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A trading-partnership model for estimating discharge permits in river systems by Ant Colony optimization

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ABSTRACT

One of the main problems in the quality control of rivers is the high control cost imposed upon pollutant units. The cooperative policy approach in the treatment process between two or more pollutant units is a new and economic perspective in the environmental management of catchment basins. Origins of large amounts pollutants which require a high cost to control pollution are trying to start partnerships with smaller units in establishing joint refineries in order to reduce their own and the whole system's costs. In this study, considering the one way direction of the river's water, the Streeter – Phelps equations were used to simulate the river. The Ant Colony Optimization was used as an efficiency model in order to acquire the best scenario of cooperation based on the maximum elimination of pollution and reduction of treatment costs without straying from the river's quality standards. Also the ratio – trade system was used for commercial purposes. After this the cost of the depleting units was split evenly between them using the cooperative game theory. The efficiency of the model was evaluated by qualitative and quantitative analysis of the Zarjub River in Gilan province of Iran. Three main scenarios were taken to mind for cooperative trading to take place. Carrying out the trade – partnership model could play positively large role in sufficing the quality the control of river water.

Abbreviations

TDP:	Transferable Disposal Permits
TRS:	Trade-Ratio Systems
PDF:	Probability Density Function
TMDL:	Total Maximum Daily Load
DO:	Dissolved Oxygen
BOD:	Biological Oxygen Demand

1. Introduction

One of the main problems in the quality management of rivers is the high cost imposed on polluting units. The cooperative policy approach between two or more polluting units and determining a point along the river to offload the hog-wash from the refinery is a new and economical perspective in environmental management of catchment basins. The polluting units with high control costs are trying to establish partnerships with other polluting units in creating joint refineries and pinpointing the best area for offloading along the river in terms of the capacity of acceptance, in order to reduce their own and the whole system's costs.

Trading the disposal permit in a basin can be applied in two ways. In the first method each of the polluting units are considered separately in the trade-ratio system. But in the second method some of the industries can be considered as a group and carry out the trade system for them in order to reduce costs and motivate them to take part in the trade.

In past years several studies have been carried out on transferable disposal permits (TDP) and cooperative approaches in water quality management systems, some of these studies are Eheart (1980), Brill (1984) and Schwarze and Zapfel (2000). Hung and Shaw (2005) developed a new system for trading disposal permits for water pollution named trade – ratio system. The proposed system enabled an efficient financial approach and an ideal trade model to be carried out and also obeyed the environmental standards. This system's important feature is that it splits different areas and enables free permit trading based on the trade – ratio system. In this study this system has been announced as the superior system when compared with other systems. It should be mentioned that this system has been designed for the pollution load index and indefinites in the system were not taking into consideration.

Sarang et al. (2008) analysed the trade of disposal permits by analysing a few pollutants. By using mathematical analysis on the disposal trade permit programme for a few pollutants and its financial efficiency, they stated their view on maintaining the river water's quality. They deduced that proportionate weights are a function of water quality, peripheral damages and costs of peripheral treatment.

Niksokhan et al. (2009) developed a model for trading disposal permits for river using the Bargain theory. Using Young's Bargain theory and based on the preference of the decision makers and those affected, the agreed point was determined on the curve of interaction between the goals derived from the NSGA – II efficiency method. The curve shows the interaction between the overall cost of refining and the probability of violating standards of water quality which is the main goals of water quality management in river. The maximum disposal of waste by each of the units was determined using an efficiency model and by comparing the outcome values on the interaction curve the method of transaction between the buying units and selling units will

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be ascertained. Therefore the efficiency policy will be set in such a way that the preference of both sides will be met as much as possible.

Mesbah et al. (2009) analysed and developed the TRS model for disposal permit trading. By developing the TRS model for trading BOD and controlling DO standards along the river he proposed the developed TRS model. He used the phase regression to consider the available indefinites in estimating the functions of treatment cost. He managed to reduce the treatment costs of the river in his study by using pollution bar trading, but did not analyse the possibility of cooperative disposal.

Daylami et al. (2011) analysed some possible partnerships between similar disposers, which could lead to a more efficient control in quality of river water. The partnership could proceed by having an initially joint treatment procedure or by increasing the pollution load in river in a certain suitable point along the river. The model at hand is able to calculate the initial treatment level and the related costs for the polluters in an individual or cooperative situation.

Ant colony optimization (ACO) is one of the most recent techniques for approximate optimization. The inspiring source of ACO algorithms are real ant colonies. More specifically, ACO is inspired by the ants' foraging behavior. At the core of this behavior is the indirect communication between the ants by means of chemical pheromone trails, which enables them to find short paths between their nest and food sources. This characteristic of real ant colonies is exploited in ACO algorithms in order to solve, for example, discrete optimization problems. Depending on the point of view, ACO algorithms may belong to different classes of approximate algorithms. Seen from the artificial intelligence (AI) perspective, ACO algorithms are one of the most successful strands of swarm intelligence. The goal of swarm intelligence is the design of intelligent multi-agent systems by taking inspiration from the collective behavior of social insects such as ants, termites, bees, wasps, and other animal societies such as flocks of birds or fish schools. Examples of "swarm intelligent" algorithms other than ACO are those for clustering and data mining inspired by ants' cemetery building behavior, those for dynamic task allocation inspired by the behavior of wasp colonies, and particle swarm optimization.

To summarise, according to the studies carried out in recent decades trading disposal permits has been proved an efficient method in managing water sources, but in the studies carried out no consideration has been taken in partnering in the disposal permit trading and efficiently devising the load with a cooperative perspective, but in this study these have been taken into account. This method analyses trade through two perspectives, cooperative and non -cooperative and the two are based on criteria such as costs, efficient water quality control and probability of violation of standards and the results were to use to determine the most ideal cooperation scenario. The efficiency of the suggested model in the Zarjob River in Gilan province of Iran has been analysed.

2. Method and material

2.1. Case study

In this study for the purpose analysing the suggested model, the quantitative and qualitative information from the Zarjob River were used. This river originates from the Talesh mountain range and crosses through Rasht city and terminates in Anzali marshes. The area being studied is 26.5 km long and runs through Rasht city. The polluting sources include 8 different points; therefore the area being studied was divided into 8 segments. Calibrating the decline coefficient BOD and aeration rate was carried out by sampling throughout the length of the river and analysing the durability of the pollutants in order to minimize the difference between DO and BOD via calculations of the qualitative variables of the river.

Table 1. Characteristics of Zarjub river & quality of discharges.

Reach Number	Reach length (km)	Discharge flow (m3/s)	Flow (m3/s)	Discharged BOD(mg/l)	Wastewater Dissolve oxygen (mg/l)	Wastewater Temperature(°C)	Decomposition rate Coefficient at 20°C (1/day)	Aeration rate at 20 °C (1/day)
1	6.9	0.07	0.117	124	3.2	24	0.09	0.45
2	2.9	0.08	1.491	82	4	24	0.05	0.35
3	0.9	0.02	2.814	39	4.4	24	0.1	0.38
4	2.2	0.01	3.114	35	2.3	25	0.1	0.41
5	4.9	0.01	3.531	310	5.45	24	0.1	0.35
6	0.8	0.01	4.251	400	7.18	23	0.08	0.35
7	4.7	0.1	4.368	23	5.5	23	0.1	0.35
8	3.2	0.02	4.378	280	5	23	0.1	0.4

2.2. Ant Colony optimization

This algorithm is a member of the ant colony algorithms family, in swarm intelligence methods, and it constitutes some met heuristic optimizations. Initially proposed by Marco Dorigo in 1992 in his PhD thesis, the first algorithm was aiming to search for an optimal path in a graph, based on the behaviour of ants seeking a path between their colony and a source of food. The original idea has since diversified to solve a wider class of numerical problems, and as a result, several problems have emerged, drawing on various aspects of the behaviour of ants.

In the natural world, ants (initially) wander randomly, and upon finding food return to their colony while laying down pheromone trails. If other ants find such a path, they are likely not to keep travelling at random, but to instead follow the trail; returning and reinforcing it if they eventually find food (see Ant communication).

Over time, however, the pheromone trail starts to evaporate, thus reducing its attractive strength. The more time it takes for an ant to travel down the path and back again, the more time the pheromones have to evaporate. A short path, by comparison, gets marched over more frequently, and thus the pheromone density becomes higher on shorter paths than longer ones. Pheromone evaporation also has the advantage of avoiding the convergence to a locally optimal solution. If there were no evaporation at all, the paths chosen by the first ants would tend to be excessively attractive to the following ones. In that case, the exploration of the solution space would be constrained.

Thus, when one ant finds a good (i.e., short) path from the colony to a food source, other ants are more likely to follow that path, and positive feedback eventually leads to all the ants' following a single path. The idea of the ant colony algorithm is to mimic this behavior with "simulated ants" walking around the graph representing the problem to solve.

An ant is a simple computational agent in the ant colony optimization algorithm. It iteratively constructs a solution for the problem at hand. The intermediate solutions are referred to as solution states. At each iteration of the algorithm, each ant moves from a state x to state y, corresponding to a more complete intermediate solution. Thus, each ant computes a set Ak(x) of feasible expansions to its current state in each iteration, and moves to one of these in probability. For ant k, the probability P_{xy}^{k} of moving from state x to state y depends on the combination of two values, viz., the attractiveness η_{xy} of the move, as computed by some heuristic indicating the a priori desirability of that move and the trail level τ_{xy} of the move, indicating how proficient it has been in the past to make that particular move.

The trail level represents a posteriori indication of the desirability of that move. Trails are updated usually when all ants have completed their solution, increasing or decreasing the level of trails corresponding to moves that were part of "good" or "bad" solutions, respectively.

In general, the kth ant moves from state x to state y with probability

$$P_{xy}^{k} = \frac{(\tau_{xy}^{\alpha})(\eta_{xy}^{\beta})}{\sum y \in alloeed_{y}(\tau_{xy}^{\alpha})(\eta_{xy}^{\beta})} \tag{1}$$

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where, τ_{xy} is the amount of pheromone deposited for transition from state x to y, 0 ≤ α is a parameter to control the influence of τ_{xy}, η_{xy} is the desirability of state transition xy (a priori knowledge, typically $1/d_{xy}$, where d is the distance) and β ≥ 1 is a parameter to control the influence of η_{xy}, τ_{xy} and η_{xy} represent the attractiveness and trail level for the other possible state transitions. When all the ants have completed a solution, the trails are updated by

$$\tau_{xy} \leftarrow (1-\rho)\tau_{xy} + \sum_k \Delta\tau_{xy}^k \quad (2)$$

where τ_{xy} is the amount of pheromone deposited for a state transition τ_{xy}, ρ is the pheromone evaporation coefficient and is $\Delta\tau_{xy}^k$ the amount of pheromone deposited by kth ant, typically given for a TSP problem (with moves corresponding to arcs of the graph) by

$$\begin{cases} \Delta\tau_{xy}^k = Q/L_k & \text{if ant k uses curve xy in its tour} \\ 0 & \text{otherwise} \end{cases}$$

where, Lk is the cost of the kth ant's tour (typically length) and Q is a constant.

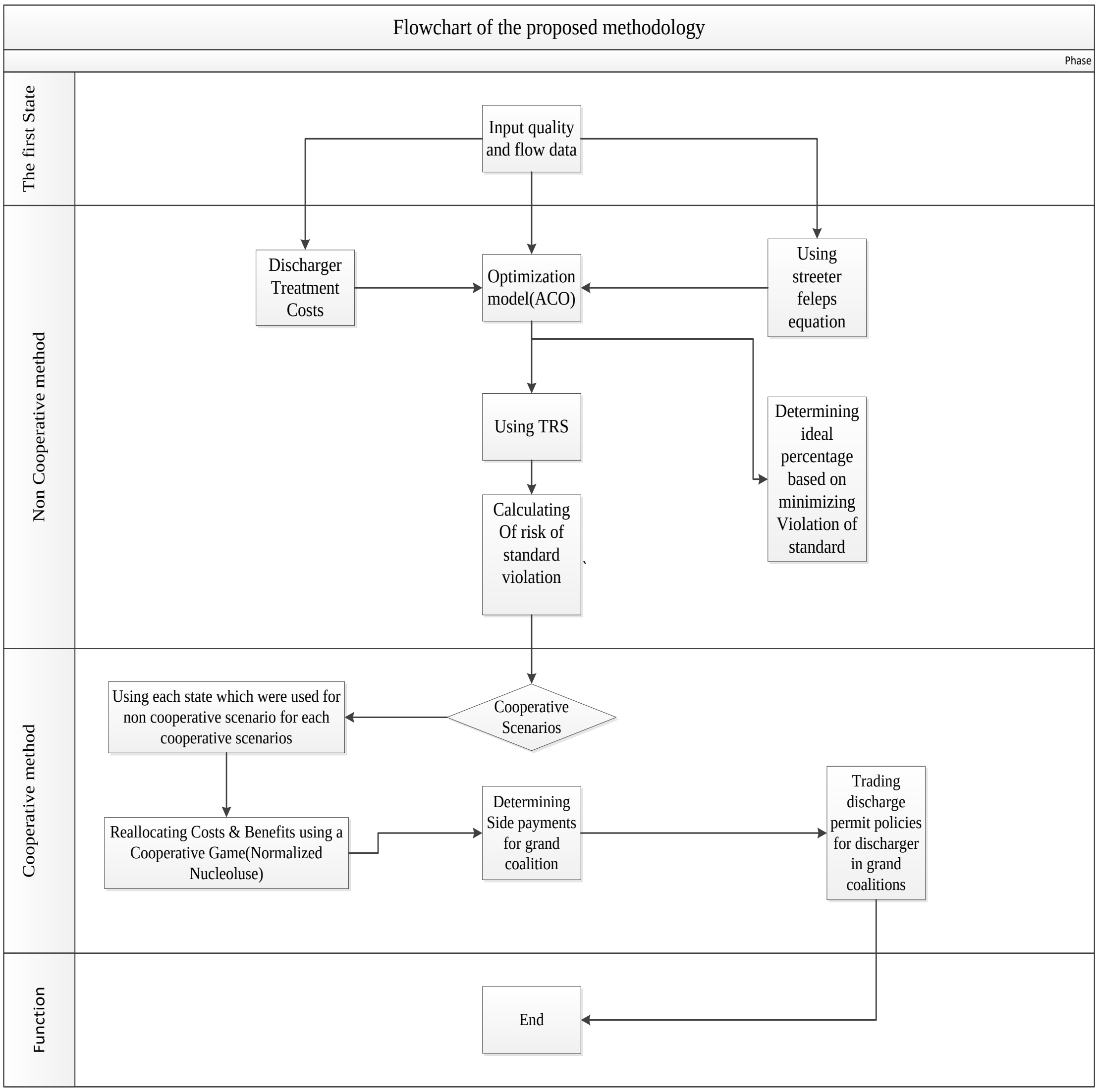

Fig. 1. Flow chart for proposed methodology.

2.3. Trade-ratio systems

In the river system because the water current is in a single direction, the TRS which was presented by Hung and Shaw (2005) can be used for disposal permit trading between different units. This system considers the auto treatment ability of the river and how the pollutants disperse and determines the trade – ratio between the units and by using efficiency methods presents the most efficient trade model. Trade- ratio between a selling and a buying unit shows an increase in pollution load for the buying unit which is achieved by purchasing a permit from the selling unit.
The TRS system has three specifications:

1- The capacity of acceptance for each area is calculated by considering the load transferred from areas higher up.
2- The coefficients of trade between areas are determined by considering the transfer coefficient.
3- Disposal permit trade not only suffices environmental standards it also reduces the whole system's costs.

$\overline{T}_{ki}$: The amount of TDPs that discharger i buys from discharger k, t_{ik} : trading ratio, C_i : abatement costs of discharger i, e_i : effluent level of discharger i, e_i^0 : primary effluent level of discharger i

$$Min\sum_{k>i}^{n} c_i(e_i^0 - e_i),\ i=1,\cdots,n \quad (3)$$

$$e_i - \sum_{k=1}^{i-1} t_{ki}T_{ki} + \sum_{k>i}^{n} T_{ik} \le \overline{T_i},\ i=1,\cdots,n \quad (4)$$

$$T_{ik},\ T_{ki} \ge 0. \qquad \forall i,k \quad (5)$$

$$e_i \in [0, e_i^0]. \qquad \forall i \quad (6)$$

2.4. Probability for violation of standards

One of the factors for the existence of indefinites in the river system is the complication of the environment and its random variables. These indefinites include those which exist in the entries of simulation model which are due to their innate uncertainty and also those indefinites which exist in the simulation model which are due simplifying assumptions in order to make a model of complicated environments. Analysing the indefinites in indefinite systems is important as it leads to the calculation of the risk involved in the system. In the river system the probability function parameters are obvious so by using indefinite analysis the Probability Density Function (PDF) index for water quality can be calculated and by considering this probability density function the risk involved in the system can be calculated. The probability of violation of standards is a probability which shows the chance of violating the quality standards in a certain period of time. The value for this standard is a definite amount and if the quality value passes this figure the quality is deemed unsuitable. To overcome this problem and considering the uncertainty in determining the quality of the water, Sasikumar and Mujudar (2000) stated a definition based on the fuzzy collection [9,10]

2.5. Cooperative Game theories

In such games there are no restrictions on the agreements that may be reached among the players. In addition, we assume that all payoffs are measured in the same units and that there is a transferrable utility which allows side payments to be made among the players. Side payments may be used as inducements for some players to use certain mutually beneficial strategies.

Thus, there will be a tendency for players, whose objectives in the game are close, to form alliances or coalitions.

The coalitional form of an n-person game is given by the pair (N, v), where N = {1, 2, ... , n} is the set of players and v is a real-valued function, called the characteristic function of the game, defined on the set, 2N, of all coalitions (subsets of N), and satisfying

(i) $v(\theta) = 0$, and

(ii) (superadditivity) if S and T are disjoint coalitions ($S \cap T = \phi$), then $v(S) + v(T) \le v(S \cap T)$.

Compared to the strategic or extensive forms of n-person games, this is a very simple definition. Naturally, much detail is lost. The quantity $v(S)$ is a real number for each coalition $S \subset N$, which may be considered as the value, or worth, or power, of coalition S when its members act together as a unit. Condition (i) says that the empty set has value zero, and (ii) says that the value of two disjoint coalitions is at least as great when they work together as when they work apart. The assumption of super additivity is not needed for some of the theory of coalitional games, but as it seems to be a natural condition, we include it in the definition.

2.5.1. Normalized nucleolus

An interesting value function for n-person cooperative games may be found in the nucleolus, a concept introduced by Schmeidler (SIAM J. Appl. Math, 1969). Instead of applying a general axiomatically of fairness to a value function defined on the set of all characteristic functions, we look at a fixed characteristic function, v, and try to find an imputation x = (x1, ... , xn) that minimizes the worst inequity. That is, we ask each coalition S how dissatisfied it is with the proposed imputation x and we try to minimize the maximum dissatisfaction (Thomas S. Ferguson, 2008).

As a measure of the inequity of an imputation x for a coalition S is defined as the excess

$$e(S,x) = (v(S) - \sum_{i\in S} x_i)/\sum_{i\in S} x_i \quad (7)$$

Which measures the amount (the size of the inequity) by which coalition S falls short of its potential v(S) in the allocation x. Since the core is defined as the set of imputations such that $\sum_{i\in S} x_i$ ≥ v(S) for all coalitions S, we immediately have that an imputation x is in the core if and only if all its excesses are negative or zero (Niksokhan el al, (2009)).

$$\min \varepsilon$$

$$\sum_{i\in N} x_i \ge v(S)/(1+\varepsilon) \quad \forall S \subset N \quad (8)$$

$$\sum_{i\in N} x_i = v(N),\ x_i \ge 0 \quad \forall i \quad (9)$$

2.6. Scenario definition

Considering the river's topography, speed of water, distance of polluting units, the kind of sewage produced, the flow of sewage from each unit and also the amount BOD produced by each of the units, different cooperation and disposal scenarios are developed. In this study of Zarjob River three cooperation scenarios based on the distance of the units from each other have been considered. Sub scenarios were formed in combination of twos based on the main scenario [1].

- The first scenario is related to units D2, D3, D4 cooperating with each other
- The second scenario is related to units D2, D4, D5 cooperating with each other
- The third scenario is related to units D6, D7, D8 cooperating with each other

3. Results and discussion

The first step in executing the intended model is determining the ideal treatment percentages for each of the pollution units with the objective of minimizing the amount of violation of standards of water quality (dissolved oxygen) (first objective) and calculating the overall cost for pollution control (second objective). Ideal percentages for different scenarios are shown in Table 2.

Table 2. Ideal percentages for different scenarios by Ant Colony optimization.

Scenarios	D1	D2	D3	D4	D5	D6	D7	D8	Best point from Upstream
Non cooperative	90	63	36	2	37	45	86	55	-
The first	22	9			41	98	99	87	9.9
The second	88	99	58			14	98	85	14.9
The third	66	99	81	2	86	47			21

By placing the model's entry parameters, based on the scenario intended in the simulator and optimizer which were defined for the river being studied, the cost of each scenario without violating any standards of quality will be calculated. In calculations related to costs, the cost of treatment, transferring and the overall cost with minimizing the violation of standards and overall cost of pollution control considering the fee for transferral to the best discharge point are shown in Table 3.

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Table 3. Dischargers cost.

Scenarios	Treatment Costs (billion Tomans)	Costs of transferring (billion Tomans)	Total Cost (billion Tomans)
Completely Treatment	3.244	-	3.244
Non cooperative	1.708	-	1.795
The first	1.390	0.074	1.464
The second	0.856	0.253	1.109
The third	0.783	0.213	0.996

To carry out disposal permit trading, considering the one way direction of the water current the trade – ratio system was used. Using this model, the amount of pollution given out by the units after trading (e), initial disposal permits (Ti) and the amount of disposal permits which the upstream unit purchases from the downstream unit (Tki) was calculated and the results are presented in Table 4.

Table 4. Results of TRS (kg/day).

Scenarios	Non cooperative	The first	The second	The third
e3	7.5	0	21.9	2.2
e5	7.6	199	199	268
e6	17	51	216.2	318.6
e7	100	0	0	0
e8	68	-	-	-
T1	13.8	37	18	18
T2	0	33	0	0
T3	6.5	3	10.5	5.5
T4	0.72	242	133	144
T6	0	0	280	282
T7	404	-	-	-
T12	13.2	37	17.8	17.8
T23	0.6	0	2	1.1
T24	18.8	55.7	19.4	4.3
T26	0	12.2	0	0
T34	0	3.1	0	0
T35	0	0	0	4.6
T36	0	0	0	5.6
T45	12.7	0	0	0
T46	6.3	0	0	5
T56	7.4	41.3	0	2
T68	33	-	-	-
T78	12.5	-	-	-

The degree of enhancement in water treatment in each scenario was calculated considering the minimum concentration of dissolved oxygen in the river which was measured at 0.9 mg/l. From the values acquired from the model in the third scenario which has the lowest quality optimizing, the least amount of dissolved oxygen measured in the river reached 3.64 mg/l. The minimum values for dissolved oxygen after executing cooperative trading in scenarios 1, 2 and 3 were 4, 3.83 and 3.64 mg/l consecutively, which show the effectiveness of the models in quality optimization of the river.

To calculate the fuzzy risk, the undesirable quality of water based on the concentration of DO was considered as a trapezium membership function. In the study at hand the random variable entries, amount of upstream flow, discharge of the disposer and some the qualitative and quantitative indexes including temperature and BOD in each of the currents. The coefficient of degradation BOD (k) and aeration rate (k2) as the indefinites in the parameters of the simulator were also considered. The index of water quality control in control points is DO the concentration function of which is determined by considering the probability density function of the input variables, equations obligating pollutant transfers and by utilizing the Monte Carlo uncertainty analysis. To put into equation the uncertainty of the model for determining the fuzzy risk, the input parameters of the model were considered as uncertainties with a normal distribution.

On average in a non-trading situation there is a 0.20 probability of violation of standards present, whereas in the non- cooperative trade, first, second and third scenarios this value of probability reaches 0.18, 0.06, 0.18, 0.18 consecutively, which goes to show the effectiveness of the cooperation and trade policies in elevating the quality of river water.

After executing cooperation policies between polluting units and creating different cooperative scenarios the total cost of the system dropped noticeably.

In order to minimize the violation of standards in the first scenario reduced costs by 14% which sums up to 1.464 billion Tomans compared to the initial state and 245 million Tomans less than the non-cooperative trade. The ideal discharge point was determined at 9.9 km upstream. From the overall cost 74 million Tomans is devised to transfer fees. The second scenario had a reduction of 35% in costs equal to 1.109 billion Tomans compared to the initial state and 599 million Tomans less when compared to the non-cooperative trade scenario.

The ideal discharge point was determined at 14.9km upstream and 188 million Tomans was devised to transfer fees. In the third scenario this reduction in costs was also 42% equal to 0.996 billion Tomans compared to the initial state and 712 million Tomans compared to non-cooperative trade scenario. 213 million Tomans was devised to transfer fees.

The ideal discharge point was determined 21 km upstream. Based on minimizing the total cost of pollution control, in the Third scenario a reduction of 42% in costs equal to 712 million Tomans compared to the non-cooperative trade scenario. The ideal discharge point was determined at 21 km upstream. 213 million Tomans was devised to transfer fees.

Whilst analysing the different scenarios in should considered that there should be no extra cost imposed upon units participating in this partnership, as a result of increasing the treatment percentage. Those units who did not participate in the partnership discharge the same amount of pollution in the river as they did before executing the policy and if there is a need for further discharge they can purchase the capacity needed from the units who did participate.

In minimizing the violation of standards the objective is reaching a higher quality of water and the results were considered as the total maximum daily load (TMDL). In the second situation which is related to minimizing total costs of pollution control, in order to reduce these costs units were allowed larger discharges, but it as a sequel at some points in the river, the DO standard may not be abided. In any one of these two perspectives, the ideal discharge points for the units cooperating with each other was calculated and the transfer fees were considered.

3.1. Devising partnership profits

After devising the costs again using cooperative game methods: the treatment cost is (yi) the devised profit is (xi) and the cost for the discharger is (i) in the main coalition and before the dividing costs (cgi) and peripheral costs are (CGi-yi).

The extra costs are part of the selling side's profit (the side who has participated in the coalition and made a profit) that are paid to the purchasing side (the side who has participated in the coalition and has made little profit or loss). If the extra costs are positive it means this amount has been received from other units and if it is negative it mean it has been paid to other units. Therefore justice has been served through these extra costs. To analyse and compare the lack of extra cost imposition as a result of lower pollutant discharge and higher treatment on units who have not participated in the cooperative model, we use Tables 5 and 6. In this study the results of the Normalized Nucleus game were used for calculations.

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Table 5. Coalitions cost & benefit.

Coalitions	Cost of dischargers in coalitions							Total costs of coalitions	Benefit of coalitions
	2	3	4	5	6	7	8		
S1	0.112	0.060	0.183	-	-	-	-	0.355	0.245
S2	-	0.064	0.056	0.256	-	-	-	0.376	0.599
S3	-	-	-	-	0.162	0.021	0.227	0.410	0.712
S11	-	0.114	0.051	-	-	-	-	0.166	0.065
S12	0.428	-	0.023	-	-	-	-	0.450	0.208
S13	0.293	0.035	-	-	-	-	-	0.328	0.227
S21	-	-	0.029	0.547	-	-	-	0.576	0.102
S22	-	0.058	-	0.231	-	-	-	0.289	0.097
S23	-	0.114	0.051	-	-	-	-	0.166	0.065
S31	-	-	-	-	0.292	0.168	-	0.460	0.051
S32	-	-	-	-	0.160	-	0.224	0.384	0.042
S33	-	-	-	-	-	0.105	0.664	0.769	0.028

Table 6. Reallocated costs & benefits by normalized nucleolus.

Discharger	2	3	4	Total	3	4	5	Total	6	7	8	Total
Reallocated benefits	0.183	0.040	0.021	0.245	0.199	0.199	0.199	0.599	0.237	0.237	0.237	0.712
Reallocated Costs	0.245	0.084	0.03	0.332	-	-	0.348	0.348	0.055	0	0.427	0.074
Side Payment	-0.133	-0.024	0.157	0	0.064	0.028	-0.092	0	0.107	0.093	-0.200	0

As is observed, in table 6 the extra costs are also mentioned. These show the paid costs (positive figures) or received costs (negative figures). In fact in this method of transaction the selling and buying sides are determined. According to the acquired results from the Normalized nucleus method, for example in the first scenario, discharger 4 is the seller. In this game this discharger, consecutively receives 0.133 and 0.024 billion Tomans from dischargers 2 and 3 so that as well as a profit of 0.183 billion Tomans for each of them, the devised cost for each discharger is 0.245 and 0.084 billion Tomans consecutively. Therefore after devising the costs again for discharger 4, it comes to 0.03 billion Tomans so they all profit 0.021 billion Tomans.

3.2. Evaluation of water quality

The results of implying models are shown in Figures1-6. "U(x,t)" is Concentration's function (mg/lit),"x" is distance variable(km) and "t" is time variable(s). The acceptable concentration of BOD is 30 mg/l.

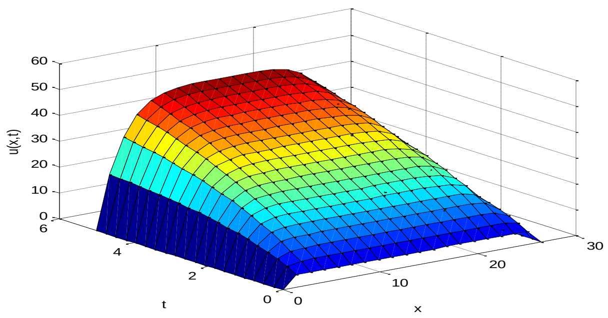

Fig. 2. Concentration of BOD before implying model in non-cooperative scenario.

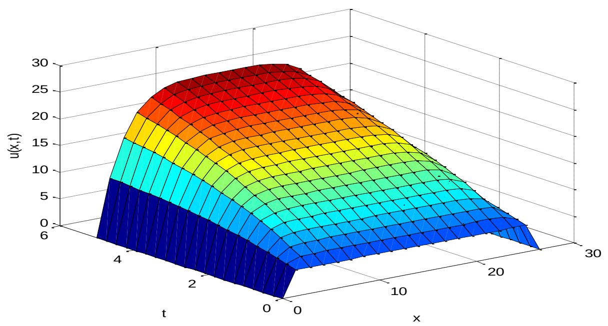

Fig. 3. Concentration of BOD after implying model in non-cooperative scenario.

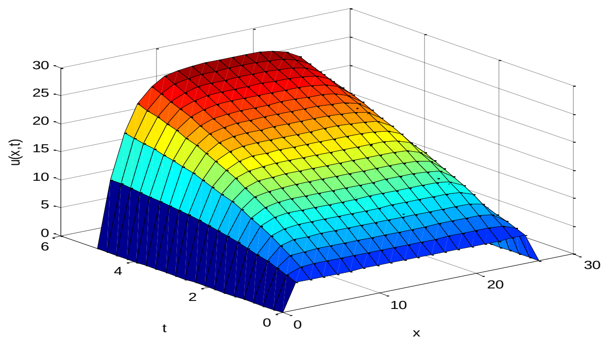

Fig. 4. Concentration of BOD in Scenario one after implying model.

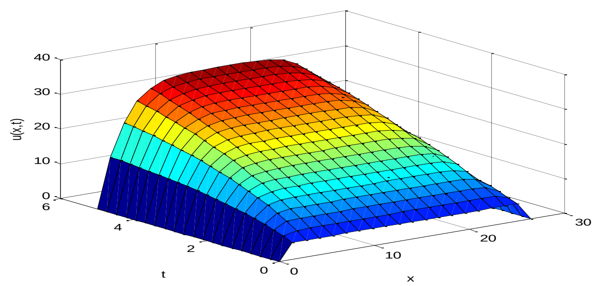

Fig. 5. Concentration of BOD in Scenario two after implying model.

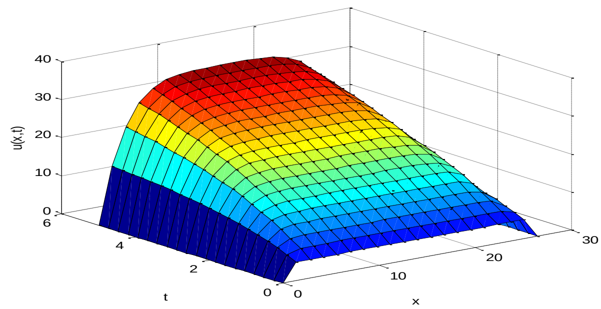

Fig. 6. Concentration of BOD in Scenario two after implying model.

4. Conclusions

In this study between the different scenarios the first scenario has the lowest risk of violation of standards with a probability of 0.06. Also scenario third with the objective of minimizing Costs, had a reduction of 2.248 billion Tomans compared to complete treatment and 245

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million Tomans compared to the non-cooperative condition and a total cost of 0.996 billion Tomans and an optimum discharge point based on self -treatment, 21 km upstream. This reduction in costs was influenced by the point discharge.

In the non-cooperative situation, the total cost was 3.24 billion Tomans, in the cooperative situation the total cost was 1.708 billion Tomans, in the first scenario of cooperation the cost was 1.464 billion Tomans, in the second scenario 1.109 billion Tomans and in the third scenario the cost was 0.996 billion Tomans. The profits were 245, 599 and 712 million Tomans consecutively compared to the non-cooperative trade based on minimizing the violation of standards. The highest percentage of increase in them minimum concentration of dissolved oxygen in the river after executing the model was in scenario one and equal to 4 mg/l. After overall consideration of the indexes of minimizing costs, obeying standards and risk of violating standards scenario one proved to be the best scenario.

References

Alvarez-Vezquez L. J., Martinez M. E., Vezquez-Mendez l. and Viler M.A., An application of optimal control theory to river pollution remediation, Applied Numerical Mathematics 59 (2009) 845-858.

Broekx C. J., Vandenberghe S., Sels V., Maynaets H., Vercaemt E., euntjens P., Hulle S. V., Wustenberghs H., Bauwens W., Huygens M., Coupling a hydrological water quality model and an economic optimization model to set up a cost – effective emission reduction scenario for nitrogen, Environmental Modelling & Software 26 (2011) 44–51.

Daylami A., Shamsai A. and Niksokhan M. H., A cooperative approach for waste load management in rivers, WFL Publisher, Science and Technology, Journal of Food, Agriculture & Environment (2011).

Dorigo M., and Stutzle T., Ant Colony Optimization, Massachusetts Institute of Technology, QA402.5.D64 (2004).

Eheart J.W., Ng T.L., Role of Effluent Permit Trading in Total Maximum Daily Load Programs: Overview and Uncertainty and Reliably Implications, Journal of Environmental Engineering, ASCE 130 (2004) 615–621.

Ferguson, T.S, Game Theory, UCLA (2008).

Guo P., Tanaka H., Dual Models for Possibility Regression Analysis, Computational Statistics & Data Analysis 51 (2006) 253 – 266.

Hunga M., and Shaw D., A Trading-ratio System for Trading Water Pollution Discharge Permits, Journal of Environmental Economics and Management 49 (2005) 83–102.

Karmakar S., and Mujumdar P. P., An Inexact Optimization Approach for River Water Quality Management, Journal of Environmental Management 81 (2006) 233–248.

Mesbah, et al. [2006], Developing a Fuzzy-based Model for Water Quality Trading in River Systems, University of Tehran (Persian, with English abstract).

Niksokhan M.H., Kerachian R., and Karamouz M., A Game Theoretic Approach for Trading Discharge Permits in Rivers, Journal of Water Science Techno 60 (2009) 793-804.

Sarang A., and Lence B. J., and Shamsai A., Multiple Interactive Pollutants in Water Quality Trading, Environmental Management 42 (2008) 620-646.

Streeter H.W., Phelps E.B., A study of the pollution and natural purification of the Ohio River, Ш Factors concerning the phenomena of oxidation and reareation, Public Health Bulletin, Public Health Service Washington DC No. 146 (1925).

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