Determination of the pollution control flow for drought management in a multi-reservoir system

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Abstract. The pollution, changing according to various standards, is directly proportional to water quality in rivers. In this study, data and restrictions prescribed for standards of water quality such as Turkish Standards Institute (TSI), European Commission (EC), and the World Health Organization (WHO) were used to determine water pollution. For this purpose, correlation analysis was made to identify strong relationships between data. Regression analysis and Artificial Neural Networks (ANN) models are developed based on these standards by data obtained from correlation analysis. The Lower Sakarya River is selected as application area, and measurement of the water quality values of this river is used in these models. Pollution control flows in the river are obtained by the ANN models and regression analysis. The obtained results are compared with regard to these standards.

1. Introduction

Inflow released from reservoir to the river for drought management in a multi-reservoir system is expected to be on the pollution control flows in the rivers. Therefore, the pollution control flow of the river presented between reservoirs in the system should be determined. Plus, pollution value in the river depends on factors such as the water quality and the properties of the river bed, and it contains data and constraints presented by standards such as TSI, EC, and WHO. In these standards, generally, constraints present in the amounts of substances, which negatively affect the water quality, have been investigated.

Water pollution discharges substances and energy waste into the biological source, human health, fishing life, and the water quality and causes inhibitive corruptions and the chemical , physical, bakteriological, radioactie and ecological properties of the water source

can be observed with changing as negatively in be used for other aims of water by direct or indirect ways.

Intense and unconscious usage of the pollution sources such as industrialization, urbanization, agricultural pesticides with population growth and chemical fertilizers are indicators of the causes of water pollution. For example, water resources have been contaminated as the result of drug granules thrown in the water, agricultural pesticide spray carried by wind over lands, and factory waste's discharge into the lakes and river. On the other hand, unconscious and excessive use of the chemical fertilizers causes soil infertility; therefore, both water pollution within natural circle of life and other adverse effects occur [1].

There have been some studies about the water pollution in rivers, reservoirs, and basins in the last decade [2-6]. For example, a water quality model for Zayandeh Rud river was developed. The main objective of the developed model was to create a simple river pollution model to be used for quick analysis of river water quality. The model focuses on ANN algorithm instead of usual river quality models which

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accounts for the physical processes of pollutant changes along the river [3]. Estimation of dissolved oxygen capacity for water quality control of Melen River in Tukey was investigated using ANN algorithm at each measurement point in the river by the limited data. The required data were collected and determined from experimental studies, and also correlation coefficient was obtained by ANN model [4]. A model for optimal pollution control for the Fei-Tsui Reservoir Basin in Northern Taiwan was developed [5]. The potential of ANN algorithm in the estimation of the Biological Oxygen Demand (BOD) of the Melen River in Turkey was examined by comparing the results with observed BOD. In addition, sensitivity analysis was conducted to determine the degree of effectiveness of the variables by various performance statistics [6].

Some studies about effects of drought on pollution were performed by artificial neural network [7-9]. Drought effects on river pollution with ANN were studied [8]. As a result, some pollution parameters were directly affected by usage of the integrated models for water management. Water quality for evaluating the evolution of pollutants in river systems was proposed during drought periods in diverse action measure scenarios, including water management and water quality measures [9].

Water and sediment samples were collected along the Lower Sakarya River Basin from pre-determined sampling stations between February 2007 and January 2008 monthly during 12 months of time. A total of 40 elements such as Vanadium, Chromium, and Manganese in water were analyzed by Inductively Coupled Plasma-Mass Spectrometer (ICP-MS). In addition, selected physical and chemical parameters of water and sediment samples were measured at the sampling point and/or laboratory. Effects of anthropogenic activities on the Lower Sakarya River were investigated. The impacts of dam, levels, and bridge constructions, sand-gravel mining activities, and water withdrawals during the industrialization period of the Sakarya River Basin were explored by analyzing flow, sediment, and channel cross section data from different periods in time along with comparing historical (pre- and post-1975) periods [10].

In this study, ANN models were developed to determine pollution control flow during drought management in a multi-reservoir system by correlation analysis and water quality values of standards such as TSI, EC, and WHO. The Lower Sakarya River was selected for application. Strong relationships between the measured water quality data and the observed flow rates of the river are determined by correlation analysis. The strong correlations in terms of impact data with each other were assigned as input data and as output data by ANN models and also by the regression analysis. As a result of these processes, the obtained

Figure 1. View of the Sakarya River Basin.

results from these models and regression analysis are compared with regard to these standards.

2. Application area: The Sakarya River Basin

The Sakarya River Basin, one of most important river basins in Turkey, as shown in Figure 1, is surrounded by basins of the Kızılırmak River, the Western Black Sea, Marmara, Susurluk, Gediz, Akarcay, and Konya. The Sakarya River Basin is commonly divided into three zones as upper, middle, and lower sections.

There are 20 dams built between years 1936 and 2002 for domestic and industrial water supply, irrigation, flood control, and energy purposes on a multi-reservoir system of the basin. The relatively larger dams, with their locations, rivers, types, purposes, and reservoir capacities are shown in Table 1.

When the basin is investigated, it is observed that industrial companies have densely been located in the Lower Sakarya River. Therefore, it can be said that there was water pollution in its region. When the region is investigated to measure water quality values and other flow data, it is observed that the sediment values for the water quality were measured, as given in Table 2, by the Scientific and Technological Research Council of Turkey and were prepared to report these data.

3. Water quality standards

The flow rate for pollution control produced by water quality standards may be used in the management of events, such as drought control of a multi-reservoir system. A country's economic conditions and living standards should be adapted to its location. Therefore, water quality standards of TSI, EC, and WHO were used in this study.

Water quality standards are arranged by taking

Table 1. General characteristics of relatively large dams on the Sakarya River.

Dams	Location	River	Type	Purpose	Reservoir capacity (hm³)
Çubuk I	Ankara	Çubuk	Concrete Gravity	Domestic and industrial water supply, Flood control	12.50
Sarıyar	Sarıyar- Nallıhan	Sakarya	Concrete Gravity	Energy	1900
Çubuk II	Ankara-Çubuk	Çubuk	Soil-filled	Domestic and industrial water supply	24.60
Bayındır	Ankara	Bayındır	Soil-filled	Domestic and industrial water supply	6.97
Kurtboğazı	Ankara	Kurtboğazı	Soil-filled	Domestic and industrial water supply	101.50
Musaözü	Eskişehir	Mollaoğlu	Soil-filled	Irrigation	1.67
Porsuk	Eskişehir	Porsuk	Concrete Gravity	Domestic and industrial water supply, Irrigation, Flood control	431
Gökşekaya	Eskişehir	Sakarya	Concrete Arch	Energy	910
Dodurga	Bilecik	Sarısu	Soil-filled	Irrigation, Flood control	22
Kaymaz	Eskişehir	Çayırlık	Soil-filled	Irrigation	1.43
Enne	Kütahya	Dereboğazı	Soil-filled	Domestic and industrial water supply	7
Asartepe	Ankara	İlhan	Soil-filled	Irrigation	20
Kunduzlar	Eskişehir	Yönek	Soil-filled	Irrigation	22
Çamlıdere	Ankara	Bayındır	Rock-filled	Domestic and industrial water supply	1226
Çatören	Eskişehir	Haramşi	Soil-filled	Irrigation	47
Eğrekkaya	Ankara	Sey	Soil-filled	Domestic and industrial water supply	113
Akyar	Ankara	Bulak	Soil-filled	Domestic and industrial water supply	56
Yenice	Eskişehir	Sakarya	Soil-filled	Energy	57.60
Beyköy	Eskişehir	Sakarya	Concrete	Energy	River power plant
Kızıldamlar	Bilecik	Söğüt	Rock-filled	Irrigation	10.70

Table 2. Sediment values for the water quality on the lower Sakarya River.

Elements	S	Months (kg/day)											
		January	February	March	April	May	June	July	August	September	October	November	December
Aluminum	Al	0,4964	0,0595	0,1452	0,0431	0,0125	0,0506	0,0168	0,0207	0,0302	0,0898	0,1152	0,1249
Antimony	Sb	0,0330	0,0549	0,0467	0,0148	0,0103	0,0103	0,0168	0,0081	0,0139	0,0301	0,0239	0,0418
Arsenic	As	0,0270	0,0608	0,0348	0,0445	0,0176	0,0241	0,0453	0,0186	0,0274	0,0496	0,0371	0,0954
Copper	Cu	0,0033	0,0055	0,0186	0,0359	0,0010	0,0024	0,0017	0,0054	0,0060	0,0030	0,0082	0,0042
Barium	Ba	0,3448	0,6162	0,3810	0,3678	0,1696	0,1581	0,2520	0,1451	0,2269	0,3658	0,2677	0,4957
Beryllium	Be	0,0007	0,0110	0,0009	0,0475	0,0319	0,0122	0,0170	0,0308	0,0270	0,0653	0,0325	0,0469
Boron	B	0,9643	2,3737	21,7100	2,0525	0,7070	1,2023	1,5454	0,6013	0,7308	2,6191	1,1196	4,1540
Mercury	Hg	0,0007	0,0011	0,0009	0,0004	0,0002	0,0002	0,0003	0,0002	0,0003	0,0006	0,0005	0,0008
Zinc	Zn	0,0428	0,0737	0,0527	0,0367	0,0103	0,0103	0,0168	0,0081	0,0139	0,0313	0,0527	0,1684
Silver	Ag	0,0007	0,0011	0,0009	0,0004	0,0003	0,0002	0,0003	0,0002	0,0003	0,0342	0,0024	0,0010
Iron	Fe	1,4839	0,8214	0,5051	0,6616	0,3767	0,2679	0,5055	0,2873	0,3848	0,4805	0,4783	0,7949
Cadmium	Cd	0,0007	0,0011	0,0009	0,0004	0,0003	0,0002	0,0003	0,0002	0,0003	0,0342	0,0024	0,0010
Chrome	Cr	0,0068	0,0105	0,0093	0,0074	0,0021	0,0021	0,0034	0,0016	0,0029	0,0060	0,0052	0,0084
Lead	Pb	0,0013	0,0012	0,0013	0,0061	0,0004	0,0023	0,0003	0,0005	0,0003	0,0054	0,0015	0,0020
Manganese	Mn	0,3625	0,3436	0,0720	0,0977	0,0132	0,0316	0,0245	0,0510	0,0719	0,1032	0,1202	0,3638
Molybdenum	Mo	0,0100	0,0228	0,0127	0,0192	0,0038	0,0092	0,0136	0,0052	0,0105	0,2260	0,0253	0,0328
Nickel	Ni	0,0204	0,0266	0,0245	0,0286	0,0088	0,0128	0,0118	0,0071	0,0179	0,0189	0,0205	0,0414
Selenium	Se	0,0330	0,0549	0,0093	0,0043	0,0021	0,0021	0,0034	0,0016	0,0028	0,0060	0,0048	0,0084
Sodium	Na	247,52	398,09	15,98	306,95	179,12	176,92	236,64	141,63	231,94	353,99	232,33	609,77
Thallium	Tl	0,0007	0,0011	0,0009	0,0442	0,0255	0,0247	0,0256	0,0138	0,0238	0,0581	0,0232	0,0796
Flow rate	Q	76,50	127,00	108,00	48,70	23,80	23,80	38,80	18,70	32,10	69,60	55,30	96,70

into consideration the organoleptic properties, the microbiological properties, the chemical properties, and the indicator features. In the chemical properties of the water quality standards, a number of elements are taken into consideration such as Antimony (Sb), Arsenic (As), Barium (Ba), Boron (B), Mercury (Hg), Zinc (Zn), Iron (Fe), Silver (Ag), Chrome (Cr), Manganese (Mn), Nickel (Ni), Selenium (Se), Aluminum (Al), Gold (Au), and Copper (Cu), which are given in Table 3.

4. Correlation and regression analyses

Pearson's product-moment correlation coefficients were used to determine the effects of flow rate of the water quality parameters. Correlation analysis was performed in order to determine relationships between twenty elements and flow rate. Results are given in Table 4. Effects of twelve water quality parameters (Antimony (Sb), Arsenic (As), Barium (Ba), Boron (B), Mercury (Hg), Zinc (Zn), Iron (Fe), Silver (Ag), Chrome (Cr), Manganese (Mn), Nickel (Ni), and Selenium (Se)) on flow rate (Q) were determined by using correlation analysis. Flow rate was positively and very significantly correlated with Antimony (Sb), Barium (Ba), Mercury (Hg), Silver (Ag), Chrome (Cr), Manganese (Mn), Nickel (Ni), and Selenium (Se) at the 0.05 level (2-tailed).

Effects of eight water quality parameters (Antimony (Sb), Barium (Ba), Mercury (Hg), Silver (Ag), Chrome (Cr), Manganese (Mn), Nickel (Ni), and Selenium (Se)) on flow rate (Q) were determined by regression analysis; regression equation relationships between eight water quality parameters and flow rate are obtained as follows:

$$Q = 1.41 - 0.63Sb - 0.242Ba - 0.164Hg$$
$$+0.037Ag - 0.895Cr + 0.025Mn + 2.48Ni$$
$$-0.166Se. \qquad (1)$$

5. Artificial Neural Networks (ANN) models

Each one of the proposed ANN models has modeling, training, and test stages. It includes the examination of data, definition of the parameters of cost prediction, and election of the network structure and rules. in this case, eight sediment elements (Antimony (Sb), Barium (Ba), Mercury (Hg), Silver (Ag), Chrome (Cr), Manganese (Mn), Nickel (Ni), and Selenium (Se)) as input data and flow rate (Q) as output data on ANN models have been taken into consideration.

The proposed ANN model has been designed to consist of an input layer of sixteen neurons regarding the eight input factors, and an output layer of neuron as the goal (Figure 2). Weights to layer 1 from input

Table 3. Values of the water quality standards such as TSE, EC, and WHO.

Standards	Turkish Standards Institute (TSI)	European Commission (EC)	The World Health Organization (WHO)
Elements (mgL^{-1})			
Aluminum	0,2	0,2	0,2
Gold	0	0	0
Antimony	0,005	0,005	0,02
Arsenic	0,01	0,01	0,01
Copper	2	2	2
Barium	0	0	0,7
Beryllium	0	0	0
Bismuth	0	0	0
Boron	1	1	0,5
Mercury	0	0,001	0,001
Zinc	0	0	0
Iron	0,2	0,2	0,3
Gallium	0	0	0
Germanium	0	0	0
Silver	0	0	0
Cadmium	0,005	0,005	0,003
Tin	0	0	0
Calcium	0	0	0
Cobalt	0	0	0
Chrome	0,05	0,05	0,05
Lead	0,01	0,01	0,01
Lithium	0	0	0
Magnesium	0	0	0
Manganese	0,05	0,05	0,4
Molybdenum	0	0	0,07
Nickel	0,02	0,02	0,02
Platinum	0	0	0
Potassium	0	0	0
Rhodium	0	0	0
Selenium	0,01	0,01	0,01
Cesium	0	0	0
Silicium	0	0	0
Sodium	200	200	200
Strontium	0	0	0
Thallium	0	0	0
Tantalum	0	0	0
Titanium	0	0	0
Thorium	0	0	0
Tungsten	0	0	0
Vanadium	0	0	0

Table 4. Correlations between twenty elements and flow rate.

		Al	Sb	As	Cu	Ba	Be	B	Hg	Zn	Fe	Ag	Cd	Cr	Pb	Mn	Mo	Ni	Se	Na	Tl	Flow rate
Al	Pearson Correlation	1																				
	Sig. (2-tailed)																					
Sb	Pearson Correlation	0,377	1																			
	Sig. (2-tailed)	0,228																				
As	Pearson Correlation	-0,012	0,624*	1																		
	Sig. (2-tailed)	0,971	0,03																			
Cu	Pearson Correlation	-0,079	0,027	0,048	1																	
	Sig. (2-tailed)	0,806	0,933	0,883																		
Ba	Pearson Correlation	0,232	0,901**	0,780**	0,208	1																
	Sig. (2-tailed)	0,467	0,000	0,003	0,516																	
Be	Pearson Correlation	-0,355	-0,297	0,298	0,141	-0,072	1															
	Sig. (2-tailed)	0,258	0,348	0,346	0,663	0,823																
B	Pearson Correlation	0,103	0,524	0,092	0,352	0,274	-0,311	1														
	Sig. (2-tailed)	0,751	0,080	0,777	0,262	0,388	0,326															
Hg	Pearson Correlation	0,407	0,992**	0,608*	0,108	0,922**	-0,282	0,495	1													
	Sig. (2-tailed)	0,189	0,000	0,036	0,738	0,000	0,375	0,102														
Zn	Pearson Correlation	0,220	0,685**	0,897**	0,033	0,733**	0,136	0,215	0,673*	1												
	Sig. (2-tailed)	0,492	0,014	0,000	0,919	0,007	0,673	0,503	0,016													
Fe	Pearson Correlation	0,868**	0,526	0,289	0,03	0,552	-0,305	-0,03	0,572	0,414	1											
	Sig. (2-tailed)	0,000	0,079	0,362	0,927	0,063	0,334	0,916	0,052	0,181												
Ag	Pearson Correlation	0,407	0,992**	0,608*	0,108	0,922**	-0,282	0,495	1**	0,673*	0,572	1										
	Sig. (2-tailed)	0,189	0,000	0,036	0,738	0,000	0,375	0,102	0,000	0,016	0,052											
Cd	Pearson Correlation	-0,011	0,125	0,157	-0,150	0,135	0,596*	-0,030	0,118	-0,054	-0,088	0,118	1									
	Sig. (2-tailed)	0,974	0,700	0,627	0,633	0,676	0,041	0,930	0,716	0,867	0,785	0,716										
Cr	Pearson Correlation	0,352	0,915**	0,652**	0,396	0,942**	-0,157	0,503	0,945**	0,680*	0,572	0,945**	0,083	1								
	Sig. (2-tailed)	0,262	0,000	0,022	0,203	0,000	0,627	0,096	0,000	0,015	0,052	0,000	0,798									
Pb	Pearson Correlation	-0,017	0,027	0,270	0,582*	0,267	0,609*	-0,020	0,089	0,092	0,059	0,089	0,575	0,313	1							
	Sig. (2-tailed)	0,958	0,933	0,396	0,047	0,402	0,036	0,962	0,783	0,775	0,857	0,783	0,051	0,321								
Mn	Pearson Correlation	0,620*	0,724**	0,625**	-0,100	0,775**	-0,178	-0,05	0,752**	0,749**	0,830**	0,752**	-0,057	0,694*	0,019	1						
	Sig. (2-tailed)	0,031	0,008	0,030	0,749	0,003	0,580	0,868	0,005	0,005	0,001	0,005	0,86	0,012	0,954							
Mo	Pearson Correlation	-0,020	0,174	0,258	-0,130	0,210	0,626*	-0,030	0,168	0,036	-0,062	0,168	0,994**	0,146	0,610*	0,003	1					
	Sig. (2-tailed)	0,950	0,589	0,418	0,694	0,512	0,030	0,929	0,603	0,911	0,849	0,603	0,000	0,651	0,035	0,992						
Ni	Pearson Correlation	0,239	0,685**	0,846**	0,382	0,812**	0,159	0,293	0,709**	0,896**	0,464	0,709**	-0,008	0,817**	0,370	0,699*	0,086	1				
	Sig. (2-tailed)	0,454	0,014	0,001	0,220	0,001	0,621	0,356	0,010	0,000	0,129	0,010	0,981	0,001	0,237	0,011	0,791					
Se	Pearson Correlation	0,435	0,719**	0,266	-0,100	0,727**	-0,530	0,001	0,751**	0,300	0,674**	0,751**	-0,082	0,650**	-0,110	0,755**	-0,060	0,318	1			
	Sig. (2-tailed)	0,157	0,008	0,402	0,749	0,007	0,077	0,997	0,005	0,344	0,016	0,005	0,799	0,022	0,732	0,005	0,849	0,314				
Na	Pearson Correlation	0,035	0,371	0,866**	-0,110	0,628*	0,448	-0,370	0,378	0,755**	0,362	0,378	0,210	0,410	0,308	0,676*	0,301	0,694*	0,289	1		
	Sig. (2-tailed)	0,914	0,236	0,000	0,728	0,029	0,144	0,238	0,226	0,004	0,247	0,226	0,512	0,185	0,331	0,016	0,342	0,012	0,362			
Tl	Pearson Correlation	-0,257	-0,085	0,633*	0,041	0,135	0,846**	-0,210	-0,100	0,491	-0,142	-0,100	0,412	0,018	0,523	0,073	0,479	0,460	-0,436	0,702*	1	
	Sig. (2-tailed)	0,419	0,793	0,027	0,898	0,675	0,001	0,506	0,757	0,105	0,660	0,757	0,184	0,955	0,081	0,821	0,115	0,132	0,157	0,01		
Flow rate	Pearson Correlation	0,369	0,994**	0,642**	0,130	0,931**	-0,265	0,526	0,996**	0,692**	0,545	0,996**	0,115	0,954**	0,108	0,727**	0,169	0,731**	0,718**	0,39	-0,060	1
	Sig. (2-tailed)	0,238	0,000	0,024	0,686	0,000	0,405	0,079	0,000	0,013	0,067	0,000	0,722	0,001	0,738	0,007	0,600	0,007	0,009	0,21	0,850	
N		12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12

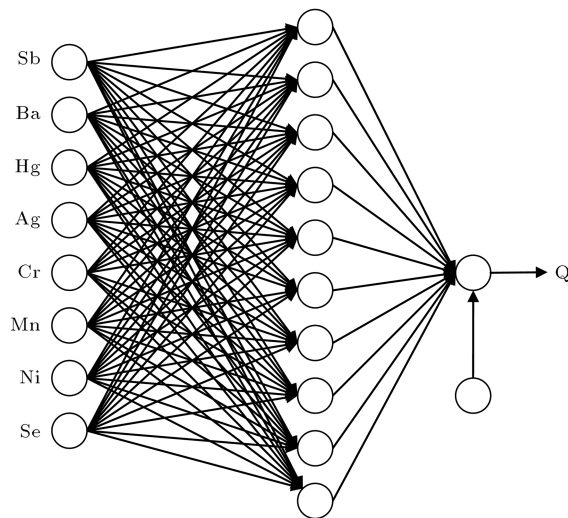** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed).

Figure 2. The architecture and weights of proposed model.

neurons are:

$$[0.71058 \quad 0.099434 \quad -0.54531 \quad -1.0173 \quad 1.0878$$

$$0.40886 \quad -0.98358 \quad 0.09111; \quad -0.48569 \quad 0.13286$$

$$-0.72310 \quad 0.53897 \quad -0.92896 \quad -0.31073$$

$$-0.80442 \quad 0.47085; \quad 0.69567 \quad -0.54005$$

$$-0.38672 \quad 0.35026 \quad -1.1857 \quad 1.0261 \quad 1.7407$$

$$-0.22432; \quad 0.050264 \quad 0.40351 \quad 0.49542 \quad 0.71903$$

$$-0.83535 \quad 1.5295 \quad -0.35532 \quad 0.039178; \quad -0.75345$$

$$-0.41414 \quad -0.67751 \quad -0.55995 \quad -0.81098$$

$$0.69575 \quad -0.48685 \quad -0.95609; \quad -0.76218$$

$$-1.0253 \quad 0.080904 \quad -0.6896 \quad 0.20275 \quad 0.79014$$

$$-0.41852 \quad -0.72343; \quad 1.3626 \quad 0.059414 \quad 1.23$$

$$1.3251 \quad 0.21909 \quad 1.3493 - 0.61639 \quad 0.77024;$$

$$-0.34869 \quad -1.0324 \quad 0.074715 \quad 0.69178$$

$$-1.6874 \quad 0.30112 \quad 1.0659 \quad -0.86889; \quad 0.76821$$

$$-0.74223 \quad -0.011534 \quad -0.23857 \quad 0.74984$$

$$-0.68425 \quad -0.8795 \quad 0.72681; -0.91694$$

$$-0.555030.14621 \quad -0.59148 \quad 0.89443$$

$$-0.11839 \quad 0.88469 \quad -0.6698].$$

Weights from the hidden layer to the output layer are:

$$[0.58584 \quad -0.30292 \quad 1.4812 \quad 0.64869 \quad -0.72639$$

$$0.28489 \quad -1.3803 \quad 1.6485 \quad 0.8801 \quad -1.1253]$$

The bias values from the input layer to the hidden layer are:

$$[-1.7472; \quad -2.0164; \quad -1.0633; \quad -0.79299; \quad 0.44741;$$

$$-0.17386; \quad 0.80567; \quad -1.3564; 1.5362; -1.9836]$$

and the bias value from the hidden layer to output layer is:

$$[0.50037].$$

Therefore, an effective bias, weights, and the number of hidden neurons are determined by trials for the hidden layers, since there is no rule to determine it. Lastly, real data are compared with the predicted and actual data.

6. Results

Determination of the pollution control flow of each reservoir needs to be in values of river without water pollution of inflows released from reservoir to river in events such as drought management in a multi-reservoir system. In this study, first, the correlation analysis is made to investigate the gravity influence of elements which causes water pollution and disturbs water quality on flow rate. When the data obtained from correlation analysis are investigated, it is observed that only eight of twenty elements have been the gravity influence on flow rate. Later, ANN models are developed to be used as input data of eight pollution elements and also as output data of the flow rate against these elements. In ANN models, training and testing are performed by the measured data of the Lower Sakarya River. At the same time, the regression equation is obtained by regression analysis applied to these eight data and flow rate.

The pollution control flow causing the water pollution is obtained by data and constraints presented for the standards of water quality such as TSI, EC, and WHO in the developed ANN models and the regression equation for the Lower Sakarya River. Table 5 shows the comparison of the results obtained from ANN models and regression analysis. With ANN model of calculation, it has ended up with a deviation of 0.97% from real data. In order to reach this result, several trials have been made by changing weights and the number of hidden neurons. It can be seen from the table that the quality of this method is somehow high, and predicting the cost with this method is preferable. It can be seen that the results of the prediction of the data are comparable. The average deviation produced

Table 5. Comparison of the results obtained from ANN models and regression analysis.

Actual data	Reg	Dev%	ANN (1)	Dev%	ANN (2)	Dev%	ANN (3)	Dev%	ANN (4)	Dev%
76,500	76,224	0,004	76,471	0,000	76,498	0,000	81,386	0,064	77,143	0,008
127,000	111,277	0,124	126,562	0,003	125,956	0,008	126,367	0,005	125,891	0,009
108,000	108,935	0,009	107,991	0,000	108,006	0,000	126,989	0,176	108,494	0,005
48,700	48,285	0,009	48,720	0,000	48,722	0,000	18,800	0,614	48,787	0,002
23,800	6,132	0,742	23,752	0,002	27,055	0,137	18,738	0,213	22,544	0,053
23,800	37,840	0,590	23,993	0,008	27,399	0,151	48,724	1,047	24,911	0,047
38,800	27,530	0,290	38,534	0,007	27,061	0,303	42,103	0,085	39,392	0,015
18,700	24,011	0,284	20,325	0,087	27,201	0,455	18,707	0,000	19,564	0,046
32,100	48,011	0,496	32,304	0,006	28,409	0,115	35,684	0,112	30,528	0,049
69,600	67,369	0,032	69,590	0,000	69,605	0,000	70,942	0,019	69,702	0,001
55,300	79,971	0,446	55,237	0,001	55,433	0,002	124,876	1,258	55,619	0,006
96,700	78,386	0,189	96,697	0,000	96,695	0,000	83,669	0,135	96,515	0,002
MAPE		0,268		0,010		0,098		0,311		0,020

Table 6. Values of the pollution control flow for the standards (m^3/s).

	Standards		
Models	Turkish Standards Institute (TSE-2005)	European Commission (EC-1998)	The World Health Organization (WHO-2003)
Regression analysis	72.949	72.949	153.270
ANN1 model	90.234	90.234	126.994

by regression is 26.79%. The difference is higher than that of ANN models. The worst result is obtained by regression analysis.

The resulted data range from 6.132 m^3/sec to 126.562 m^3/sec and the average flow is approximately 59.756 m^3/sec. As can be seen from Table 5, ANN1 model gives a better result for forecasting flow. There an is approx. 19% difference between two methods. Flow values of the pollution control for TSI, EC, and WHO are given in Table 6 by ANN1 model and regression analysis.

When data given in Table 6 are investigated, it is observed that data and constraints presented for the standards of the water quality, such as TSI and EC, were the same data obtained by ANN1 model and regression equation. Therefore, data and constraints of both standards are formed due to having very close values with each other. As the data and constraints of WHO are more prohibitive than other standards, the values of the pollution control flow appear as bigger than the values obtained from other standards. In addition, when data given in Table 2 and Table 6 are investigated, it is seen that the constraint of the pollution control flow in river is provided for three months according to TSI and EC, but water pollution is continued in the other months.

7. Conclusions

Determination of the pollution control flows of each reservoir needs to be in values of river without water pollution of inflows released from reservoir to river in events such as drought management in a multi-reservoir system. Therefore, the correlation analysis was made to investigate the gravity influence of elements which cause water pollution on flow rate in the river. The data obtained from correlation analysis were used in ANN model and the regression analysis. The pollution control flow was determined by data, and constraints were presented for the standards of the water quality such as TSI, EC, and WHO. The regression analysis and ANN model were developed for the Lower Sakarya River. It was observed that ANN model is 19% better than regression analysis when obtained results are compared with regard to these standards. It is seen that pollution control flow is raised when the constraints about water quality are increased. In addition, the constraint of the pollution control flow in river is provided for three months according to TSI and EC, but water pollution is continued in the other months. Therefore, water structures need to prevent sediment transport urgently.

In further studies, the pollution control flows may

be determined for those regions by similar analyses in the Upper and Middle Sakarya River. Thus, it can be said that its pollution control flows for drought control and management in a multi-reservoir system on the Sakarya River will be carried out more effectively and successively.

Acknowledgements

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Biography

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