

STRATEGIC PLANNING AND MANAGEMENT OF WATER RESOURCES QUALITY BY DETERMINING THE TRENDS OF HUMAN IMPACTS IN BASINS WITH NON-AVAILABLE WATER QUALITY DATA

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ABSTRACT

Surface water quality is directly influenced by sources of pollution created by human activities as well as natural phenomena within a basin. Human induced impacts are usually of more concern in water resources quality management because unlike many natural causes, they are capable of being managed and controlled.

Developing countries and countries in transition are striving to manage their water resources more effectively. In such countries on one hand, human activities mainly consisting of industrial and agricultural development followed by demography changes skyrocket causing accelerating external drivers on the quality of water resources. On the other hand however, water quality monitoring systems, as a tool for detecting trends of pollution variations are usually unavailable.

In this study regarding the purpose of strategic planning and management of basin-level water resources quality, the potential loads of Nitrogen, Phosphorus and BOD pollutants are applied as indicators to determine trends of pollution sources within a basin in the north of Iran where agricultural and industrial activities are practiced in a great extent adjacent to the surface water resources. The approach developed in this study is applied to determine trends of proposed indicators in order to provide information necessary for decision making upon the optimum water resources pollution control strategies within the studied area.

1 INTRODUCTION

Fresh water resources with appropriate quality are scarce. Therefore it is necessary to bring into consideration water quality issues in quantitative allocation-demand management of water resources. Water consumption results in decreased flow followed by water quality degradation at the downstream of the intake point. This phenomenon,

limiting downstream water consumption, emphasizes the significance of water quality considerations within the strategic planning and management of water resources development.

Present views on Integrated Water Resources Management (IWRM) roots back to the international conference on Water and Environment (Dublin, 1992) at which sustainable development policies of water consumption and action plans for the Rio Conference were identified. As an outcome, the principles agreed on in both conferences (including the protection of aquatic ecosystems) were thereafter considered in international water resources management negotiations. Four international meeting were held regarding water issues from 2000 to 2009 in which environmental considerations were emphasized as a basic requirement of IWRM. In the fifth meeting (Turkey, 2009) different water-related issues were investigated within the framework of a DPSIR model supporting the integrated view.

The water quality management plan of Kyung-an River in Korea is developed based on potential pollution load estimations (Jin-Ho et al. 2003), water quality measurements and discharge rates of different tributaries. A non-point pollution source rapid assessment approach is developed by HUANG Ren et al. (2009) for the Haihe river basin in China which suffers from water quality data deficiency based on an Information Statistics (IS) model in order to assess the impact of agricultural return flow. In this model agricultural pollution load, total share of different pollution sources and finally runoff volume are estimated as effective factors in water resources pollution resulted from agricultural activities.

2 STUDY AREA

Sefidrood Basin, one of the seven sub-basins of the Caspian Sea in Iran, is located at the intersection of Alborz and Zagross Mountain Ranges. The area of this basin is 59196 km² of which 76.4 percent is covered with mountains. The main river in the basin is Qezelozan River which is named Sefidrood River after it joins Shahrood River from east. Mean precipitation of the basin is about 410 mm and the maximum mean annual discharge in hydrometric stations is about 130 m³/sec at Roodbar Station. There are six reservoirs in the basin the largest of which is Sefidrood with the total capacity of 1765 MCM. The location of Sefidrood Basin is presented in Figure 1.

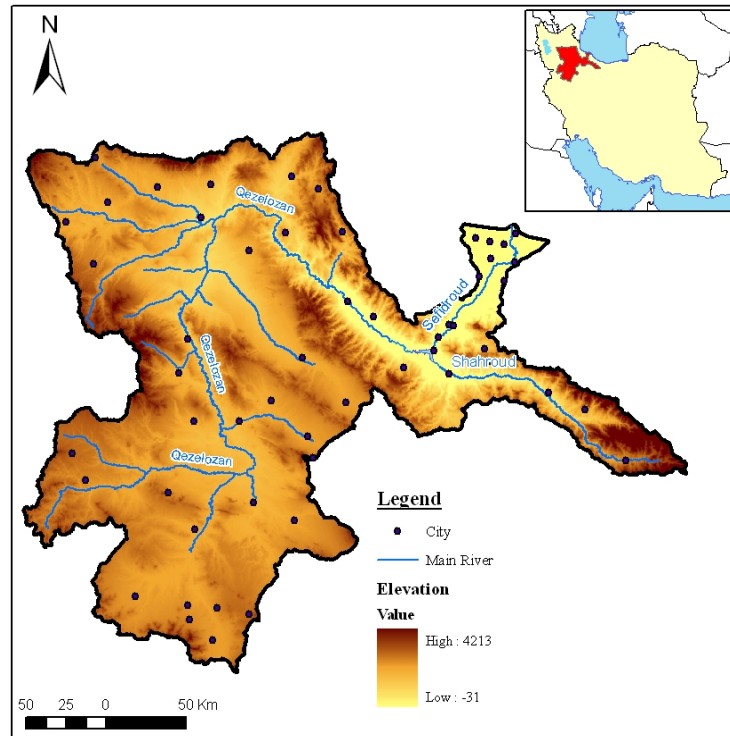


Figure 1. Location of Sefidrood Basin in Iran

2.1 Major Pollution Sources of Sefidrood Basin

The major sources of pollution in the basin include: urban and rural sewerage and industrial wastewater regarding point sources and agricultural return flows as well as forest and rangeland runoff regarding non-point sources.

Based on the censuses of year 2006, the population of Sefidrood basin is 2087883 of which 55 percent lives in rural areas. There are 3284 industrial units within the basin. The major landuse includes rangelands that cover 53 percent of the basin followed by agricultural lands, with a 42 percent cover. The distribution of pollution point sources are shown in Figure 2.

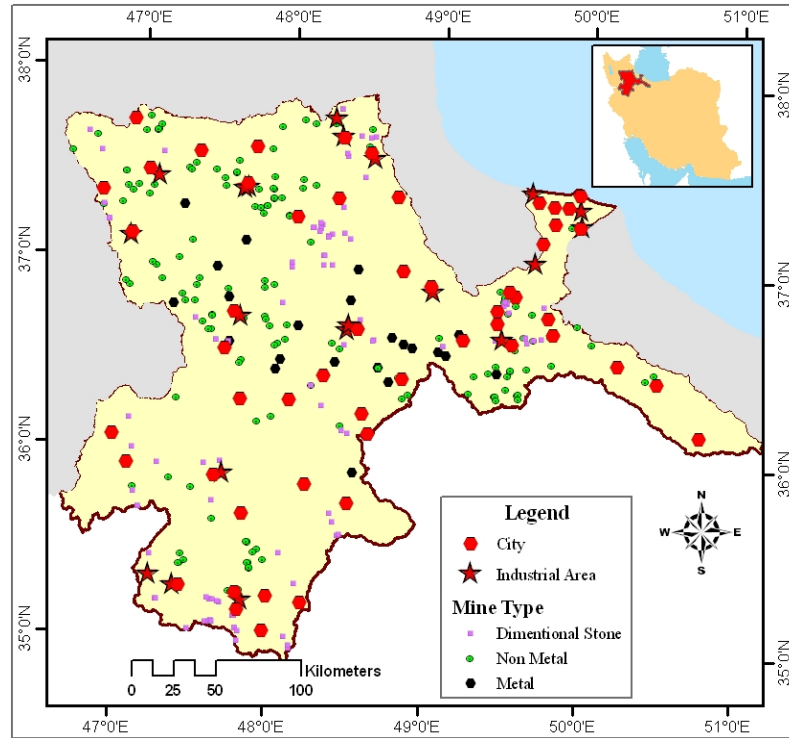


Figure 2. Spatial distribution of different sources of pollution in Sefidrood Basin

3 STUDY APPROACH

3.1 Potential Load Estimation

Regarding the large-scale of this study, aimed to identify basin-level water resources development strategies, only major pollution sources are considered. Population centers are determined based on the locations of different urban and rural areas available as a GIS information layer. The factors of water consumption and wastewater production per capita are determined based on previous studies carried out within the basin (Jamab, 2005). The factors are applied to estimate the sewage volume resulted at each population center (rural and urban areas). Load factors of Nitrogen, Phosphorous and BOD contaminants are then applied to the estimated sewage volume to obtain the layers of potential sewage pollution load distribution.

Industrial wastewater is estimated based on the wastewater volume of different industrial units within the basin provided by the Ministry of Industry and Mining (2006). The distribution of industrial potential pollution load is then estimated by applying the appropriate load factors of each group of pollutant industries.

Landuse export coefficients of Nitrogen and Phosphorus, presented in Table 1, are estimated based on previous studies within the country (A.G. Roozbahani, 2006) with respect to the type of landuse (irrigated farming, dry farming, rangeland, bare land and

forest) as well as rainfall conditions of Sefidrood Basin.

Table 1. Export coefficients of different landuse types in Sefidrood Basin (kg/km².year)*

<i>Landuse Type</i>	<i>Irrigated Farming</i>	<i>Dry Farming</i>	<i>Rangeland</i>	<i>Forest</i>	<i>Bareland</i>
Total Nitrogen	870	120	780	260	260
Total Phosphorous	150	40	70	30	20

*IWRM update studies, MGCE

3.2 Integration of Potential Load Layers

Maps of potential load distribution are developed by integrating layers of similar pollution parameters obtained for different sources (sanitary wastewater, industry and landuse) in GIS. In other words, the potential load value of each pixel of the final layer of a certain pollution parameter is obtained by the summation of load values of that parameter for different sources in that pixel.

Finally, in order to develop a map of general potential of water resources pollution within the basin, different criteria is defined to classify each pollution parameter. The criteria for nitrogen and phosphorous classification were defined based on the amount of these parameters produced by a unit area of irrigated farming. The criterion for BOD classification was however defined based on the average value of per capita BOD production. Previous research (A.G. Roozbahani, 2006) in Talesh- Talab Anzali Basin (TTAB, a high rainfall region adjacent to Sefidrood Basin where condensed agriculture is practiced) has given the factor 20 kg/hectar.year for Nitrogen and 3.5 kg/hectar.year for Phosphorous. According to the fact that rainfall is high in TTAB (1019 mm) and the major cropping pattern includes rice which corresponds to high consumption of fertilizer, the zones of load values above 75% of the obtained factors in TTAB are considered high potential for producing Nitrogen and Phosphorus. The average per capita BOD production is considered 50 gr/capita.day, so if the total BOD load divided by population in each region is less than the mentioned value, one can conclude that that specific region has a low potential of BOD production. Adversely, larger values of estimated BOD production per capita in a region indicate industrial development. The classification of potential pollution loads of different parameters are presented in Table 2.

Table 2. Classification of different potential pollution loads

<i>Criteria</i>	<i>Total Nitrogen (ton/km².year)</i>	<i>Total Phosphorous (ton/km².year)</i>	<i>Total BOD (ton/capita.year)</i>
High	More than 1500	More than 250	More than 75
Moderate	500 – 1500	50- 250	50 – 75
Low	Less than 500	Less than 50	Less than 50

The estimated potential loads of Nitrogen, Phosphorus and BOD are presented separately in Figures 3 through 5. The figures show a rather lumped BOD distribution in comparison to other parameters due to the fact that only point sources contribute to BOD production.

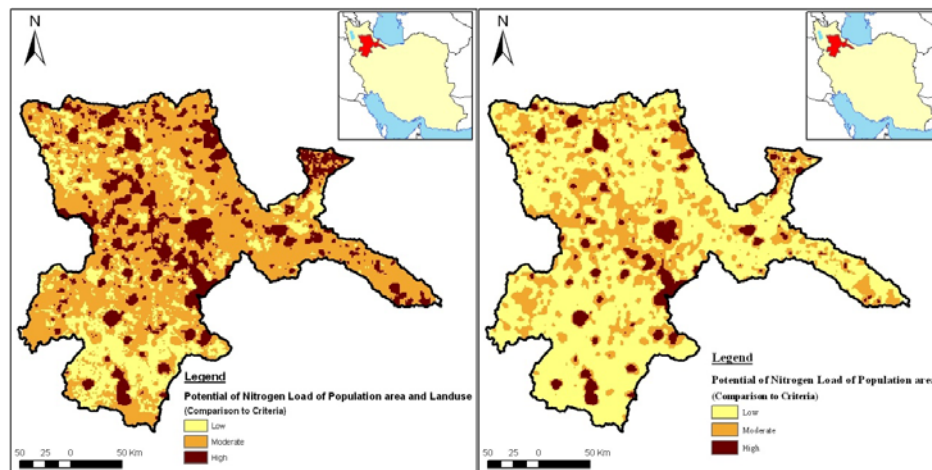


Figure 3. Distribution of estimated Nitrogen load classes resulted from sanitary wastewater and landuse

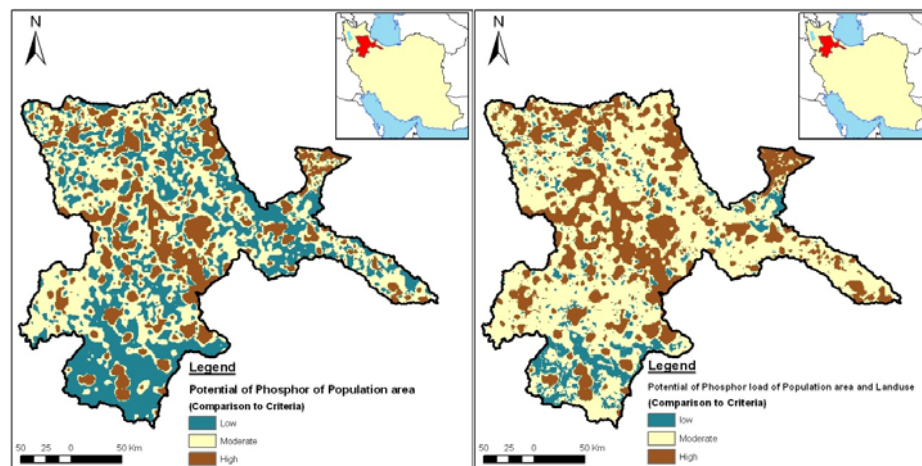


Figure 4. Distribution of estimated Phosphorus load classes resulted from sanitary wastewater and landuse

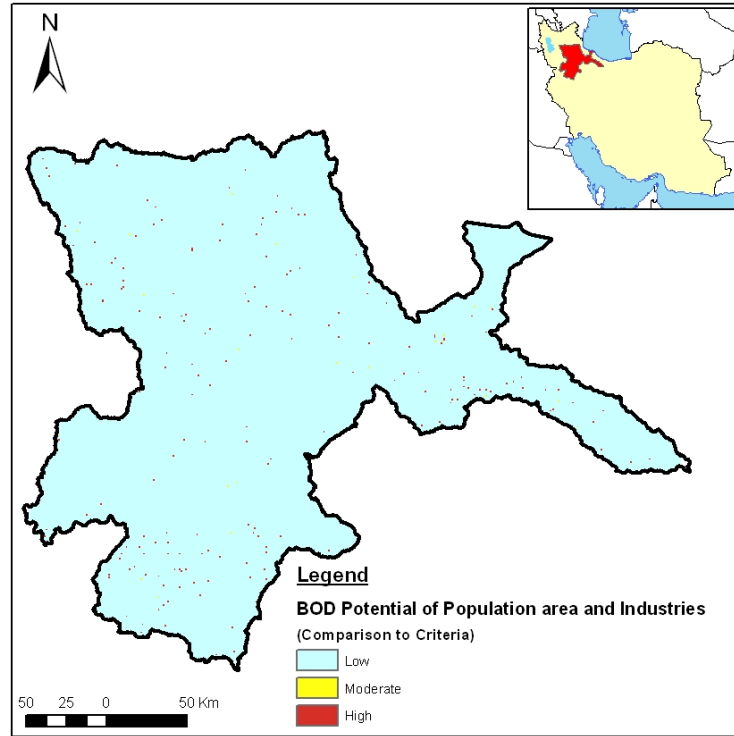


Figure 5. Distribution of estimated BOD load classes resulted from sanitary sewage and industrial wastewater

3.3 Integration of Developed Potential Load Layers

Based on the classes determined in Table 2, in order to estimated the overall pollution condition of each pixel, weights 1, 2 and 3 are given to classes "low", "moderate" and "high" for each parameter. The overall value of each pixel is then determined by the summation of weights of the different classes of pollution parameters. The final classification of the overall pollution potential is determined as in Table 3.

Table 3. Classification of overall potential pollution load

<i>Criteria</i>	<i>Criteria Weight</i>	<i>Overall Classification</i>
High	3	Summation of weights ≥ 6
Moderate	2	$3 < \text{Summation of weights} < 6$
Low	1	Summation of weights ≤ 3

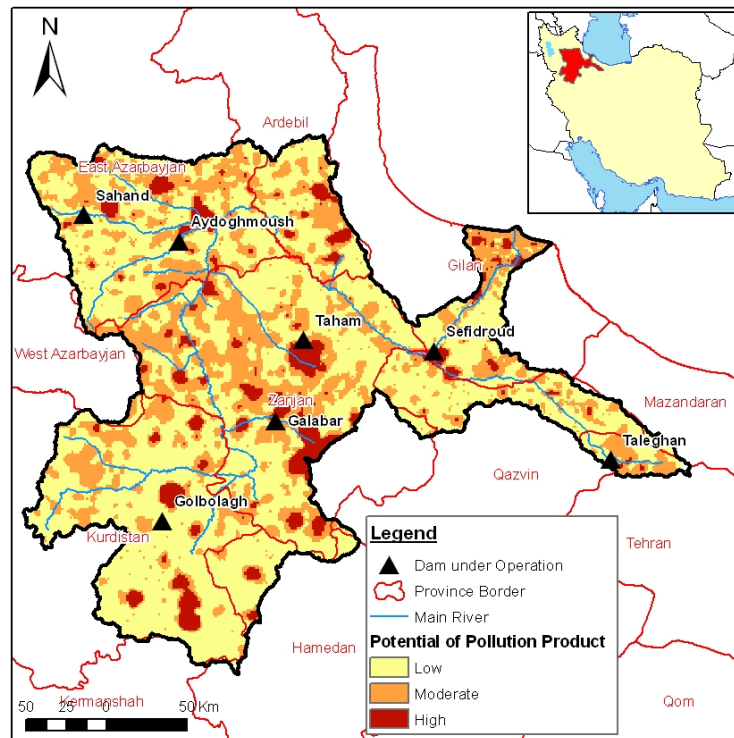


Figure 6. Potential pollution of water resources of Sefidrood Basin

The obtained results indicate that 7.4% of the basin is covered with zones of high potential pollution. Specifically, the upstream of Taham and Gelabar Reservoirs, having faced water quality problems regarding eutrophication already, are located within the zones of high pollution.

3.4 Pollution Trends

Figure 6 indicates that Sefidrood Basin overlaps with 11 provinces partially, the largest of which is Zanjān. Consequently, this basin faces numerous authorities and stakeholders in management and development of water resources. The potential pollution distribution map of water resources developed in this study provides a basis to determine the trend of water pollution within the basin from upstream to downstream as well as the share of each province in polluting the water resources. The pollution share of each parameter is shown in Table 4 for different provinces within the Sefidrood Basin. Results indicate that Zanjān, with over 40% pollution share of all parameters, has the major role in polluting water resources of the Basin. The next polluting provinces are Kurdistan and Azarbayjan-Sharghi regarding Nitrogen and Phosphorus and Gilan, located at the downstream, regarding BOD which is expectable due to the dense population of this region.

Table 4. Pollution shares of different provinces within Sefidrood Basin

Province	Pollution Load Share (%)		
	Nitrogen	Phosphorus	BOD
Zanjan	40.05	44.07	4601
Kurdestan	17.07	17.02	802
Azərbaycan Şərqi	16.09	17.02	608
Gilan	7.04	7.05	36.08
Ardebil	7.03	6.01	1.03
Ghazvin	5.08	3.08	0.05
Tehran	2.00	1.05	0.02
Hamedan	1.06	1.06	0.01
Azərbaycan Qərbi	0.05	0.04	0.00
Mazandaran	0.02	0.01	0.00
Kermanshah	0.00	0.00	0.00

In order to identify the national water resources development strategies regarding water quality, it is necessary to predict the temporal variations of water pollution in addition to their spatial distribution over the basin. Having outlined the 20-year development perspective of the country in the master political documents for the 2025 target, population growth and industrial developments are considered in different scenarios and the obtained pollution potential is studied throughout the basin. Agricultural development is not considered in any scenario because protection of natural landuse as well as modified agricultural techniques are stated in the master legislative documents of the basin rather than common development practices that result in additional pollution of water resources.

In the first scenario, identified as the least, the immigration rate is considered constant during the study period (2006 – 2025). In the second scenario however, identified as the most, immigration rate is considered from zero to 2.5 percent for urban areas as well as -2.5 to zero for rural areas. In the third scenario which is most possible, the immigration factor is considered less than the first scenario while the population growth rate is considered somewhere between the first and second. In addition to the three scenarios identified, one scenario is considered for industrial development.

The potential pollution load of different parameters are estimated at the 2025 target year in each scenario and the share of each province is determined as presented in Table 5. The potential pollution load of sewage is estimated assuming no additional wastewater treatment plants so that the impact of no wastewater treatment network development can be assessed in order to determine the action priorities in the pollution control strategy.

Table 5. The share of different provinces in water resources pollution of Sefidrood Basin

Province	Pollution Potential (2006) (ton/year)			Pollution Potential (2025) (ton/year)		
	<i>N</i>	<i>P</i>	<i>BOD</i>	<i>N</i>	<i>P</i>	<i>BOD</i>
Zanjan	16.996	8.592	869.862	18.302	9.482	974.246
Kurdestan	7.451	3.311	154.801	7.927	3.61	173.377
Azarbaijan-Sharghi	7.1	3.306	129.091	7.593	3.619	144.581
Gilan	3.102	1.434	693.956	3.303	1.567	777.231
Ardebil	3.069	1.168	24.225	3.235	1.275	27.132
Ghazvin	2.456	737	9.134	2.541	790	10.23
Tehran	831	281	3.038	869	305	3.402
Hamedan	669	300	2.476	703	323	2.774
Azarbaijan_Gharbi	227	76	874	240	83	979
Mazandaran	78	20	7	79	21	7
Kermanshah	7	1	5	7	1	5
Total	41.985	19.224	1887.468	44.798	2.075	2113.964

Based on the data given in Table 5, Nitrogen, Phosphorus and BOD will potentially increase about 6.7%, 9.6% and 12% respectively at year 2025 in comparison to 2006, if pollution is not controlled over the basin.

4 SUMMARY AND CONCLUSION

In this study a GIS-based approach was developed to provide a basis for the strategic planning and management of water resources quality in Sefidrood Basin which suffers from insufficient water quality data. In this approach, both spatial and temporal trends of different water resources pollution sources are detectable in order to determine the priority action plans as well as mid-term and long-term water pollution prevention and mitigation measures as well as the legal organizations and stakeholders responsible for implementing the plans. By the application of this method, master legislatives documents can also be assessed in respect to the pollution impacts of their social and economical development targets.

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