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Utilization of Mathematical Modeling for Self-purification of Tajan River and Its Impact on Caspian Sea (Mazandaran Province, North of I.R. Iran)

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Abstract

The Caspian Sea is the largest (in surface area) land locked body of water in the world. The Caspian Sea is a rich source of natural resources and raw materials hosting a unique variety of living species and a developed natural examine system. The area of the Caspian Sea is 386400 km^2. Five countries share the 7000 km coastline of the Caspian Sea. Water quality monitoring programs are undertaken to provide information to answer question relating to the management of water bodies and their catchments. They may be a single exercise to examine a particular issue or they may be on going monitoring programs to ensure that acceptable water quality is maintained. Self purification processes must be considered in the management of aquatic systems, particularly in the context of different standards, on water quality, which emphasizes the conservation or restoration of good ecological quality. Tajan River has a Shahid Rajaee Dam, which is located about 25 km south of Sari the Capital City of Mazandaran province. The minimum discharge regulated by the authorities of Dam in Tajan River as reported is 5 m^3/sec. The effluent from Sari treatment plant after three years will be around 0.17 m^3/sec. and after 20 years will be around 1.03 m^3/sec. The dilution of treated wastewater in Tajan River after 23 years will be 1:5. This amount of Wastewater entering Tajan River will give an additional flow to the farmers to use for agricultural purposes or discharge to the Caspian Sea. Annual maximum and minimum rainfalls in Sari in ten (10) years from 1989 to 1999 are 1004 mm and 456 mm respectively. To design and implement monitoring programs for Tajan River water factors such as frequency of sampling, analytical methods site selection and criteria for water use area, was defined, accordingly. Monitoring station was selected as upstream of the River, Inside Sari City and downstream close to Caspian Sea (Delta). Samples were collected in 500-ml Sterilized bottles on a monthly basis for physical, chemical and microbiological analysis. Sampling and analyses were carried out in accordance with the Standard methods. The Results of water quality at different sampling location shows moderate range of 7.6 to 8.2 pH. Total dissolved Solids (TDS) were in the range of 350 mg/l to1100 mg/l hence at Delta up to 10800 mg/l. Maximum Value for BOD and COD were 18 mg/l and 53 mg/l maximum value of Nitrates is 2.6 mg/l the results show that the river quality is in moderate range. Based on collected data from different water quality monitoring stations, mathematical model used to assess the efficacy of self purification of Tajan River. The trend of results shows the river is in moderate condition.

1. Introduction

Water quality monitoring programs are undertaken to provide information to answer question relating to the management of water bodies and their catchments. They may be a single exercise to determine a particular issue or they may be on going monitoring programs to ensure that acceptable water quality is maintained. The restoration ecology of aquatic ecosystem is now one of the challenges of the future. It is difficult to propose restoration rules, including limitation on polluted inputs, without focusing on study of aquatic ecosystem functioning. Self purification processes must be considered in the management of

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aquatic systems, particularly in the context of different standards, on water quality, which emphasizes the conservation or restoration of good ecological quality. The important problem comes from the difficulty of research about aquatic ecosystem functioning, because of multiple and complex interactions between physical, chemical and biological factors. In particular, hydric exchanges between surface and groundwater are important factors, playing a role in the self – purification processes. Pathways through the stream – bed actually determine the driving removal, retention and uptake of particulate or dissolved matters like nutrients.

The Caspian Sea is the largest (on its surface area) land locked body of water in the world. The Caspian Sea is a rich Source of natural resources and raw materials hosting a unique Variety of living species and a developed natural economic system. The fresh water flows into the Caspian Sea from the northern and Southern parts of Caspian region. The Volga Ural and Terek Rivers contribute 88 % of the freshwater flows in to the Caspian Sea. Azerbaijan and I.R IRAN respectively contribute 7 % and 5 % of the freshwater flows into the Caspian Sea. The Southern part of the Caspian Coastal zone (the Iranian side) is a narrow coastal plain with an average width of about 50 km, produced by a general retread of the sea, which probably once extended as far as the foot of the Alborz Mountains the famous mount Damavand is in the middle of the Alborz ranges. It is the highest peak in Iran with an altitude of 5671 meters. The Iranian Caspian coastline includes two different geomorphologic provinces one is the central coast with its high dip topography and the other is a low plane in the western and eastern ends of the shoreline. The average slope of the beaches can be classified in three types (Mehrdadi, 2001 & 2003).

1) High land slopes with 0.5 percent or more
2) Moderate land slopes with 0.1 to 0.5
3) Lowland beaches with gentle slopes of less than 0.1 percent.

Most of the beaches with high and moderate slopes are sandy and mixed with coarse or medium grade sand easily dispersed by waves (UNDP, 2003).

In the south of the Caspian Sea (Iranian side), there are habitats that are ecologically important and contain many valuable Species of flora and fauna. These play a major role in marine life cycles and fisheries resources. The Caspian Sea is rich in marine fish of commercial value the sea is world famous due to the presence of unique specie of sturgeon which is of commercial value due to its black Caviar. In recent years, sturgeons landing have decreased dramatically: from 30,000 tons in 1985 to only 5, 672 tons in 1995. The whole Caspian coastline is a major sanctuary in the migration pattern of migratory birds from the northern hemisphere to the south. Important Sensitive areas in Mazandaran Province are Miankleh Peninsula: 70000 ha., 36º 50'N, and 53º 45' E9, Lapoo–Zagmarz : 200 ha., 36º 50' N and 53º 17' E 8, Seyad Mahalleh and Zarrinkola Complex 1600 ha., 36º 44' N and 33º 00' E 7and man made Ab-Bandans (Fig.1).

2. Environmental issues

The Caspian Sea is currently undergoing increasing anthropogenic pressure. Hence there is an increase of eutrophication, water Pollution by heavy metals chemical pollution, the major environmental issues and overall decline in environmental quality, threats to biodiversity, decline in human health, decline in fish stocks as wall as sturgeon, damage to coastal habitats and damage to coastal infrastructure. The Table 1 shows the overall pollution load to the sea from the different sources share by five countries (CEP, Report, 2001).

Tab. 1: Total pollution load to the Caspian Sea at different sources

	BOD	N	P	E. Coli	oil	Hg	Cd
Sources	T/Y	T/Y	T/Y	10-15 C/y	T/Y	T/Y	T/Y
Rivers	641000	827000	88000	145000	75000	14	141
Municipalities	80000	24000	6000	5000	19000	1	2
Industries	25000	2000	1000	0	28000	2	6
Atmosphere	0	39000	800	0	350	0	0
Total	746000	892000	95800	150000	122350	17	149

3. Back Ground

The River and tributaries are an important source of water for irrigation, town drinking supplies, stock and domestic use, habitat for plants and animals, recreation and visual amenity. The quality and usefulness of river water for these purposes and the safety of water users is threatened by domestic waste, industrial effluent discharges and pollutants originating from road transport, deliberate dumpings, urban storm water systems and spray drift.

Point source pollution in a river system differs in many ways from non-point source pollution has characterized as:

1) Sourced from single or multiple points.
2) Having a travel time determined by river flow rate.
3) Being effected by weirs or barriers in the river.
4) Estimating the pollution travel time with different flow, rates.
5) Identifying downstream water users likely to be affected, the duration of the effect and effected water users contact details.

Tajan River originated from Dodonge and Chardonge Mountain has a Shahid Rajaee Dam which is located about 25 km south of Sari the capital city of Mazandaran Province, Sari is Situated about 20 km towards south of the Caspian Sea with the current population of around 400000, Sari area comprises mostly of fairly flat and with general slope of about 0.7 % (7 per 1000) from the south towards the north (Caspian Sea). The average elevation of the city above sea level is +40 m. The land around the city as well as Tajan River is used mostly for harvesting of rice orchards of orange and other trees. The Tajan River are passing through the city and flowing towards north; discharging in to the Caspian Sea the water of Tajan River is used to irrigate farms and gardens in and around and the city. Tajan River is a Source for many irrigation creeks. (Canals and Ab-Bandans which is a local system for storing water in ditches during high flow period of River Tajan and being used later on for agricultural Purposes). For many years, even though the city has been developed a lot and the land use pattern has been changed from agricultural to residential, the direction of these creeks and canals has not changed as these canals are mostly earthen and often pass through the city towards agricultural land. The flows of Tajan River are being recorded for last many years at various stations on the Tajan River. The maximum flooding of the river was in 1979 when there was a moment maximum and daily maximum flow of 650.9 and 418 m^3/ sec, respectively. Daily maximum flow in these twenty-five years was between 340 m^3 /sec. to 418 m^3 /sec.

4. Water quality models

The models used in water quality management can be divided into loading models and receiving water models. The Loading Models simulate and estimate pollution generation at the source and is movement from the source area to the receiving water body. In most cases the loading models provide flow (hydrograph) and concentrations histograms at various points in the watershed and entry points into the receiving water body. The Receiving Water Models simulate the movement and spread of materials through streams, river impoundments, estuaries or near shore ocean dispersion. Generally, these models are divided into:

A. Near –field models: which Simulate the spread of the pollutants from the point (effluent) or line (diffuser) discharge until a point or location on the receiving water body where the discharge is completely mixed with the receiving flow.
B. Far–field models: Describes the movement and transportation of pollutants downstream often a long distance, after the plume is mixed completely with the bulk flow of the receiving water body. Typically, far-field models assume that the pollutant concentrations are homogeneous (completely mixed) and the models are one- or two – dimensional.

The use of models is beneficial and greatly enhances the planning process for the following reasons.

1. Models can provide a forecast of the impact of planned actions on water quality and pollution loadings; as well Models provide an understanding of the processes involved in pollution generation from non-point sources.
2. Regulators almost always require proof of water quality impact during conditions for which monitoring data may not be available, especially in cases when planned action is in a planning stage and has not been implemented. Such impact can only be established by modeling.
3. Models can be undated continuously according to the state of the art of modeling technology and understanding of the modeled process.
4. Models can generate numerous alternatives and their impact on the environment according to the specifications. Various strategies can be investigated, and the impact of remedial measures can be evaluated.
5. Models can estimate and analyze trade – offs between planning objectives. A system providing the lowest pollutant load may not be optional for other objectives, such as enhancement or even feasibility of agricultural production (e.g., limiting or eliminating pesticide and fertilizer use may result in significant yield reduction, urban development versus no future development). If the environmental objective is known, the alternative to achieving it can be measured in terms of economic efficiency by considering the willingness of those involved by the measures to pay for the consequences. If there is a financial limit, it must be treated as a constraint (Vladimir, N., 2003).

5. Methods

To design and implement water quality monitoring programs for Tajan River, factors such as frequency of sampling, analytical methods, site selection and criteria for water quality and water use area, was defined accordingly. Monitoring station was selected and named as upstream of the River, (Takam bridge), inside Sari city (Tajan bridge), and downstream, close to the Caspian Sea (delta, Khazar-Abad). Figure 1, Depicts the sampling locations. River water samples were collected in 500 – ml sterilized bottles on a monthly basis for physical, chemical and microbiological analyses. Sampling and analyses for water quality monitoring were carried out in accordance with the standard methods (APHA/AWWA/WPCF. 1995). Water samples were processed for, Total coli forms and fecal coli forms using the standard membrane filter technique (Bartram, 2000 & WHO, 1998).

Field sanitary surveys along the Tajan River at the time of water sampling where made. The aim of the sanitary inspection was to identify sources of existing and potential microbiological hazards that could affect the safe use of Tajan river water.

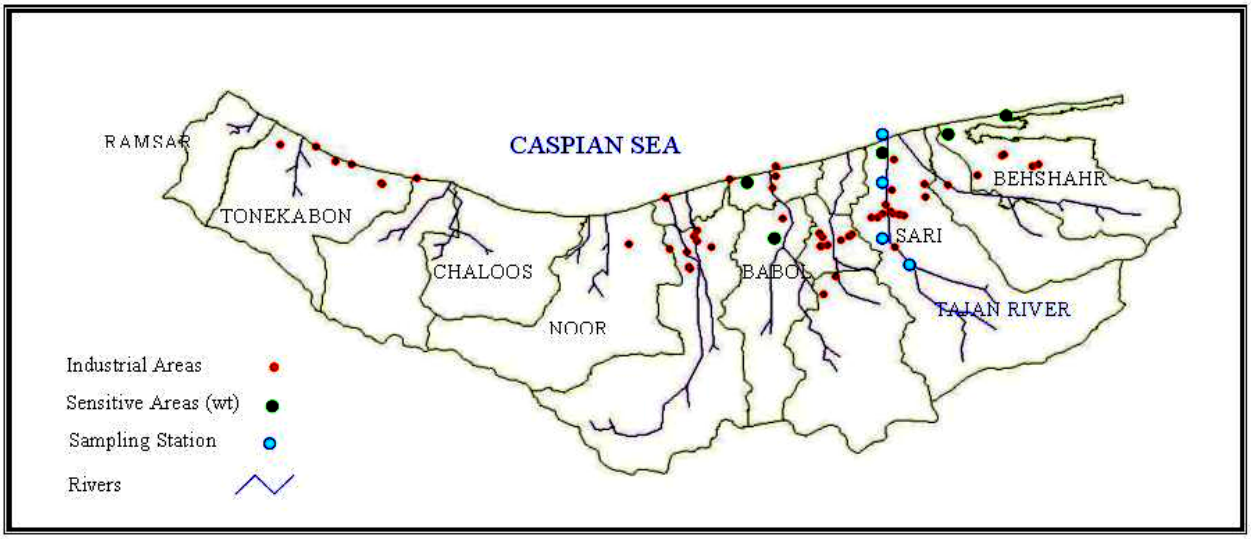

Fig.1: Distribution of industrial sectors, rivers, sensitive areas and sampling station of Tajan River of Mazandaran Province.

6. Results

The result of water quality at different sampling location along the Tajan River in Mazandaran province shows considerable variation in different station at different seasons.

The figure 2 shows the variation of DO on seasonal basis at different stations. The trend shows the maximum valves of DO are at the time of autumn. Around Tajan Bridge as well as around down stream of diversion dam in Tajan river the dissolves oxygen concentration is more as compare to other site because of aeration take place, accordingly due to different in elevation as well as hydraulic jump accrued in that specific area. Usually in autumn and winter the concentration of DO are more because of lowest temperature and hence the stability of DO on water body shall be high as compare to warm water baby (Figure 3).

Results are presented for three sites sampled in Tajan River as Takam Bridge and Delta as well as BOD and COD concentration along the river (Figs. 4, 5, 6 and 7). The higher concentration of BOD, COD, DO and bacteria is greatly influenced by many factors such as weather conditions, rainfall, onshore winds and most importantly direct and indirect domestic and industrial effluent .Fecal coliforms test was made and results variations suggest that a fecal pollution pattern for different sampling stations are more or less same, except in Tajan Bridge stations as well in summer due to minimum flow at summer seasons. Water quality in rivers and streams can be controlled by reducing the effluent concentration of the domestic as well industrial waste in put, reducing the upstream concentration, reducing the effluent volume, and increasing the upstream

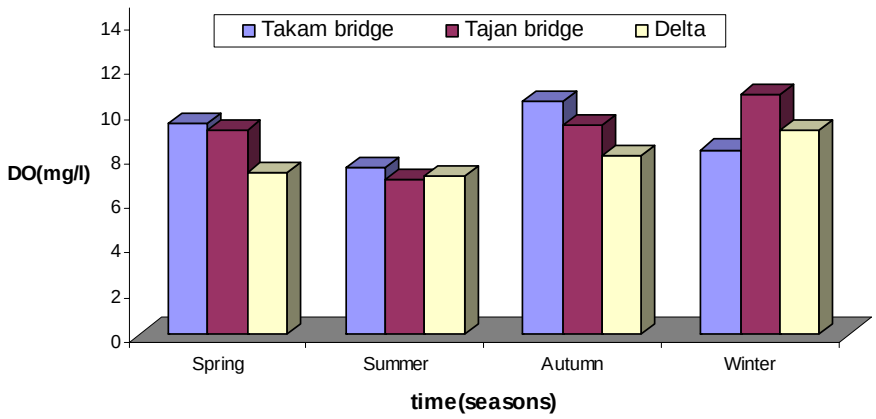

Fig. 2: Variation of DO (mg/l) on seasonal basis at different stations

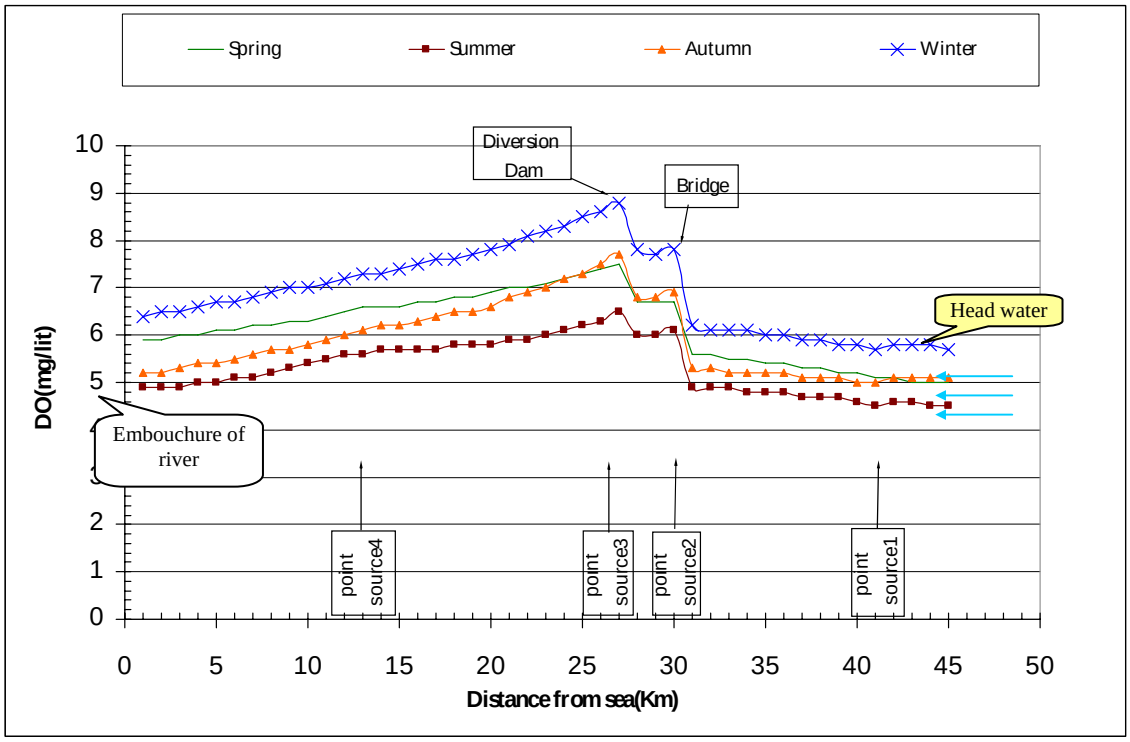

Fig. 3: Output of the model for DO concentration along the river

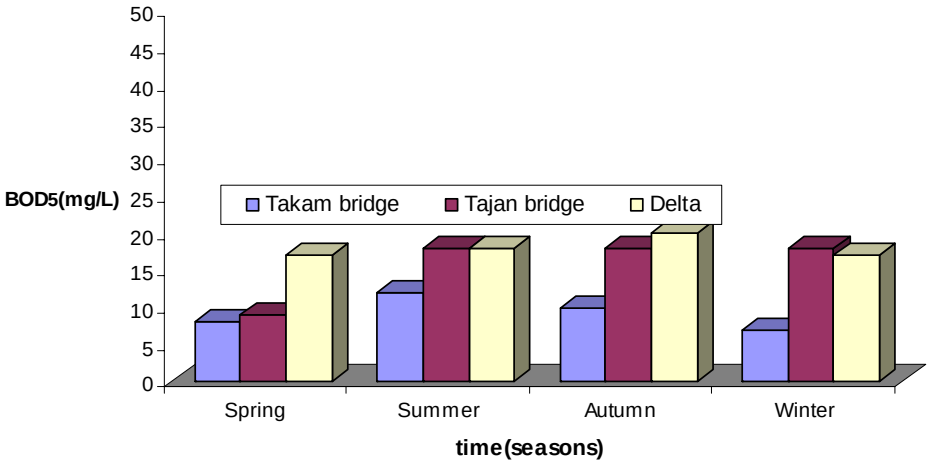

Fig. 4: Variation of BOD5 (mg/l) on seasonal basis at different stations

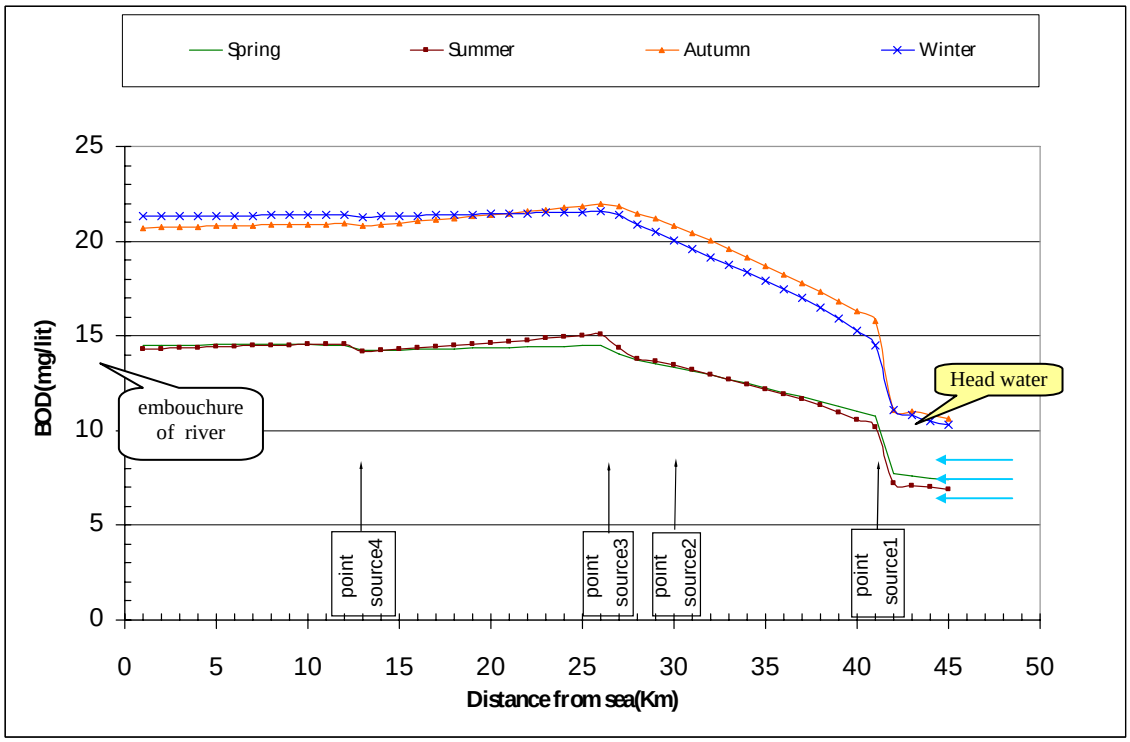

Fig. 5: Output of the model for BOD5 concentration along the river

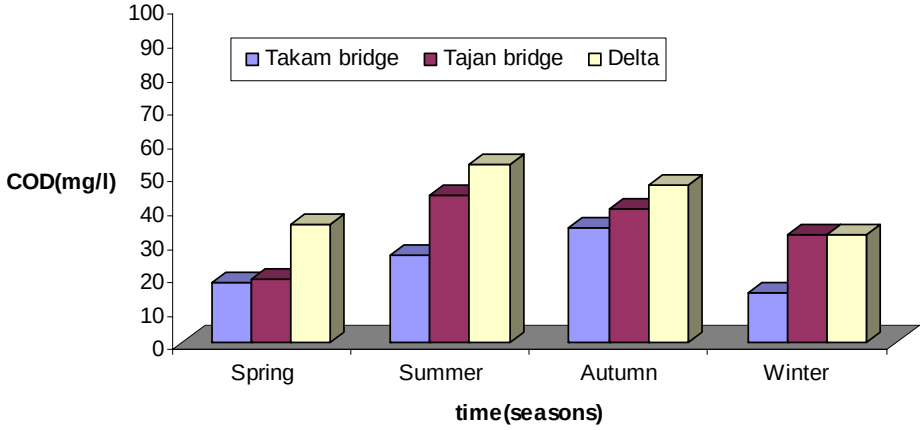

Fig. 6: Variation of COD (mg/l) on seasonal basis at different stations

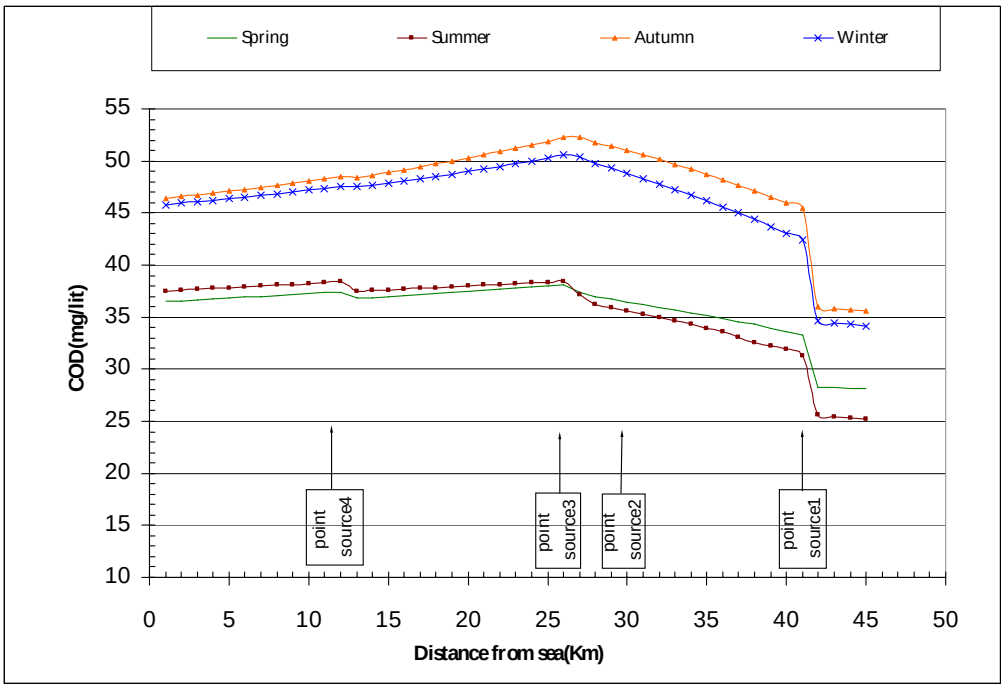

Fig. 7: Output of the model for COD concentration along the river

7. Conclusions

1. Tajan river water quality can be important by reducing the effluent concentration of the waste input and increasing the upstream flow.

2. Output of the model shows the DO concentration and BOD concentration along the Tajan River are satisfactory.
3. The maximum value of BOD and COD are 20 mg/l and 50 mg/l respectively at Tajan Bridge due to minimum flow in river at summer season, as compare to spring season which is less than 10 mg/l and 20 mg/l respectively
4. To improve DO in rivers, estuaries, the point and non-point reduction of sources of carbonaceous waste material (CBOD) and nitrogenous waste material (NBOD) through reduction of effluent concentration/effluent flow, aeration of the effluent of a point source can improve the initial value of DO, increase in river flow Through low-flow augmentation to increase dilution .
5. Water quality at different sampling location along the Tajan river like COD, BOD, TSS, DO, Total coliforms, Fecal Coli forms, Turbidity shows considerable variation in different monitoring station at different seasons due to fluctuation of flow along the river, influence of weather condition, domestic, industrial and agricultural effluent, also surface water flow.
6. We conclude that, Caspian Sea is under going overall decline in environmental quality, threats to biodiversity, decline in fish stocks and damage to coastal habitats. Total pollution of BOD, P from rivers to the Caspian Sea is 641000 T/Y and 88000 T/Y respectively share by five countries
7. The results are indicative of a need for continued monitoring; it is also suggested to implement management measures such as wastewater management, river management and public awareness to reduce the level of contaminants.

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