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Numerical Modelling Means for the Fight against Eutrophication of Lakes: Artificial Destratification and Selective Racking

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ABSTRACT: The object of this work is to test two applications: Artificial destratification and Selective Racking to fight the eutrophication of lake. For this we consider a jet described by the equations of Navier stocks whose resolution is based on the finite difference method. For the first treatment (artificial Destratification), the idea is to consider a rectangular area filled with water, and start the jet from the bottom to the surface. For the second treatment (selective Racking), it considers another rectangular field full of water, but the jet will now be on the left lateral border into the hole located in the right side border.

KEYWORDS: Equations of Nervier stocks, artificial destratification, selective racking, Method of Finished Differences.

1 INTRODUCTION

Eutrophication of lakes is a natural and a very slow process by which water bodies receive a large amount of nutrients (particularly phosphorus and nitrogen), which stimulates the growth of algae and aquatic plants. This process, takes place normally over a period going of several thousands to some dozens of thousand years. However, human activities have accelerated in many lakes by increasing the amount of nutrients that reach them, causing changes in the balance of these aquatic ecosystems [1]. Lakes being more than 3 metres deep possess, in summer a vertical thermic stratification that was provoked by the difference of density between the surface layers heated, whereas the water layers remained cold. The stability of water, blocking the vertical exchange within the water column, causes a depletion of the stock of hypolimnetic oxygen (lower half of the water) [2].In this work, we are going to apply both methods of rehabilitation of the eutrophes plans (aeration and selective racking), on the model described by the Equations of Nervier stocks, whose resolution is based on finite difference method [3].

2 PRESENTATION OF METHODS

Among the methods of rehabilitation of the eutrophes plans, we can use: the aeration and the racking:

2.1 AERATION BY DESTRATIFICATION

Aeration is now one of the proven processes. It is either limited to the deep layers (hypolimnetic aeration) or diffused over the entire (aeration by destratification) water column, this technique also disrupts the growth of algae and prevents the formation of undesirable compounds such as ammonia, methane or hydrogen sulphide.

The impact of this technique is evaluated on stratification by experimental work (Baines, WD and Leitch, AM1992 [4] Geoffrey Schladow 1993 [5]).

The aeration by desertification consists in creating one or several curtains of ascending bubbles that generates an effect of area topspin on several hundred meters. This mass movement causes a flow of water from the bottom to the lake surface. It causes their aeration through contact with the surface of the stretch of water and, thus, has consequence for oxidizing, the preservation of condition within all the column of water.

2.2 SELECTIVE RACKING

Concerning the racking, we count in the literature several experimental works. Monismith, S. 1988 [6]) examined the Generation of the internal waves by unsteady effect of racking of the water of a laminated reservoir. Sharp, J.J (1993) [7] Studied the racking by using circular structures partially submerged.

Hocking, C.G 1988 [8] proposed an algorithm of the selective racking for the case of the laminated reservoirs.

3 APPLICATIONS

We tried to solve the equations of Navier-Stokes and the equation of the transport of the mass of a jet at the bottom of a canal. In terms of vortex function ω**,** function of current $\boldsymbol{\psi}$, and concentration C, by applying both methods aeration by desertification and the selective racking with the corresponding initial and limit (borderline) conditions, These equations are:

$$\frac{\partial\omega}{\partial t} + \left(\vec{U}.\vec{\nabla}\right)\omega = \frac{1}{\mathcal{R}\mathrm{e}}\Delta\omega + \frac{1}{\mathcal{F}r^2}\left[\vec{\nabla}C \wedge \frac{\vec{g}}{\|\vec{g}\|}\right].\vec{k} \quad (1)$$

$$\Delta\psi = -\omega \quad (2)$$

$$\vec{U} = \vec{\nabla} \wedge (-\psi\vec{\mathrm{k}}) \quad (3)$$

$$\frac{\partial C}{\partial t} + \left(\vec{U}.\vec{\nabla}\right)C = \frac{1}{\mathcal{R}eSc}\Delta C \quad (4)$$

With the following notations:

- $\vec{\nabla}$ and Δ are respectively the gradient operator and the Laplacian operator.
- t is the time variable.
- $\vec{k}$ is the directly perpendicular vector in the plan of the flow.
- $\vec{U}$ Is the velocity Victor.
- ψ is the function of current
- ω is the vortex function , such a $\vec{\omega} = \omega\vec{k} = \vec{\nabla} \wedge \vec{U}$
- C is the concentration of the pollutant.
- $\vec{g}$ Acceleration of gravity.
- Re, Sc, Fr Represent respectively the numbers of: Reynolds, Schmidt and Froude.

3.1 APPLICATION 1: AERATION BY DESTRATIFICATION

To test this approach, we consider a rectangular domain D1, filled with water, with a width of 4 m and length 6m. We introduce in the middle of the bottom a jet of the pollutant of the concentration C (fig 1).

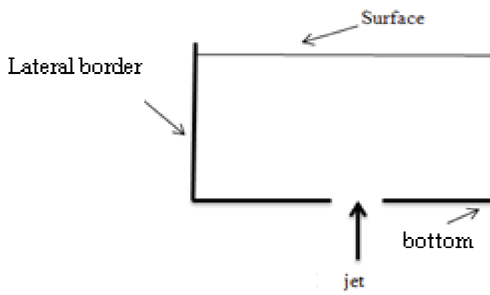
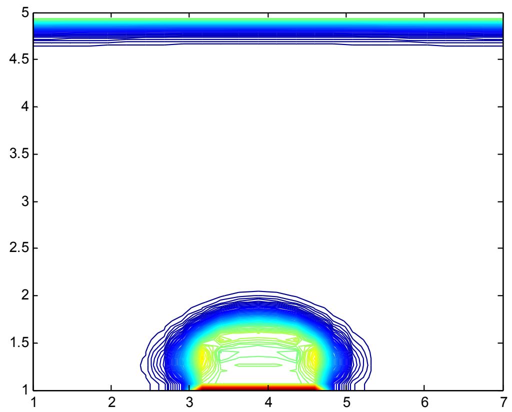


Fig. 1: the domain D1

3.1.1 Results

In Figures (2.3), the results are presented as iso-values of the concentration C at different time. We see that the jet traces hypolimnetic bottom water to the surface.



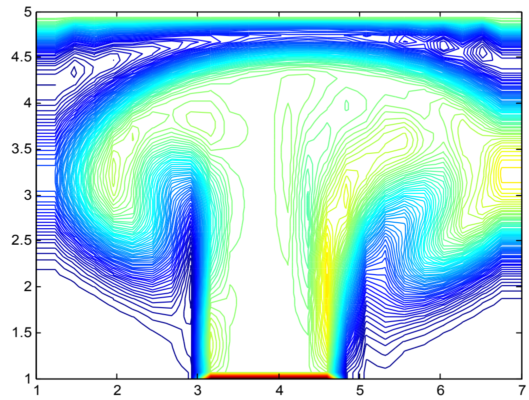


Fig. 2: iso-concentrations at time t = 1 s Fig. 3: iso-concentrations at time t = 10 s

The Figures (4, 5) represent the velocity fields in different time.

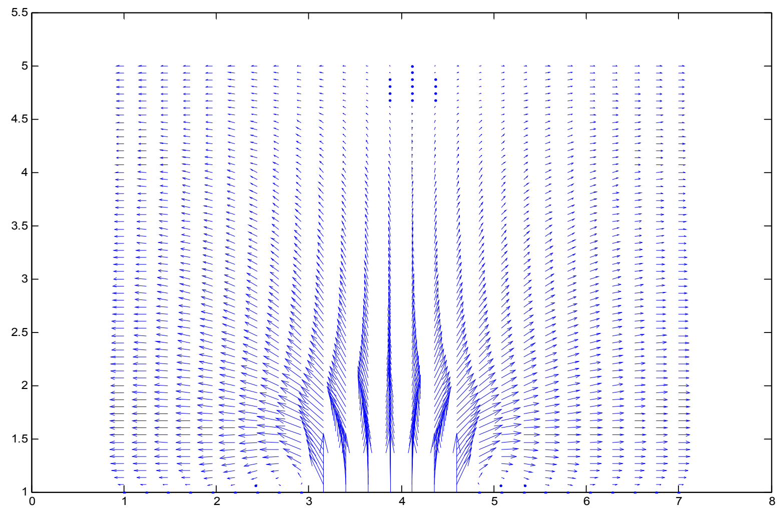


Fig 4: The velocity field at time t = 1s.

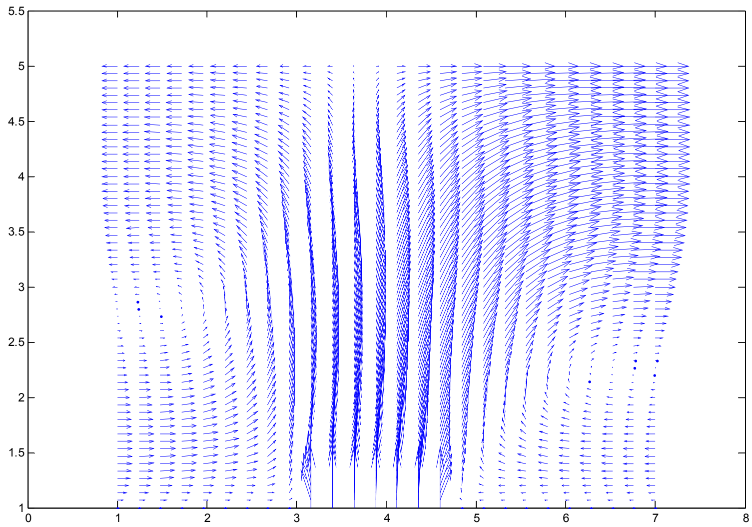


Fig 5: The velocity field at time t = 10 s

3.1.2 CONCLUSION

According to the obtained result (figures 2,3) by the application of the Aeration by Destratification on our mode , We see that the jet goes to the surface and by consequence hypolimniques waters are going to go back up of the bottom, what is confirmed by the results representing the field speed (figures 4,5) .

In the latter figs we see two cells of symmetric circulations being situated from part is of other one of the axis of the centred jet

3.2 APPLICATION 2: SELECTIVE RACKING

To test the treatment of the racking on our model, we take a rectangular domain D2, filled with water, with a width of 4m And a length of 6m with the initial conditions and in the limits correspondents.

But this time, we put on the wall approval an opening (fig 6).

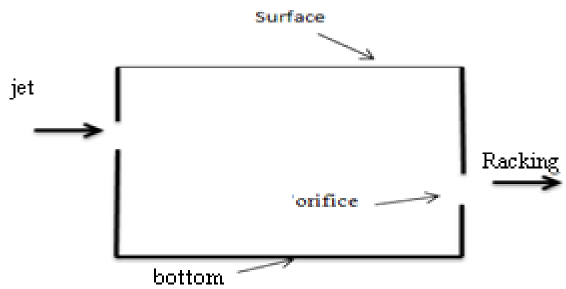
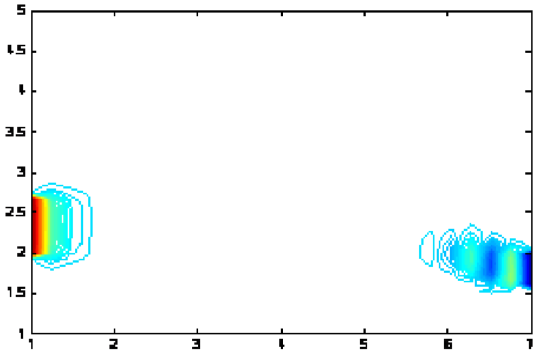


Fig 6 : the domain D2.

3.2.1 RESULTS

Figures (7,8,9) give the movement of the jet orifice to form iso concentration values according to different times



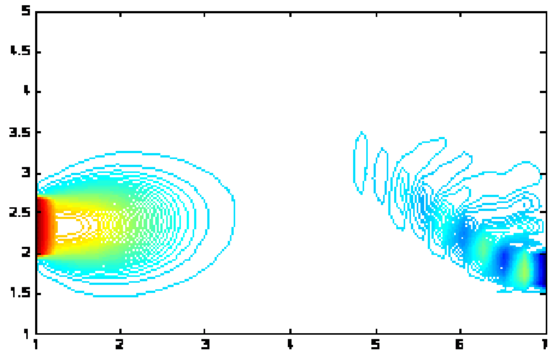


Fig 7: Racking at time t = 1 s. Fig 8: Racking at time t = 6 s.

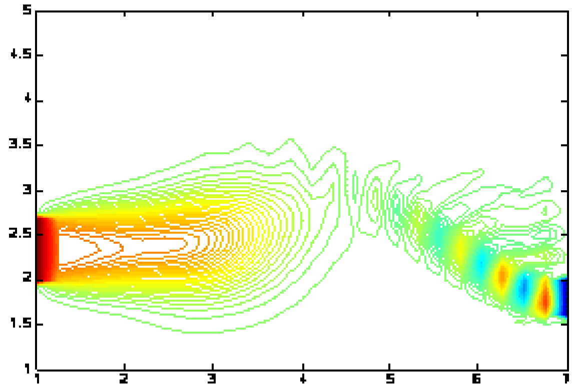


Fig 9: Racking at time t = 10 s.

On figures (10,11,12), we see the results obtained from the field of speed led by the racking in positions different from The opening.

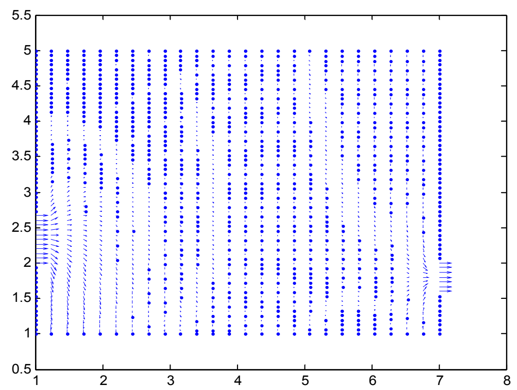


Fig 10: Field of speed leads by the racking in 10s of simulation. The opening is close To the bottom

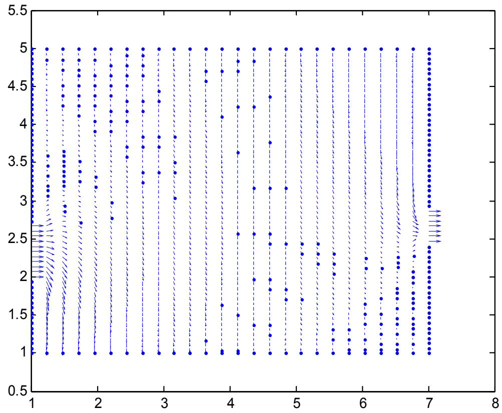


Fig 11: Field of speed leads by the racking in 10s of simulation. The opening is in the middle.

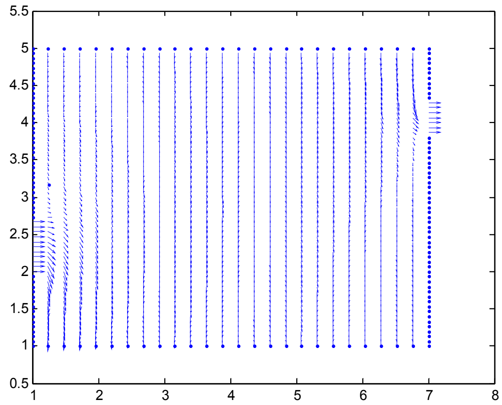


Fig 12: Field of speed leads by the racking in 10s of simulation. The opening is close To the surface.

The Figures (13,14,15) present the distribution of the horizontal speed in time t=10s, in positions different from the opening

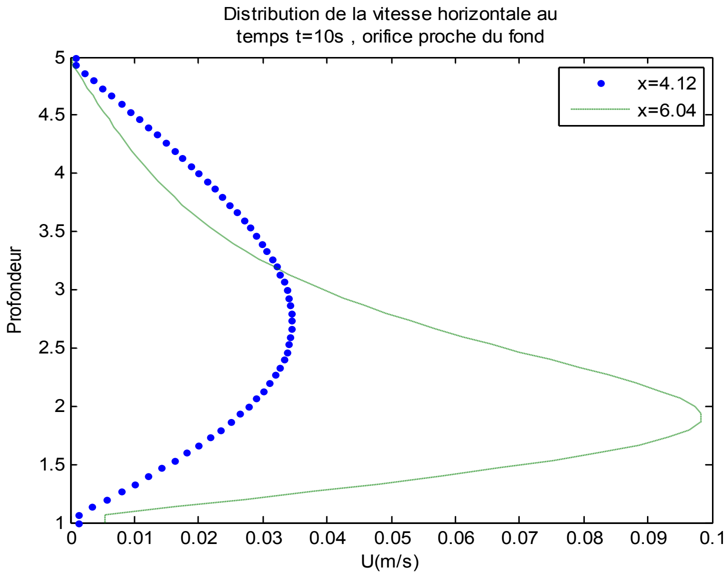


Fig 13: vertical Distribution of the horizontal speed in two points of the canal, in t=10 of simulation. The opening close to the bottom.

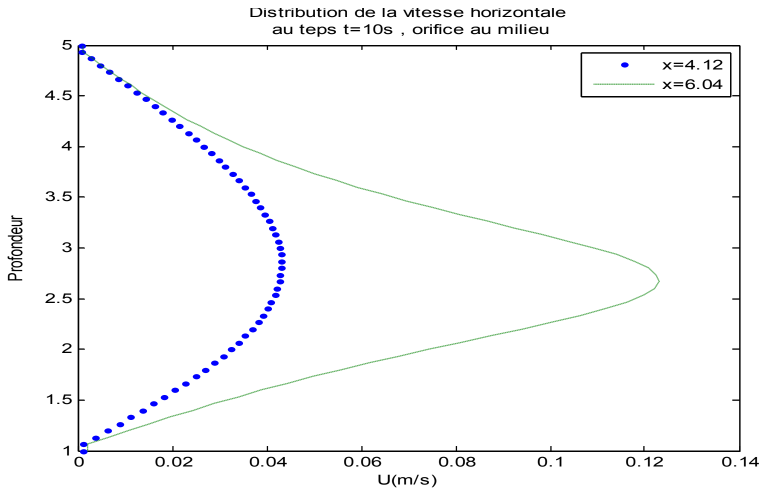


Fig 14: vertical Distribution of the horizontal speed in two points of the canal, in t=10 of simulation. The opening in the middle

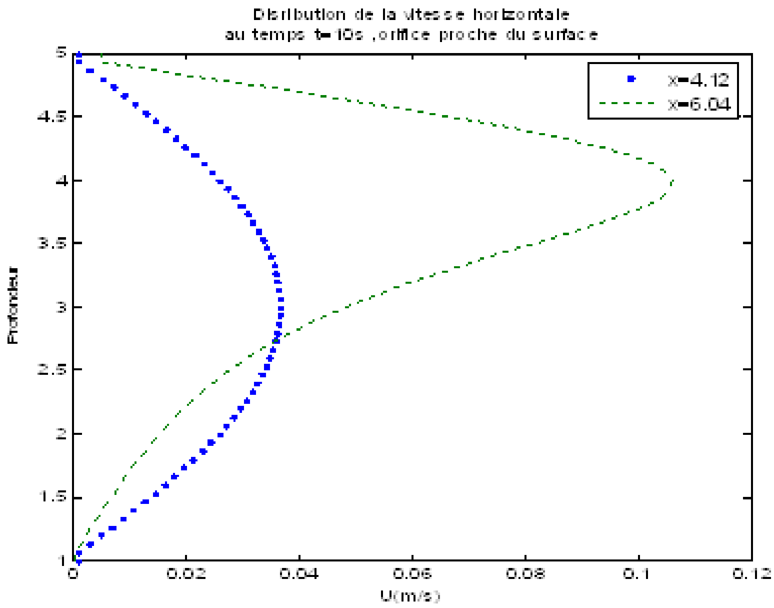


Fig 15: vertical Distribution of the horizontal speed in two points of the canal in t=10 of simulation. The close Opening of surface.

Figures (16,17,18), we present The distribution(casting) of the concentration in positions different from the opening.

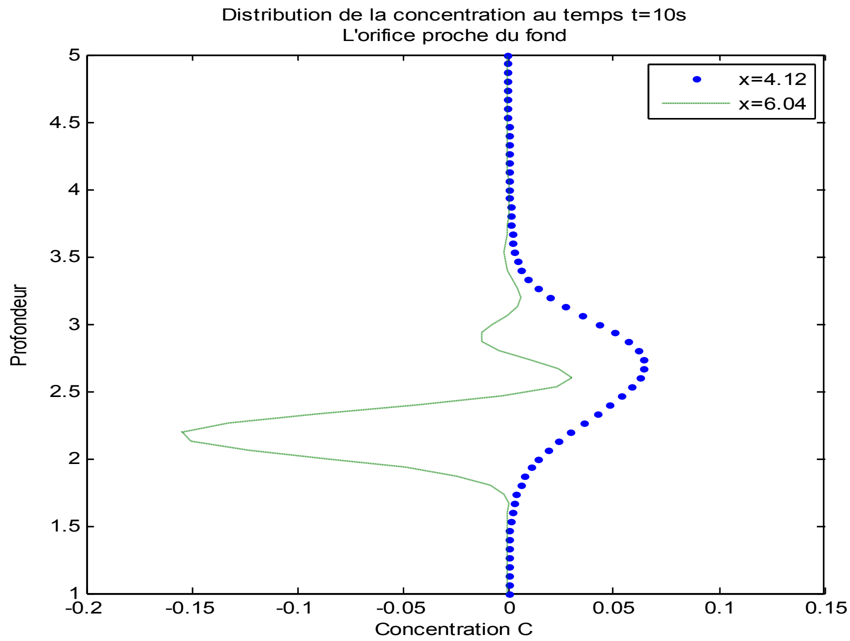


Fig 16: vertical Distribution of the concentration in two points of the canal, in t=10 of simulation. The opening close to The bottom.

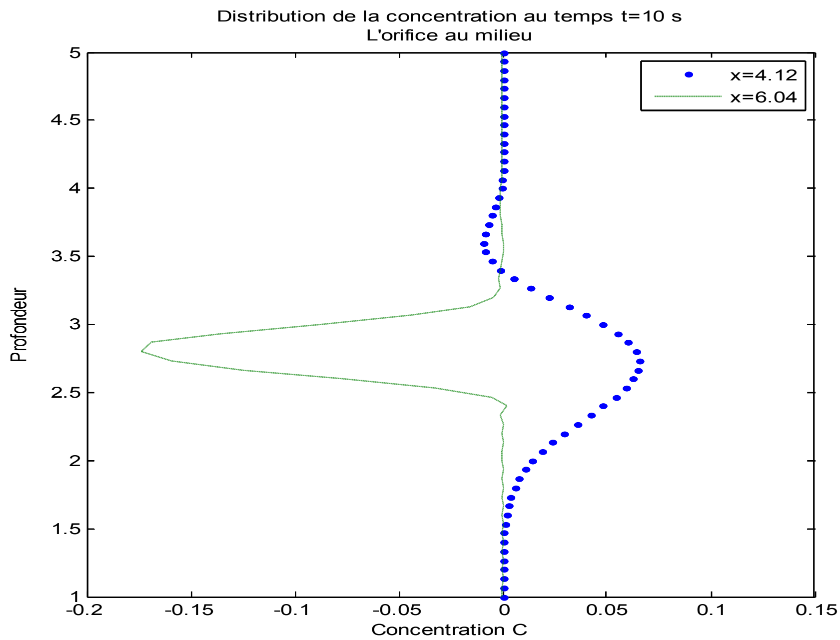


Fig 17: vertical Distribution of the concentration in two points of the canal, in t=10 of simulation. The opening close to the Middle.

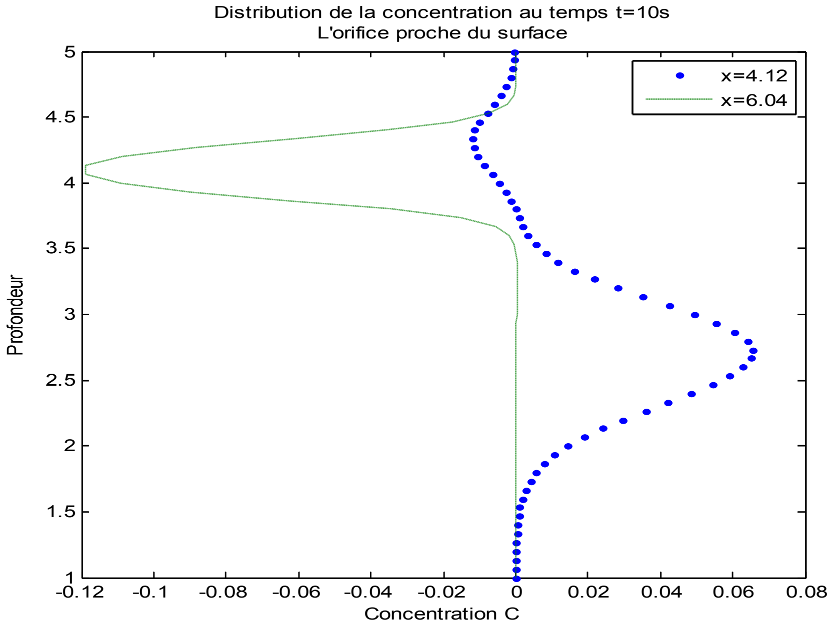


Fig 18: vertical Distribution of the concentration in two points of the canal, in t=10 of simulation. The opening close of surface.

3.2.2 Conclusion

According to the reached results (figures 7…. 15), we notice that there is a movement of the jet towards the opening and That it becomes established as a horizontal zone of retreat at the level of the release whatever is the position of the Opening. We notice according to the profiles of the concentration (figures 16,17, 18) that the distribution of the Concentration is better when the opening is close to the bottom. Indeed the simulation based on the principle of the Racking has shown that it forms a fine layer of retreat and it emphasized the impact of the position of the opening during The racking.

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