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Recovering the salinity intensity of distributed sources in the river using inverse simulation-optimization approach

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ABSTRACT: In recent years, the issue of identifying the polluting sources in the rivers has been one of the most important topics in scientific research in the field of water. In the main research, the pollutant sources have been considered as the point sources, and in order to recover pollutant concentration, it is necessary to have an observation point for each source. In this study, the places where groundwater enters to river are considered as distributed sources with known locations and length and the goal is to recover the intensity of sources, using only one observation point. The sources which considered are distributed sources with constant loading and significant distance from each other. The existence of distance among sources prevents the complete mixing of concentration at the observation point. This matter and also the constant intensity of loading, makes it possible to recover several distributed sources using only one observation point. For this purpose, the inverse solution of the advection-dispersion equation is done using the simulation-optimization approach. To design the backward model, MIKE11, linked with a genetic algorithm in MATLAB. Considering one observation point for recovering the intensity of several distributed sources is the advantage of the present study. The model was verified by using hypothetical examples, 40km section of Karun River, and by applying 5 and 15 percent noise to the observation data. The results demonstrate that the backward model can recover the intensity of several sources not only with one observation point but also with data from the concentration versus time curve at the observation point. The accuracy of the model in recovering resource intensity, according to statistical indicators, is more than 99%.

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1- Introduction

Determining the intensity of salinity entering the river from the adjacent aquifer, as a distributed source of pollution in the rivers, is an important and challenging issue that can help minimize the consequences and damages of pollutant sources in rivers. Previous studies on solving the inverse problem of the pollutant transport equation fall into three categories in terms the method applied, including [1]:

- probabilistic and geostatistical methods
- mathematical methods
- simulation-optimization methods

In the probabilistic and geostatistical methods, probabilistic and geostatistical distributions is used. In the mathematical methods, the inverse problem is solved only in a mathematical framework. In the simulation-optimization method, the researchers combine an optimization algorithm with other numerical methods of transport and hydrodynamic equations. Ghane et al (2016) applied Backward Probability Method (BPM) in identifying the pollution source location and release time in surface waters, mainly in the rivers. To accomplish this task, a numerical model is developed based on the adjoint analysis, Then the developed model is verified using analytical solutions as well as real data. The results demonstrated that all suspected points, determined by the BPM could be a possible pollution source [2]. Barati Moghaddam et al (2022) developed a practical method for the simultaneous identification of the number, locations, and release histories of multiple pollutant point sources in a river network using minimum observation data. For this purpose, they solved the inverse advection-dispersion equation using the Backward Probability Method (BPM) [3]. Lu et al (2020) developed a parallel exploratory search strategy based on the Bayesian approach to simultaneously identify the characteristics of pollutant sources and unknown parameters of the groundwater. They significantly reduced the computational cost (about 400 times) by using a combined surrogate model [4].

The assessed problem in this research is entering salinity from distributed (non-point) sources to the rivers and the goal is to identify the salinity intensity of the sources by measuring the temporal distribution of concentration in one observation point in downstream of the river.

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2- Methodology

2- 1- Forward transfer model in one-dimensional domain

Forward model is used to generate information at the observation point and also to verify the problem. The equations of forward model include Saint-Venant equations (flow model equations) and advection-dispersion equations. The Saint-Venant equations include mass conservation and momentum conservation equations, which are shown in equations (1) and (2). The advection-dispersion equation is also shown in equation (3).

$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=0 \tag{1}$$

$$\frac{\partial Q}{\partial t}+\frac{\partial(\frac{Q^2}{A})}{\partial x}+gA\frac{\partial h}{\partial x}+gAS_f=0 \tag{2}$$

$$\frac{\partial(AC)}{\partial t}+\frac{\partial(QC)}{\partial x}-\frac{\partial}{\partial x}\left(AD\frac{\partial C}{\partial x}\right)=-AkC+C_sQ_s \tag{3}$$

In the above equations, Q is discharge, A is cross-sectional area, h is water level, S_f is friction slope, C is pollutant concentration, D is dispersion coefficient, k is decay coefficient, Cs is concentration of pollutant sources, Qs is the discharge of pollutant sources, and x and t are respectively the spatial and temporal dimensions.

2- 2- Inverse transfer model in the river

In order to prepare an inverse model, the inverse solution of the transfer equation in the river is applied, using a simulation-optimization approach. For this purpose, a link code between the MIKE11 simulation model and the genetic optimization algorithm in MATLAB has been developed. The objective function is defined as follows:

$$F=\sum_{i=1}^{n}(c_i^{obs}-c_i^{cal})^2 \tag{4}$$

In the above equation, C_i^{obs} is observed salinity concentration at the observation point and C_i^{cal} is calculated salinity concentration, which is calculated from the inverse solution of transfer equation for different iterations.

3- Results and Discussion

3- 1- First example: Recovering the salinity intensity of a distributed source with one observation point

After designing and executing the forward model in this example, diagram of concentration versus time at the observation point is obtained as shown in Figure 1. Due to the existence of only one distributed source with constant loading (S1=15kg/s), only one step is formed in the diagram of concentration versus time at the observation point. By using available data in the diagram and running the inverse model, the salinity intensity of S1 was recovered with high accuracy (Table 1).

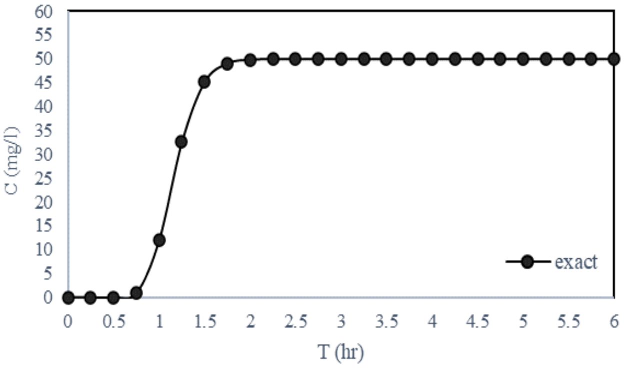

Fig. 1. Diagram of concentration versus time at observation point of the first example

Table 1. Exact and computed salinity intensity of S1

Source Number	W exact (kg/s)	W computed (kg/s)	RE$_W$
S1	15	15.00002	0.00013

3- 2- Second example:Recovering the salinity intensity of two distributed sources with one observation point

The purpose of this example is to investigate the appropriate arrangement of two distributed salinity sources with constant loading, in terms of the distance between them, to prevent the complete mixing of source concentrations at the observation point. Two sources are examined in three cases with different distances from each other. By comparing obtained results, observed that in adjacent or very close sources, the concentration versus time curves at the observation point will contain little or no information required to recover both sources.

3- 3- Third example:Validation of the inverse model using hypothetical salinity sources for the Karun River

In this example, the inverse model is validated by considering three hypothetical sources for a section of the Karun River. The recovery results of S1, S2, and S3 are presented in Table 2.

4- Conclusion

By using only one observation point located downstream of several distributed sources that are located at an appropriate distance from each other, the salinity intensity of sources can be recovered. The appropriate distance between the sources

Table 2. Exact and computed salinity intensity of S1, S2 and S3 and relative error index

Source Number	*W* exact (kg/s)	Start chainage (m)	End Chainage (m)	*W* calculated (kg/s)	RE_W(%)
S1	18	1000	1500	17.9752	0.1378
S2	44	16000	16700	44.0205	0.0466
S3	20	32500	34100	20.0036	0.018

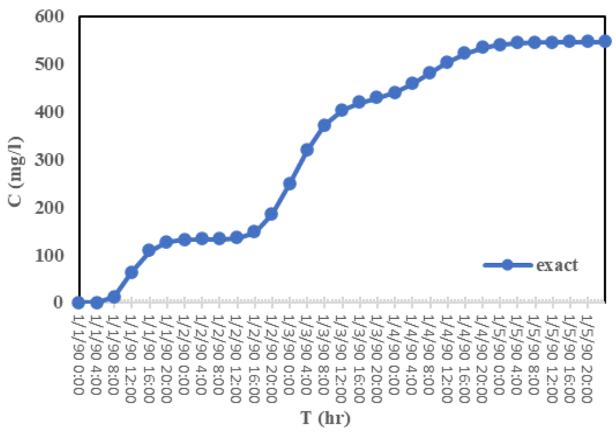

Fig. 2. Diagram of concentration versus time at observation point (p=37.543km)

leads to the non-complete mixing of source concentrations at the observation point.

Despite the error level of 5 and 15 percent in observation data, the proposed inverse model is capable of recovering the salinity intensity of distributed sources with high accuracy.

The accuracy of the model in recovering the source intensity, even with errors of observation data, is more than 99 percent.

References

[1] M. Mazaheri, Mathematical Model for Identification of Pollution Sources in the Rivers: Reconstruction of Location and Release History of the Sources, Ph.D. Thesis in Water Structures Engineering, Department of Water Structures Engineering, Tarbiat Modares University, Iran, (2011) (In Persian).

[2] A. Ghane, M. Mazaheri, J.M.V. Samani, Location and release time identification of pollution point source in river networks based on the Backward Probability Method, Journal of Environmental Management, 180 (2016) 164-171.

[3] M. Barati Moghaddam, M. Mazaheri, J.M.V. Samani, F. Boano, An Innovative Framework for Real Time Monitoring of Pollutant Point Sources in River Networks, Journal of Stochastic Environmental Research and Risk Assessment, (2022) 1-28.

[4] W. Lu, H. Wang, J. Li, Parallel heuristic search strategy based on a Bayesian approach for simultaneous recognition of contaminant sources and aquifer parameters at DNAPL-contaminated sites, Environmental Science and Pollution Research, (2020), 1-15.

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