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Time Series Analysis of Water Quality of Ramgarh Lake of Rajasthan

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Abstract

In this chapter an attempt has been made to study the effect of certain pollutants on water of Ramgarh Lake of Rajasthan. Time series analysis of the observed data has been done using trend, single exponential smoothing and double exponential smoothing methods.

Keywords: Pollutants, trend, single, double exponential smoothing, time series.

1. Introduction

Seventy percent of the earth's surface is covered by water. Water is undoubtedly the most precious natural resource that exists on our planet. Water is an important component of the eco-system and any imbalance created either in terms of amount which it is represent or impurities added to it, Can harm the whole eco-system. Water pollution occurs when a body of water is adversely affected due to the addition of large amount of pollutant materials to the water. When it is unfit for its intended use, water is considered polluted. There are various sources of water pollution (for detail refer to Jain (2011))

Some of the important water quality factors are:

1) Dissolved oxygen (D.O.)
2) Biological oxygen demand (B.O.D.)
3) Nitrate

4) Coliform
5) P.H.

Chemical analysis of any sample of water gives us a complete picture of its physical and chemical constituents. This will give us only certain numerical value but for estimating exact quality of water a time series system has been developed known as water quality trend, which gives us the idea of whole system for a long time (see Jain(2011)).

In this chapter we are calculating the trend values for five water parameters of Ramgarh lake in Rajasthan for the year 1995-2006 and for three parameters of Mahi river for the year 1997-2008.these methods viz. trend analysis, single smoothing are used to analyze the data.

2. Methodology

After ensuring the presence of trend in the data, smoothing of the data is the next requirement for time series analysis. For smoothing the common techniques discussed by Gardner(1985) are trend, simple exponential smoothing (SES), double exponential smoothing (DES), triple exponential smoothing (TES) and adaptive response rate simple exponential smoothing (ARRSES). Jain (2011) used trend method to analyze the data. We have extended the work of Jain (2011) and analyzed the data using SES and DES and compared these with the help of the available information. The methods are described below:

1. Fitting Of Straight line

The equation of the straight line is-

U_t=a+b_t

where,

u_t=observed value of the data, a=intercept value, b=slope of the straight line and

t=time (in years)

Calculation for a and b:

The normal equations for calculating a and b are

$$\sum U_t = n\,a + b\sum t$$

$$\sum t\,U_t = at + b\sum t^{**}2$$

2. Single Exponential Smoothing

The basic equation of exponential smoothing is

$$S_t = \alpha\, y_{t-1} + (1-\alpha)\, S_{t-1}, \quad 0 \le \alpha \le 1$$

and parameter α is called the smoothing constant.

Here, S_i stands for smoothed observation or EWNA and y stands for the original observation. The subscripts refer to the time periods 1,2,3…..,n.

The smoothed series starts with the smoothed version of the second observation.

3. Double Exponential Smoothing

Single smoothing does not excel in following the data when there is a trend. This situation can be improved by the introduction of a second equation with a second constant γ, which must be chosen in conjunction with α.

$$S_t = \alpha\, y_t + (1-\alpha)\,(S_{t-1} + b_{t-1}), \quad 0 \le \alpha \le 1$$

$$b_t = \gamma\,(S_t - S_{t-1}) + (1-\gamma)\, b_{t-1}, \quad 0 \le \gamma \le 1.$$

For forecasting using single and double exponential smoothing following method is used-

Forecasting with single exponential smoothing

$$S_t = \alpha y_{t-1} + (1-\alpha) S_{t-1} \quad 0 \le \alpha \le 1$$

The new forecast is the old one plus an adjustment for the error that occurred in the last forecast.

Boot strapping of forecasts

$$S_{t+1}=\alpha\, y_{origin}+(1-\alpha)\, S_t$$

This formula works when last data points and no actual observation are available**.**

Forecasting with double exponential smoothing

The one period-ahead forecast is given by:

$$F_{t+1}=S_t+b_t$$

The m-periods-ahead forecast is given by:

$$F_{t+m}=S_t+mb_t$$

(for detail of these methods refer to Gardner (1985)).

4. Results and Discussion

Table 1 shows the data on Dissolved Oxygen (D.O.) for Ramgardh Lake for the years 1995-2006 and fitted values using trend, single and double exponential smoothing.

Table 1: Data on Dissolved Oxygen (D.O.) for Ramgardh Lake for the years 1995-2006 and fitted values using trend, single and double exponential smoothing

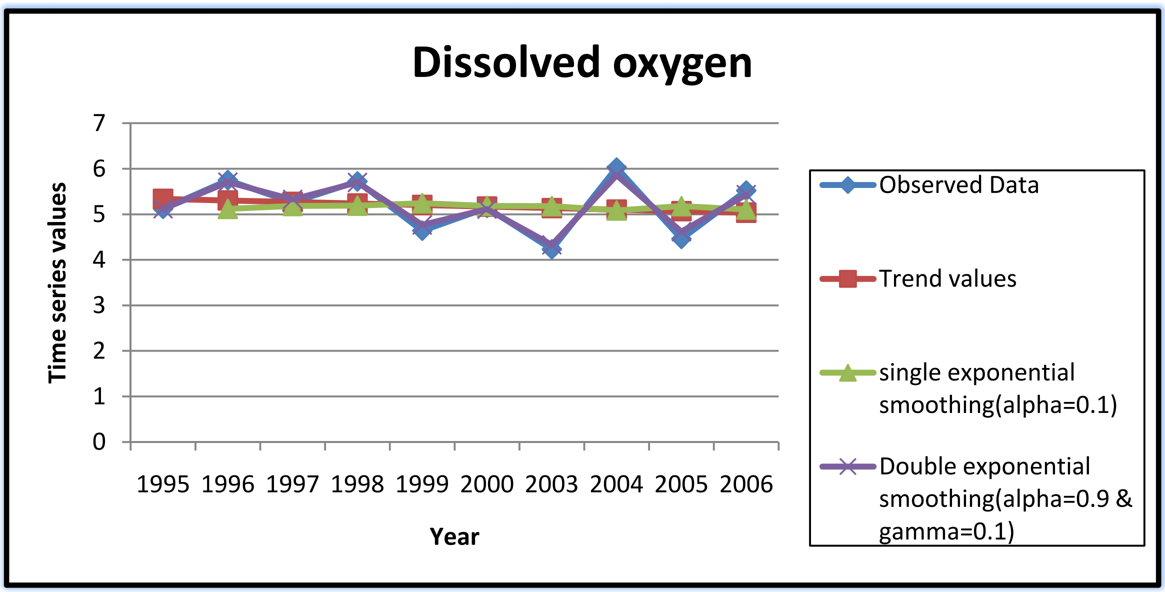
	Observed Data	**Trend values**	**Single exponential smoothing(alpha=0.1)**	**Double exponential smoothing(alpha=0.9 and gamma=0.1)**
1995	5.12	5.3372		5.12
1996	5.75	5.3036	5.12	5.707
1997	5.26	5.27	5.183	5.32857
1998	5.72	5.2364	5.1907	5.698556
1999	4.64	5.2028	5.24363	4.765484
2000	5.14	5.1692	5.183267	5.110884
2003	4.23	5.1356	5.17894	4.329044
2004	6.026	5.102	5.084046	5.858346
2005	4.46	5.0684	5.178242	4.616965
2006	5.52	5.0348	5.106417	5.4327
Total	51.866	51.86	46.46824	51.96755

For trend, the fitted line is

$U_t = 5.1866 - 0.0169 * t$

with mean squared error (MSE) 0.3077. For single exponential smoothing various values of α are tried and minimum MSE = 0.3915 was obtained for α = 0.1. For smoothing of the data, Holt's double exponential smoothing was found to be most appropriate. Various combinations of α and γ both ranging between 0.1 and 0.9 with increments of 0.1 were tried and MSE = 0.0094 was least for α = 0.9 and γ = 0.1.

Figure 1- Graph of observed data and fitted values using trend, single and double exponential smoothing of Dissolved Oxygen (D.O.) for Ramgardh Lake for the years 1995-2006



Adequate dissolved oxygen is necessary for good water quality. Oxygen is a necessary element to all forms of life. Natural stream purification processes require adequate oxygen levels in order to provide for aerobic life forms. As dissolved oxygen levels in water drop below 5.0 mg/l, aquatic life is put under stress (for details see www.state.ky.us).

Form Table 1 and Figure 1, we observe that level of D.O. in Ramgarh Lake was above the required standard 5.0 mg/l, except for the two years 1999 and 2005.

Table 2: Comparison of forecasts

Period	Observed Data	Forecast(single)	Forecast(double)
1	5.12		5.32
2	5.75	5.7437	6.23084
3	5.26	5.25923	5.77869651
4	5.72	5.714707	6.510832048
5	4.64	4.6460363	5.013406419
6	5.14	5.14043267	5.815207177
7	4.23	4.239489403	4.32655631
8	6.026	6.016580463	7.511558059
9	4.46	4.467182416	4.621632535
10	5.52	5.515864175	6.686376834
11		5.147775731	5.6266
12		5.184998158	5.7442
13		5.218498342	5.8618
14		5.248648508	5.9794
15		5.275783657	6.097
16		5.300205291	6.2146
17		5.322184762	6.3322
18		5.341966286	6.4498
19		5.359769657	6.5674
20		5.375792692	6.685

Figure 2: Graph of forecasts

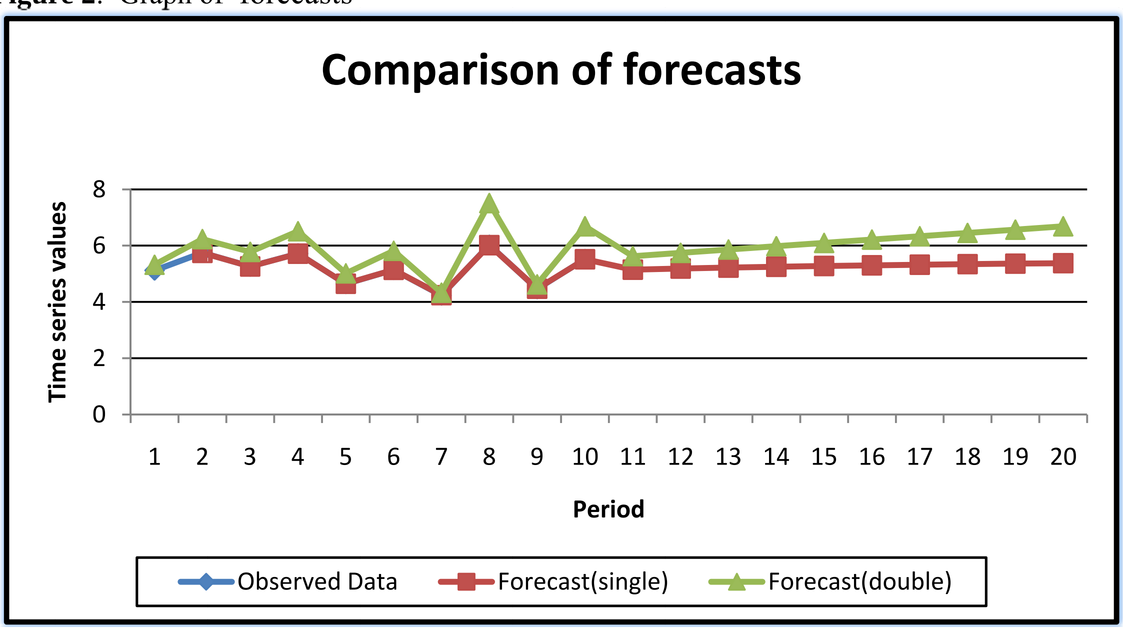


Table 3 shows the data on Nitrate for Ramgardh Lake for the years 1995-2006 and fitted values using trend, single and double exponential smoothing.

Table 3: Data on Nitrate for Ramgardh Lake for the years 1995-2006 and fitted values using trend, single and double exponential smoothing

Year(x)	**Observed Data**	**Trend values**	**Single exponential smoothing(alpha=0.1)**	**Double exponential smoothing(alpha=0.9 and gamma=0.1)**
1995	0.32	0.588		0.32
1996	1.28	0.546	0.32	1.176
1997	0.38	0.504	0.416	0.46096
1998	0.08	0.462	0.4124	0.104883
1999	0.04	0.42	0.37916	0.028797
2000	0.92	0.378	0.345244	0.815205
2003	0.24	0.336	0.40272	0.300708
2004	0.25	0.294	0.386448	0.247331
2005	0.186	0.252	0.372803	0.184874
2006	0.3	0.21	0.354123	0.281431
Total	3.996	3.99	3.388897	3.920189

For trend, the fitted line is

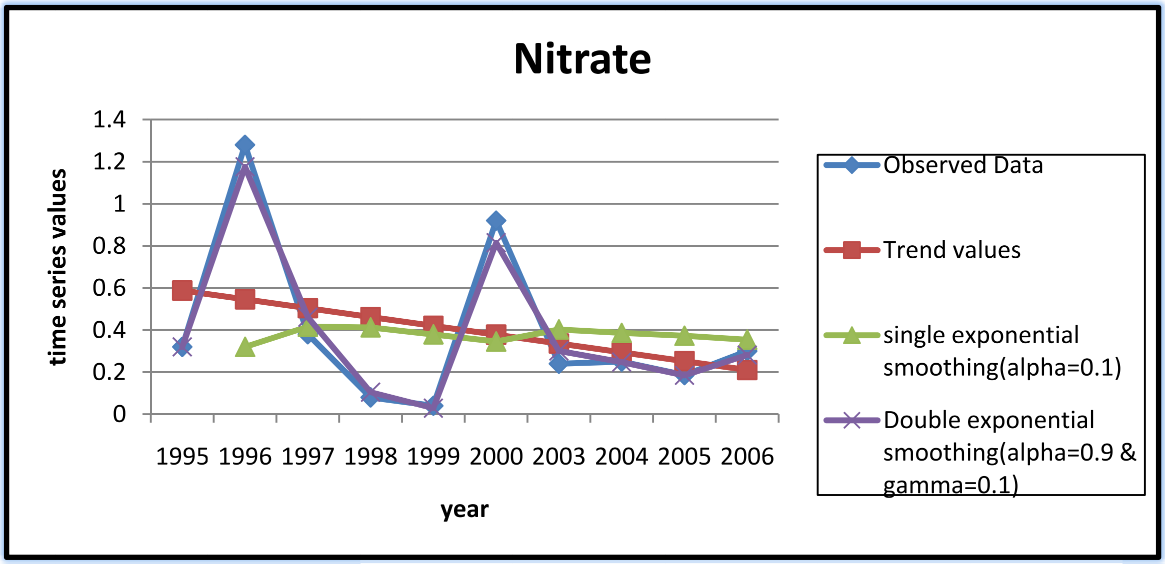
$U_t = 0.3996 - 0.0216 * t$

with MSE= 0.3078. For single exponential smoothing various values of α are tried and minimum MSE = 0.3412 was obtained for $\alpha = 0.1$. For smoothing of the data, Holt's double exponential smoothing was found to be most appropriate. Various combinations of α and γ both ranging between 0.1 and 0.9 with increments of 0.1 were tried and MSE = 0.0033 was least for $\alpha = 0.9$ and $\gamma = 0.1$.

Nitrites can produce a serious condition in fish called "brown blood disease." Nitrites also react directly with hemoglobin in human blood and other warm-blooded animals to produce methemoglobin. Methemoglobin destroys the ability of red blood cells to transport oxygen. This condition is especially serious in babies under three months of age. It causes a condition known as methemoglobinemia or "blue baby" disease. Water with nitrite levels exceeding 1.0 mg/l should not be used for feeding babies. Nitrite/nitrogen levels below 90 mg/l and nitrate levels below 0.5 mg/l seem to have no effect on warm water fish (for details see www.state.ky.us).

Form Table 3 and Figure 3, we observe that level of Nitrate in Ramgarh Lake was below the standard 1.0 mg/l, except for the year 1996.

Figure 3: Graph of observed data and fitted values using trend, single and double exponential smoothing of Nitrate for Ramgardh lake for the years 1995-2006



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Form Table 3 and Figure 3, we observe that level of Nitrate in Ramgarh Lake was below the standard 1.0 mg/l, except for the year 1996.

Table 4: Comparison of forecasts

Period	Observed Data	Forecast(single)	Forecast(double)
1	0.32	0.416	0.24
2	1.28	0.4124	1.1896
3	0.38	0.37916	0.328832
4	0.08	0.345244	-0.07203
5	0.04	0.40272	-0.12795
6	0.92	0.386448	0.847085
7	0.24	0.372803	0.223314
8	0.25	0.354123	0.17474
9	0.186	0.34871	0.114309
10	0.3	0.348711	0.244291
11		0.34384	0.24426
12		0.339456	0.20712
13		0.33551	0.16998
14		0.331959	0.13284
15		0.328763	0.0957
16		0.325887	0.05856
17		0.323298	0.02142
18		0.320968	-0.01572
19		0.318872	-0.05286
20		0.316984	-0.09

Figure 4 : Graph of forecasts

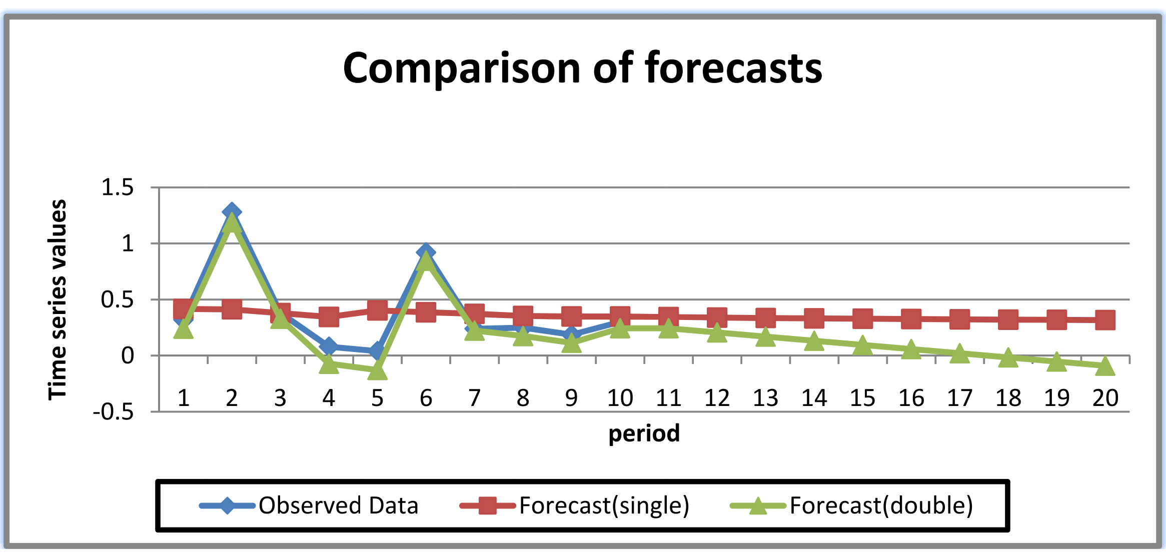


Table 5 shows the data on B.O.D. for Ramgardh Lake for the years 1995-2006 and fitted values using trend, single and double exponential smoothing.

Table 5: Data on Biological oxygen demand (B.O.D.) for Ramgardh Lake for the years 1995-2006 and fitted values using trend, single and double exponential smoothing

Year(x)	**Observed Data**	**Trend values**	**single exponential smoothing(alpha=0.1)**	**Double exponential smoothing(alpha=0.9 & gamma=0.1)**
1995	1.96	5.122		1.96
1996	14.09	4.762	1.96	12.87167
1997	1.84	4.402	3.173	3.047483
1998	1.8	4.042	3.0397	1.920392
1999	1.46	3.682	2.91573	1.490847
2000	2.78	3.322	2.770157	2.633116
2003	2.76	2.962	2.771141	2.742563
2004	1.976	2.602	2.770027	2.049477
2005	2.78	2.242	2.690624	2.697155
2006	3.58	1.882	2.699562	3.489379
Total	35.026	35.02	24.78994	34.90208

Biochemical oxygen demand is a measure of the quantity of oxygen used by microorganisms (e.g., aerobic bacteria) in the oxidation of organic matter. Natural sources of organic matter include plant decay and leaf fall. However, plant growth and decay may be unnaturally accelerated when nutrients and sunlight are overly abundant due to human influence. Urban runoff carries pet wastes from streets and sidewalks; nutrients from lawn fertilizers; leaves, grass clippings, and chapter from residential areas, which increase oxygen demand. Oxygen consumed in the decomposition process robs other aquatic organisms of the oxygen they need to live. Organisms that are more tolerant of lower dissolved oxygen levels may replace a diversity of natural water systems contain bacteria, which need oxygen (aerobic) to survive. Most of them feed on dead algae and other dead organisms and are part of the decomposition cycle. Algae and other producers in the water take up inorganic nutrients and use them in the process of building up their organic tissues (for details refer to www.freedrinkingwater.com).

For trend, the fitted line is

$$U_t = 3.5026+0.18094 * t$$

with MSE= 11.74366. For single exponential smoothing various values of α are tried and minimum MSE = 17.1093 was obtained for α = 0.1. For smoothing of the data, Holt's double exponential smoothing was found to be most appropriate. Various combinations of α and γ both ranging between 0.1 and 0.9 with increments of 0.1 were tried and MSE = 0.3000 was least for α = 0.9 and γ = 0.1.

Figure 5: Graph of observed data and fitted values using trend, single and double exponential smoothing of B.O.D. for Ramgardh Lake for the years 1995-2006

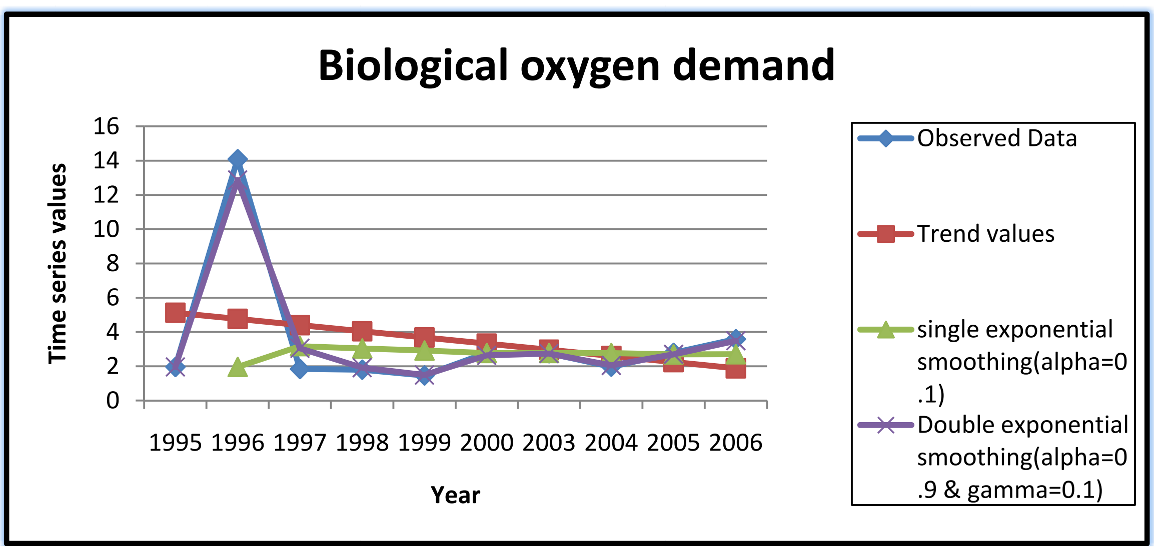


Table 6: Comparison of forecasts

Period	Observed Data	Forecast(single)	Forecast(double)
1	1.96		1.906667
2	14.09	3.173	13.91483
3	1.84	3.0397	3.003915
4	1.8	2.91573	1.768471
5	1.46	2.770157	1.311164
6	2.78	2.771141	2.585629
7	2.76	2.770027	2.710768
8	1.976	2.690624	1.951553
9	2.78	2.699562	2.673792
10	3.58	2.787606	3.547575
11		2.7871	3.5474
12		2.86639	3.6055
13		2.937751	3.6636
14		3.001976	3.7217
15		3.059778	3.7798
16		3.1118	3.8379
17		3.15862	3.896
18		3.200758	3.9541
19		3.238683	4.0122
20		3.272814	4.0703

Figure 6 : Graph of forecasts

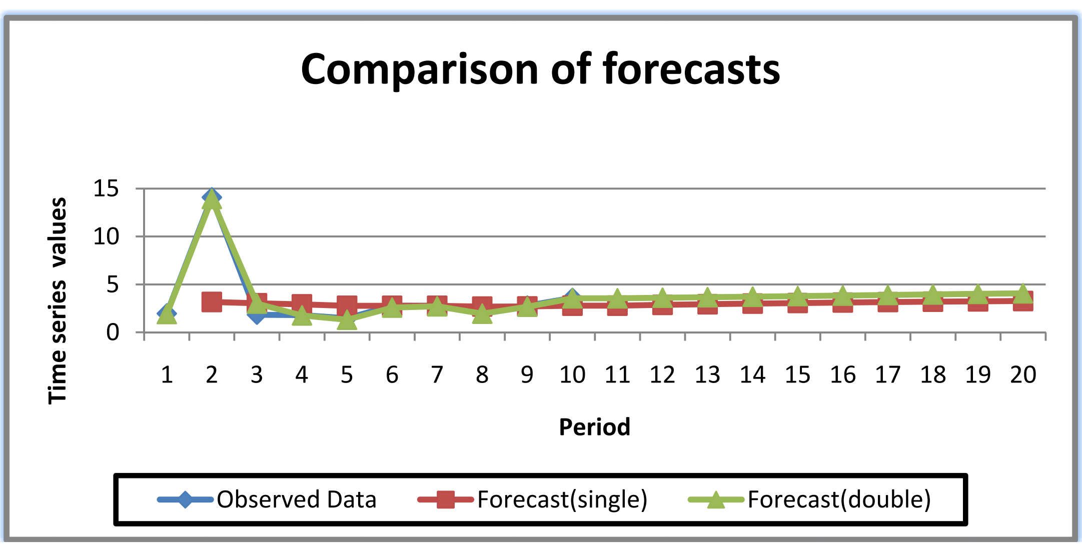


Table 7 shows the data on Total Colifirm for Ramgardh Lake for the years 1995-2006 and fitted values using trend, single and double exponential smoothing.

Table 7 : Data on Total Colifirm for Ramgardh lake for the years 1995-2006 and fitted values using trend, single and double exponential smoothing

Year(x)	**Observed Data**	**Trend values**	**single exponential smoothing(alpha=0.6)**	**Double exponential smoothing(alpha=0.9 & gamma=0.1)**
1995	1169	687.894		1169
1996	285	615.314	1169	339.2333
1997	840.75	542.734	638.6	751.5507
1998	144	470.154	759.89	173.7353
1999	65.33	397.574	390.356	42.47463
2000	121.5	324.994	195.3404	81.95854
2003	119	252.414	151.0362	87.21566
2004	720.6	179.834	131.8145	632.042
2005	86	107.254	485.0858	123.3548
2006	61.66	34.674	245.6343	47.21817
Total	3612.84	3612.84	4166.757	3447.783

Total coliform bacteria are a collection of relatively harmless microorganisms that live in large numbers in the intestines of man and warm- and cold-blooded animals. They aid in the digestion of food. A specific subgroup of this collection is the fecal coliform bacteria, the most common member being Escherichia coli. These organisms may be separated from the total coliform group by their ability to grow at elevated temperatures and are associated only with the fecal material of warm-blooded animals. The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the fecal material of man or other animals. The presence of fecal contamination is an indicator that a potential health risk exists for individuals exposed to this water (for details see www.state.ky.us).

For trend, the fitted line is

$U_t = 361.284 - 36.2989^{*} t$

with MSE= 99896.33. For single exponential smoothing various values of α are tried and minimum MSE = 205949.6 was obtained for α = 0.6. For smoothing of the data, Holt's double exponential smoothing was found to be most appropriate. Various combinations of α and γ both ranging between 0.1 and 0.9 with increments of 0.1 were tried and MSE = 2432.458 was least for α = 0.9 and γ = 0.1.

Figure 7: Graph of observed data and fitted values using trend, single and double exponential smoothing of Total Coliform for Ramgardh Lake for the years 1995-2006.

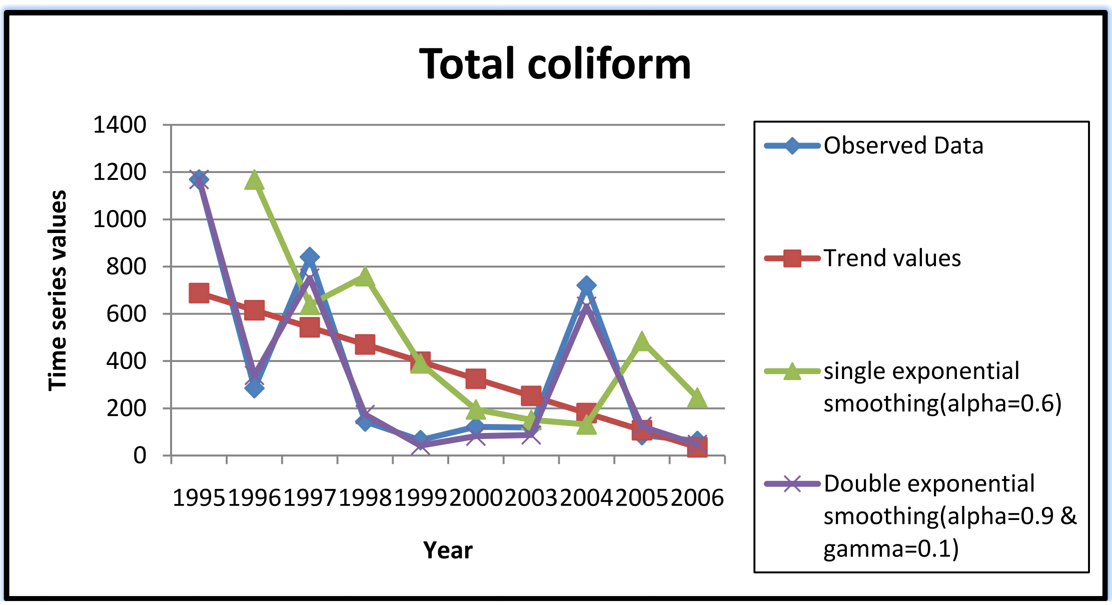


Table 8: Comparison of forecasts

Period	Observed Data	Forecast(single)	Forecast(double)
1	1169		827.3333
2	285	638.6	-51.2433
3	840.75	759.89	441.3534
4	144	390.356	-163.224
5	65.33	195.3404	-273.915
6	121.5	151.0362	-198.843
7	119	131.8145	-164.98
8	720.6	485.0858	459.5482
9	86	245.6343	-82.7583
10	61.66	135.2497	-145.897
11		135.248	-145.897
12		91.0952	-339.012
13		73.43408	-532.127
14		66.36963	-725.242
15		63.54385	-918.357
16		62.41354	-1111.47
17		61.96142	-1304.59
18		61.78057	-1497.7
19		61.70823	-1690.82
20		61.67929	-1883.93

Figure 8: Comparison of forecasts

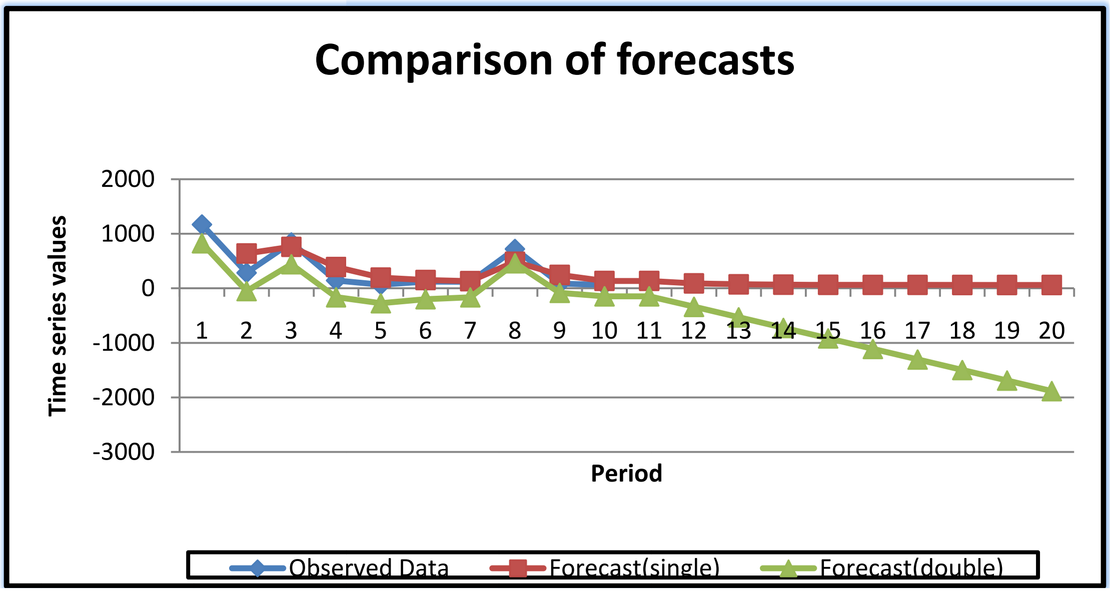


Table 9 shows the data on pH for Ramgardh Lake for the years 1995-2006 and fitted values using trend, single and double exponential smoothing.

Table 9: Data on pH for Ramgardh Lake for the years 1995-2006 and fitted values using trend, single and double exponential smoothing

Year(x)	Observed Data	Trend values	single exponential smoothing(alpha=0.2)	Double exponential smoothing(alpha=0.9 & gamma=0.1)
1995	7.64	6.29		7.64
1996	7.48	6.65	7.64	7.509667
1997	7.87	7.01	7.608	7.844963
1998	8.05	7.37	7.6604	8.042746
1999	8.44	7.73	7.73832	8.414177
2000	8.3	8.09	7.878656	8.327645
2003	7.25	8.45	7.962925	7.371503
2004	8.28	8.81	7.82034	8.191954
2005	7.87	9.17	7.912272	7.912923
2006	8.006	9.53	7.903817	8.003557
Total	79.186	79.1	70.12473	79.25914

pH is a measure of the acidic or basic (alkaline) nature of a solution. The concentration of the hydrogen ion [H+] activity in a solution determines the pH. A pH range of 6.0 to 9.0 appears to provide protection for the life of freshwater fish and bottom dwelling invertebrates. The most significant environmental impact of pH involves synergistic effects. Synergy involves the combination of two or more substances which produce effects greater than their sum. This process is important in surface waters. Runoff from agricultural, domestic, and industrial areas may contain iron, aluminum, ammonia, mercury or other elements. The pH of the water will determine the toxic effects, if any, of these substances. For example, 4 mg/l of iron would not present a toxic effect at a pH of 4.8. However, as little as 0.9 mg/l of iron at a pH of 5.5 can cause fish to die (for details see www.state.ky.us).

For trend, the fitted line is

$U_t = 7.9186 + 0.1845 * t$

with MSE = 0.9995. For single exponential smoothing various values of α are tried and minimum MSE = 0.1831 was obtained for $\alpha = 0.2$. For smoothing of the data, Holt's double exponential smoothing was found to be most appropriate. Various combinations of α and γ both ranging between 0.1 and 0.9 with increments of 0.1 were tried and MSE = 0.002735was least for $\alpha = 0.9$ and $\gamma = 0.1$.

Figure 9: Graph of observed data and fitted values using trend, single and double exponential smoothing of pH for Ramgardh Lake for the years 1995-2006.

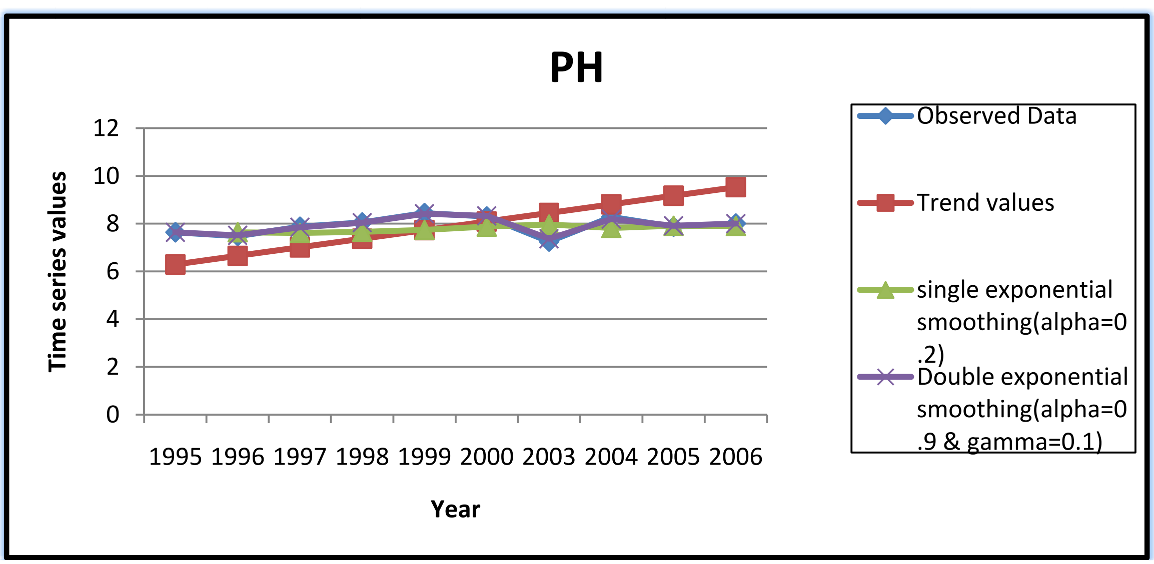
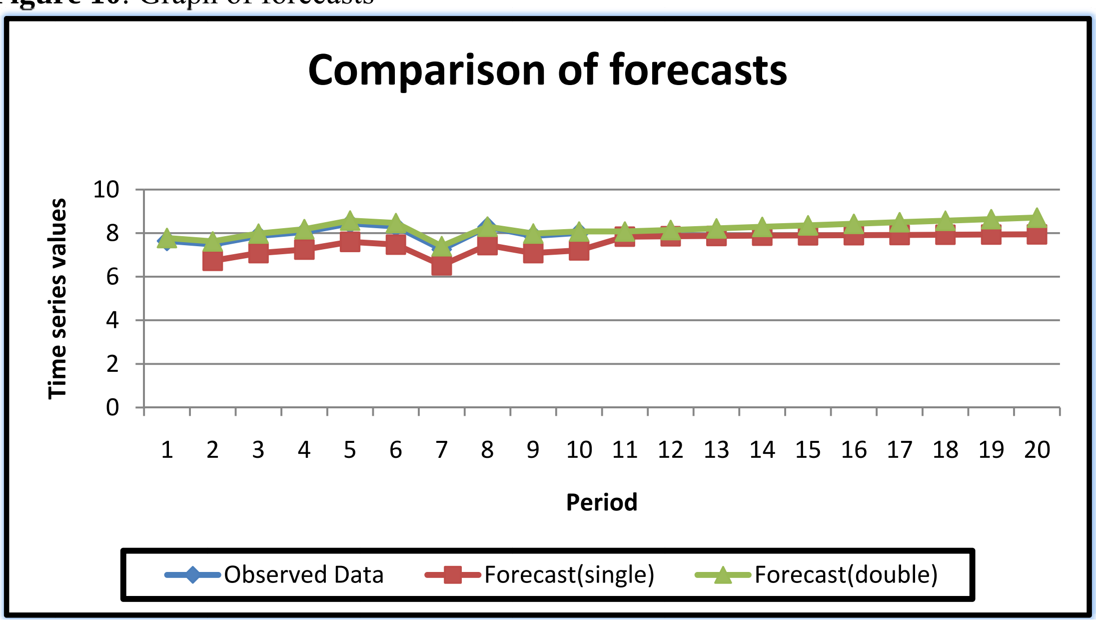


Table 10: Comparison of forecasts

Period	Observed Data	Forecast(single)	Forecast(double)
1	7.64		7.776667
2	7.48	6.732	7.619633
3	7.87	7.083	7.977463
4	8.05	7.245	8.181774
5	8.44	7.596	8.576446
6	8.3	7.47	8.465033
7	7.25	6.525	7.399539
8	8.28	7.452	8.299231
9	7.87	7.083	7.981569
10	8.006	7.2054	8.074402
11		7.8368	8.074395
12		7.85372	8.14524
13		7.868948	8.216085
14		7.882653	8.28693
15		7.894988	8.357775
16		7.906089	8.42862
17		7.91608	8.499465
18		7.925072	8.57031
19		7.933165	8.641155
20		7.940448	8.712

Figure 10: Graph of forecasts



We observe from the calculations for the different parameters of pollutants that double smoothing follows the data much closer than single smoothing. Furthermore, for forecasting single smoothing cannot do better than projecting a straight horizontal line, which is not very likely to occur in reality. So for forecasting purposes for our data double exponential smoothing is more preferable.

Conclusion

From the above discussions, we observe that the various pollutants considered in the article may have very hazardous effect on quality of water. Increase of pollutants in water beyond a certain limit may be dangerous for aquatic animals. Also, according to recent reports, most of the tap and well water in the India are not safe for drinking due to presence of various pollutants in inappropriate percentage. Now, we have reached the point where all sources of our drinking water, including municipal water systems, wells, lakes, rivers, and even glaciers, contain some level of contamination. So, we need to keep a routine check of the quality of water so that we can lead a healthy life.

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