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Research Article

OPTIMIZING NET FLOW OF POLLUTANTS TO RIVER GANGA FROM ITS TRIBUTARIES IN UTTARAKHAND HIMALAYAS, USING GOAL PROGRAMMING

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ABSTRACT
Water quality has become a very big issue today, because of tremendously growing population, changes in land use and urban expansion and development. The excess nutrients have the potential to degrade the quality of water if incorporated into runoff from farms into streams. Bhagirathi, Alaknanda, Mandakini and Bhilangana are important tributaries of Ganga in Uttarakhand. The pollution of these rivers collectively forms the pollution of Ganga. Nitrate- nitrogen (NO_3-N), Total Phosphate (TP) and Fecal Coliform (FC) are main pollutants which prevail in Uttarakhand. In this paper we are trying to optimize these pollutants using Goal Programming (GP), as a method of analysis.

Key Words: *Nitrate- nitrogen (NO_3-N), Total Phosphate (TP), Fecal Coliform (FC), optimization, Goal programming (GP)*

INTRODUCTION
River Ganga is the life line of north India. It is catering to the needs of about 7 states. Not only it is a source of water but it is a center of spirituality of millions of Indians. Any kind of pollution in it affects the health of body as well as soul of people of this country. But for last few decades the pollution in this river is increasing day by day. The main reasons of which are growing population, changes in land use, urbanization, etc.

Many projects like Ganga Action Plan, Sparsh Ganga, etc., had been launched and are working to reduce the pollution in Ganga and improve quality of its water. In the area of Uttarakhand the pollution in Ganga is not because of Industries and thus is less toxic, but is due to excess population and washing of nutrients from fields into river. So, the main constraints of our study are Nitrate- nitrogen (NO_3-N), Total Phosphate (TP) and Fecal Coliform (FC).

River Ganga is in the process of developing total maximum daily loads due to increase in different pollutants in its tributaries. As a number of hydro projects are being started in different tributaries, population of the area is also increasing and use of chemical fertilizers is increasing in the area due to which pollution is also increasing in the areas. These factors are increasing amount of pollutants in these rivers which is further adding pollutants to river Ganga.

Goal Programming
Goal programming (GP) is a multi-objectives analytical approach devised to address decision-marking problems where targets have been assigned to all attributes and where the decision makers (DMs) are interested in minimizing the non-achievement of the corresponding goal. The model allows taking into account simultaneously many objectives while the decision-marking is seeking the best solution from among a set of feasible solutions. GP was first introduced by Charnes and Cooper (1961), and further developed by Lee (1972), Ignizio (1976), Tamiz, Jones, and Romero (1998), Romero (2001), Chang (2004); among others. The oldest form can be expressed as follows:

(GP model)
Minimize $\sum \left| f_i(X) - g_i \right|$ subject to
$X \varepsilon F$. F is a feasible set.

Where $f_i(X)$ is the linear function of the i^{th} goal, g_i is the aspiration level of the i^{th} goal (Liao and Chin-nung, 2009). Charnes and Cooper (1961) have introduced the concept of GP to solve the unsolvable linear programming problems. The true aim of GP is the simultaneous solution of a system involving multiple conflicting goals according to the DM's priority structure (Tiwari *et al.*, 1986). Many research programmes in the field of water resources and system planning have focused on the goal that pursues the sustainable land development, water resources conservation and water quality management by using deterministic multi objective programming techniques (Chang *et al.*, 1995).

Our Pollutants

The main pollutants prevailing in the rivers of the Himalayan valley of Uttarakhand are Nitrate- nitrogen, Total phosphate and Fecal Coliform.

1. **Nitrate- Nitrogen (NO_3- N):** In soil various forms of nitrogen is converted into nitrates by different bacteria. Nitrate is a major ingredient of farm fertilizer and is necessary for crop production. It occurs naturally in soil in organic forms from decaying plant and animal residues. Varying amount of nitrate runoffs from farmlands into nearby water bodies.

Nitrate in water is undetectable without testing because it is colourless, odourless and tasteless.

2. **Total Phosphates (TP):** Phosphorus is usually present in water as phosphates. It is a plant nutrient required for growth and is a fundamental element in the metabolic reactions of plants and animals. Sources of phosphorus are human and animal waste i.e. sewage, industrial waste, soil erosion and surface runoff of fertilizers.

1. **Fecal Coliform (FC):** The presence of fecal-coliform bacteria in aquatic environmental indicate that the water has been contaminated with the fecal material of man or other animals. At the time this occurred, the source water may have been contaminated by pathogens or disease-producing bacteria or viruses which can also exist in fecal material. Some water-borne pathogenic diseases include typhoid fever, viral, and bacterial gastroenteritis and hepatitis A. The presence of fecal contamination is an indicator that a potential health risk exists for individuals exposed to this water (AHEC, 2011; Kumar *et al.*, 2010).

Area of Study

The study focuses on the quality of water discharged from 4 tributaries of river Ganga. They are Alaknanda, Bhagirathi, Mandakini and Bhilangana. Our area of study lies in the Uttrakhand hills covering the districts Chamoli, Tehri and Pauri. The main areas of study and sampling are Tehri, Vishnuprayag, Maneri Bhali, Vanala, Nandprayag, Vishnugad, Pipalkoti Srinagar, Koteshwar, Kotlibhel, etc. The main areas of sampling are the areas of hydro-eliectric power plants and tourist spots which are more prone to pollution. The main reasons of increase of pollutants in these areas are hydro electric power plants, increasing tourism and population.

MATERIALS AND METHODS

The method used to solve the multi objective optimization problem called goal Programming (GP). The basic idea of the method is to convert the original multiple objectives into a single goal and resulting model yields an optimum solution with reference to all conflicting objectives of the problem (Prez *et al.*, 2006).

Data

Table 1: This table shows daily average discharges of the four tributaries

	River	Average discharge (m^3/ sec)
1.	Bhagirathi	257.78
2.	Alaknanda	164.79
3.	Mandakini	49.00
4.	Bhilangana	32.88

Table 2: The average quantity of pollutants prevailing in these rivers taken from different areas is given

Pollutant	River	Quantity (mg/l)
NITRATE- NITROGEN (NO_3- N)	Bhagirathi	2.70
Maximum permissible concentration = 10 mg / l	Alaknanda	2.48
	Mandakini	4.93
	Bhilangana	4.27
TOTAL PHOSPHATE (TP)	Bhagirathi	2.49
Maximum permissible concentration = 0.1 mg / l	Alaknanda	1.26
	Mandakini	4.96
	Bhilangana	3.99
FECAL COLIFORM (FC)	Bhagirathi	408
Maximum permissible concentration = 500 MPN/l	Alaknanda	795
	Mandakini	615
	Bhilangana	345

Total maximum load = Q $_{mean\ daily}$ X maximum permitted conc. X conversion factor.

Table 3: Mean Export Co-efficients

Pollutant	Max. Permitted conc. (mg/l)	Total max. Load (kg/ yr)
Nitrate- Nitrogen (NO_3- N)	10.0	15.908×10^7
Total Phosphate (TP)	0.1	15.908×10^5
Fecal Coliform (FC)	500 MPN	7.955×10^{15}

Mathematical Model

In the proposed model we have three objectives:

(i) Z_1 = Objective function of total discharge of Nitrate – nitrogen (NO_3- N)

(ii) Z_2 = Objective function of total discharge of Total Phosphate (TP).

(iii) Z_3 = Objective function of total discharge of Fecal Coliform (FC).

Four decision variables are:

(i) X_1 = Optimal flow of river Bhagirathi.

(ii) X_2 = Optimal flow of river Alaknanda.

(iii) X_3 = Optimal flow of river Mandakini.

(iv) X_4 = Optimal flow of river Bhilangana.

Final Mathematical Model

Min $Z_1(x) = 2.70X_1 + 2.48X_2 + 4.93X_3 + 4.27X_4$

Min $Z_2(x) = 2.49X_1 + 1.26X_2 + 4.96X_3 + 3.99X_4$

Min $Z_3(x) = 408X_1 + 795X_2 + 615X_3 + 345X_4$

Subject to:

1) $X_1 + X_2 + X_3 + X_4 = 22 \times 10^{12}$ lit. / year.

2) $X_1 \geq 8.129 \times 10^{12}$ lit. / year

3) $X_2 \geq 5.197 \times 10^{12}$ lit. / year

4) $X_3 \geq 1.545 \times 10^{12}$ lit. / year

5) $X_4 \geq 1.037 \times 10^{12}$ lit. / year

6) $2.70X_1 + 2.48X_2 + 4.93X_3 + 4.27X_4 \leq 15.908 \times 10^7$

7) $2.49X_1 + 1.26X_2 + 4.96X_3 + 3.99X_4 \leq 15.908 \times 10^5$

8) $408X_1 + 795X_2 + 615X_3 + 345X_4 \leq 7.955 \times 10^{15}$

Descriptions of restrictions considered in the final problem are the following

Restriction 1: The maximum average flow of river Ganga at Devprayag should not exceed 22 x 10^{12} lit. / year or 697.615 m^3/ litre as this is average capacity of the basin and increase in water may cause flood like situation.

Restriction 2: Due to flow of Bhagirathi River.

Restriction 3: Due to average flow of river Alaknanda.

Restriction 4: Due to average flow of river Mandakini.

Restriction 5: Due to average flow of river Bhilangana. (As these rivers have their limitations in amount of water they pour and sometimes due to excessive rain fall they break all the barriers and bring high amount of pollutants with them.)

Restriction 6: Restriction related to maximum amount of Nitrate- Nitrogen permitted per litre of river water.

Restriction 7: Restriction related to maximum amount of Total Phosphates permitted.

Restriction 8: Restriction related to maximum number of Fecal Coliforms permitted.

RESULTS AND DISCUSSION

Results

Table 4: The optimized flows according to amount of pollutants discharged

S. No.	River	Optimized discharge
1.	Bhagirathi	258.00 m^3/ sec.
2.	Alaknanda	208.35 m^3/ sec.
3.	Mandakini	155.22 m^3/ sec.
4.	Bhilangana	47.80 m^3/ sec.

Table 5: Quantity of pollutant discharged

S. No.	Pollutant	Optimized quantity	Result
1.	Nitrate- nitrogen	2.81 mg/ sec	Achieved
2.	Total- Phosphate	2.04 mg/ sec	Not Achieved
3.	Fecal Coliform	144 MPN/ sec	Achieved

The average total optimized flow of water in the Ganga basin at Devprayag is found to be about 669.37 m^3/ sec which is less than the capacity of the Ganga basin at this place. There has been considerable change in the amounts of individual discharges of four tributaries, which could be done by regulating water from barrages and dams.

The optimized flows according to amount of pollutants which they throw in River Ganga are as: Bhagirathi 258.00; Alaknanda 208.35; Mandakini 155.22; and Bhilangana 47.80 (all in m^3/sec.), which are increased from the existing average flows without exceeding the maximum permitted flow of river Ganga.

So, we can say that this aspect is practically possible in the direction of avoiding water pollution. The optimized average amount of nitrate- nitrogen is about 2.81 mg/ sec which is too less than the prescribed limit.

The numbers of fecal coliforms were found to be 144 MPN/ sec which again are inside the boundaries described by government authorities. The amount of Total Phosphate however could not be optimized and found to be 2.04 mg/ sec, which is above government standards.

Conclusion

The problem was solved using the software LINDO. It is obvious from the solution that optimum discharge of water from the tributaries has been achieved considerably. The amounts of Nitrate- nitrogen and fecal coliform have been optimized in the river water. The goal for Total phosphate remains unachieved. The results shown in this work shows in a multiple objective problem it is very difficult rather impossible to reach all the goals, but reaching an optimal solution is feasible and more realistic. Thus, multi- objective goal programming can be a useful tool in optimizing pollution of river water from various sources and thus helpful in conservation of environment, water and human health. We can say that amount of pollutants in river Ganga in Uttarakhand Himalayas can be optimized up to a considerable level which will definitely affect the quality of water in further course of river.

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