Distribution of Pollutant in Longitudinal Direction of Open Channel Flow

SOHEIL SAEEDFAR

A project report submitted in partial fulfillment
of the Requirements for the award of the degree of
Master of Engineering (Civil – Hydraulics and Hydrology)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

January 2012

To my beloved mother and father

ABSTRACT

Predicting of distribution of pollutant in a rectangular open channel on passive mixing of pollutant in longitudinal direction is reported. A finite numerical difference scheme developed by author was extended to determine longitudinal advection and dispersion of concentration of pollutant into the open channel flow. To compute the concentration and depicting the graph versus time, modeling a channel to obtain velocity in small steps of the length of the channel was inevitable. Modeling of the channel is based on Saint-Venant equation as the governing equation. For solving the governing equations, direct numerical method by using partial differential equation into finite difference equations have been considered. In numerical method for the solution of the partial derivative equations, the computations are performed on the x-t grid depending on the length of channel. Explicit scheme for solution is considered. The unknown variables (velocity, depth, and concentration of pollutant) at a future time step $t + \Delta t$ are considered by a number of variables at the previous time steps. The graphs of concentration versus time and discharge versus time were depicted and compared to each other. Also the graphs of concentration with the depicted graph of experimental data were compared. Model results and field data were generally in good agreement. About 70% of the results from numerical method were matched with the data from experimental performance.

ABSTRAK

Peramalan pengagihan bahan pencemar dalam saluran terbuka segi empat tepat pada percampuran pasif pencemar dalam arah membujur dilaporkan. Skim perbezaan terhingga berangka yang dibangunkan oleh penulis telah dilanjutkan untuk menentukan adveksi membujur dan penyebaran kepekatan pencemar ke dalam aliran saluran terbuka. Untuk mengira kepekatan dan menggambarkan graf melawan masa, pemodelan saluran untuk mendapatkan halaju dalam langkah-langkah yang kecil panjang saluran perlu dilakukan. Pemodelan saluran adalah berdasarkan persamaan Saint-Venant sebagai persamaan pentadbir. Untuk menyelesaikan persamaan yang mengawal, secara langsung kaedah berangka dengan menggunakan persamaan kebezaan separa ke dalam persamaan beza terhingga telah dipertimbangkan. Dalam kaedah berangka bagi penyelesaian persamaan terbitan separa, pengiraan adalah dilaksanakan ke atas grid xt bergantung kepada panjang saluran. Skim eksplisit untuk penyelesaian dipertimbangkan. Pemboleh ubah yang tidak diketahui (halaju, kedalaman, dan kepekatan pencemar) pada masa akan datang langkah $t + \Delta t$ dianggap oleh beberapa pembolehubah pada langkah-langkah masa yang lalu. Graf kepekatan berbanding masa dan pelepasan melawan masa telah digambarkan dan berbanding antara satu sama lain. Juga graf kepekatan dengan graf yang digambarkan data uji kaji dibandingkan. Keputusan model dan data penyelidikan secara amnya menunjukkan hasil yang baik. Kira-kira 70% daripada hasil daripada kaedah berangka telah padan dengan data dari ujikaji makmal.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF APPENDICES

LIST OF SYMBOLS

B	width of channel
C	concentration of pollutant
$C-t$	concentration versus time
Q	discharge
t	time
x	coordinate in longitudinal direction
D^M	Molecular diffusion
u_0	initial velocity
u	velocity
$1D$	one-dimensional
S_o	bottom slope of channel
S_f	the slope of energy grade line
g	gravitational acceleration

LIST OF ABBREVIATIONS

ABBREVIATION	WHOLE PHRASE	PAGE
RAP	Remedial action plan	1
CFD	Computational fluid dynamic	2
PDE	Partial differential equation	7
ODE	Ordinary differential equation	7
MOC	Method of characteristics	10
CV	Control volume	18

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 General

Nowadays, one of the biggest problems in the world is shortage of fresh water. Seventy per cent of our planet is covered by water, but unfortunately, only about 2.7 per cent of that is fresh water. According to statistics of researchers, only one percent of all fresh water is consumable. Discharging wastewater into the rivers has polluted another 1.7 per cent. There are variety ways that make water resources ailing and contaminated such as; discharges the wastewater and contaminated chemic from residual industry, domestic sewage, fertilizers, pesticide and herbicides used in farms.

Remedial action plans (RAPs) should be developed for many situating such as many ailing water bodies in lakes or water resources. This study intends to predict distribution of pollutant in downstream water body of the injection point, which is required for assessing the impact of industrial and municipal waste disposal schemes into the rectangular open channel. Open channel hydraulics has usually been a much more interesting for engineers who study and research about free surface flow. Free surface flow such as rivers and channels can be regarded as one of the most difficult physical processes in the environment. The first one of complexities is physical flow processes and their mathematical computations. And the second one is about solution of derived equations. In general, numerical open channel can be perceived as a sub-domain of Computational Fluid Dynamic (CFD). CFD is applicable in open channel flow modeling.

Numerical open channel hydraulic developed as early as in the year 1960s and 1970s. Chow V.T (1959) Open Channel Hydraulics, Bird R.B, Steward W.E, Lightfoot E.N (1960) Transport Phenomena, Henderson F.M (1966) Open Channel Flow, Liggett (1975) Basic Equations of Unsteady Flow, Abbott M.B, Basco D.R (1989) Computational Fluid Dynamics, Akan A.O (2006) Open Channel Hydraulics, and many others who helped to develop and improve this knowledge.

To obtain the general equation for incompressible flow, domination of one component of the velocity vector is considered as a typical attribute of the open channel flow in which allows us to determine the flow process as one-dimensional phenomenon. On the other hand, to the other types of surface water flows, to derive the governing equations two principals of conservation form are considered; Momentum Conservation Law, and Mass Conservation Law.

There are various ways to perform derivations; one of them is the system of equation for Unsteady Gradually Varied Flow. Then the governing equations must be known (Continuity and Momentum Equation). These equations are called the Saint-Venant equations.

Considering of Mass Transport equation (Nokes et al (1984) formula), help us to derive one-dimension advection-diffusion transport of contamination into the water body.

1.2 Statement of the problem

The pollution of Water happens when pollutant is discharged directly/indirectly into the water body without enough treatment to remove harmful compound. Nowadays, releasing contaminated substances into the environment are consistently occurred. Then, for any remedial action against this predicament, human being needs to have enough knowledge to determine how pollutant distributes into the water body. Therefore, determination of contamination transport into the artificial channels and finding some factors that accelerate this process are significant.

Therefore, this study is going to determine how the type of contaminated substances, velocity of flow, type of flow, bed slop of channel, and other factors can affect on distribution process of pollutant in open channel flow.

1.3 Objective of the Study

Objective of this study is investigation of distribution of pollutant into the rectangular open channel flow, base on the following statements;

1.3.1. To modeling a channel in order to control of distribution of pollutant in open channel flow.

1.3.2. To find the parameters affect on distribution of pollutant in open channel flow

1.4 Scope of the Study

The scope of this study can be described as follows:

1.4.1. Considering Acid as contaminated substance into fresh water

1.4.2. Rectangular shape for the cross section of channel is considered

1.4.3. Considering the Saint-Venant equations as two governing equations to obtain the unknown variable of velocity u, and scalar equation of Nokes et al (1984) to obtain concentration of pollutant c

1.4.4. Using of the package of FORTRAN programming (RivRoute) to compute and obtaining the result of modeling of the channel

Reference

1. Merle Potter, David C. Wiggert (2007). Book, Fluid Mechanics
2. Pavel Novak, Vincent Guinot, Alan Jeffrey, Dominic E. Reeve (2010). Book, Hydraulic Modeling – An Introduction Principles Methods and Applications.
3. John D. Anderson, Jr.(1995). Book, Computational fluid Dynamics. The Basic with applications
4. Klaus A. Hoffmann, Steve T. Chiang (1993), Book, Computational fluid dynamics for engineering
5. Bruce R. Munson, Donald F. Young, Theodor H. Okiishi, Wade W. Huebsch (2008), Book, Fundamentals of fluid mechanics
6. Sarbjit Sing, Zulfequar Ahmad, Umesh C. Kothyari (2010), Journal of Hydraulic Research. Mixing coefficients for longitudinal and vertical mixing in the near field of a surface pollutant discharge
7. Ali A. M. Gad (2004), Eighth international water technology conference, An artificial neural network model for predicting longitudinal dispersion coefficients in rivers
8. Alexander J. Smit, (1999), Book. Physical introduction to: fluid mechanic.
9. Yiqing Guan, M. Altinakar, International Journal, Development of an Integrated Model for Simulating Two Dimensional Pollutant Transport in Rivers
10. S. T. Wang, A. F. Mcmillan and B. H. Chen, (1978), International Journal, Dispersion of pollutants in channels with non-uniform velocity distribution

11. Mapundi K. Banda, Mohammed Seaid, Guido Thommes (2008), International journal for numerical methods in engineering, Lattice Boltzmann simulation of dispersion in two-dimensional tidal flows
12. Singh, S., Ahmad, Z., Kothyari, U.C. (2009). Two-dimensional mixing of pollutants in streams with transverse line slug source. J. Hydraulic Res. 47(1), 90–99.
13. Alexander J. Smit, (1999) wiley. Physical Introduction to Fluid Mechanic
14. Romuald Szymkiewicz (2010), Numerical Modeling in open channel hydraulics. Springer Dordrecht Heidelberg London New York
15. Guan, Y., Altinakar, M.S., Krishnappan, B.G. (2002). Two-dimensional simulation of advection-dispersion in open channel flows. Proc. 5th Intl. Conf., Hydroinformatics, Cardiff, UK, 226–231.
16. French, R.H. (1979). Transfer coefficients in stratified channel flow. J. Hydraul. Div. ASCE. 105(9), 1087–1101.
17. Garde, R.J., Ranga Raju, K.G. (2006). Mechanics of sediment transportation and alluvial stream problems. Wiley Eastern Limited, New Delhi, India.
18. Guan, Y., Altinakar, M.S., Krishnappan, B.G. (2002). Twodimensional simulation of advection-dispersion in open channel flows. Proc. 5th Intl. Conf., Hydroinformatics, Cardiff, UK, 226–231.
19. Jobson, H.E., Sayre, W.W. (1970a). Predicting concentration profiles in open channels. J. Hydraul. Div. ASCE. 96(10), 1983–1996.
20. Jobson, H.E., Sayre, W.W. (1970b). Vertical transfer in open channel flow. J. Hydraul. Div. ASCE 96(3), 703–724.

21. Khan, I.M., Simons, R.R., Gras, A.J. (2007). Vertical diffusion of pollution from line source near a wall. J. Hydraulic Res. 45(3), 365–369.

22. Kim, D.G., Seo, I.W. (2000). Modeling the mixing of heated water discharged from a submerged multiport diffuser. J. Hydraul. Eng. 38(4), 259–270.

23. Lipsett, A.W., Beltaos, S. (1978). Tributary mixing characteristics using water quality parameters. Report SWE-78/04. Alberta Research Council, Edmonton, CA.

24. McNulty, A.J. (1983). Dispersion of a continuous pollutants source in open channel flow. PhD thesis. University of Canterbury, Christchurch, NZ.

25. McNulty, A.J.,Wood, I.R. (1984). A new approach to predicting the dispersion of a continuous pollutant source. J. Hydraulic Res. 22(1), 23–34.