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Original Research Paper

Evaluation of Bacteriological Parameters in Water Using Artificial Neural Network

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ABSTRACT

This paper deals with the application of artificial neural network (ANN) for the evaluation of bacteriological parameters in water. It dependents on temperature, conductivity, dissolved oxygen, total dissolved solids, depth of water, chlorides, phosphates, nitrates, biochemical oxygen demand, total Kjeldahl nitrogen, fecal coliform, total coliform and fecal steptococci before and after the domestic waste mixing zone of River Kabini, tributary of Cuavery at Nanjanagud, Mandya district, Karnataka. The ANN predicted values are close to the actual laboratory tested values. In this paper 150 actual measured values and laboratory tested values have been taken. For predictions of values using ANN, input and outputs parameters, learning rate parameters, error tolerance, number of cycles to reduce the randomly assigned weights are required, for processing this, the back propagation algorithm and delta rule are required, to input these values to ANN the actual measured and laboratory tested values are used as input and output parameters. The learning rate parameter is 0.55, error tolerance is 0.001 and 5600 number of cycles have been chosen. The first ANN pattern chosen is 10-11-11-3 (ten neuron in input layer, two hidden layers of eleven neuron each and three neuron in output layer) and second parameter is 0.55, error tolerance is 0.001 and 4500 number of cycles, have been chosen. The ANN pattern chosen is 10-12-12-13 (ten neuron in input layer, two hidden layers of eleven neuron each and three neuron in output layer). Back propagation algorithm has been used to train the network, and delta rule is used to adjust the weights and to reduce the errors. The network predicted values, measured and laboratory tested values have been shown in figures and graphs.

INTRODUCTION

Artificial neural networks (ANN) have emerged as a computationally powerful tool in artificial intelligence with the potential of mapping an unknown nonlinear relationship between the given set of inputs and outputs. Their application can be widely seen in civil engineering field such as design, analysis and optimization. Basically, neural networks map an input vector from one space to another. The translation is not specified, but is learned. Explicit characteristics of what is to be learned are not specified. Rather, a network is given a set of inputs and their associated outputs (Hojjath Adeh & Hyo Seon Park 1995). The network consists of some layers of interconnected neurons (patterned after their biological equivalent). While elec-trochemical signals propagate through set of brain neurons, the input values pass through the artificial network to yield output values. In the computational model this is represented by an activation function, which includes a set of weights associated with each input value. The learning process is used to determine the proper weights.

The River Kabini, tributary of Cauvery at Nanjanagud Mysore district, water is used for drinking purpose for Nanjanagud Taluk to about 10 lakhs people and for irrigation of 25 thousand hectares of land and also for fisheries and other activities (Gowda 1996). The water gets polluted due to the bathing, cattle wading, washing of cloths and mixing with domestic waste. By observing the Kabini river water as polluted, the study was planned to understand its water quality.

Bacteria are present in the domestic water due to contamination by fecal matter, sewage disposal into the river, and various activities of animals (Feachem 1974). The quality of the water was determined in the laboratory for some samples and for the rest was predicted using ANN.

ARTIFICIAL NEURAL NETWORK

An artificial neural network (ANN) comprises of a number of interconnected units (artificial neurons). Each unit has an input/output characteristic and implements a local computation or function. The output of any unit is determined by its input/output characteristics, its interconnection to the other unit and external input.

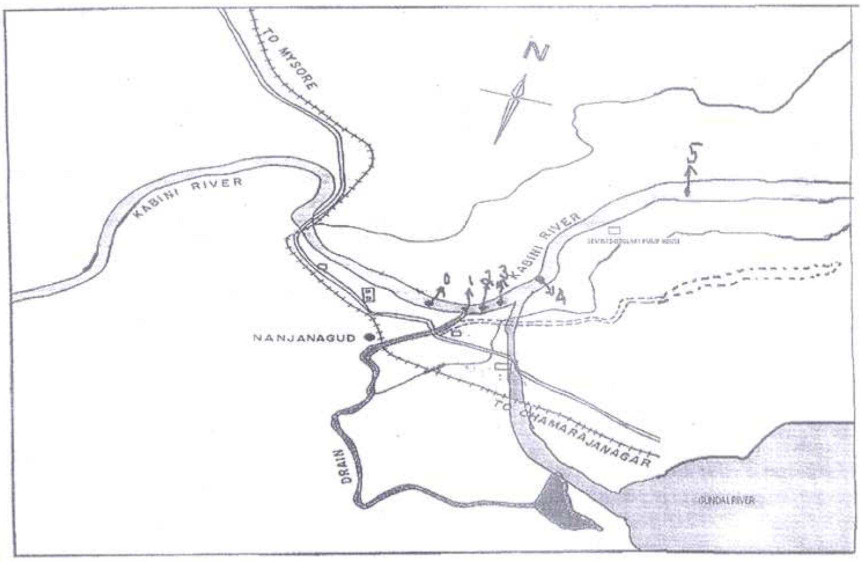

Fig. 1: Sketch showing the study stretch of River Kabini and sampling locations.

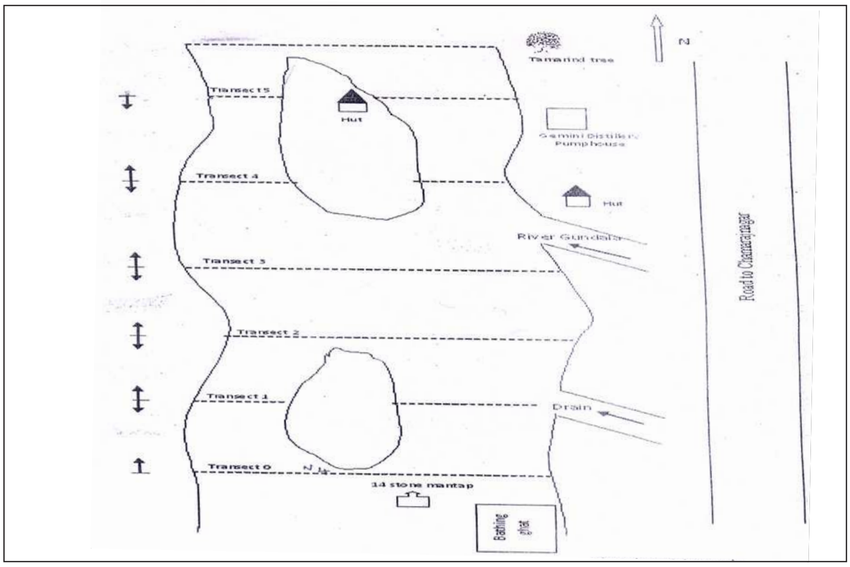

Fig. 2: Sketch showing salient features of study stretch along with transects of River Kabini.

A neural network is a computational structure inspired by the study of biological neural processing. There are many different types of neural networks; from relatively simple to very complex, just as there are many theories on how biological neural processing works.

A layered feed-forward neural network has layers, or subgroups of processing elements (Rehak et al. 1989). A layered processing element makes independent computation of data that it receives and passes the result to another layer. The next layer make its independent computations and pass on the results to yet another layer. Finally, a subgroup of one or more processing elements determine the output from the network. Each processing element makes its computation based upon a weighed sum of its inputs. The first layer is the input layer and last, the output layer. The layers that are placed between the first and the last layers are the hidden layers. The processing elements are seen as units that are similar to the neurons in a human brain, and hence, they are referred to as cells, neuromines or artificial neurons. A threshold function is sometimes used to quantify the output of a neuron in the output layer.

Fig. 3 is a layered feed-forward neural network. The circular nodes represent neurons. Here, there are three layers, an input layer, a hidden layer and an output layer. The

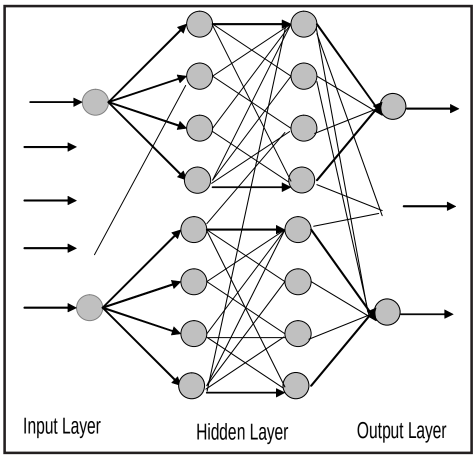

Fig. 3: The network-model.

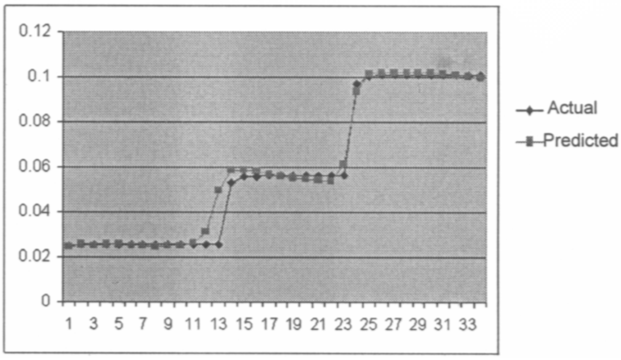

Fig. 4: Comparison of actual and ANN predicted TC values.

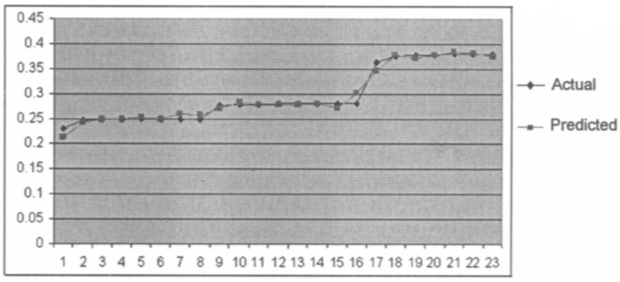

Fig. 5: Comparison of actual and ANN predicted TC values.

directed graph mentioned shows the connections from nodes from a given layer to other nodes in other layers.

Since, the output may not be what is expected, the weights may need to be altered. Some rule then needs to be used to determine how to alter the weights. There should also be a criterion to specify when the process of successive modification of weights ceases. This process of changing the weights, updating the weights is called training; training is an external process.

A network trained so that application of a set of inputs produces the desired (or at least consistent) set of outputs. Each such input (or output) set is referred to as a vector. Training is accomplished by sequentially applying input vectors while adjusting network weights according to a predetermined produce. During training, the network weights are gradually converge to values such that each input vector produces the desired output vector.

Training algorithms are categorized as supervised and unsupervised. Supervised training requires the pairs of each input vector with a target vector representing the desired output; together these are called a training pair. Usually a network is trained over a number of such training pairs. An input vector is applied. The output of the network is calculated and compared with the corresponding target vector, and the difference (error) is fed back through the network and weights are changed according to an algorithm that tends to minimize the error. The vectors of the training set are applied sequentially and errors are calculated and weights are adjusted for each vector, until the error for the entire training set is at an acceptably low level.

The delta rule uses local information on error; the generalized delta rule uses error information that is not local. It is designed to minimize the total of the squared errors of the output neurons. In trying to achieve this minimum, the steepest descent method, which uses the gradient of the weight surface, is used (this is also used in the delta rule). For the next error calculation, the algorithm looks at the gradient of the error surface, which gives the direction of the largest slope on the error surface. This is used to determine the direction to go to try minimizing the error. The algorithm chooses the negative of this gradient, which is the direction of steepest descent. Imagine a very hilly error surface, with peaks and valleys that have a wide range of magnitude. Imagine starting your search for minimum error at an arbitrary point. By choosing the negative gradient on all iterations, you eventually end up at a valley. You cannot know, however, if this valley is the global minimum or a local minimum. Getting stuck in a local minimum is one well-known potential problem of the steepest descent method.

MATERIALS AND METHODS

Application of artificial neural network for the prediction of water quality dependent parameters, the subject of this paper, is primarily non-linear (Gowda 1980, Thomann & Mueller 1987). In the river seven points have been identified out of which two points are before domestic waste mixing to the river, N_1 and N_4, which give the real values of back concentration river water quality, other five points are at outfall, 100m 300m, 500m and 1000m away from the mixing zone, which are undergoing for self purification. Along the transverse direction of all the seven points, at every 3 meters intervals, water samples have been collected

Table 1: Weights assigned by ANN.

1	-7.338053	8.163480	5.989786	5.442607	-10.787592	-3.505791	6.699404	-5.663089	-7.658278	-4.089007	-2.655298
1	3.230293	-3.646806	-1.580070	-1.0418840	5.504576	0.809472	-3.473856	3.216449	2.320471	1.620874	0.545485
1	2.027847	-1.781531	-1.273548	-0.951749	2.780365	1.109857	-2.636755	2.456899	1.446560	0.915243	0.7494360
1	1.336225	-0.310327	-1.091805	-0.826280	1.305260	0.961980	-0.879146	0.079661	-0.048661	1.275873	-0.302054
1	2.036104	-2.20951	-2.139710	-3.017953	-0.473185	-1.001682	-1.384917	-1.576713	3.096551	-0.208609	-1.649792
1	3.558969	-3.461274	-1.295211	-1.350443	8.823780	0.941444	-7.059799	4.629129	1.402664	3.232330	1.461417
1	2.480278	-2.921108	-1.047292	-0.037612	4.128894	0.427810	-3.583191	2.451053	1.006401	1.818173	0.745203
1	-0.614348	1.611844	0.385325	0.140338	4.012722	-2.029079	0.455743	3.150717	0.871268	1.284639	-0.048474
1	0.989653	-1.237635	-1.171045	-0.854239	2.014193	-0.443372	0.391540	0.423827	1.739622	-0.201055	-0.953289
1	2.157036	-1.863636	-0.303344	-1.084639	3.21713	-0.512133	0.2.494104	1.000938	0.841274	0.052461	1.152604
2	0.168624	8.626802	5.789681	1.111817	-0.458999	-0.739816	1.005970	-0.445509	-0.779096	-0.182045	-0.896630
2	-0.6682414	-5.657170	-9.504874	-1.272583	0.028532	-0.913545	-1.039260	0.211227	0.440606	-0.550982	-0.643628
2	-0.760797	-2.616849	-7.238111	-0.713312	-0.912342	-0.153006	-0.738340	0.098895	0.174514	-0.697061	-0.048317
2	-0.504029	-2.063952	-7.222047	-0.933054	-0.742555	-0.132151	-0.359920	1.278213	-0.773136	0.218453	-0.772803
2	-0.073151	13.201703	1.783280	-0.421508	-0.260959	0.475294	-0.048340	-0.485696	1.544559	0.558505	-0.470350
2	-1.663053	3.160007	1.247239	0.174961	0.511498	-0.066435	-2.368574	0.116526	-2.511208	0.704728	0.298533
2	-0.955838	-8.345610	-7.767878	0.373660	-0.563383	-0.892319	-1.616587	-0.034288	-1.854599	0.507692	-0.325798
2	-0.482094	8.094195	0.901784	-1.068967	0.607087	-1.219263	-1.016879	0.369819	0.109324	-0.380143	-0.068558
2	0.438140	6.879783	6.562255	1.79708	-1.270403	0.877748	1.088857	-0.758522	0.443384	-0.584871	-0.402797
2	-0.424220	5.356637	1.514272	-1.065841	0.159397	-0.972500	-0.436453	-0.919864	0.396276	-1.142255	0.775639
2	-0.422279	3.928556	0.204964	-0.376256	0.563159	-0.225075	-0.935878	-0.468175	1.264941	-0.657968	-0.397169
3	-1.326714	-0.333669	1.075185								
3	0.401519	-0.727832	-2.334147								
3	1.810842	-0.945916	-0.304234								
3	-1.615148	-0.698992	-0.445458								
3	-1.347278	-2.617199	-0.108503								
3	-0.695391	-0.769020	0.636560								
3	-1.051518	0.471198	1.732639								
3	-1.777531	-1.917157	0.104522								
3	-1.084608	-0.901144	1.589609								
3	-1.611046	-2.931747	0.360838								
3	-1.150586	-1.440427	0.186791								

(Figs. 1 and 2). Some of the water quality parameters were measured at the river such as distance, temperature, conductivity, depth of water, total dissolved solids and dissolved oxygen, while the remaining parameters like chlorides, phosphates, nitrates, BOD, total Kjeldahl nitrogen, fecal coliform, total coliform and fecal steptococci were tested in the laboratory (APHA 1992). All the 14 parameters are considered as training data in the network for training, and to get output (Chojnowski & Mancini 1979). Eleven parameters such as distance, temperature, conductivity, depth of water, chlorides, phosphates, nitrates, BOD, fecal coliform, total coliform and fecal steptococci are taken as input parameters, and the output parameters are dissolved oxygen, BOD and total Kjeldahl nitrogen .

A four-layer artificial neural network is proposed, which is shown in Fig. 3. The input layer contains the normalized values of actual measured values and laboratory tested values such as distance, temperature, conductivity, depth of water, total dissolved solids and dissolved oxygen, the remaining parameters such as chlorides, phosphates, nitrates, BOD, total Kjeldahl nitrogen, fecal coliform, total coliform and fecal steptococci as an input for the purpose of training. The network uses supervised learning using generalized delta rule. For this learning both, a set of known values and corresponding known output values.

The learning algorithm in the form of generalized delta rule is:

$$\Delta W_i = \eta(p_{actual}-p_{network})\ K \qquad ...(1)$$

Where η is a learning rate constant (0.85), p_{actual} is the actual known values of output parameters, dissolved oxygen, BOD and total Kjeldahl nitrogen. K weights assigned by ANN. A learning rate constant of 0.85 was found to be suitable after several trial runs. Initially the weights are randomly regenerated and as the iterations continue, the weights get modified to approximate values. The program is coded in C++. About 150 input values and associated output values were used while training the net. About 150 different input values were used to test the output patterns of the net. Tables 1, 3 and 6 show the weights assigned by the ANN. Tables 2, 4 and 5 show the actual measured values, laboratory tested values and ANN predicted values. The graphs (Fig. 4, Fig. 5) show the differences of actual measured values and laboratory tested values and ANN predicted values.

CONCLUSION

Water quality dependent parameters such as distance, temperature, conductivity, dissolved oxygen, total dissolved solids, depth of water, chlorides, phosphates, nitrates, BOD, total Kjeldahl nitrogen, fecal coliform, total coliform and

Table 2: Input and output parameters of sampling 2 ANN.

Sl No	Dis	Temp	Cond	TDS	Dep	Chld	Phosphate	NO_3	BOD	TKN	Act Fc	ANN Fc	Act TC	ANN TC	Act FS	ANN FS
1	0.00	0.280	0.2340	0.13	0.000	0.078	0.0312	0.492	0.635	0.110	0.515	0.519885	0.0251	0.024581	0.115	0.134882
2	0.03	0.280	0.2315	0.12	0.030	0.084	0.0350	0.671	0.791	0.130	0.492	0.496602	0.0255	0.025580	0.174	0.159989
3	0.06	0.280	0.2294	0.12	0.050	0.096	0.0401	0.654	0.906	0.149	0.490	0.476861	0.0255	0.025268	0.179	0.170891
4	0.09	0.279	0.2288	0.12	0.050	0.098	0.0409	0.668	0.925	0.152	0.490	0.487687	0.0256	0.025643	0.180	0.171529
5	0.12	0.279	0.2264	0.12	0.095	0.098	0.0411	0.670	0.929	0.153	0.490	0.483373	0.0256	0.025424	0.180	0.177243
6	0.15	0.278	0.2240	0.11	0.150	0.098	0.0411	0.671	0.930	0.153	0.490	0.477019	0.0256	0.025081	0.180	0.183454
7	0.18	0.278	0.2226	0.11	0.160	0.098	0.0411	0.671	0.930	0.153	0.490	0.491583	0.0256	0.025196	0.180	0.180022
8	0.21	0.278	0.2218	0.11	0.150	0.184	0.0851	0.538	0.945	0.157	0.490	0.472057	0.0256	0.024717	0.180	0.188886
9	0.24	0.276	0.2212	0.11	0.140	0.196	0.0871	0.532	0.945	0.158	0.490	0.490800	0.0256	0.024959	0.180	0.184724
10	0.27	0.276	0.2208	0.11	0.135	0.198	0.0874	0.531	0.945	0.158	0.490	0.509073	0.0256	0.025176	0.180	0.179842
11	0.30	0.277	0.2200	0.11	0.130	0.198	0.0874	0.531	0.945	0.158	0.490	0.515799	0.0256	0.025955	0.180	0.175340
12	0.33	0.277	0.2200	0.11	0.125	0.198	0.0874	0.531	0.945	0.158	0.490	0.442272	0.0256	0.031336	0.180	0.178277
13	0.36	0.277	0.2200	0.11	0.120	0.198	0.0874	0.531	0.945	0.158	0.235	0.252889	0.0256	0.049502	0.194	0.195445
14	0.39	0.277	0.2200	0.11	0.120	0.198	0.0874	0.531	0.945	0.158	0.213	0.197575	0.0533	0.058840	0.195	0.200000
15	0.42	0.277	0.2200	0.11	0.110	0.370	0.0911	0.396	0.413	0.159	0.210	0.208119	0.0558	0.058563	0.195	0.193984
16	0.45	0.277	0.2200	0.11	0.110	0.394	0.0914	0.383	0.363	0.159	0.210	0.209504	0.0560	0.058084	0.195	0.193891
17	0.48	0.277	0.2200	0.11	0.115	0.398	0.0914	0.381	0.355	0.159	0.210	0.209413	0.0561	0.057082	0.195	0.195992
18	0.51	0.277	0.2200	0.11	0.120	0.398	0.0914	0.381	0.354	0.159	0.210	0.208989	0.0561	0.056041	0.195	0.197946
19	0.54	0.278	0.2200	0.11	0.100	0.398	0.0914	0.381	0.354	0.159	0.210	0.211254	0.0561	0.055490	0.195	0.196914
20	0.57	0.278	0.2200	0.11	0.110	0.398	0.0914	0.381	0.354	0.159	0.210	0.210073	0.0561	0.054600	0.195	0.198052
21	0.60	0.278	0.2200	0.11	0.110	0.399	0.0915	0.381	0.354	0.161	0.210	0.210149	0.0561	0.054035	0.195	0.197462
22	0.63	0.278	0.2208	0.11	0.120	0.229	0.0989	0.222	0.659	0.161	0.210	0.215311	0.0561	0.053341	0.195	0.163214
23	0.66	0.278	0.2214	0.11	0.135	0.204	0.1061	0.199	0.703	0.161	0.210	0.201494	0.0561	0.061607	0.195	0.233719
24	0.69	0.278	0.2219	0.11	0.140	0.200	0.1015	0.195	0.710	0.161	0.160	0.164625	0.0971	0.093888	0.582	0.561396
25	0.72	0.278	0.2220	0.11	0.145	0.199	0.1006	0.195	0.712	0.161	0.160	0.158088	0.1007	0.101768	0.615	0.626370
26	0.75	0.278	0.2220	0.11	0.140	0.199	0.1004	0.195	0.712	0.161	0.160	0.158052	0.1010	0.102276	0.619	0.62664
27	0.78	0.278	0.2228	0.11	0.120	0.199	0.1003	0.195	0.712	0.161	0.160	0.158877	0.1011	0.102240	0.619	0.621809
28	0.81	0.278	0.2235	0.11	0.095	0.199	0.1015	0.423	0.819	0.157	0.160	0.162231	0.1011	0.102410	0.619	0.630301
29	0.84	0.278	0.2238	0.11	0.100	0.199	0.1014	0.433	0.823	0.157	0.160	0.161843	0.1011	0.102230	0.619	0.626697
30	0.87	0.278	0.2250	0.11	0.095	0.199	0.1013	0.434	0.823	0.157	0.160	0.161536	0.1011	0.101987	0.619	0.622249
31	0.90	0.278	0.2270	0.11	0.090	0.199	0.1013	0.434	0.823	0.157	0.160	0.160907	0.1011	0.101548	0.619	0.618781
32	0.93	0.278	0.2290	0.11	0.095	0.199	0.1013	0.434	0.823	0.157	0.160	0.159751	0.1011	0.100814	0.619	0.616565
33	0.96	0.278	0.2308	0.11	0.080	0.199	0.1013	0.434	0.823	0.157	0.160	0.159014	0.1011	0.100278	0.619	0.614666
34	1.00	0.277	0.2330	0.11	0.000	0.199	0.1013	0.435	0.824	0.157	0.160	0.159176	0.1011	0.100174	0.619	0.611918

Table 3: Weights assigned by ANN.

1	-1.613551	-2.526554	-4.855781	-0.930744	0.567675	-2.129139	-0.644359	0.808504	0.515665
	-1.159868	1.292571	1.034480						
1	0.668488	0.549843	1.826289	-0.153983	0.241244	-0.651641	0.713229	-0.063727	0.013182
	0.010814	-0.374773	-1.136585						
1	0.150409	-0.617325	1.234402	-1.327568	-0.633397	-1.137944	0.564643	0.417766	0.223885
	-0.909767	-0.039396	0.176418						
1	-0.262620	0.162888	0.170566	0.451549	0.093045	0.154667	-0.807132	0.316693	0.713528
	0.617689	0.103079	-0.811993						
1	-2.645143	1.689595	3.821222	-0.008693	-0.356368	-0.2822497	1.149858	-0.650139	-1.911206
	-2.152170	-2.185769	0.631630						
1	2.473173	-0.939600	0.882254	2.499219	-1.939049	-0.074210	-1.366518	-0.365951	1.008800
	0.136632	0.836124	-3.396835						
1	-0.261192	-1.146726	-2.125763	-0.407968	0.084938	10.76796	-0.650734	-1.097196	-0.066297
	0.413577	0.303629	1.021546						
1	-0.270446	-0.091436	-3.012879	0.747805	0.355214	-1.240109	-0.204940	-0.421843	-0.341635
	1.055994	0.414331	-0.065386						
1	1.295888	-3.183480	-0.780351	-0.367868	2.055228	-1.840082	-1.231835	-0.831780	-0.044123
	1.269174	2.227614	-0.876719						
1	1.552361	1.014377	4.026210	0.991647	-1.754767	0.588121	-0.482781	-0.498785	-1.067457
	-0.875278	-0.860866	-1.315906						
2	0.554689	-1.485519	-1.635982	-2.236273	-0.366663	-1.541640	-1.044412	0.289874	-1.086835
	-1.001285	0.043959	0.079840						
2	0.921652	-0.478716	-0.937629	-0.870621	0.011807	-1.127917	0.627147	0.941237	
	2.485849	-0.905736	0.876651	-1.162776					
2	0.847180	-2.316719	-0.764988	-4.144320	-1.564611	-3.038238	0.583239	0.922605	
	2.426857	-1.601611	-0.057928	0.211091					
2	-0.437353	-0.946123	-0.408914	-1.258328	-0.624592	-1.223833	-1.281763	0.3211242	
	0.732944	0.399886	-0.009132	-0.625653					
2	-1.167526	0.652083	0.852973	0.298578	-0.149351	0.470085	0.006354	-1.009309	
	-1.354311	-0.635520	-1.911255	0.198987					
2	-0.433648	-1.500649	-0.685956	0.248590	-1.314803	-0.473496	-1.037694	0.488704	
	0.940335	-1.735715	0.767080	-0.806553					
2	-0.245338	-0.064194	-0.891212	0.634847	0.292782	0.997401	-0.374600	-0.733703	
	1.758453	-0.425140	0.815224	0.847377					
2	-0.055645	0.151720	-0.921521	1.023794	0.308387	-0.380604	0.035368	-0.265345	
	-0.142237	0.179782	0.180676	0.149342					
2	0.561296	-1.303054	-0.077283	-0.673996	0.274227	0.083464	-0.719247	-1.217384	
	-1.635075	0.620231	0.089147	-0.199454					
2	1.115088	-0.388530	0.392194	-0.392987	-1.033394	-1.062870	-1.185747	-0.297540	
	-2.160238	-0.942017	-0.403240	-0.680646					
2	0.093490	0.353643	-0.565966	-0.375494	-0.719276	-0.109770	-1.006351	-1.587978	
	-2.272674	0.673858	-1.959923	-0.624476					
2	-1.868245	0.958484	-0.311350	2.491431	-0.308162	1.614115	0.705447	0.293065	
	0.237600	-0.628584	-0.973473	-1.089956					
3	-1.416015	-0.874283	-2.571140						
3	-2.422536	-0.041729	-0.568625						
3	-1.111445	-0.417673	-0.289063						
3	-2.629190	1.448884	0.333612						

fecal steptococci before and after the domestic waste mixing zone of River Kabini have been taken for the study.

It was observed that all the parameters of water quality dependent parameters are independent and there is no inter relations among the values for some parameters and the variation is nonlinear.

It has been found that a four-layered artificial neural network (10-12-12-3) is effectively predicted almost close to the actual measured and laboratory tested values. The artificial neural network is trained for the above topology and conditions with back propagation algorithm taking data as input vector. The percentage difference/error between the actual measured, laboratory tested values and the predicted values is within 15%. The percentage of error can be still reduced by increasing input parameters. Time required for prediction is very less as compared to the practical applications. So we can effectively use ANN to predict some of the values, where it is not possible to go for actual measurement and laboratory testing.

Table 4 input and output parameter of sampling2 ANN.

Sl No.	Dis	Temp	Cond	TDS	Dep	Chld	pH	NO_3	TKN	BOD	Act Fc	ANN Fc	Act TC	ANN TC	Act Fs	ANN Fs
1	0.00	0.291	0.2030	0.10	0.000	0.210	0.295	0.010	0.130	0.162	0.200	0.220197	0.23	0.214077	0.060	0.073020
2	0.03	0.291	0.2038	0.10	0.050	0.230	0.398	0.080	0.148	0.181	0.183	0.193938	0.247	0.243212	0.090	0.088960
3	0.06	0.291	0.2039	0.10	0.095	0.278	0.482	0.090	0.151	0.219	0.181	0.182160	0.249	0.249382	0.094	0.092243
4	0.09	0.290	0.2039	0.10	0.135	0.290	0.502	0.090	0.151	0.228	0.180	0.179302	0.249	0.248589	0.095	0.093770
5	0.12	0.290	0.1992	0.10	0.130	0.292	0.506	0.090	0.157	0.230	0.180	0.172527	0.250	0.253924	0.095	0.097999
6	0.15	0.289	0.1956	0.10	0.120	0.207	0.700	0.384	0.159	0.237	0.180	0.182570	0.250	0.248970	0.095	0.094660
7	0.18	0.289	0.1920	0.09	0.165	0.201	0.724	0.421	0.159	0.237	0.180	0.161535	0.250	0.260173	0.095	0.101520
8	0.21	0.289	0.1912	0.09	0.215	0.199	0.730	0.429	0.159	0.237	0.180	0.151968	0.250	0.256852	0.095	0.102245
9	0.24	0.289	0.1912	0.09	0.225	0.199	0.731	0.431	0.158	0.237	0.101	0.134740	0.276	0.269295	0.117	0.107712
10	0.27	0.289	0.1902	0.09	0.230	0.383	0.598	0.824	0.158	0.239	0.092	0.086796	0.279	0.282840	0.120	0.120425
11	0.30	0.288	0.1890	0.09	0.240	0.395	0.587	0.532	0.158	0.239	0.090	0.096554	0.279	0.277365	0.120	0.118746
12	0.33	0.288	0.1892	0.09	0.225	0.397	0.585	0.467	0.157	0.239	0.090	0.095190	0.280	0.277575	0.120	0.119186
13	0.36	0.289	0.1918	0.09	0.215	0.398	0.584	0.451	0.157	0.239	0.090	0.090917	0.280	0.278998	0.120	0.120171
14	0.39	0.289	0.1986	0.09	0.250	0.399	0.584	0.435	0.155	0.240	0.090	0.087109	0.280	0.280128	0.120	0.122176
15	0.42	0.289	0.1945	0.09	0.270	0.168	0.543	0.277	0.155	0.240	0.090	0.095472	0.280	0.272380	0.120	0.115530
16	0.45	0.288	0.1864	0.09	0.280	0.119	0.534	0.244	0.155	0.240	0.090	0.074032	0.280	0.302387	0.120	0.127679
17	0.48	0.288	0.1878	0.09	0.250	0.107	0.532	0.236	0.155	0.240	0.047	0.054639	0.365	0.347244	0.146	0.141908
18	0.51	0.289	0.1916	0.09	0.230	0.105	0.531	0.234	0.156	0.240	0.041	0.042839	0.377	0.378908	0.149	0.151168
19	0.54	0.289	0.1978	0.09	0.240	0.268	0.768	0.311	0.156	0.240	0.040	0.042576	0.379	0.372852	0.150	0.146874
20	0.57	0.289	0.1998	0.09	0.220	0.290	0.800	0.318	0.154	0.240	0.040	0.039323	0.379	0.378487	0.150	0.148401
21	0.60	0.289	0.1989	0.09	0.180	0.295	0.807	0.319	0.153	0.240	0.040	0.036822	0.380	0.385352	0.150	0.150854
22	0.63	0.289	0.1951	0.10	0.090	0.297	0.809	0.319	0.153	0.240	0.040	0.038644	0.380	0.383181	0.150	0.151247
23	0.66	0.289	0.1920	0.10	0.000	0.299	0.812	0.321	0.154	0.240	0.040	0.041817	0.380	0.376571	0.150	0.149907

Table 5: Input and output parameters of sampling 2 ANN.

Sl No.	Dis	Temp	Cond	TDS	Dep	Chld	pH	NO_3	BOD	TKN	Act Fc	ANN Fc	Act TC	ANN TC	Act FS	ANN FS
1	0.00	0.280	0.2320	0.14	0.000	0.362	0.131	0.9500	0.0652	0.110	0.410	0.411885	0.380	0.377908	0.900	0.898857
2	0.03	0.280	0.2270	0.11	0.050	0.383	0.173	0.1000	0.0746	0.119	0.376	0.378911	0.440	0.436719	0.141	0.139898
3	0.06	0.280	0.2260	0.11	0.075	0.464	0.210	0.1210	0.0902	0.139	0.371	0.382322	0.448	0.425999	0.149	0.156717
4	0.09	0.279	0.2260	0.11	0.075	0.484	0.219	0.1260	0.0940	0.148	0.370	0.376520	0.449	0436611	0.149	0.148937
5	0.12	0.279	0.2260	0.11	0.088	0.487	0.220	0.1270	0.0947	0.149	0.370	0.368464	0.449	0.449206	0.150	0.145094
6	0.15	0.279	0.2250	0.11	0.110	0.245	0.181	0.1920	0.0989	0.150	0.370	0.354400	0.450	0.466909	0.150	0.169712
7	0.18	0.278	0.2220	0.11	0.122	0.211	0.175	0.1780	0.1011	0.150	0.370	0.340303	0.450	0.493835	0.150	0.143191
8	0.21	0.277	0.2220	0.11	0.130	0.203	0.173	0.1740	0.1016	0.150	0.370	0.328466	0.450	0.512303	0.150	0.134206
9	0.24	0.278	0.2220	0.11	0.120	0.201	0.173	0.1730	0.1017	0.150	0.267	0.317003	0.596	0.529694	0.116	0.124025
10	0.27	0.279	0.2220	0.11	0.125	0.199	0.044	0.0497	0.0946	0.151	0.253	0.267518	0.616	0.598214	0.121	0.116697
11	0.30	0.280	0.2220	0.11	0.130	0.199	0.036	0.0455	0.0950	0.151	0.251	0.259776	0.619	0.608483	0.112	0.116356
12	0.33	0.280	0.2224	0.11	0.115	0.199	0.034	0.0445	0.0943	0.151	0.250	0.253016	0.619	0.615959	0.111	0.111828
13	0.36	0.279	0.2232	0.11	0.110	0.199	0.034	0.0443	0.0941	0.152	0.250	0.247654	0.619	0.620593	0.110	0.109802
14	0.39	0.280	0.2238	0.11	0.110	0.199	0.034	0.0441	0.0940	0.152	0.250	0.242970	0.620	0.623996	0.110	0.109336
15	0.42	0.280	0.2242	0.11	0.100	0.045	0.310	0.0213	0.0850	0.152	0.250	0.246563	0.620	0.622809	0.110	0.110238
16	0.45	0.280	0.2250	0.11	0.080	0.013	0.368	0.0165	0.0830	0.152	0.128	0.133078	0.900	0.906018	0.110	0.109243
17	0.48	0.280	0.2274	0.11	0.070	0.005	0.382	0.0153	0.0830	0.152	0.113	0.114638	0.934	0.934719	0.110	0.109890
18	0.51	0.280	0.2292	0.12	0.065	0.003	0.387	0.0149	0.0830	0.152	0.111	0.108618	0.939	0.942146	0.110	0.110985
19	0.54	0.281	0.2308	0.12	0.060	0.083	0.417	0.0361	0.0880	0.154	0.110	0.114838	0.939	0.935568	0.110	0.105562
20	0.57	0.281	0.2320	0.12	0.055	0.094	0.414	0.0390	0.0880	0.155	0.110	0.116372	0.940	0.931350	0.110	0.107724
21	0.60	0.281	0.2330	0.12	0.050	0.097	0.415	0.0396	0.0880	0.155	0.110	0.113008	0.940	0.934745	0.110	0.109470
22	0.63	0.281	0.2330	0.12	0.020	0.098	0.415	0.0398	0.0880	0.155	0.110	0.107112	0.940	0.941552	0.110	0.111129
23	0.66	0.281	0.2330	0.12	0.000	0.099	0.416	0.0401	0.0890	0.156	0.110	0.103051	0.940	0.945882	0.110	0.112485

REFERENCES

APHA 1992. Standard Methods for the Examination of Water and Wastewater, 18th edition, American Public Health Association, Washington DC.

Chojnowski, K.J. and Mancini, J.L. 1979. Influence of light on coliform mortality rates in freshwater and seawater. Journal of Water Pollution Control Federation (WPCF), 51(10): 2538-2539.

Feachem, R. 1974. An improved role for fecal coliform to feacal streptococci ratios in the differentiation between human and non-human pollution sources. Journal Water Research, 9: 689-690.

Gowda, T.P.H. 1980. Stream Tube Model for Water Quality Prediction in Mixing Zones in Shallow River. Water Resources Paper 14, Water Resources Branch, Ontario, Ministry of Environment, Toronto, Canada.

Gowda, T.P.H. 1996. Bacteriological studies of bathing areas at natural water bodies due to storm-water run-off. Journal of Indian Association of Environmental Management, 23: 131-142.

Hojjath Adeh and Hyo Seon Park 1995. Counter propagation neural net-

Table 6: Weights assigned by ANN.

1	0.431621	-0.368065	2.117953	-1.549242	-0.375771	-6.035349	-0.224395	0.325310
	1.124194							
1	0.144828	-1.595948	-1.646610	3.169868	-0.784585	-0.155024	-1.4301161	1.704750
	-0.178341							
1	0.74 6489	0.369439	0.252708	1.056714	0.847055	1.183290	-1.418689	0.681068
	0.176068							
1	-0.056996	-0.546531	-0.926615	1.527175	-0.983845	0.014919	-0.304416	-0.548887
	0.335254							
1	-0.767123	0.348429	-1.587474	2.491656	0.323670	0.846033	-0.568046	1.125751
	1.060989							
1	0.893420	-0.528489	-1.763336	4.579753	-1.247066	2.573370	-1.594414	0.473824
	0.820253							
1	-0.472555	-0.567539	2.801553	-6.840038	1.913384	0.132788	4.395786	-4.732265
	-3.654853							
1	-2.650468	1.895241	-2.929707	2.687156	-1.438469	1.34393	-1.554056	1.558943
	-0.555574							
1	0.560361	-0.690758	0.191792	1.285707	0.275356	1.076224	-0.110984	0.815164
	0.420213							
1	-0.621296	-0.458303	-0.414527	1.096207	0.046825	0.552495	-0.142401	0.000790
	0.983108							
2	-0.226561	-0.285312	0.441962	0.290188	3.449588	-0.521266	-1.534725	-0.982248
	0.193156							
2	-0.269906	-1.327427	-1.978930	0.230255	-1.337076	-1.716340	0.508261	1.905578
	-0.397896							
2	-0.650322	2.836007	-0.631243	-2.749273	4.637379	0.548238	-2.206465	1.041494
	-0.720245							
2	0.090827	-6.772154	-0.309407	5.992021	-1.814643	-1.398111	-0.116061	-2.967294
	2.155425							
2	-1.093247	1.475841	-1.015190	-0.366641	1.779404	-1.138842	-1.193982	0.347552
	-1.849967							
2	-1.059674	-2.054948	-1.094138	2.713005	-1.417980	-0.358899	-0.969760	-1.953356
	-2.642720							
2	-1.836141	3.586881	-1.140457	-2.548259	2.287240	0.097247	-0.494143	-0.287933
	-2.134782							
2	-0.326310	-4.267011	0.091715	3.947323	-1.591715	-0.095898	0.986774	1.089343
	1.881436							
2	0.216529	-3.333574	0.440408	2.285664	1.371442	0.417405	-0.153080	0.645788
	1.352888							
3	0.261098	1.117775	0.366001					
3	-1.612021	2.786573	0.211603					
3	-0.558954	-0.387345	-0.652755					
3	0.319847	-2.212675	0.779124					
3	-0.378760	1.785694	-4.451090					
3	0.066421	-0.704717	-0.135596					
3	0.481153	1.996963	2.114434					
3	-0.521655	-1.000113	2.798352					
3	-1.140248	1.126374	0.471728					

works in structural engineering. Journal of Structural Engineering, 121: 1205-1212.

Mancini, L.J. 1978. Numerical estimates of coliform mortality rates under various conditions. Journal of Water Pollution Control Federation, pp. 2477-2484.

Rehak, D., Thewalt, C.R. and Lip, B. Do. 1989. Neural network approaches in structural mechanics computations. Proceedings of Structures Congress, Sanfrancisco, California, May 1-5, 168-176.

Thomann, R.V. and Mueller, J.A. 1987. Principles of Surfaces Water Quality Modeling and Control. Harper and Row Publishers, New York.