Spatial and temporal variations of selected indices of water and sediment quality in Zayande-rood River, Isfahan, Iran

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Abstract

Restoration of Zayande-Rood River which is threatened by human activities requires perpetual monitoring of water and sediment quality, on the one hand, and identification of different polluting sources, on the other. This paper reviews some essential findings of previous works about the contamination state of Zayande-rood river. Spatial and temporal variation of some quality indicators (temperature, pH, total dissolved solids, electrical conductivity, total nitrogen and phosphorous, Na, Ca, K, Cl, Cd, Fe, Ni, Pb, sulfate and bicarbonate) measured in river water are discussed. In addition, some properties of point-source pollutants are presented. Variation of total and soluble concentration of some heavy metals in polluting sources and riverbed sediments are discussed. Moreover, the different chemical forms of these heavy metals are assessed. Results show that most of polluting agents in the point-source pollutants are above the critical levels. However, due to the low rate of swage flow, no significant effects were observed in the river quality. Among the point-source pollutants, South Isfahan Refinery is the most contaminating source. The variation of cations, anions, salinity, and total dissolved solids are highly correlated; these values increase gradually towards the eastern region of Isfahan (Baraan and Roodasht). After the introduction saline drainage water of farmlands, these values increase sharply. High concentration of nitrogen in the lowermost side of the river witnesses the unsustainable agricultural management of the region, especially, high application of chemical fertilizers. Heavy metals concentration only increase in the lowermost side of the river; however, the absolute values of these metals are low throughout the river. In contrast, high concentration of soluble and exchangeable forms of heavy metals in riverbed sediments warns the potential hazards of river water pollution.

Introduction

Zayande-rood river is the vital arter of Isfahan province; therefore, its water quality for drinking, agricultural, industrial, and wildlife purposes is of great importance. Contamination of Zayande-rood river with different pollutants such as organic and inorganic materials is threatening the environmental health and agricultural sustainability of the region. The drainage water of agricultural lands in the river catchments is the main source of nitrogen and phosphorous contamination; excess amounts of some other cations and anions are also related to this source. However, heavy metals are introduced to the river mainly through urban and industrial swages.

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It is reported that the spatial and temporal variability of river pollutants as well as kind of pollution are mainly controlled by land management patterns at river margins (Kalbasi,1994). What that accelerates the rates of river pollution are unsustainable economic structure and over population in urban areas. Furthermore, the lack of governmental and nongovernmental organizations (dependent upon native communities of the river catchments) intensifies the problem. For instance, Micciccippi River was dramatically polluted after World War II due to numerous causes such as over population, increased industrial activities and introduction of pesticides and fertilizers to farm lands. As an effect, in 1960 decade, the aquatic wildlife of the river fell down drastically. For several decades, this problem was the main concern of the government so that new policies were established to inhibit the process of water pollution and even to restore the initial condition (LaDNR,1999).

Regarding the high rate of increasing population and of the extension of urban and industrial activities around Zayande-rood river, it is vital to anticipate the virtual effects of such activities in order not to encounter with catastrophic reactions of nature. The main steps to fulfill this mission are, firstly, perpetual monitoring of water and sediment quality of the river along its route and, secondly, recognizing the main sources of pollution together with their compositional properties (Kalbasi, and Mousavi,1995; Kalbasi,1994).

Investigations conducted on Zayande-rood river are mainly confined to the assessment of spatial and temporal variation of chemical, physical, and biological indicators of water and sediment quality. The main objective of this paper is to present and discuss the essential findings of these investigations in the following fields: 1- quality monitoring of water and sediment in space and time; 2- recognition of actual and potential sources of Zayande-rood river contamination. The specific objectives of this paper are the following: 1- to assess chemical, physical, and biological properties of point-source pollutants; 2- to assess water quality indicators in river water; 3- comparison of water quality indicators of Iran with global standards; 4- to assess the chemical forms of heavy metals in riverbed sediments in order to know the degree of sediment contamination.

Materials and Methods

In most investigations, sampling of polluting sources and river water were conducted along the Zayande-rood from Zobahan Dam to Gavkhooni Swamp. The main potentially polluting sources of the Zayande-rood river were: Simin Factory, Islam-Abad Power Plant, Polyackril Factory, Zohreh Manufacture, Marghab Manufacture, South Isfahan Refinery, and drainage water of Zarinshahr, Segzi, and Shahkaram(Abolghasemi,1999; Isfahan provience organization of environmental conservation; Razeghi,1985). Sampling from river water was performed alonge the river (Figure, 1), and in time intervals of 3 (Kalbasi,1994) and 7 (Kalbasi;Mousavi.1995) years. The sampling stations along the river are: Morgan Bridge, Kaleh Bridge, Zarinshahr Bridge, Nekoo-Abad Dam, Baba-Mahmood Bridge, Vahid Bridge, Bozoorgmehr Bridge, Ziar Bridge, Shah-Karam, Ejhieh Bridge, Farfan, Eshkahloran, Varzaneh Bridge, Gavkhooni Swamp.

The following properties were measured in the polluting sources: dissolvable oxygen; biological oxygen demand (BOD); chemical oxygen demand (COD); reaction (pH); total (TP), organic, and inorganic phosphorous; total (TN), organic, nitrate-, and nitrite-nitrogen; color; electrical conductivity (EC); total dissolved solids (TDS); total suspending solids (TSS); and Temperature. In the river water samples the following characteristics were measured: temperature, TDS, pH, EC, TN, TP, Na, Ca, Mg, K, Cl, Cd, Fe, Ni, Pb, bicarbonate, and sulfate.

Total and soluble concentration of some heavy metals including Pb, Cd, Cr, Co, Ni, Cu, Zn, Fe, Mn, and Ag were also determined in the polluting sources and in riverbed sediments. In addition, the various chemical forms of these metals, including soluble, exchangeable, carbonate, with organic materials, with Fe and Mn oxides, and residual forms, were identified in sediments through successive extraction method.
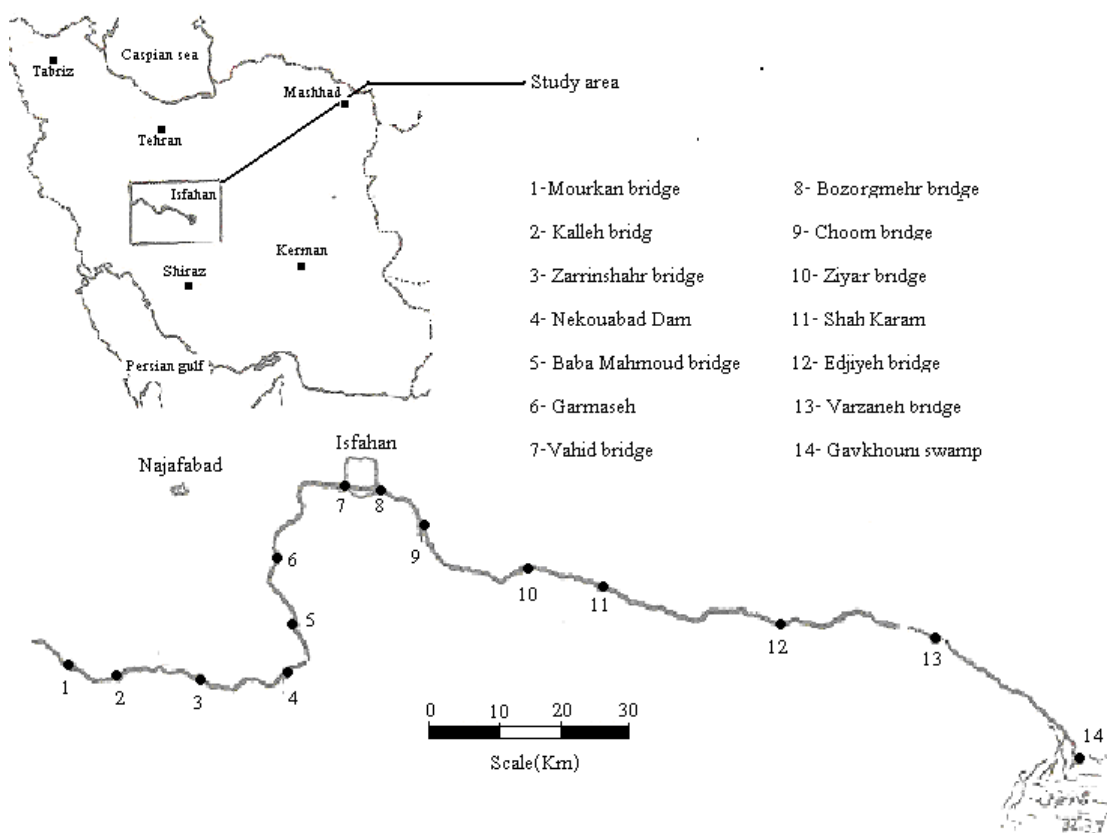

Figure 1: Location of sampling stations along Zayande-rood river.

Results and Discussion

1- Point-pollutant Sources

Selected properties of point-source pollutants together with daily average volume of each source are presented in table 1. Threshold values based on accepted standards of Iran are contained in the table; Values above threshold levels are marked in bold font. One of the most important factor which mainly controls the amount of pollutant entrance to the river

Sources	Mean swage flow (m³d⁻¹)	EC (dSm⁻¹)	cl⁻ (mgL⁻¹)	NO (mgL⁻¹)	NO₃⁻ (mgL⁻¹)	NO₂⁻ (mgL⁻¹)	NH₃ (mgL⁻¹)	N_T (mgL⁻¹)	P_I (mgL⁻¹)	P_O (mgL⁻¹)	P_T (mgL⁻¹)	TSS (mgL⁻¹)	TDS (mgL⁻¹)	COD (mgL⁻¹)	BOD (mgL⁻¹)	pH	Temp. (°C)	Disolved Oxygen (mgL⁻¹)
Zarin-shahr Drainage	-	-	-	۵.۳	۴.۸	۷	**۸.۲**	۱۳.۵	۰.۸	۳.۲	**۴.۰**	۲۵	۳۱۱۰	۴۰	۱۵	۸.۲	۷.۹	**۴.۲**
Polyackril	**۳۰۰۰**	-	-	-	-	-	-	-	۲.۰	-	**۱۵.۰**	**۳۱۶۰**	۲۷۲	**۱۳۸**	۷	-	۲۳.۸	**۲.۶**
Islam-Abad Power Plant	**۳۰۰۰**	-	-	۲۱.۸	۵.۵	-	**۵.۲**	۲۷.۰	۰.۲۸	۳.۳	۰.۶	**۱۴۰۰**	۷۴۶	۸۰	۴۵	**۹.۰**	۲۸.۵	**۲.۶**
Simin Manufacture	**۳۲۰۰**	-	-	۳۰.۰	۲.۱	-	**۱۱.۰**	۴۱.۰	۰.۶	۱.۴	**۲.۰**	۲۱	۴۷۷۶	**۵۸۰**	**۱۷۸**	۷.۲	۲۶.۵	۰.۶
Zohreh MAnufacture	**۸۰**	-	-	۴.۵	۶.۳	-	۰	۴.۵	۰.۱	۰.۵	۰.۶	۲۷	۷۳۰	**۲۸۴**	**۱۱۰**	۶.۸	۹.۰	**۴.۷**
South Refinery	**۱۲۰۰۰۰**	-	-	۸.۰	۱.۲	-	**۳۳.۰**	۴۱.۰	۳.۱	۴.۴	**۷.۵**	۱۱۵	۹۳۴	**۵۳۵**	**۱۵۷**	۷.۹	۱۷.۵	۱.۸
Marghab Manufacture	**۲۰**	-	-	۴۵.۵	۴.۸	-	**۴۹.۵**	-	۲.۱	۱.۲	**۳.۳**	**۲۶۰**	۲۶۹۸۵	**۱۲۶۷**	**۵۸۰**	**۳.۹**	۶.۵	**۲.۷**
Segzi Drainage	-	۲۷.۱	**۵.۳**	۲.۰	۸.۲	۲.۶	**۱۳.۵**	۴.۴	۵.۵	۱.۰	**۷.۶**	**۱۰۱۰**	۲۰۷۶۰	**۶۶۰**	**۲۱۰**	۸.۲	۱۲.۰	**۴.۱**
Shah-Karam Drainage	-	۱۶۱۰	**۳۱۰**	۱۲.۰	۴.۵	۴.۰	**۲۲**	۳۴	۰.۸	۰.۵	**۱.۳**	۲۰	۱۲۵۰	**۲۶۰**	**۹۸**	۷.۵	۶.۹	**۵.۸**
Critical levels for industrial swage	-	-	۱	-	۵۰	۱۰	۲.۵	-	-	-	۱	۴۰	**	۱۰۰	۵۰	۶.۵ to ۸.۵	*	۲
Critical levels for urban swage	-	-	-	-	۵۰	۱۰	۲.۵	-	-	-	۱	۴۰	-	۳۰	۶۰	۶.۵ to ۸.۵	*	-

Table 1. Summary statistics of point-source pollutants and the critical levels (bold values are above the critical level).

* entering swage must not change the river water temperature more than 3 °C, within the range of 200m from entrance point.

** entering swage must not change the soluble material of river water more than 10%, within the range of 200m from entrance point

is the mean flow of swage. South Isfahan swage refinery, with the mean flow of 130000 m^3/day, has the highest flow among polluting sources.

The pH value of most point-source pollutants are within the accepted range; however, the reaction of Islam-Abad Power Plant and Marghab Manufacture are 4 and 9, respectively, which are outside of the standard range; high reaction of Islam-Abad Power Plant is related to the addition of calcium carbonate in the process of waste water refinement.

Table 1 demonstrates that pollutant concentration is above critical level (sometimes more than 50 times) in the majority of polluting sources. However, in order to evaluate the real effects of each pollutant, it is necessary to, not only consider the mean flow of each polluting source, but also the water quality variations along the river. This is what we deal with in the next sections.

Heavy metals concentrations in waste and drainage water are presented in table 2. All these values are below the critical levels presented by Environmental Organization of Iran. These values then compared with the standards of more conservative countries. This comparison shows that Pb concentration of Segzi drainage, Poliackril, Simin and Zohreh manufactures and Cd concentration of Simin Manufacture are above the critical level of Jordan standards. Moreover, Ni concentration of Simin Manufacture is very close to the critical level. It is important to note that the low levels heavy metals in water together with the instrumental difficulty of measuring of the metals in very low concentrations, necessitates the study of heavy metals, both in suspended solids and riverbed sediments. For instance, Yilmazer and Yaman (1999) showed that heavy metal concentrations in Ceyhan river are far below these values in suspended particles. The study revealed that almost 100 percent Mn, Cu, Ni, Cd, Cr, Co, are held in suspended solids. The contamination state of riverbed sediments of Zayande-rood river is presented in next sections.

2- The quality of river water

The variations of temperature, total dissolved solids(TDS), reaction(pH), electrical conductivity(EC), total Nitrogen and phosphorous, sodium, sodium, calcium, potassium. Cholor, Bicarbonate, Sulphate, Cadmium, Iron, Nickle and lead are shown in table 2 (Isfahan province organization of environmental conservation, 1987-1997).

Table 2. Summary statistics of heavy metals (ppm) in point-source pollutant (bold values are above the critical levels of Jordan).

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Sources	Pb	Cd	Cu	Zn	Cr	Co	Fe	Mn	Ni	Ag
Polyackril	۰.۰۸	۰.۰۱	۰.۰۲	۰.۷۴	۰.۰۲	۰.۰۳	۰.۳۵	۰.۰۶	۰.۰۴	۰.۰۱
Islam-Abad Power Plant	۰.۰۴	۰.۰۱	۰.۰۸	۰.۰۳	۰.۰۱	۰.۰۲	۰.۳۹	۰.۱۱	۰.۰۴	۰.۰۱
Simin Manufacture	۰.۰۹	۰.۰۲	۰.۰۲	۰.۰۱	۰.۰۲	۰.۰۴	۰.۰۹	۰.۰۵	۰.۰۸*	۰.۰۱
Zohreh MAnufacture	۰.۰۳	< d.l.	۰.۰۱	< d.l.	< d.l.	۰.۰۱	۰.۰۵	۰.۰۷	۰.۰۲	۰.۰۱
South Refinery	۰.۱۰	۰.۰۱	۰.۱۱	۰.۱۲	۰.۰۲	۰.۰۲	۰.۵۲	۰.۰۹	۰.۰۳	۰.۰۱
Segzi Drainage	۰.۰۹	۰.۰۱	۰.۰۳	۰.۰۱	۰.۰۱	۰.۰۶	۰.۱۲	۰.۰۴	۰.۰۸	< d.l.

* very close to the critical level of Jordan

<d.l.: lower than detection limit of instrument

River water temperature depending on the temperature of the environment, increases along the river just before South sewage refinery. After introduction of sewage, having temperature of 17.5^{0C}, river water temperature increases dramatically. This increase is

dependent of environment temperature; because after South sewage refinery temperature decreases again.

Along the river, from Sharif abad Bridge to Gavkhouni swamp there is an increasing trend in water temperature, because of the changing environment and decrease of the river flow.
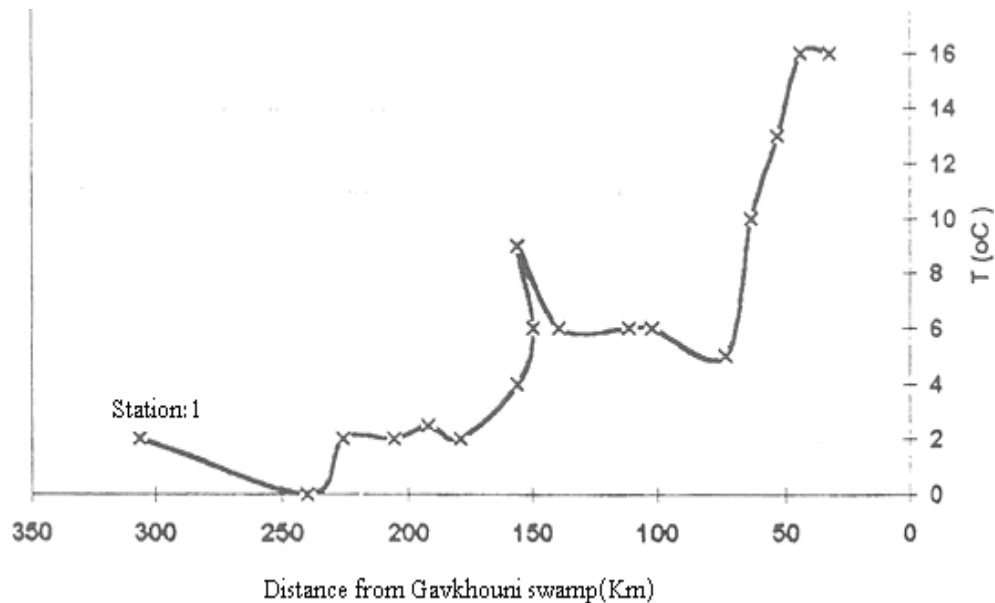

Figure 2: Variations of temperature along the Zayande-rood river

Along the river to Sharif abad Bridge, TDS and EC do not have significant variations, but after the Bridge, introduction of saline drainage water from farmlands, EC and TDS increase sharply(figures 3,4). Based on table 1, EC and TDS drainage water of Shah karm and Segzi are high. Uppermost parts of river are not saline and

The variations of river flow is not high too, as a result, increasing of EC from there to Isfahan, and a little next toit, is not high. Where as the high salinity of the lands in lowermost parts of river, including Roudasht and Northern Baraan is the main source of river salinity in this parts.

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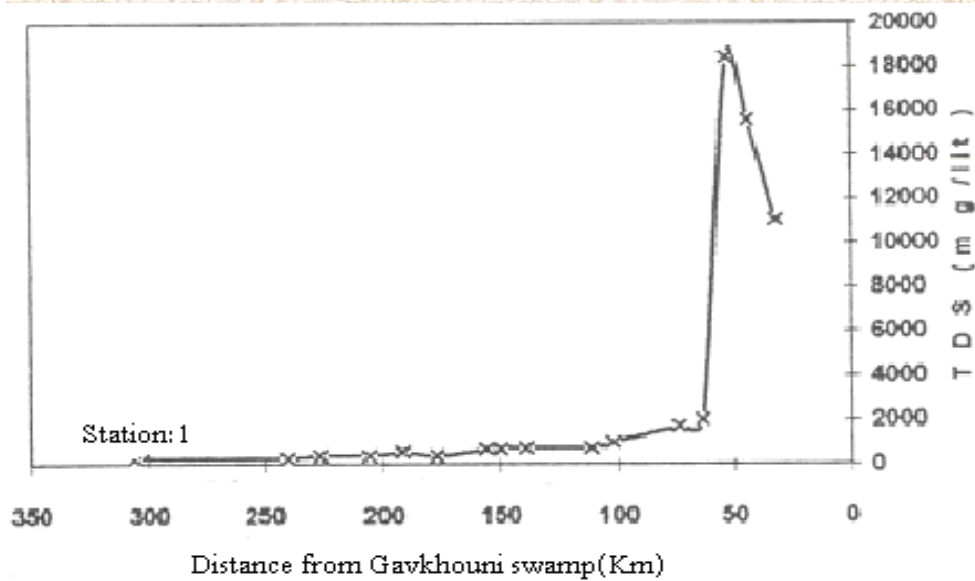February 18-19, 2015 Birjand, Iran

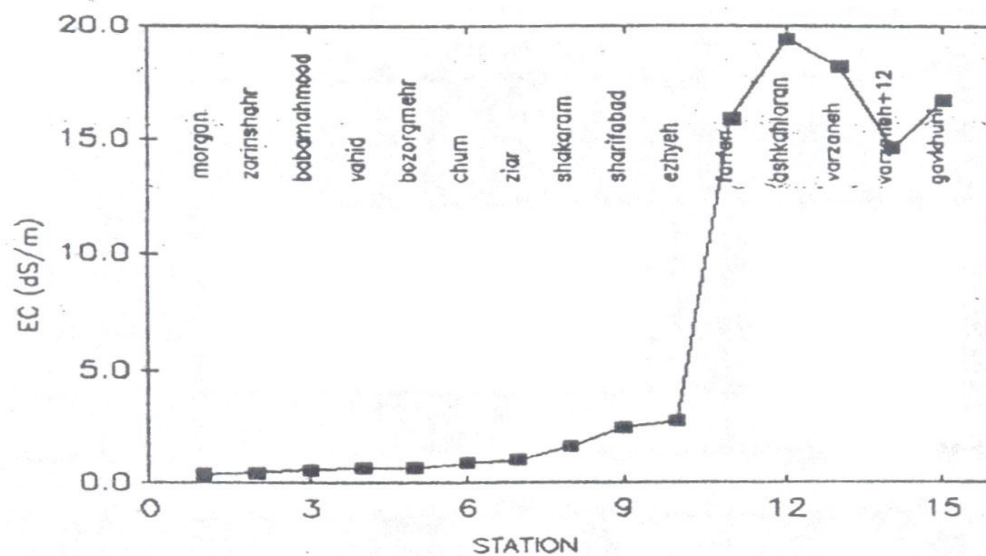Figure 3: Variations of TDS along the Zayande-rood river

Figure 4: Variations of EC along the Zayande-rood river

Variations of Nitrogen and phosphorous have similar trends. Before South sewage refinery The Phosphorous concentration is low, but after introduction of waste water at

Choom Bridge, this value increase. Next to the Choom Bridge, Phosphorous concentration starts to decrease and reaches to initial concentration. This further reduction can be attributed to high fixing capability of suspended materials (Fig 5). Drastic increase in nitrogen is related to introduction of sewage too. There is small increase in Nitrogen concentration after Edjiyeh Bridge, due to introduction drainage water of farmlands and no potential possibility for the chemical fixation of nitrogen compounds.
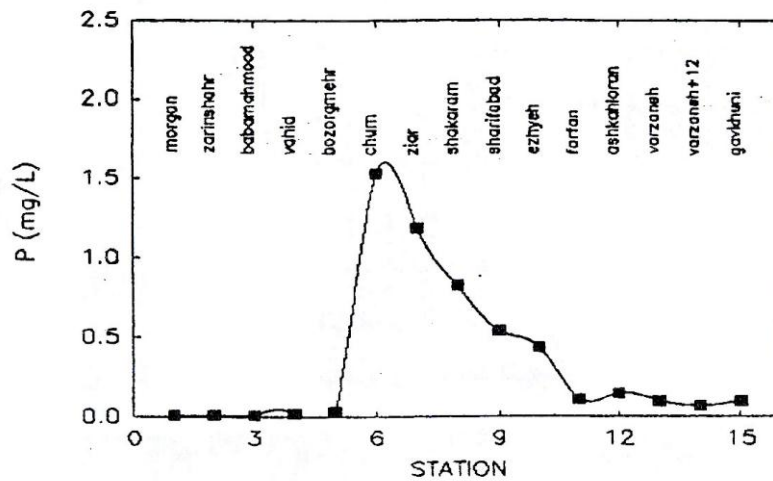

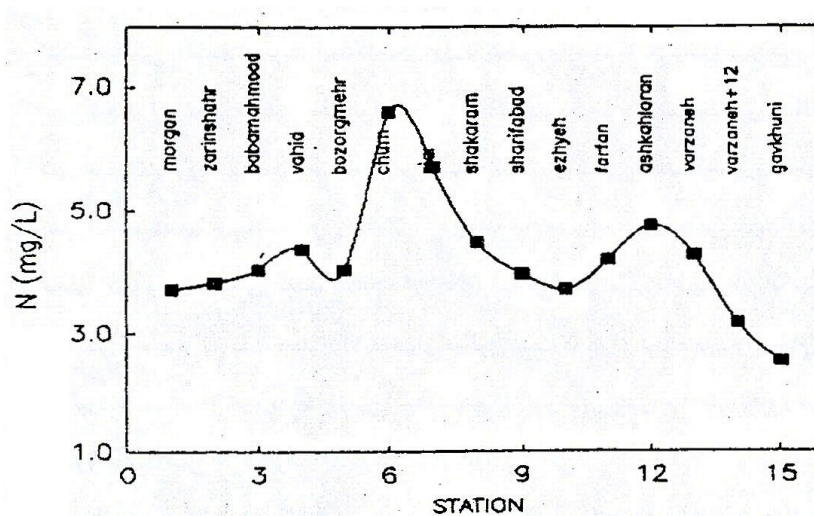Figure 5: Phosphorous Variations along the Zayande-rood river

Figure 6:Nitrogen Variations of along the Zayande-rood river

The overall trend of cations and anions variations, except Bicarbonate, are similar to EC(Figs 7,8). Concentrations of cations and anions increase gradually to Ziyar Bridge; and then increase severely to Varzaneh Bridge. The main factor including this trend is injection of saline drainage water of farmlands to river. It is necessary to confirm that industrial sewages (point source pollutant) do not have effect on the concentration of cations, anions and Ec value.

As mentioned before, Calcium and Bicarbonate have similar behavior. Bicarbonate do not have high variations along river, because of low concentration of in farmlands drainage water. Concentration of Calcium and Bicarbonate before Ziyar Bridge in comparison with other cations and anions is more and after the Bridge this discrepancy diminished. Reduction of CO_2 pressure due to decrease of biological activity; is the main cause of this behavior. K concentration in comparison with Ca, Mg and Na is low.
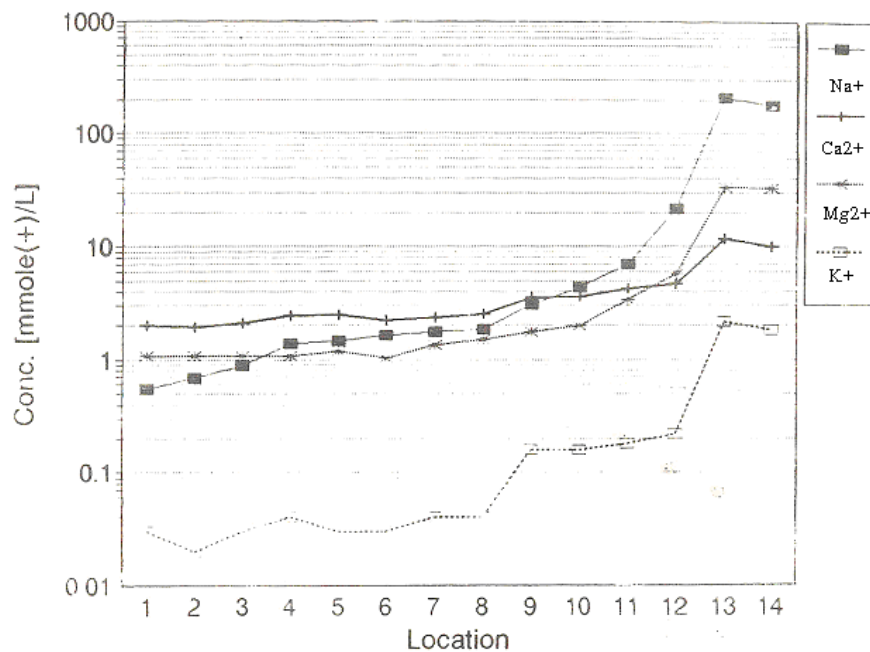

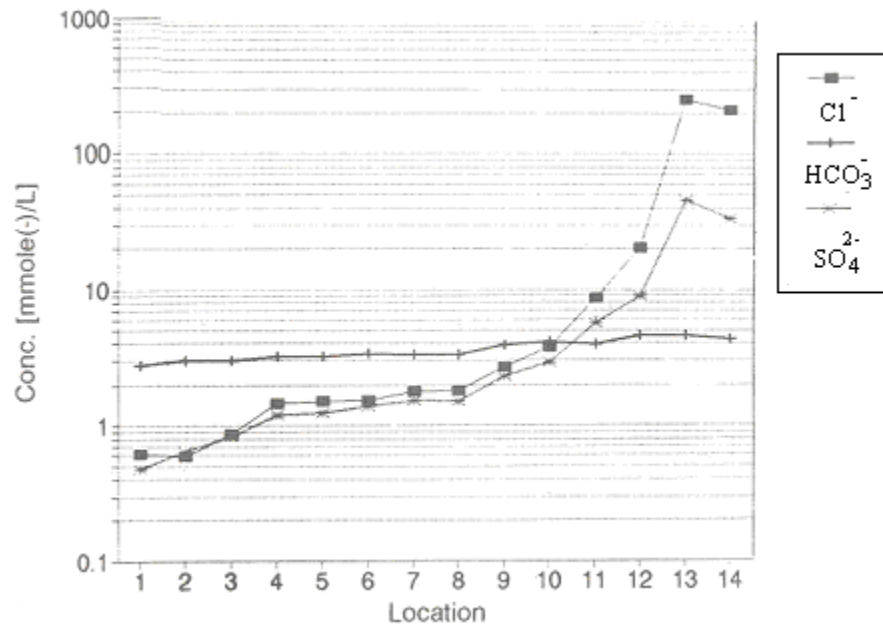Figure 7: Variations of cations along the Zayande-rood river

Figure 8: Variations of anions along the Zayande-rood river

Variations of heavy metals along river are visualized in figure 9. Pb, Ni, and Cd have similar trend, in a way that they have low concentrations and low variations before Edjiyeh Bridge and next to the Bridge this figures increase.

Industrial contaminant between Edjiyeh and Varzaneh Bridges is the main determinant of this trend. In Gavkhouni swamp, concentration of these element are reduced, probably due to dilution.

Iron has different trend in comparison with three aforementioned elements. While concentration of this element decrease from uppermost parts of river to Edjiyeh Bridge, but is more than other elements; the injection of sewage of Zob Ahan (steel factory) and Military industrial factories next to Zarrin Shahr Bridge is the main reason of this trend. Next to Varzaneh Bridge, concentration of Iron, like other elements, increases(Kalbas,1994).
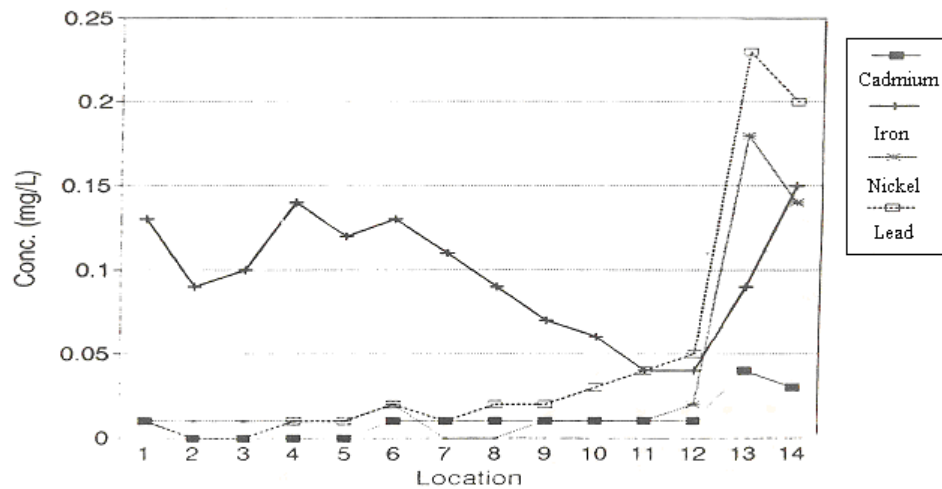
Figure 9: Variations of heavy metals along the Zayande-rood river

3- Riverbed sediments

Total concentration of heavy metals and physical and chemical properties of sediments, including Ec, %Caco$_3$, %OM, silt and clay percentage are shown in table 3.

The results indicate that total concentration of heavy metals in sediments have high spatial variability. The trend of these variations depend on parent materials, pollutant sources, texture of sediment, carbonate percentage, %OM and manganese and Iron oxides goes without saying that the role and importance of these parameters are different for each of these elements. Variation of Fe and Mg are more depend on parent materials and are less affected by pollutant sources. Results of successive extraction. Showed that the exchangeable and soluble forms of Pb, Cd, Cr, Co and Ni have high contribution in the total amount of these elements polluting hazard, this potentially exist in sediments too(Sabzehghabaeim,1996).

Conclusion:

The results of point-source pollutant studies, showed that concentration of pollutant materials excluding heavy metals are above permissible limits. However, due to the low flow, they have had low effects on water quality in period of investigation, but, the long term effects must be taken into account. Among point-source pollutant, South Sewage

Sources	CaCO₃ (%)	Organic Matter (%)	CEC (meq/100gr)	Sand (%)	Silt (%)	Clay (%)	Pb	Cd	Cu	Zn	Cr	Co	Fe	Mn	Ni	Ag
Morgan Bridbe	۱۰.۵	۰.۱۸	۵.۶	۹۴.۶	۰.۶	۴.۸	۲۸	۱.۵	۴۱	۴۶	۴۲	۱۹	۳۸۰۰۰	۷۵۰	۴۵	۴.۰
After Poliackril Outlet	۱۹.۵	۰.۳۹	۶.۴	۹۵.۱	۲.۲	۲.۸	۲۴	۱.۵	۲۱	۳۳	۲۹	۱۵	۲۴۵۵۰	۶۰۰	۲۵	۲.۰
After Islam-Abad Power Plant	۴۸.۷	۰.۸۹	۸.۵	۹۵.۵	۲۵.۰	۵.۵	۴۳	۲.۰	۳۸	۸۸	۲۶	۱۷	۱۶۰۳۰	۴۰۰	۶۰	۲.۰
Bozorgmehr Bridge	۲۱.۷	۱.۵۰	۱۳.۶	۶۸.۷	۲۸.۰	۳.۸	۵۲	۱.۵	۳۱	۸۰	۳۱	۱۹	۲۸۷۸۰	۶۰۰	۵۴	۲.۰
After Zohreh Manufacture outlet	۲۵.۷	۲.۶۹	۱۴.۶	۵۷.۷	۲۸.۰	۱۴.۲	۴۱	۲.۰	۶۱	۱۰۲	۵۲	۱۸	۲۴۵۰۰	۴۲۵	۵۵	۲.۵
After South Refinery	۲۴.۵	۱.۳۲	۶.۹	۸۴.۷	۱۱.۸	۳.۵	۳۷	۱.۵	۴۱	۵۸	۳۳	۱۴	۲۰۰۵۰	۳۵۰	۳۶	۲.۵
Choom Bridge	۵۱.۵	۱.۳۲	۹.۵	۱۵.۲	۱۹.۶	۲۵.۳	۴۷	۲.۰	۲۳	۵۳	۳۰	۲۲	۱۷۵۰۰	۴۲۵	۵۳	۲.۰
After Segzi Drainage	۲۸	۰.۱۸	۳.۹	۹۲.۴	۰.۸	۶.۸	۲۳	۲.۰	۱۲	۲۴	۳۳	۱۴	۱۵۹۰۰	۳۷۵	۲۹	۲.۵
Gavkhooni Swamp	۳۰.۲	۰.۴۶	۱۰.۶	۸۸.۶	۲.۱	۹.۳	۲۴	۲.۰	۱۳	۲۶	۳۲	۱۴	۱۴۱۸۰	۴۰۰	۳۱	۲.۰

Table 3. Total concentration of heavy metals (ppm) and selected properties of riverbed sediments along Zayande-rood river.

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Refinery, due to high concentration of pollutants and high polluting potential, takes special attention and must be considered in ecological planning priorities. The potential hazard of this source is revealed when we consider the low concentration of some pollutants before this source; for example the amount of Nitrogen and Phosphorous show this increasing trend. The importance of South Sewage Refinery must not ignore us from other polluting sources. It is better to know that the present study, has only surveyed the variations of pollutants in space and time and has not surveyed direct effect of them on each ecosystem components.

Because of high correlation between salinity, amount of cations, anions and TDS, they show similar trends. These properties increase gradually towards east of Isfahan (Baraan and Roodasht), and then, due to introduction of saline drainage water, increase sharply. Increasing concentration of Nitrogen in lowermost parts of river, confirms the necessity of careful application of chemical fertilizers, pesticides, and herbicides which is vital for sustainable agriculture .

Concentration of heavy metals explicitly increase towards the end of the river; however, the absolute concentrations are below the critical limits. It is necessary to mention that the low concentration of heavy metal is due to low solubility of their compounds, but the total amount of them is high in environment. Concentration of Pb, Co, Ni, Cr, and Cd are high in sediments and the potential polluting power of these heavy metals must be considered.

Zayande-rood river as a vital artery of surrounding cities– especially Isfahan – has been faced by polluting hazard in recent decades, because of rapid population growth, establish of industrial factories around the river. Although this activities have unavoidable effect on river system, these unwished effects can be discounted by suitable planning.

Many countries have been envisaged by such problems; but a few of them could have solved or minimized these inevitable effects. In this regard, the historical current of ion of Micciccippi River pollution is worth of mentioning. Pollution of this river in 1960_S had reached to the degree that aquifers' life had been completely disordered. Public concerns have made the federal government to establish Environmental Protection Agency . After 25 years of assay and efforts, the river pollution reduced considerably. The application of sustainable development principles, such as improving refinery systems of municipal and industrial sewages, management of sewages of husbandry in river margins, and suitable use of chemical fertilizers, pesticides and herbicides were the main factors for the aggradations of this environment. Investigations of Louisiana University showed that the heath of fish is in a good condition; they reported that only %5 of 100 kinds of poisonous substances has been detected in fish tissues; this %5 is also under standard limits. Amount of coli-forms, as an indicator of polluting by human sewages considerably reduced (LaDNR,1999). It is necessary for us to use these experts for remediation of contaminated rivers of our country such as Zayande-Rood.

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