

## Study of Dispersion Coefficient Channel

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**Abstract.** The issue of water pollution has worsened in recent times due to releases, intentional or not, of pollutants in natural water bodies. This causes several studies about the distribution of pollutants are carried out. The water quality models have been developed and widely used today as a preventative tool, ie to try to predict what will be the concentration distribution of constituent along a body of water in spatial and temporal scale. To understand and use such models, it is necessary to know some concepts of hydraulic high on their application, including the longitudinal dispersion coefficient. This study aims to conduct a theoretical and experimental study of the channel dispersion coefficient, yielding more information about their direct determination in the literature.

### 1. Introduction

Environmental degradation has become a problem in the world. The deterioration of water quality pollution has become one of the biggest environmental problems in recent years. Water resources are being increasingly damaged, suffering from increased pollution loads that cause sediment transport and chemical and organic water contamination. This water pollution leads to special care, so the Brazilian environmental legislation is increasingly restrictive. Therefore, efforts can be made to mitigate the adverse impacts of urbanization and industrialization, it is urgent that the parameters that guide the pollutant transport equation are true to reality of pollutant dispersion to ensure strategy to manage resources regarding emissions pollutants into rivers.

One of parameters for analyzing the body fluid of a water quality is the scattering coefficient, which informs the capacity of the water body must carry and disperse the pollutants. The scattering coefficient is also called overall mass transfer coefficient. A way to study the scattering coefficient is conducting experiments using tracers. The tracer can monitor the plume of pollution and through collections determine the pollutant concentration curve. This paper discusses the theoretical and experimental study of the scattering coefficient in the laboratory channel.

### 2. Scattering coefficient

Regarding the growing concern over pollution of water resources, several studies about the spatial and temporal distribution of pollutant concentration are being carried out, as well the development of mathematical models that try to predict this distribution [1]. According to [5] the models require well-evaluated parameters to produce reliable prognostic. In rivers and streams, it is necessary to know the average flow velocity and the coefficient of longitudinal dispersion [2]. When a constituent is



immersed in a fluid, it passes through two physical transport processes: advection and molecular diffusion. The molecular diffusion occurs due to the random movement of molecules from a region of higher concentration to a region of lower concentration. According to [3], it can be rendered by the following mathematical expression:

$$j_A = -\rho \cdot D_{AB} \cdot \nabla m_A \quad (1)$$

where:  $j$  is the diffusive mass flow of species A ( $\text{kg} / (\text{sm}^2)$ );  $\rho$  is the specific mass of the mixture ( $\text{kg} / \text{m}^3$ );  $D_{AB}$  is the molecular diffusion coefficient; and  $\nabla m_A$  is the gradient of the mass fraction of species.

Advection, in turn, is due to the transport movement of fluid medium [4]. According to [2], the total rate of mass transport is the result of the addition of advective and diffusive portions, which is expressed by Equation 2 according to the Law of Fick considering uniform flow in steady:

$$\frac{\partial C}{\partial t} + U \cdot \frac{\partial C}{\partial x} = D_L \cdot \frac{\partial^2 C}{\partial x^2} \quad (2)$$

where  $C$  is the average concentration in the cross section located at a distance  $x$  from the release point (ML-3);  $U$  is the average flow velocity (LT-1);  $D_L$  is the longitudinal dispersion coefficient (L<sup>2</sup>T<sup>-1</sup>); and  $x$  and  $t$  are space variables (L) and temporal (T), respectively.

Group the variables associated to the mass transfer in the form of dimensionless numbers is common. According to [3] the dimensionless parameters are important because they allow the use of results obtained in a surface subjected to a set of convective conditions in geometrically similar surfaces subject to entirely different conditions. Such conditions may be, for example, the nature of the fluid, fluid velocity and the size of the surface. In the literature there are several dimensionless numbers, Reynolds number (Re) Schmidt number (Sc), Sherwood number (Sh), Stanton number (Stm). The Sherwood number, in particular, is a dimensionless parameter concentration on the surface and provides a measure of convective mass transfer, which occurs at the surface. It is also possible to work with the average value of Sherwood, which depends only on the number of Reynolds (Re) and Schmidt (Sc):

$$\overline{Sh} = f(Re, Sc) \quad (3)$$

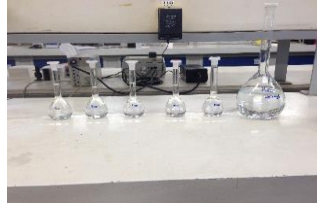
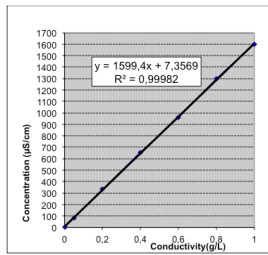
The longitudinal dispersion is related to the ability of water bodies to disperse substances that come into contact with its waters, and the scattering coefficient indicates this capacity [1]. In the literature there are two ways to obtain the scattering coefficient: by direct methods and indirect methods.

Direct methods are one of the most reliable ways of obtaining the scattering coefficient. This is obtained from experiments in the field of stimulus-response tracers [2]. Among the direct present methods in the literature can be cited: the moment method, the spreading method, the graphics Krenkel methods and Chatwin, the peak concentration method, the method of the reference concentration and setting method [5]. According to [1], currently, the propagation method is the most accepted method to estimate the longitudinal dispersion coefficient.

Several authors have established mathematical expressions that enable the indirect and quickly determination of longitudinal dispersion coefficient [4]. The use of mathematical expressions affects the work to a limitation that should be considered, and some differences between the values obtained by equations with data obtained in the field by several authors can be reported.

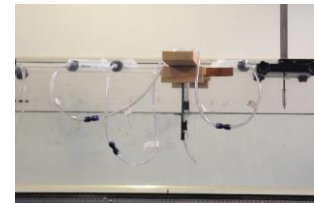
### 3. Methodology

First was necessary defines a tracer to perform the test dispersion in the channel. Thus, the chosen tracer was sodium chloride (NaCl) due to its low cost, ease of measurement and lack of toxicity. Chosen tracer experiment was performed in order to obtain the calibration curve of Figure 1. This experiment aim to obtain conductivity for different amounts of salt in distilled water. The calibration curve was obtained by serial dilutions from a stock solution of 1000 mg / L, shown in Figure 2. The equipment used for reading the conductivity of the concentrations was Mars MB - 11 (Figure 3) calibrated with conductivity solution 146.7 S / cm.

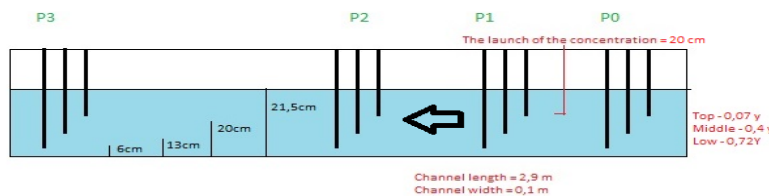


**Figure 1.** Calibration curve plotter. **Figure 2.** The method of successive dilutions. **Figure 3.** Conductivity measurement setup.

The channel used is transparent with a length of 2.9 mm, a width of 0.10m, and a depth of 30cm (Figure 4). The concentration of tracer present in the storage vessel (Figure 5) was thrown into the channel at a flow rate of 5 l / s, with a distance of 5 cm from the top of the channel and a height of 20 cm. To collect the samples concentration was chosen three points along the channel called P1, P2 and P3 at distances of 55 cm, 56 cm and 275 cm respectively. A control point called P0 was also chosen. For each point, the sample was taken from three different depths, called top, middle and bottom to 20 cm, 13 cm and 6 cm, respectively. The collections were made by syringe connected to each depth, as shown in Figure 6. The collection points and channel data can be seen in Figure 7 and Figure 8.



**Figure 4.** Channel for Hydraulic experiments. **Figure 5.** Storage tank mixing with tracer. **Figure 6.** Collection Equipment [6].



**Figure 7.** Collection points in the channel.

| Characteristic             | Point |
|----------------------------|-------|
| Haight of Water Depth (cm) | 21,5  |
| Channel Base (cm)          | 10    |
| Channel height (cm)        | 30    |
| Channel Area (cm²)         | 300   |
| Wet Area (cm²)             | 215   |
| Wet Perimeter (cm)         | 53    |
| Hydraulic radius (cm)      | 4,06  |

| Characteristic | Point    |
|----------------|----------|
| Wet Area (m²)) | 0,0215   |
| Flow (m³/s)    | 0,004973 |
| Velocity (m/s) | 0,231    |

**Figure 8.** Channel data.

#### 4. Results and Discussions

We can observe in the results of sampling using the NaCl with the discharge side three sampling points at each point the concentrations obtained through the calibration curve tracer. It is observed the behavior of the dispersion of the tracer at time P1 a peak concentration that is justified because the point is closest to the dump so (Figure 9), the other two points - P2 and P3 - had their behavior with a lower concentration (Figure 10 e Figure 11). The value found for the dispersion coefficient, was 0.00211978.

| Tempo          | Leitura ( $\mu\text{S}/\text{cm}$ )        | Diferença com P0 ( $\mu\text{S}/\text{cm}$ ) | Conc. (g/L)         | Gráficos das concentrações de sal para cada intervalo de tempo | Sal (g)                   |
|----------------|--|--|---------------------|--|---------------------------|
| INICIO 0 min   | Cima: 84,0<br>Meio: 84,0<br>Baixo: 84,0    | 0,00<br>0,00<br>0,00                         | -                   |  | -                         |
| Total          |  |  |                     |  |                           |
| TESTE 1 1 min  | Cima: 201,1<br>Meio: 89,5<br>Baixo: 87,9   | 113,41<br>5,5<br>3,9                         | 0,064<br>-<br>-     |  | 0,057<br>-0,006<br>-0,010 |
| Total          |  |  |                     |  | 0,041                     |
| TESTE 2 5 min  | Cima: 309,8<br>Meio: 182,7<br>Baixo: 160,9 | 151,16<br>4,05<br>2,25                       | 0,086<br>-<br>-     |  | 0,077<br>-0,004<br>-0,007 |
| Total          |  |  |                     |  | 0,066                     |
| TESTE 3 10 min | Cima: 376,3<br>Meio: 244,9<br>Baixo: 241,7 | 135,35<br>3,95<br>0,75                       | 0,077<br>-<br>-     |  | 0,069<br>-0,004<br>-0,009 |
| Total          |  |  |                     |  | 0,056                     |
| TESTE 4 20 min | Cima: 505,4<br>Meio: 388,2<br>Baixo: 387,4 | 121,85<br>4,85<br>3,85                       | 0,089<br>-<br>-     |  | 0,062<br>-0,003<br>-0,005 |
| Total          |  |  |                     |  | 0,054                     |
| TESTE 5 30 min | Cima: 637,3<br>Meio: 528,7<br>Baixo: 521,4 | 117,20<br>8,60<br>1,30                       | 0,066<br>0,001<br>- |  | 0,059<br>0,001<br>-0,008  |
| Total          |  |  |                     |  | 0,052                     |

**Figure 9.** Results of samples taken at the point P1 and graphs of concentrations for each collection interval at that point.

| Tempo          | Leitura ( $\mu\text{S}/\text{cm}$ )        | Diferença com P0 ( $\mu\text{S}/\text{cm}$ ) | Conc. (g/L)             | Gráficos das concentrações de sal para cada intervalo de tempo | Sal (g)                   |
|----------------|--|--|-------------------------|--|---------------------------|
| INICIO 0 min   | Cima: 84,0<br>Meio: 84,0<br>Baixo: 84,0    | 0,00<br>0,00<br>0,00                         | -                       |  | -                         |
| Total          |  |  |                         |  |                           |
| TESTE 1 1 min  | Cima: 138,7<br>Meio: 111,1<br>Baixo: 89,1  | 51,01<br>23,41<br>5,44                       | 0,026<br>0,010<br>-     |  | 0,023<br>0,017<br>-0,008  |
| Total          |  |  |                         |  | 0,032                     |
| TESTE 2 5 min  | Cima: 231,2<br>Meio: 164,7<br>Baixo: 160,0 | 72,55<br>6,05<br>1,35                        | 0,036<br>-0,001<br>-    |  | 0,035<br>-0,002<br>-0,008 |
| Total          |  |  |                         |  | 0,025                     |
| TESTE 3 10 min | Cima: 327,4<br>Meio: 253,7<br>Baixo: 249,3 | 86,45<br>12,75<br>8,35                       | 0,047<br>0,003<br>0,001 |  | 0,043<br>0,006<br>0,007   |
| Total          |  |  |                         |  | 0,057                     |
| TESTE 4 20 min | Cima: 449,4<br>Meio: 397,3<br>Baixo: 378,6 | 65,85<br>13,75<br>-4,95                      | 0,036<br>0,004<br>-     |  | 0,031<br>0,007<br>-0,017  |
| Total          |  |  |                         |  | 0,021                     |
| TESTE 5 30 min | Cima: 572,2<br>Meio: 536,3<br>Baixo: 521,4 | 52,10<br>18,20<br>1,30                       | 0,027<br>0,006<br>-     |  | 0,024<br>0,012<br>-0,008  |
| Total          |  |  |                         |  | 0,027                     |

**Figure 10.** Results of samples taken at the point P2 and graphs of concentrations for each collection interval at that point.

| Tempo          | Leitura ( $\mu\text{S}/\text{cm}$ )        | Diferença com P0 ( $\mu\text{S}/\text{cm}$ ) | Conc. (g/L)             | Gráficos das concentrações de sal para cada intervalo de tempo | Sal (g)                    |
|----------------|--|--|-------------------------|--|----------------------------|
| INICIO 0 min   | Cima: 84,0<br>Meio: 84,0<br>Baixo: 84,0    | 0,00<br>0,00<br>0,00                         | -                       |  | -                          |
| Total          |  |  |                         |  |                            |
| TESTE 1 1 min  | Cima: 89,4<br>Meio: 87,2<br>Baixo: 87,0    | 1,70<br>-0,45<br>-0,69                       | -                       |  | -0,003<br>-0,009<br>-0,011 |
| Total          |  |  |                         |  | -0,023                     |
| TESTE 2 5 min  | Cima: 190,6<br>Meio: 186,3<br>Baixo: 172,4 | 31,95<br>27,65<br>13,75                      | 0,015<br>0,012<br>0,004 |  | 0,013<br>0,022<br>0,009    |
| Total          |  |  |                         |  | 0,043                      |
| TESTE 3 10 min | Cima: 272,0<br>Meio: 261,8<br>Baixo: 250,6 | 31,05<br>20,85<br>9,65                       | 0,014<br>0,006<br>0,001 |  | 0,013<br>0,014<br>0,003    |
| Total          |  |  |                         |  | 0,030                      |
| TESTE 4 20 min | Cima: 410,2<br>Meio: 401,8<br>Baixo: 400,7 | 26,65<br>18,25<br>17,15                      | 0,011<br>0,006<br>0,006 |  | 0,010<br>0,012<br>0,013    |
| Total          |  |  |                         |  | 0,035                      |
| TESTE 5 30 min | Cima: 545,0<br>Meio: 538,3<br>Baixo: 520,2 | 24,90<br>18,20<br>0,10                       | 0,010<br>0,006<br>-     |  | 0,009<br>0,012<br>-0,010   |
| Total          |  |  |                         |  | 0,011                      |

**Figure 11.** Results of samples taken at the point P3 and graphs of concentrations for each collection interval at that point.

## 5. Conclusion

The obtained calibration curve, which allows observe the readings on conductivity for different concentrations were good, since the coefficient of determination was very close to 1 ( $R^2 = 0.998$ ). With this, we concluded that the calculated concentrations in the dispersing test in the channel from the conductivity of the samples are very efficient. By the results obtained in the dispersion test in the channel was observed that the samples taken from P1 had a higher concentration with respect to samples P2 and P3. It was also observed concentrations in deeper layers of P2 and P3 when times changed, and were not detected in P1. An increase in the value of these concentrations was also observed. The graphics allow analyze that the concentrations in P1 were very high, whereas in P3 has almost uniform concentrations of salt in water. P2 presents an intermediate position compared with P1 and P3. In P3 the three depths were much closer values compared to the other two points.

The results showed that there was dispersion of the initial concentration of NaCl spatially and temporally, based on data found for the coefficient at each point.

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