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NN-LEAP: A neural network-based model for controlling leachate flow-rate in a municipal solid waste landfill site

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Abstract

A method is proposed for modeling leachate flow-rate in a municipal solid waste (MSW) landfill site, based on a popular neural network – the backpropagation algorithm (*n*eural *n*etwork-based *lea*chate *p*rediction method; NN-LEAP). After backpropagation training, the neural network model predicts flow-rates based on meteorological data. Depending on output value, relevant control strategies and actions are activated. To illustrate and validate the proposed method, a case study was carried out, based on the data obtained from the Istanbul Odayeri landfill site. As a critical model parameter (neural network outputs), daily flow-rate of leachate from the landfill site was considered. The Levenberg–Marquardt algorithm was selected as the best of 13 backpropagation algorithms. The optimal neural network architecture has been determined, and the advantages, disadvantages and further developments are discussed.

Keywords: Neural network; Backpropagation algorithm; Leachate; Flow-rate; Modeling

1. Introduction

The major potential environmental impacts, related to landfill leachate, are ground- and surface water pollution (Islam and Singhal, 2002). Landfill leachate is formed when liquid, originating from rain, melted snow or the waste itself, percolates through landfill cells and moves to the bottom or sides of a landfill. Flowing through the waste, leachate transports a wide variety of chemicals to the extremities of a landfill. The quantity of leachate produced is highly correlated with the amount of precipitation around the landfill (Shroff, 1999). In areas of high precipitation, the production of leachate is greater than in drier areas, since much of the precipitation percolating through a landfill becomes leachate. The effect of uncontrolled infiltration of leachate into the environment is the greatest environmental impact that a sanitary landfill can have (Islam and Singhal, 2002). The management of leachate during percolation, collection and disposal assumes a critical element in landfill design, both from a technical and economic perspective. The most important meteorological parameters influencing leachate flow-rates are precipitation, air temperature and relative humidity (Shroff and Hettiaratchi, 1998). It is obvious that whatever the methodology adopted for the design of a landfill, leachate flow-rate is influenced by meteorological parameters, and rainfall represents the largest single contribution to the production of leachate. The most critical situation occurs during periods of light rainfall over a long period of time. Short bursts of heavy rain, during a storm, result in quick saturation of the cover

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material with consequent runoff of excess rain, so there is little net infiltration (Canziani and Cossu, 1989).

Peak and average leachate flow-rates, and the time and duration of peak flow-rates, are determined using the water balance method (WBM) (Fenn et al., 1975), or models such as the US EPA's hydrologic evaluation of landfill performance (HELP) model (Schroeder et al., 1994) or the flow investigation of landfill leachate (FILL) model (Khanbilvardi et al., 1995). To determine leachate volume and flow-rates, the models require input values for parameters, such as rainfall, runoff from the landfill surface, quantity of leachate recirculated (if any), groundwater intrusion, evapotranspiration from the landfill and moisture stored in the landfill system.

Artificial Neural Networks (ANNs) have become a popular tool for modeling environmental systems, such as air pollution (Abdul-Wahab and Al-Alawi, 2002; Nunnari et al., 2004; Karaca et al., 2005), simulating and forecasting residual chlorine concentrations within urban water systems (Rodriguez and Sérodes, 1999), determination of the relationship between sewage odour and biological oxygen demand (BOD) (Onkal-Engin et al., 2005), efficient rainfall runoff models (Anctil et al., 2004), prediction of wastewater treatment plant performance (Hamed et al., 2004), or forecasting of salinity in a river (Maier and Dandy, 1998). Nevertheless, very little information is available in the literature on the predictive capabilities of neural networks on leachate flow-rates in a municipal solid waste landfill site.

Istanbul is one of the most important metropolises of the world in terms of its population and industry. As a result, in Istanbul, approximately 9000 tons of solid waste is produced per day (~3 300 000 tons per year). Total MSW volume per day is 18 000 m^3 in Istanbul (for 0.5 ton/m^3) and, for 1 year, total volume is about 6.5 million m^3. These values are increasing every day with population growth. Odayeri Sanitary Landfill, in which the waste from the European side is landfilled, is in Kemerburgaz County, and has been in operation since 1995. Approximately, 7000 tons per day of municipal solid waste is removed to this landfill and 1000–1500 m^3 leachate is produced daily. Municipal solid wastes have been stored at a 25-ha (average waste height: 40 m) sector, of this 125-ha landfill in the last 5 years, and the landfill site is projected for a 25-year usage (Demir et al., 2003).

In this study, we propose a *n*eural *n*etwork-based *lea*chate *p*rediction method (NN-LEAP) for evaluating and managing leachate flow-rate in this MSW landfill site (Istanbul/Odayeri). This model uses the backpropagation (BP) algorithm to predict the daily flow-rate of leachate. NN-LEAP selects the best backpropagation algorithm and optimizes the structure of the selected algorithm for any type of input and output parameters. It was concluded that the backpropagation algorithms were very appropriate to model the nonlinear dependence of leachate flow-rate in an MSW landfill site.

2. Description of NN-LEAP method

Backpropagation algorithms use input vectors and corresponding target vectors to train a neural network (NN). NN with a sigmoid and linear output layer are capable of approximating any function with a finite number of discontinuities (Hagan et al., 1996). The standard backpropagation algorithm is a gradient descent algorithm, in which the network weights are changed along the negative of the gradient of the performance function (Nguyen and Widrow, 1990; Abdi et al., 1996). There are a number of variations of the basic backpropagation algorithm, which are based on other optimization techniques, such as conjugate gradient and Newton methods. For properly trained backpropagation networks, a new input leads to an output similar to the correct output. This NN property enables the training of a network on a representative set of input/target pairs and getting good forecasting results.

We propose a method, based on BP algorithms: the NN-LEAP method (Fig. 1), which has the following steps (Fig. 1). Firstly, for given collected data, the best fitting backpropagation algorithm, minimizing the error between neural network output and target value, is selected. Secondly, with this method, the NN outputs are established, using meteorological data for a given day, according to measurements or weather forecast determining the leachate flow-rate. If the concentration is higher than the threshold value (Fig. 1) relevant actions and warnings are proposed.

A two-layer neural network was used, with a tan–sigmoid transfer function at the hidden layer and a linear transfer function at the output layer (Fig. 2). This NN has k input and one output parameters, which are essential for accurate modeling of the leachate flow-rate. The input parameters, number of neurons at the hidden and output layer should be determined according to currently gathered data (Section 3).

3. Case study

For illustrating and validating the NN-LEAP method, a case study, based on leachate daily flow-rate, some leachate chemical and physical parameters and data from the Turkish State meteorological service (Istanbul-Florya Station), was carried out.

3.1. NN-LEAP method parameter definition

A total of 11 input parameters were defined (Table 1), which are essential for accurate modeling of