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Interactive approach for determination of salinity concentration in tidal rivers (Case study: The Karun River in Iran)

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Abstract In this research, a perceptron artificial neural network is trained and validated by a number of observed data. Inputs of artificial neural network (ANN) are distance from upstream, discharge of freshwater at upstream and tidal height at downstream and its output is salinity concentration. Because of shortage of observed data especially in extreme conditions, a numerical model was developed. This model was calibrated by observed data. Results of numerical model convert to two regression relations. Then artificial neural network is tested by reminder observed data and results of numerical model. For improving of results of test of ANN, it is trained by genetic algorithm (GA) method. GA method decreases the mean of square error (MSE) 66.4% and increases efficiency coefficient 3.66%. Sensitivity analysis shows that distance from upstream is the most effective governing factor on salinity concentration. For case study, the Karun River in south west of Iran is considered.

1. Introduction

Human activity causes abrupt variation in climatic conditions. Global warming of the earth melts polar ices and water level of seas rise rapidly. Sea water arrives to rivers that connect to sea. The salty water of sea increases salinity in rivers. Also tidal surges intensify the arrival of salt water to rivers. But fresh water of upstream of river decreases salinity of water. Unfortunately occurrence of drought and construction of large dams in upstream of rivers reduce discharge of freshwater in Middle East countries. Therefore salinity concentration grows very highly in tidal limit of the tidal rivers of Middle East countries. Increasing salinity has destroyed environmental around of tidal rivers. This increasing has damaged to people who live at downstream of rivers and they have immigrated to other regions.

Because of interaction between tidal flow and fluvial flow, new and suitable methods must be developed for determination of salinity concentration in tidal limit of tidal rivers. Numerical models cannot calculate salinity concentration rapidly for different combination of fluvial and tidal flows. Also these models have not any memory for prediction of

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Nomenclature

q	discharge of lateral inflow per unit width of main channel
α_i, α_{i+1}	correction coefficients for kinematics energy in sections i, i+1
C_C	loss of energy coefficient that depends on expansion or condensation of sections
v_x	component of speed of lateral inflow that is parallel with the direction of main channel
Q	discharge of fresh water (CMS)
A	cross section area
β	correction coefficient for momentum
g	gravitational acceleration (9.81 m/s^2)
L	distance between consecutive sections
S_0	slope of the bottom of the channel
V_i, V_{i+1}	velocity of current in sections i, $i+1$
h	water surface elevation
R	hydraulic radius (m)
n	manning's coefficient
ξ	a weight factor (0 for forward method (explicit), 0.5 for Crank-Nicolson method and 1 for backward method (fully implicit))
n_i	manning's coefficient in each part
n_e	equivalent Manning's coefficient for cross section
p_i	wetted perimeter in each part (m)
C	salinity concentration (g/lit)
U	velocity in longitude direction of the river (m/s)
D	salinity distribution coefficient in longitude direction of the river (m^2/s)
t	time step (sec)
x	distance between consecutive sections (m)
T	period time of tide (sec) (for the Karun River T = 24 h)
ω	frequency of tide (rad/s)
a	Domain of tide (m)
U_f	the velocity of fresh water (m/s)
D_x	modified distribution coefficient for the tidal rivers (m^2/s)
G	The tidal energy dissipation rate per unit mass (m^2/s^3)
J	The gain of potential energy rate per unit mass (m^2/s^3)
HT	tidal height (m)
X	distance from upstream (km)

salinity concentration in future. Thus a method that can consider numerous combinations of tidal height at the downstream and freshwater discharge at the upstream must join to numerical model. This method must utilize observed data and its results must be compared to results of numerical model. Artificial neural network has these characteristics.

Many researchers studied about determination of salinity concentration in rivers. They developed empirical formulas. These formulas show the relation between salinity concentration and discharge of fresh water and show salinity concentration in different sections in tidal rivers. These formulas are 1-D. But they did not consider effects of tidal flows for developing of their formulas [1–4].

Other researchers developed 1-D numerical models for determination of salinity concentration in the rivers [5–13]. Also Xu et al. [14] developed 3-D numerical models for determination of salinity concentration in the rivers and estuaries. They considered salinity variations under different conditions of river flow and wind in the Pamlico River Estuary (PRE). Liu et al. [15] developed a three-dimensional salinity and fecal coli form transport model and incorporated into a hydrodynamic model. Their case study was the tidal Danshuei River estuarine system of northern Taiwan. The model was applied to investigate the effects of upstream freshwater discharge variation and salinity and fecal coli form loading reduction on the contamination distributions in the tidal estuarine system. The qualitative and quantitative analyses clearly revealed that low freshwater discharge resulted in higher salinity and fecal coli form concentration. Wang et al. [16] investigate how salinity changes with abrupt increases and decreases in river discharge around the Yellow River mouth. Shi and Zhang [17] established a two-dimensional horizontal (2DH) numerical model of flow. They applied the Galerkin finite element method (FEM). The software Easy Mesh is used to triangulate the modeled planar domain. The two-step Lax–Wendroff scheme is used for integrating the equations in order to avoid the nonlinear iterative calculation. This two-dimensional horizontal finite element model was found to be well suited to the complexities of the North Passage of the partially-mixed Changjiang River estuary. In these researches, authors applied salinity distribution coefficient of the no tidal rivers for the tidal rivers.

For example Becker et al. [13] studied about relation between estuarine salinity and river inflow in the Cape Fear River Estuary (CFRE). Jiang et al. [12] investigated about water level variation, velocity, and salinity variations under different conditions of river flow and wind in the Oujiang River Estuary (ORE). Disadvantages of these researches are as follows:

(a) Considering estuary and month of tidal river, they did not apply their models to tidal limit of the tidal rivers.
(b) Investigating about salinity and fluvial flow, they did not study about relation between salinity and tidal flow.

Bowden et al. [18] used from artificial neural network for prediction of salinity concentration in the River Murray at Murray Bridge, South Australia. They did not consider effective factors on salinity concentration. Input of their network is observed salinity concentration in pervious years. They applied the partial mutual information (PMI) algorithm and the self-organizing map and genetic algorithm general regression neural network (SOM–GAGRNN) to find suitable inputs to an ANN model.

Huang and Foo [19] applied artificial neural network for determination of salinity concentration. Inputs of their network are freshwater, tide and wind. Their case study is Apalachicola River, Florida. They predicted salinity concentration in mouth of the tidal river (no in tidal limit).

Triana et al. [20] applied artificial neural network for determination of salinity concentration. Inputs of their network