International Journal of Oceans and Oceanography
ISSN 0973-2667 Volume 10, Number 2 (2016), pp. 81-91

http://www.ripublication.com

A Pollution Model of the River Ganges through Inter Criteria Analysis

Sharmila S. and I. Arockiarani

Department of Mathematics, Nirmala College for Women,
Coimbatore, Tamilnadu, India.
E-mail: sharmi.skumar@gmail.com

Abstract

In this paper we present an approach of Inter Criteria Analysis (ICA)for the pollution of river Ganges in India. The approach is based on the apparatus of the index matrices and the intuitionistic fuzzy sets. We have applied the ICA to establish the basic pollution relations (the model structure) based on different criteria involved in the Ganga river. The results have shown that the criteria are independent, they are time functions. Based on this we have developed an adequate mathematical model of the Ganga river pollution. The Method of the least squares is used for a parametric identification.

Keywords: Inter Criteria analysis, Pollution modelling, the Ganga river.

1. INTRODUCTION

The Himalayas are the source of three major Indian rivers namely the Indus, the Ganga and the Brahmaputra. Ganga drains a basin of extraordinary variation in altitude, climate, land use, flora & fauna, social and cultural life. Ganga has been a cradle of human civilization since time immemorial. Millions depend on this great river for physical and spiritual sustenance. People have immense faith in the powers of healing and regeneration of the Ganga. It is arguably the most sacred river in the world and is deeply revered by the people of this country. The River plays a vital role in religious ceremonies and rituals. To bathe in Ganga is a lifelong ambition of many who congregate in large numbers for several river centered festivals such as Kumbh Mela and numerous Snan (bath) festivals.

Trophic pollution is proposed in [11] a model for the dynamics of the integral index determining the level of the stream water. The integral index is based on the oxygen balance, organic and nutrients loading, suspended and dissolved substances. This index is applied for assessing the level of the trophic pollution of the River Ganga at

West Bengal located in the end of the Indian section of the river. Also a modified method of time series analysis is applied.

Atanassov et al. [1] introduced a new approach, namely ICA for decision making. It is based on the apparatus of index matrices (IMs) [2, 3, 4] and intuitionistic fuzzy sets (IFs) [5, 6]. The method for ICA makes it possible to compare certain criteria or objects estimated by them. Atanassova et al. [7, 8, 9] applied ICA in an EU member states competitiveness analysis. They carried out a temporal and threshold analysis, Ilkova et al. [13] have used ICA for modelling of bioprocess.

In this paper we investigate a modelling of the River Ganga pollution of the following indexes for the organic and biogenic water pollution: ammonia and nitrate nitrogen, biochemical oxygen demand, permanganate oxidation, dissolved and unsolved substances, and dissolved oxygen.

The aim of the study is to use the ICA for modelling of the River Ganga pollution in its Indian part considering different indices. The method is based on index matrices, IMs [2, 3, 4] and intuitionistic fuzzy sets, IFSs [9], and intuitionistic fuzzy pairs, IFPs, [6, 7].

GANGA – A NATIONAL RIVER

Ganga basin is the largest river basin in India in terms of catchment area, constituting 26% of the country's land mass (8, 61, 404 Sq. km) and supporting about 43% of its population (448. 3 million as per 2001 census). The basin lies between East longitudes 73°02’ and 89°05’ and North latitudes of 21°06’ and 31°21’, covering an area of 1, 086, 000 sq km, extending over India, Nepal and Bangladesh. About 79% area of Ganga basin is in India. The basin covers 11 states viz., Uttarakhand, U. P., M. P., Rajasthan, Haryana, Himachal Pradesh, Chhattisgarh, Jharkhand, Bihar, West Bengal and Delhi.

The current focus of world bank funded National Ganga River Basin Projects (NGRBP) of NMCG is on five major states on the main stem of river Ganga namely Uttarakhand, Uttar Pradesh, Jharkhand, Bihar and West Bengal. The drainage area in each state is given in Table

States	**Drainage area(km)**
Uttarakhand and Uttar Pradesh	294, 364
Madhya Pradesh and Chhattisgarh	198, 962
Bihar and Jharkhand	143, 961
Rajasthan	112, 490
West Bengal	71, 485
Haryana	34, 341
Himachal Pradesh	4, 317
Delhi	1, 484
Total	**861, 404**

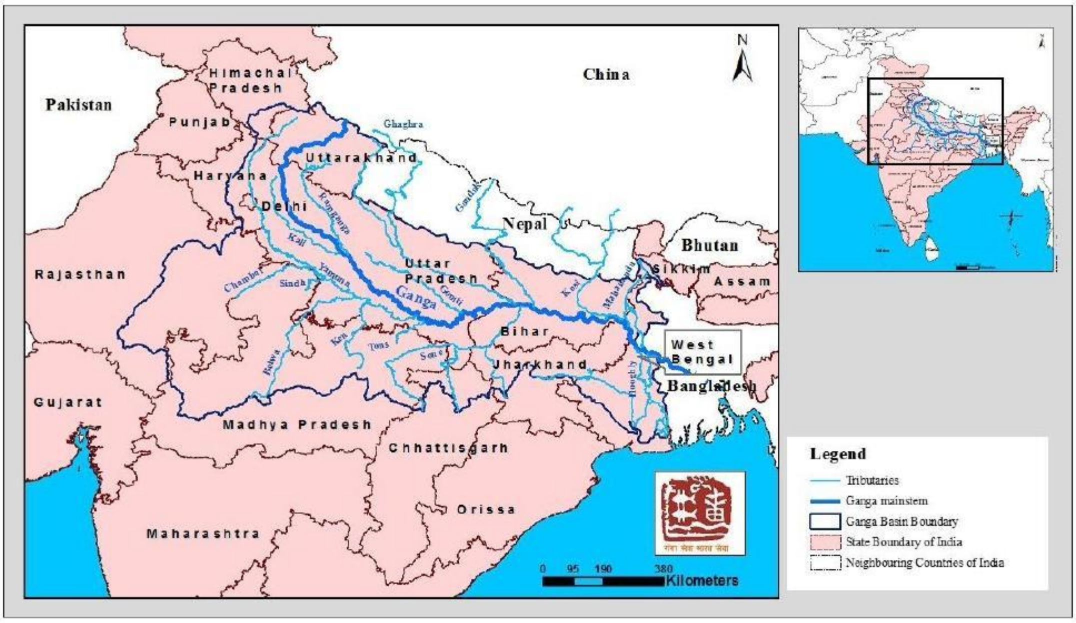
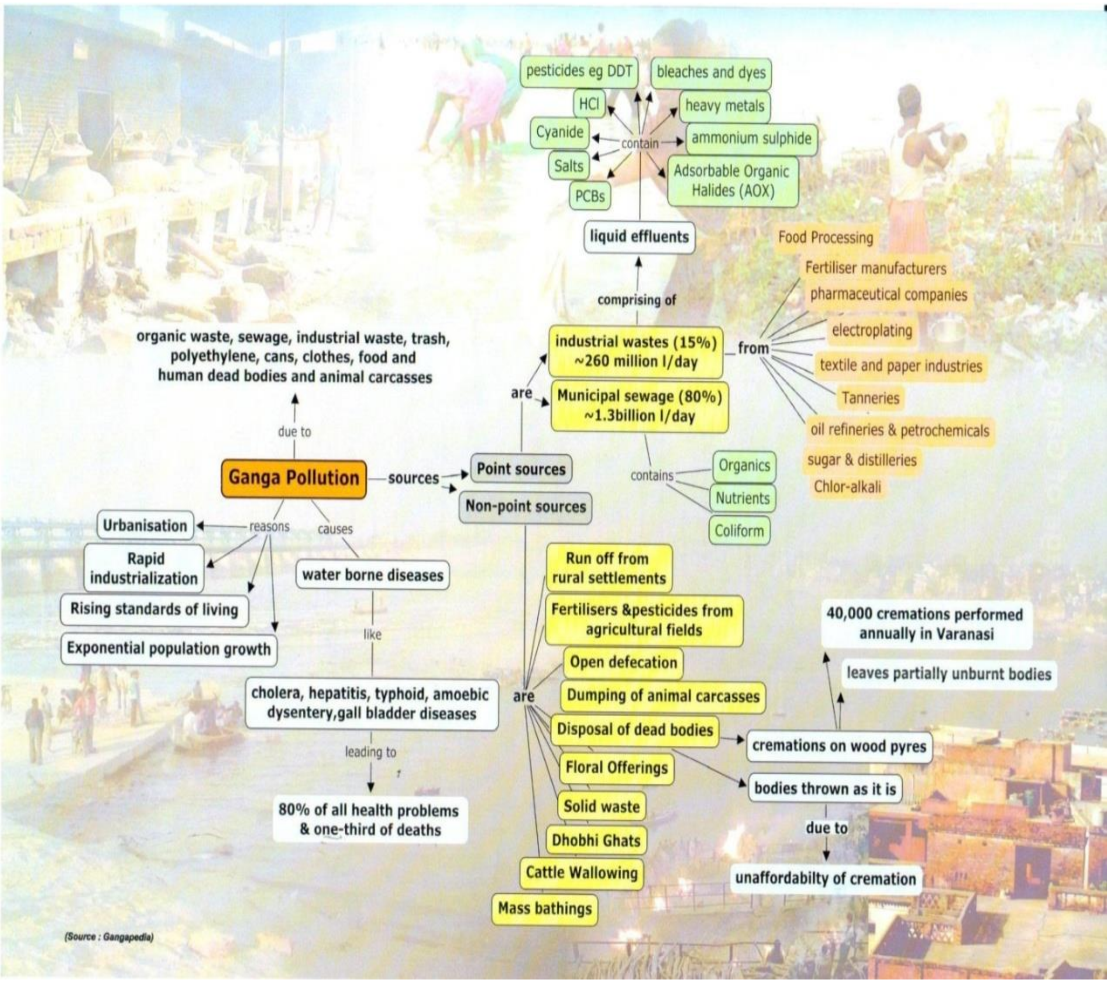


Figure 1: The River Ganga catchment area

POLLUTION THREAT

Rapidly increasing population, rising standards of living and exponential growth of industrialisation and urbanisation have exposed water resources, in general, and rivers, in particular, to various forms of degradation. The mighty Ganga is no exception. The deterioration in the water quality impacts the people immediately. Ganga, in some stretches, particularly during lean seasons has become unfit even for bathing. The threat of global climate change, the effect of glacial melt on Ganga flow and the impacts of infrastructural projects in the upper reaches of the river, raise issues that need a comprehensive response.

In the Ganga basin approximately 12, 000 million litres per day (mld) sewage is generated, for which presently there is a treatment capacity of only around 4, 000 mld. Approximately 3000 mld of sewage is discharged into the main stem of the river Ganga from the Class I & II towns located along the banks, against which treatment capacity of about 1000 mld has been created till date. The contribution of industrial pollution, volume-wise, is about 20 per cent but due to its toxic and non-biodegradable nature, this has much greater significance. The industrial pockets in the catchments of Ramganga and Kali rivers and in Kanpur city are significant sources of industrial pollution. The major contributors are tanneries in Kanpur, distilleries, paper mills and sugar mills in the Kosi, Ramganga and Kali river catchments. the river runways; non-point pollution from agricultural activity at the region, etc. There is not any industry activity near the catchment which can directly influence the surface water quality [10, 11, 12].



MODEL VALIDATION

This problem is approach as follows:

1. The experimental data and time are standardized between 0 and 1 with the formula $y_i = (x_i - x_{\min})(x_{\max} - x_{\min})$ where $x_i, x_{\max}, x_{\min}$ are actual, minimal and maximal values;
2. The arithmetic average of the experimental data is calculated by the formula $\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$

The correlation coefficient is

$$R_E^2 = \frac{\sum_{i=1}^{n}(y_i - \bar{y})(y_i^m - \bar{y}_m)}{\sqrt{\left[\sum_{i=1}^{n}(y_i - \bar{y})\right]^2 \left[\sum_{i=1}^{N}(y_i^m - \bar{y}_m)\right]^2}}$$

RESULTS AND DISCUSSION

The modelling of the pollution dynamics of the river ecosystem of the river Ganga has been carried out on the basis of the information from the National Ganga River Basin Authority (NGRBA). The following indices have been examined: Cyanide, Hcl, ammonium sulphide, Adsorbable organic halides (AOX), PCBs, Pesticides (DDT) and bleaches and dyes.

With the help of Table 1 and Figure 2, we will investigate the dependencies between the indices for the organic and biogenic water pollution. The indices for water pollution are: Cyanide, Hcl ammonium sulphide, Adsorbable organic halides (AOX), PCBs, Pesticides (DDT) and bleaches and dyes.

	Cyanide	Hcl	Ammonium sulphide	Adsorbable organic halides (AOX)	PCBs	Pesticides (DDT)	Bleaches and Dyes
Cyanide		(0.382,0.590)	(0.621,0.353)	(0.445,0.532)	(0.404,0.565)	(0.690,0.366)	(0.544,0.4280)
Hcl	(0.382,0.590)		(0.640,0.344)	(0.702,0.283)	(0.689,0.288)	(0.603,0.381)	(0.531,0.449)
Ammonium sulphide	(0.621,0.353)	(0.640,0.344)		(0.615,0.373)	(0.606,0.370)	(0.575,0.412)	(0.486,0.497)
Adsorbable organic halides (AOX)	(0.445,0.532)	(0.702,0.283)	(0.615,0.373)		(0.602,0.379)	(0.664,0.325)	(0.538,0.448)
PCBs	(0.404,0.565)	(0.404,0.565)	(0.606,0.370)	(0.602,0.379)		(0.416,0.565)	(0.450,0.528)
Pesticides (DDT)	(0.690,0.366)	(0.603,0.381)	(0.575,0.421)	(0.6643,0.325)	(0.416,0.565)		(0.475,0.510)
Bleaches and Dyes	(0.544,0.428)	(0.531,0.449)	(0.486,0.497)	(0.538,0.448)	(0.450,0.528)	(0.475,0.510)	

The low value of $\mu\in$ [0. 382, 0. 703], and the high value of $\nu\in$ [0. 284, 0. 591], as the low value of uncertainty $\pi\in$ [0. 0111, 0. 0325] (Table 1 and Figure 2) shows the investigated criteria (the organic and biogenic water pollution) are independent on each other and they cannot be excluded off the river water quality determination. In all case we have dissonance.

Based on the real and model data we have developed a program with the help of the method of least squares. With this program we define the coefficient in the model.

In Figure 2. We have presented the dependencies between μ and υ

The model and experimental data are shown from Figure 3 to Figure 9

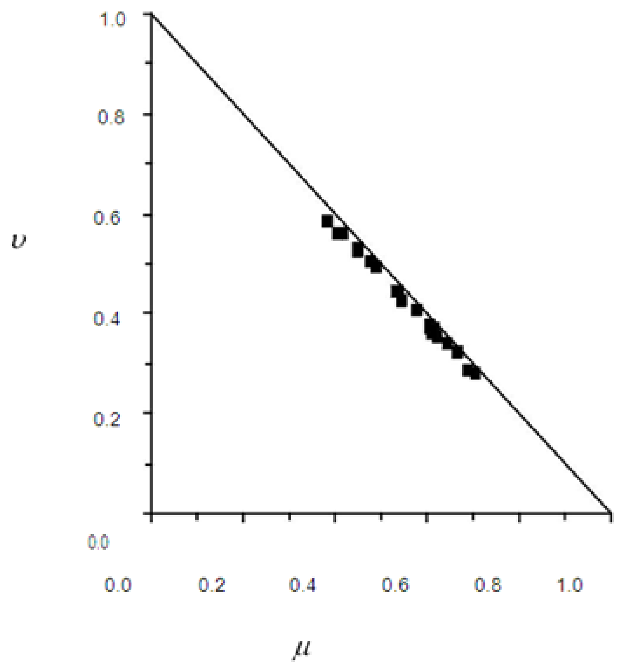


Figure 2: Relations between μ and v for the different criteria

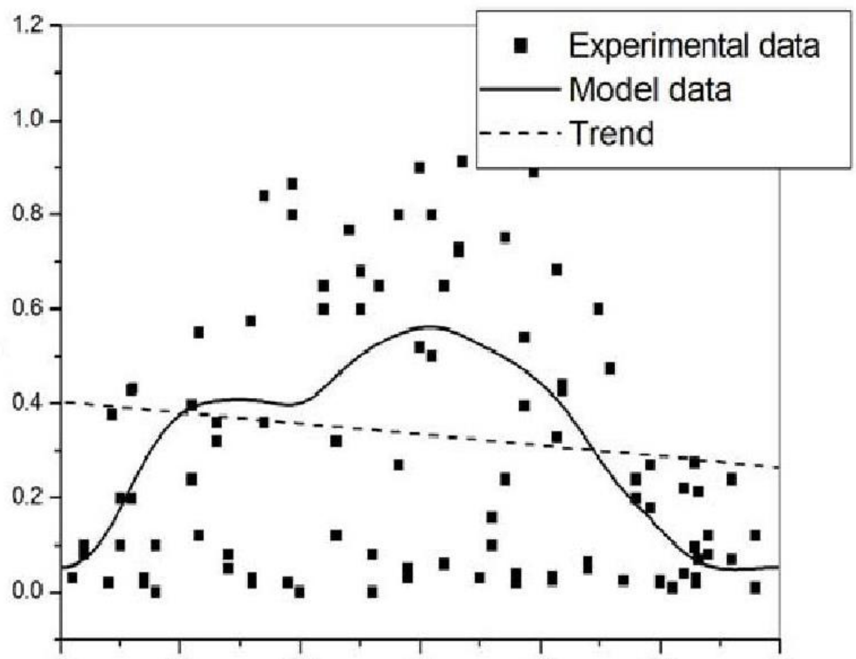


Figure 3: Experimental and model data for Cyanide (Xaxis – Month; Y-axis Cyanide)

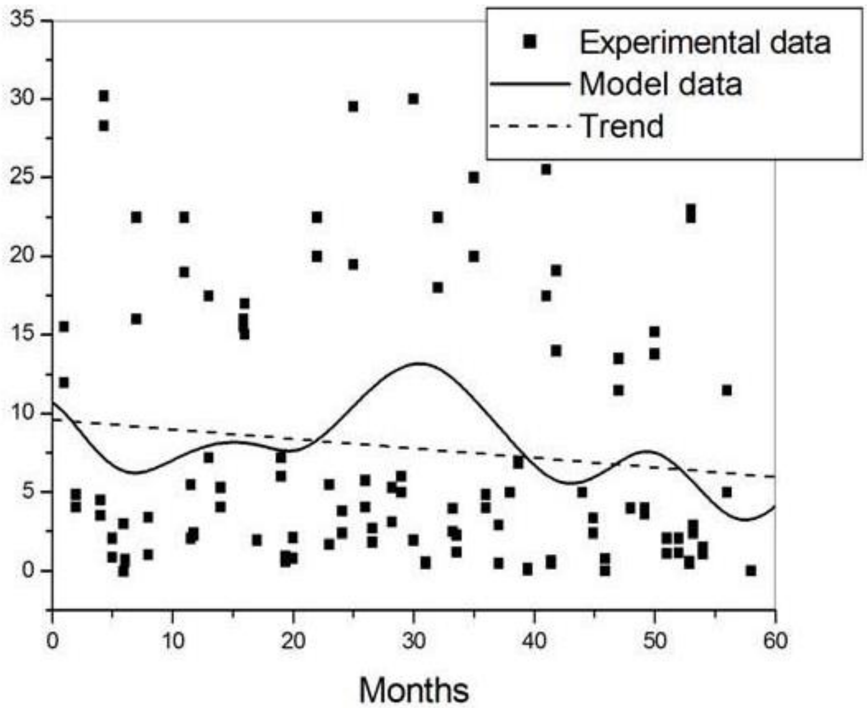


Figure 4: Experimental and model data for Hcl (X-axis-Month; Y-axis- Hcl)

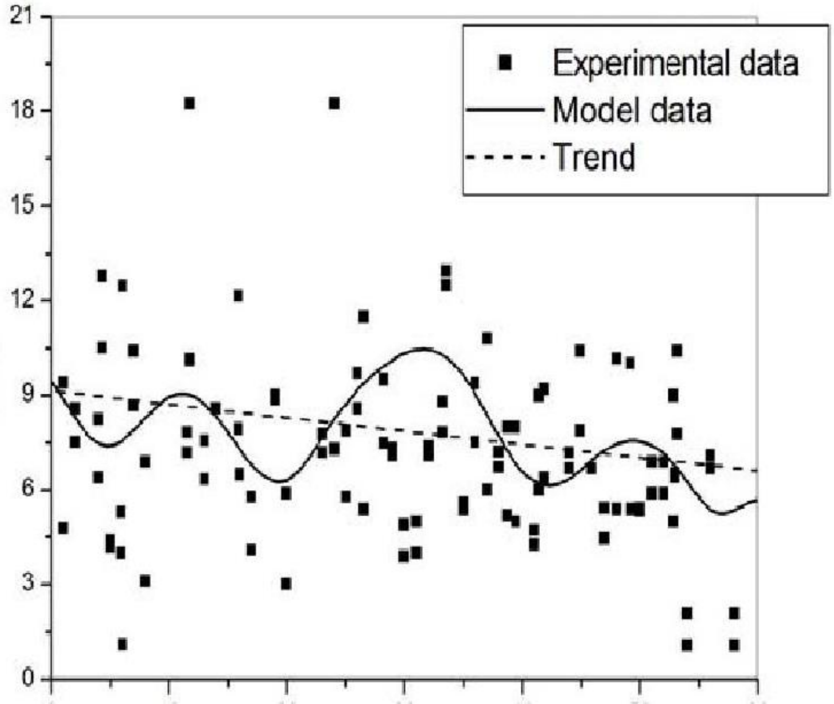


Figure 5: Experimental and model data for Ammonium Sulphide (X-axis-Month; Y-axis- Ammonium sulphide)

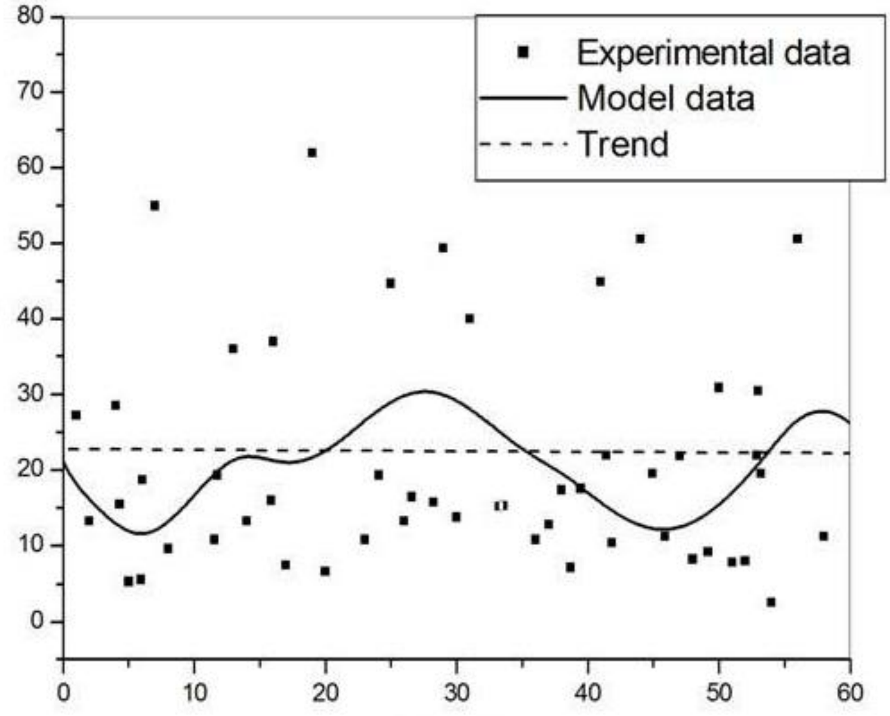


Figure 6: Experimental and model data for Adsorbable organic halides (AOX) (X-axis-Month; Y-axis- AOX)

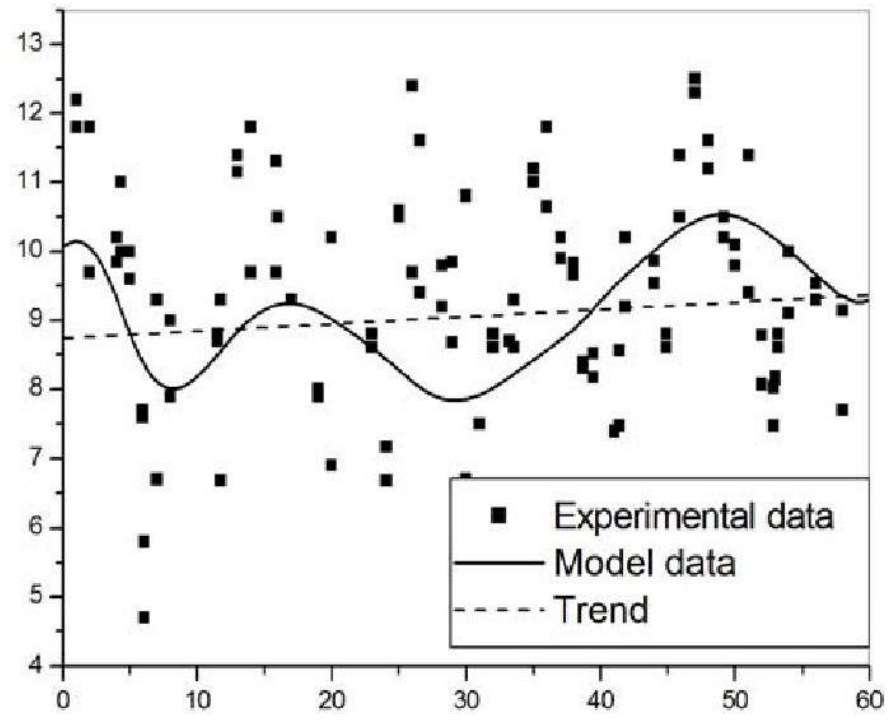


Figure 7: Experimental and model data for PCBs (X-axis-Month; Y-axis- AOX)

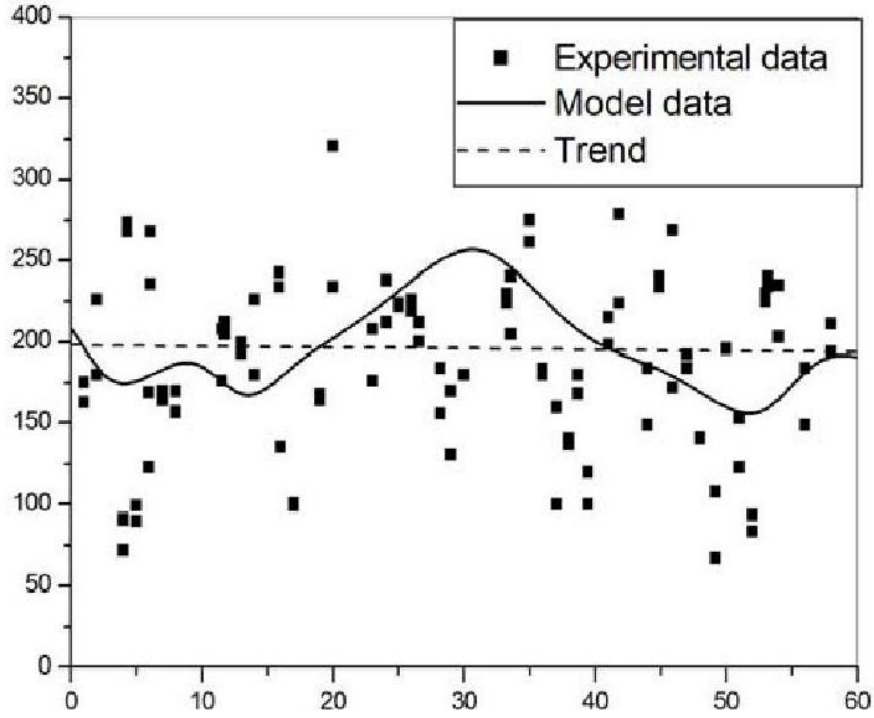


Figure 8: Experimental and model data for the Pesticides (DDT) (X-axis-Month; Y-axis- Pesticides (DDT))

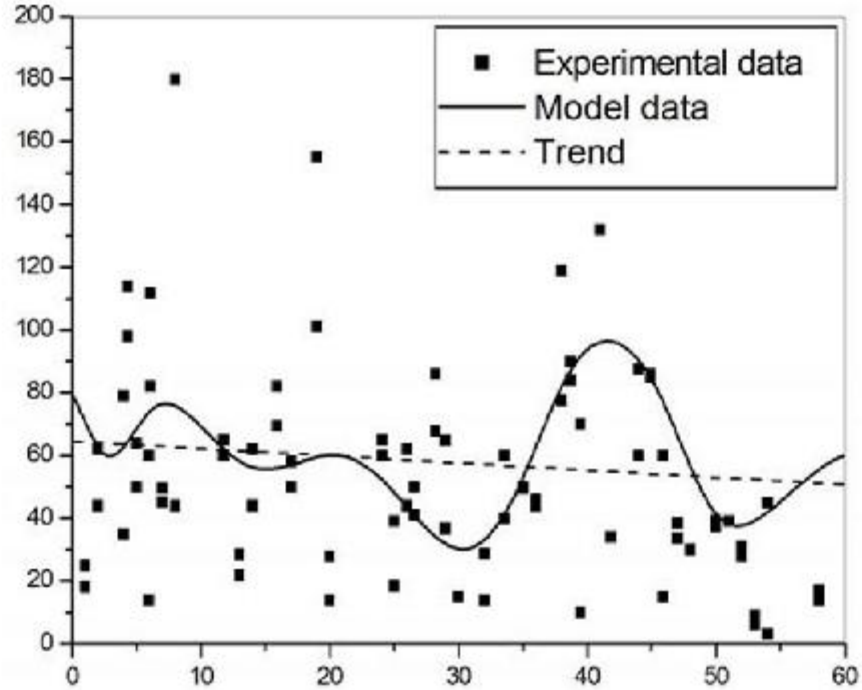


Figure 9: Experimental and model data for bleaches and dyes (X-axis-Month; Y-axis- Bleaches and Dyes)

We have developed a validation of the models by the experimental correlation coefficient (R_E^2). The experimental correlation coefficients for models (1)–(7) are from R_E^2 = 0. 584 to R_E^2= 0. 691. The tabular correlation coefficient is R_T^2□0. 262, [14]. The results show that themodels predict experimental data and the models are adequate.

CONCLUSION

With the help of the InterCriteria Analysis we have established the basic dependences between the different pollution criteria – ammonia and nitrate nitrogen, biochemical oxygen demand, permanganate oxidation, dissolved oxygen, dissolved and unsolved substances of the river Ganga at two end points. River at the two specific points. The criteria are not in positive consonance between each other (they are independent) and they are functions of time. In this way we have developed the models of the pollution dynamic. The models are adequate to experimental data, as assessed using the correlation coefficient.

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