	85.69	1028.28	
14	2.0	6.0	1.2	10.80	0.83	140.53	1967.42	
16	2.0	8.0	2.0	14.00	0.93	210.75	3372.04	416.0
18	2.0	7.1	-0.90	15.10	0.89	256.19	4611.44	
20	2.0	6.3	-0.80	13.40	0.71	252.90	5058.33	
22	2.0	5.00	-1.30	11.30	0.54	236.46	5202.12	
24	2.0	4.10	-0.90	9.10	0.40	207.03	4968.60	
26	2.0	2.80	-1.30	6.90	0.28	170.04	4420.93	
28	2.0	2.20	-0.60	5.00	0.19	131.58	3684.21	
29	2.0	2.00	-0.20	4.20	0.14	126.00	3780.00	
30	2.0	1.90	-0.10	3.90	0.13	117.00	3744.00	
31	2.0	1.80	-0.10	3.70	0.11	124.45	4231.45	

TABLE 7: SUMMARY OF THE TRACER TEST DERIVED DATA

PONDS			P	A	R	A	M	E	T	E	R	S
	t_n (days)	t_i (days)	t_p (days)	t_a (days)	t_g (days)	t_7 %	d	%	s		d	L/W
A	15	1	6.00	5.88	8.53	39.00	0.57	43.00	0.297	55	.151	1:2
B	15	2	8.00	7.67	9.89	51.00	0.66	34.00	0.191	41	.114	1:6
C	15	2	10.00	8.96	11.26	60.00	0.75	25.00	0.112	28	.100	1:9
D	15	3	14.50	12.82	16.00	85.00	1.07	-09.00	0.094	-7	.060	1:12
E	15	4	19.00	17.92	19.79	102.00	1.32	-32.00	0.040	-28	.030	1:15

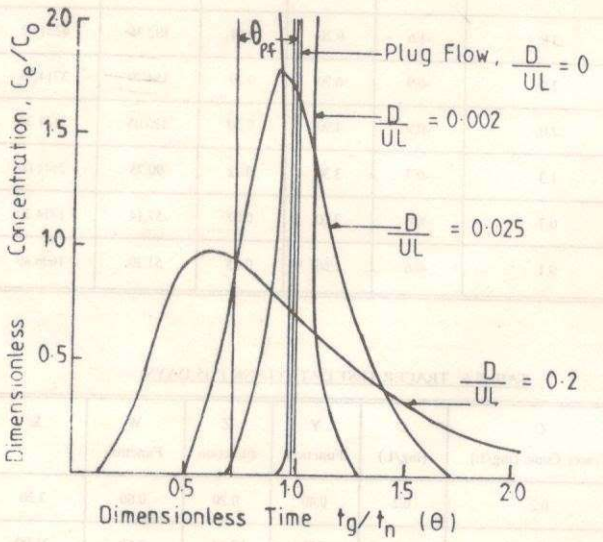


Fig 1- Dimensionless Dispersion (C-Curve) Curve

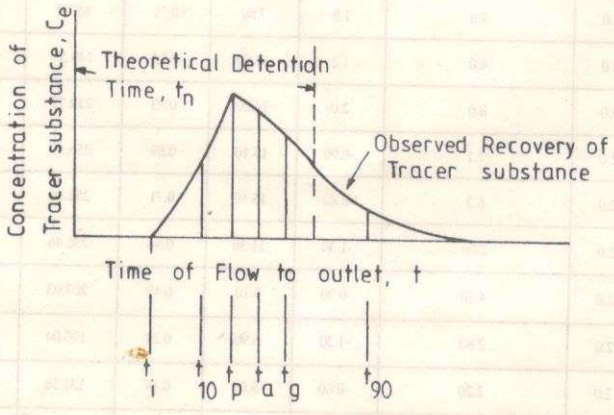


Fig. 2 :- Dimensional Dispersion Curve

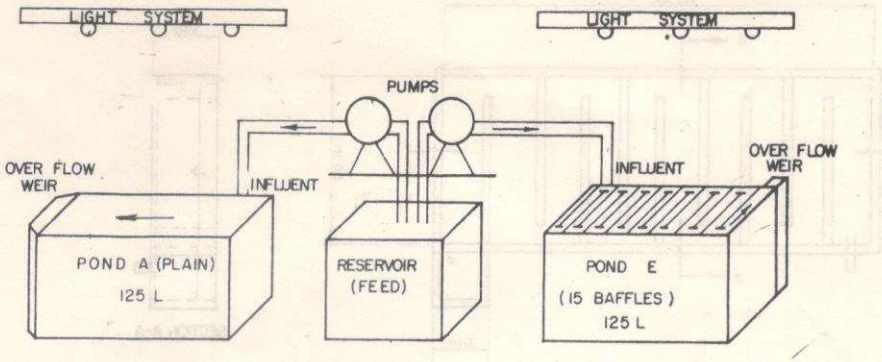


FIG.3 LABORATORY MODEL PONDS

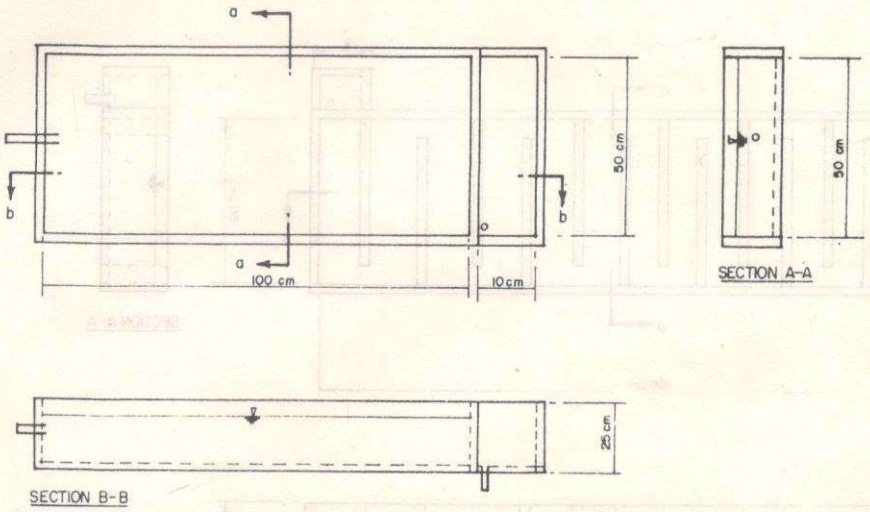


FIG 4. MODEL OF PLAIN FACULTATIVE STABILIZATION POND (CONTROL MODEL TANK A)

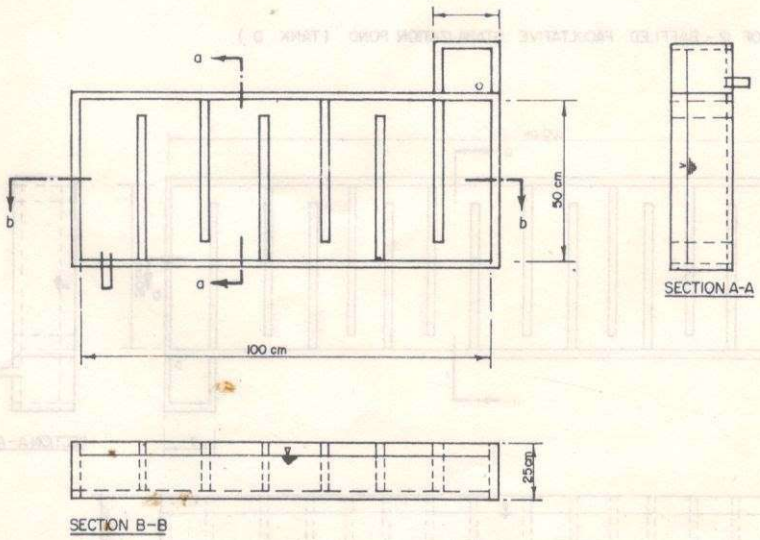


FIG 5. MODEL OF 6-BAFFLED FACULTATIVE STABILIZATION POND (TANK B)

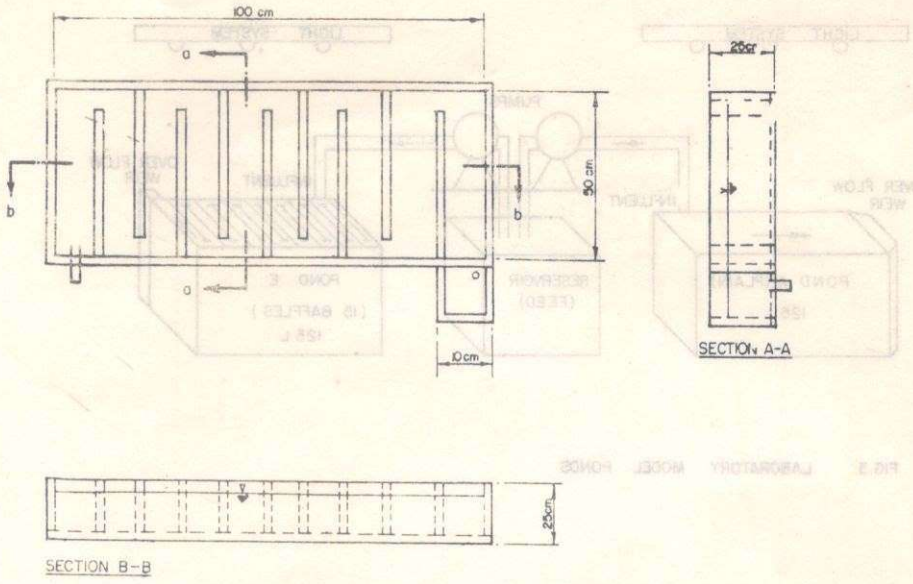


FIG. 6 MODEL OF 9-BAFFLED FACULTATIVE STABILIZATION POND (TANK C)

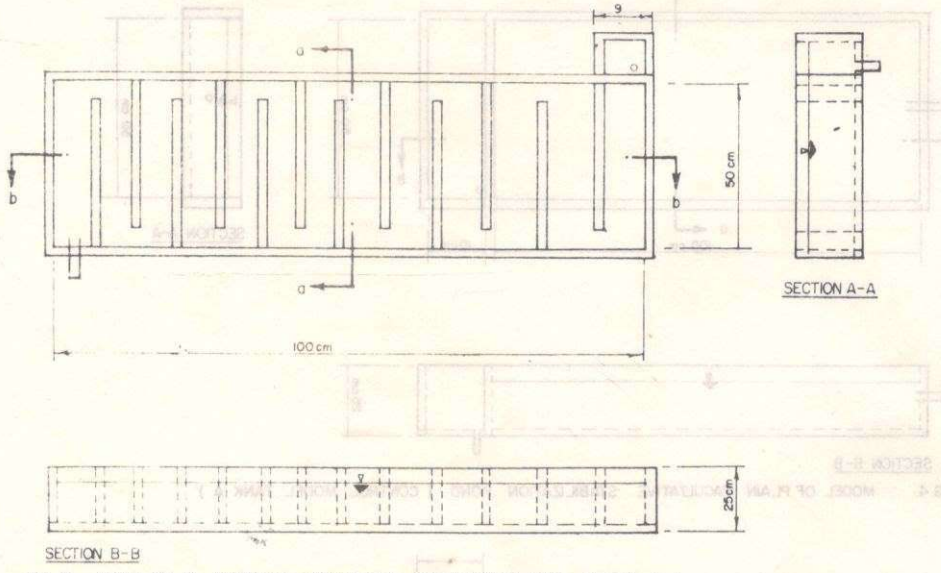


FIG 7. MODEL OF 12-BAFFLED FACULTATIVE STABILIZATION POND (TANK D)

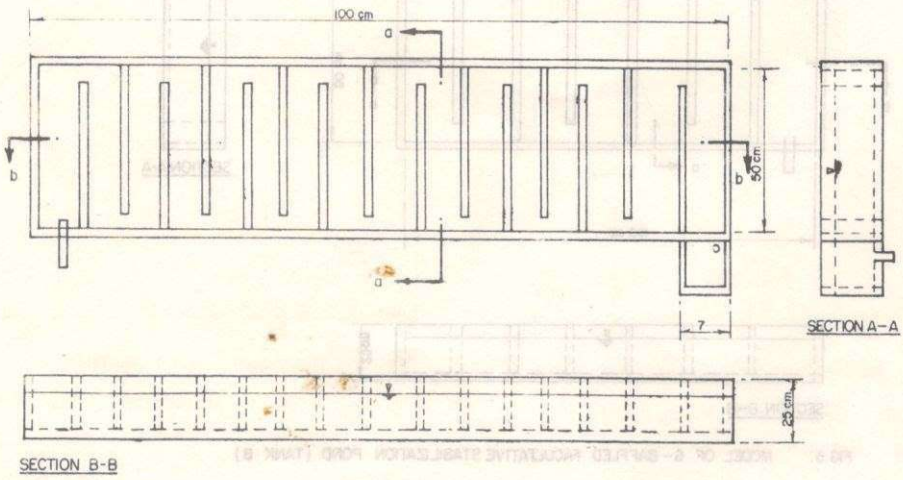


FIG 8. MODEL OF 15-BAFFLED FACULTATIVE STABILIZATION POND (TANK E)

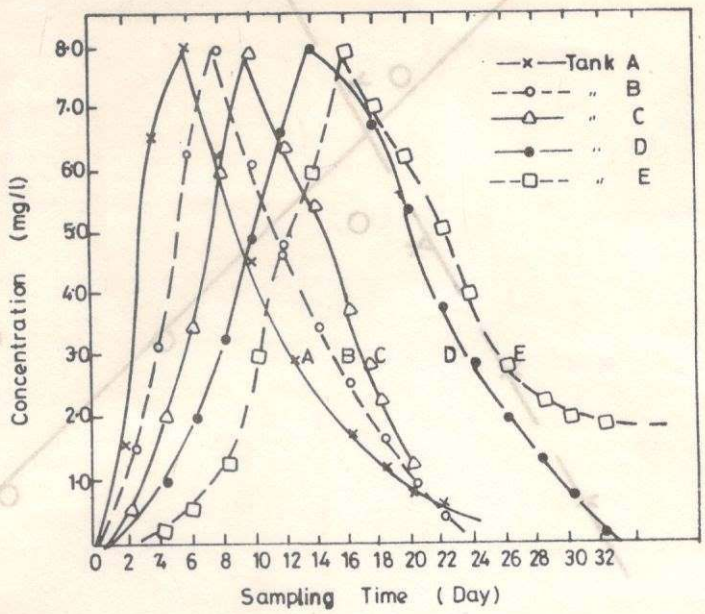


Fig.9 Tracer Test Curves — (15 Day Detention Time)

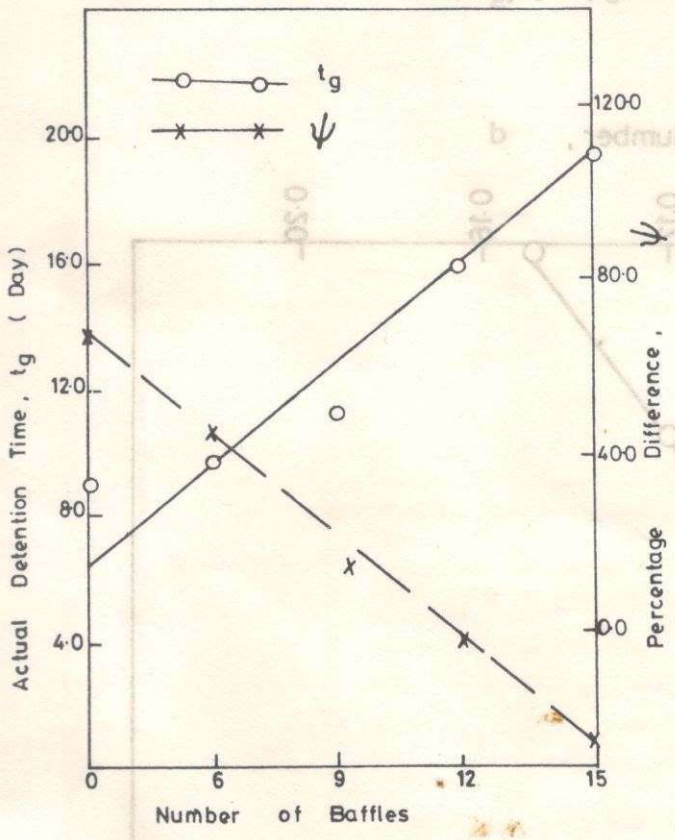


Fig.10 Actual Detention Time and Percentage Difference vs No of Baffles.

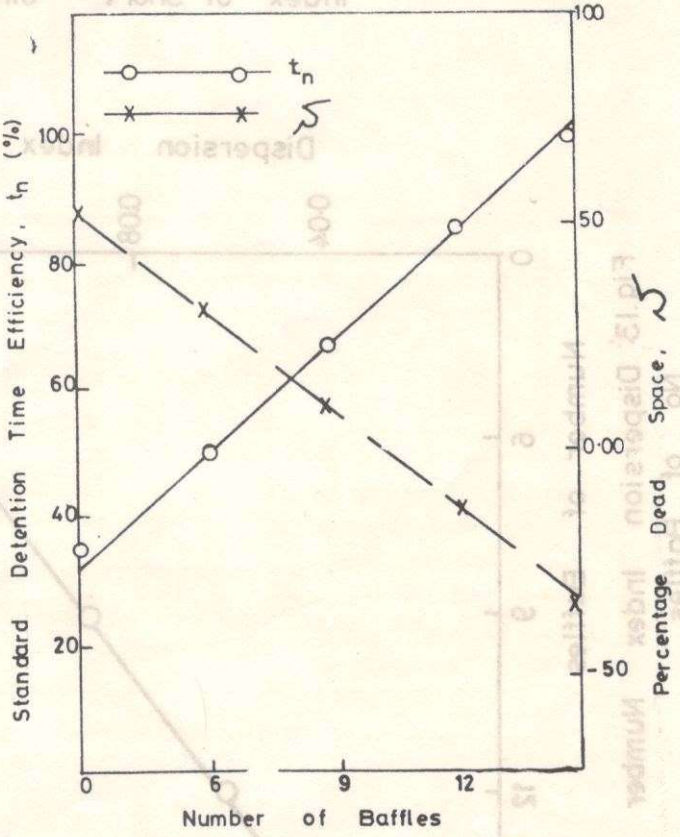


Fig.11 Standard Detention Time Efficiency and Percentage Dead Space vs No of Baffles.

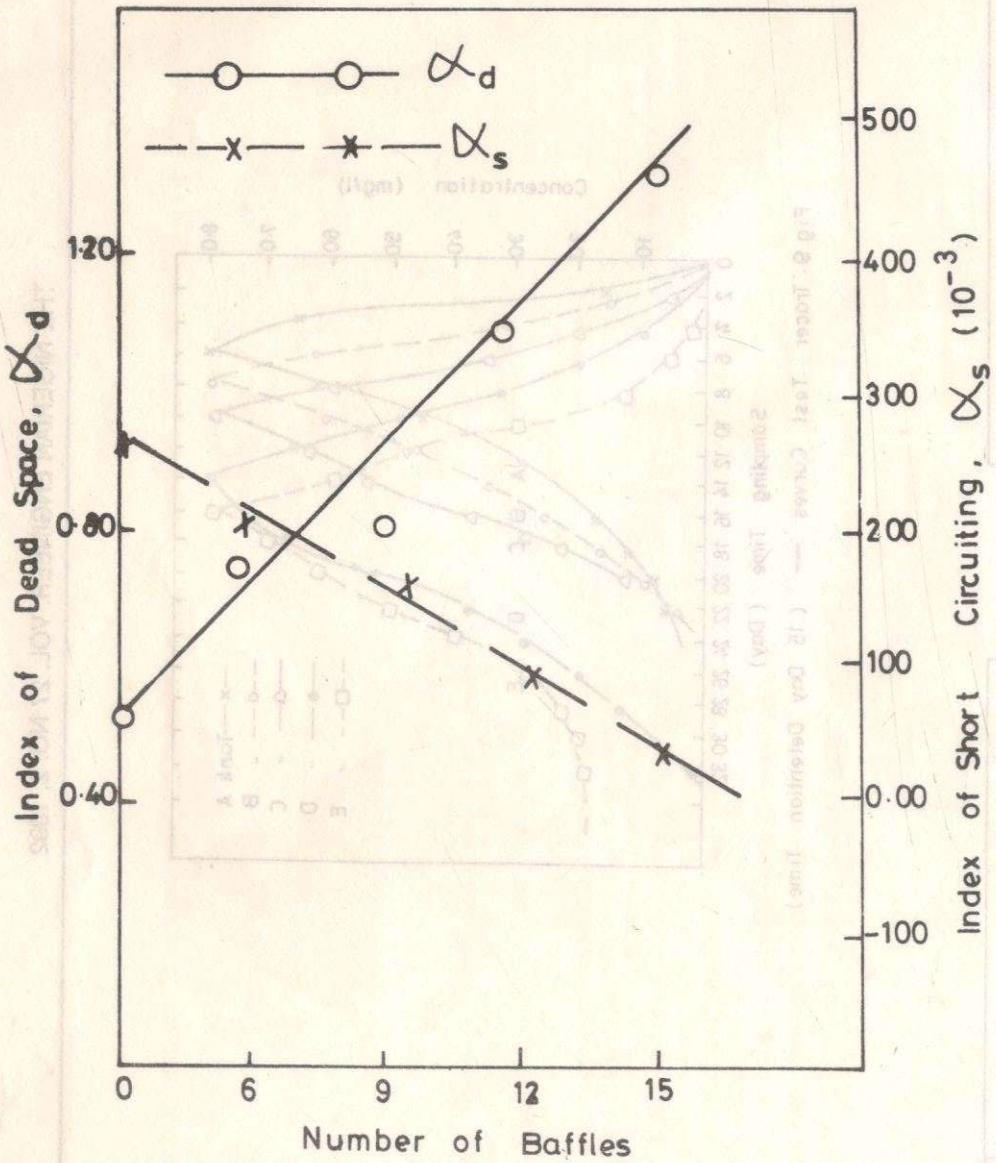


Fig.12: Index of Dead Space and Index of Short Circuiting vs No of Baffles.

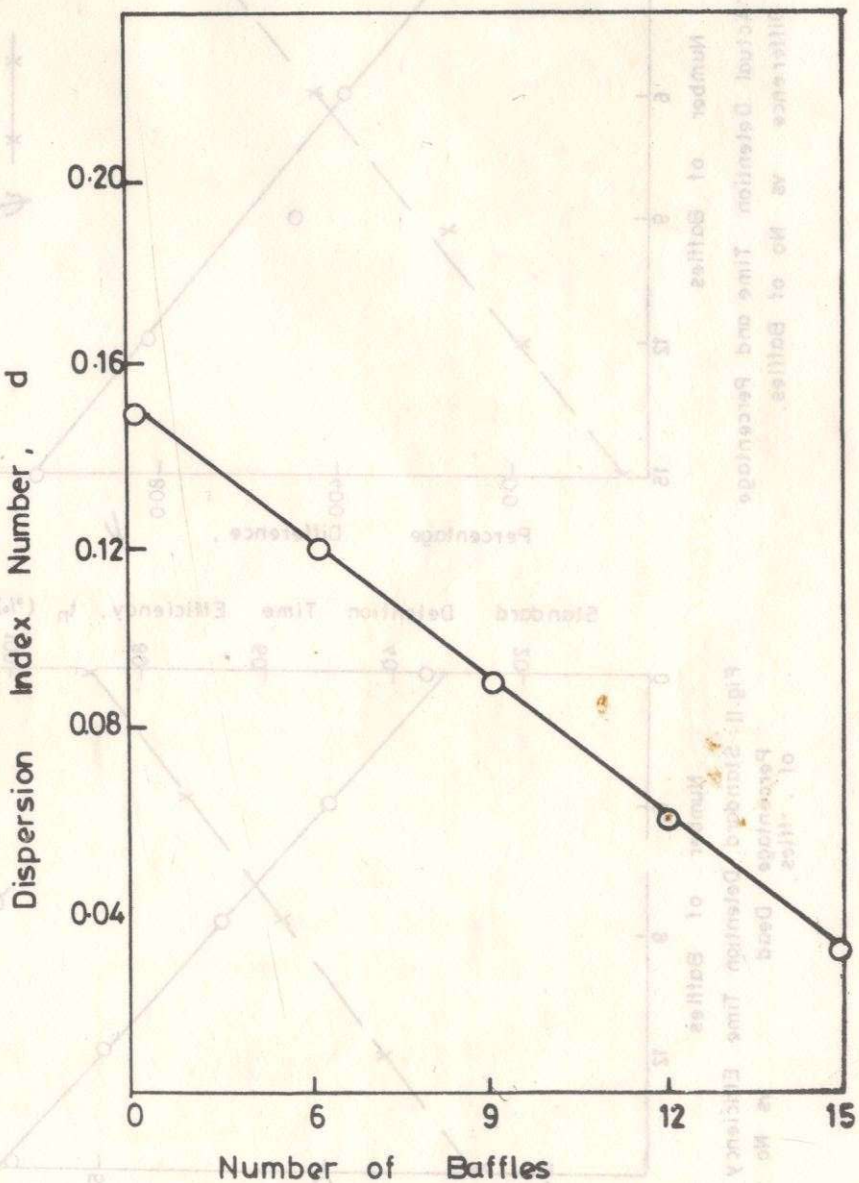


Fig.13: Dispersion Index Number vs No of Baffles.