



Quality of River Water for Irrigation and Drinking Uses and Sources of Contamination in Upper Catchment Areas

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ABSTRACT

Aim This study aimed to evaluate river water quality for any use depends on its level of quality, which can be influenced by several factors.

Materials & Methods This study was conducted in Dinavar River, upper Kaekheh Basin, Iran, to evaluate water quality and the factors affecting its uses for irrigation and drinking use during 2017-2019. Seven river sites were selected along the river catchment and subjected to field measurement and sampling. Vegetation cover and river degradation were assessed in the field. Water samples and fresh sediment were collected from the selected sites. Samples were analyzed for various physio-chemical parameters such as pH, electrical conductivity, total dissolved solids, total hardness, cation (Na^+ , K^+ , Ca^{2+} , Mg^{2+}), anions (Cl^- , HCO_3^- , SO_4^{2-}), and sodium absorption ratio.

Findings Water quality analysis showed that the water samples from five sites in plain areas were suitable for both drinking and irrigation purposes, while water quality at two upper catchment sites was significantly ($p>0.05$) affected by urban wastewater. Moreover, it was found that the Dinavar River's degradation factors increased riverbank erosion, while land use/cover change in river catchment with pollutant sources strongly affected water quality. The main pollutant sources were urban wastewater, improper agricultural activities, land use/cover change, animal manure, rural swage, and local tourism impacts.

Conclusion Since river water is of great importance for irrigation, drinking, and environmental applications in semi-arid regions, it is necessary to take measures against the pollutant sources.

Keywords Bank Erosion; Jamishan Site; Total Hardness; Upper Catchment; Urban Wastewater

CITATION LINKS

[1] Diversification in measurement methods for ... [2] A framework for assessing river health in ... [3] Habitat and hydrology condition indices ... [4] Sustainability impact assessment tools for land ... [5] Prevention through policy: Urban ... [6] Runoff and sediment losses from 27 ... [7] Cover crop and tillage systems effect on soil ... [8] Passive sampling for spatial and temporal ... [9] Applied geomorphology ... [10] Pedogenesis and clay mineralogical investigation ... [11] Predicting N, P, K and organic carbon ... [12] Assessment of stream water quality ... [13] Integrated tool for risk assessment ... [14] Vertical distribution of trace elements ... [15] Phosphorus storage dynamics ... [16] Assessment of groundwater quality ... [17] Erodibility and sedimentation potential ... [18] Biological index and pollution assessment ... [19] Occurrence and contamination of heavy ... [20] Safe sanitation in low economic development ... [21] Scheduling single irrigation for aainfed ... [22] Improving water productivity ... [23] Standard Methods for the Examination ... [24] Guidelines for laboratory analysis of soil ... [25] Applied hydrology ... [26] The gapon coefficient and the exchangeable ... [27] Diagnosis and improvement of saline ... [28] Groundwater ... [29] Drip irrigation (principle ... [30] Investigation of non-submerged vegetation ... [31] Deactivation of wastewater-derived ... [32] Factors affecting the occurrence ... [33] Modeling investigation of low salinity ... [34] Increasing chloride in rivers of the conterminous ... [35] Predicting total phosphorus levels as ... [36] Environmental and health risks associated ... [37] Evaluation of river discharges and water ... [38] Conjunctive use of surface and ground ... [39] Survey of 218 organic contaminants ... [40] Intergenerational equity based optimal ... [41] Ecological effect assessment based ... [42] Evaluating the effect of climate changes ... [43] Effect of land use change on water balance ... [44] Effect of converting forest to rainfed ...

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Introduction

The quality of river water is highly important, especially when it is considered as a drinking supply. Considering the sustainable irrigated crops yield, the irrigation water has to be of intended quality^[1]. However, the river water can be contaminated by hazardous pollutants, namely solid waste, wastewater, sludge, salt, pesticide, chemical fertilizers, and loaded particles as well as degradation of rivers and their margin^[2,3]. Rivers in the highland areas are more vulnerable to pollutant agents due to severe improper anthropogenic factors such as converting the forests and rangelands to rain-fed lands, improper tillage practice, and nonagricultural activities, including mining construction of road and gas networks^[4]. Furthermore, rivers' margin lands are more valuable and thereby under the influence of land ownership and purchase systems, improper management of natural resources, government policies, illegal land use change, and local lobbying^[5]. Therefore, continuous monitoring of water quality is essential for proper management and mitigation of health and environmental consequences, and it is more important in upstream rivers.

Investigations in 27 highland river catchments in Southeast Asia showed a severe land-use change and many negative changes in both soil and water qualities^[6, 7]. Most of these consequences stem from the discharge of agricultural, industrial, and urban pollutants, as well as their waste and leakage into the rivers^[8]. Most parts of highlands in Iran geologically comprise marl and fine-grained fractions^[9, 10]. In these areas, after converting rangelands and forests to rain-fed lands, improper tillage practices (up-down the slope) and crop residue burning contribute to severe land degradation and, consequently, water turbidity and contamination^[11].

Water quality of the river in the hilly and mountainous catchments with rain-fed and rangeland landuses is influenced by animal grazing and tillage practice. Heavy grazing harms water quality^[12]. Heavy and improper tillage practice worsens the vegetation cover and soil quality delivering large amounts of phosphor and nitrogen into the river water resources and eutrophication event^[13, 14]. Eutrophication in downstream and wetlands results in nitrate oxide (one of the effective

greenhouse gas involved in global warming)^[15]. Reservoir dams mainly store river water in hilly and mountainous areas such as the study area. This reserved water is used for drinking and irrigation supplies and is also exposed to pollution factors. This negatively causes water quality index (WQI) for both irrigation and drinking based on pH, EC (electrical conductivity), total dissolved solids (TDS), salinity, total hardness (TH), total ions and anions as well as sodium adsorption ratio (SAR)^[16]. These conditions are more vulnerable in the marly lands such as upper catchments of the Karkheh river basin (including some parts of the study area) comprising about 80% clay, silt, and dissolved materials, which induce flooding and sediment flow into the downstream area and eventually damage water quality^[17]. Furthermore, these conditions resulted in a sharp decrease in dissolved oxygen for other aquatic species, including large fish, and their gradual extinction^[18].

River water pollution occurred during precipitation seasons when runoff and floods flow overland, delivering pollutants in rivers. Therefore, monitoring of river water quality in rainy seasons requires field verification and inventory^[19]. Besides, urban waste, nonagricultural activities, as well as rural manure and rubbish disposal in the drainage system, are becoming a major concern for river water quality. Surface water quality is progressively subject to increasing contaminant sources driven from several anthropogenic activities. Thus, monitoring water quality and its affecting factors are necessary to minimize the pollutant sources^[20].

Therefore, the river water maintenance requires legal and proper management, field inventory, and allocation of necessary credit, and continuous monitoring of the river. River monitoring includes periodic assessment of water quality, important geometrical and morphometric characteristics of the river analysis affected by upstream watershed land use, river privacy, and pollution sources. This study's objective was to evaluate the water quality and threatening factors in Dinavr River, a branch of the Upper Karkheh river basin, Iran. This work represents awareness of the river water contamination due to the increase in pollutant agents, which will continue to cause a serious crisis for drinking and irrigation

demands at the local scale that was carried out in different Dinavar River sites during 2017-2019.

Materials and Methods

Study Area

This study was conducted at the Dinavar river catchment, located about 60km northeast of Kermanshah, Iran. It is the upper catchment of the Karkheh river basin (KRB) located in Zagros mountain chains (west of Iran; Figure 1). This catchment has an area of 224360ha that lies between 34°30'25" to 34°39'20"N latitude and 47°10'20" to 47°50'18" E longitude. The climate of the study area is affected by wet Mediterranean fronts capable of receiving snow and rain. The average annual precipitation, temperature, and evaporation in this area are 12°C, 450mm, and 1100mm, respectively [21].

The area's geological properties are carbonate (calcareous) and clastic (degraded) with numerous folds and faults that play a key role in water quality in both surface and groundwater resources.

Geomorphology of Dinavar River includes plain, hilly, and mountain forms with different land uses and vegetation covers (mainly rangelands). Due to geology, topography, and climatic conditions, the river water resources are suitable for agricultural, industrial, and drinking applications [21]. A large part of sediments originated from the hilly slope lands subjected to heavy tillage practices and anthropogenic activities. The northern parts of this catchment are mountainous rangelands where receive snow in winter and play an important role in supplying water for the Dinavar River. The permanent water resources in spring are mainly recharged through these mountains. Songhur city is located in the upper plain of this catchment and is responsible for most contamination factors delivered to a new-built reservoir dam called Jamishan dam. There is one hydrometric station on the different Dinavar River branches, with an average annual flow discharge of 2.38m³ [22].

River site selection: After data collation and primary field survey, seven river sites were selected, reflecting the dominant condition of upstream land use, sediment sources, and contamination agents as well as river bed

vegetation and erosion features. Site locations were recorded by the global positioning system (GPS).

Field measurement: Land uses and activities in both catchment and river bed affecting river pollution and siltation were determined via satellite imagery (SPOT 2011 with the resolution of 5.3m) using ArcGIS and field verification;

- Dominant erosion in bed and banks of the site were determined;
- The nonagricultural activities such as surface sand and gravel mining, bypass agents, and flood control dyke were monitored; and
- Morphology characteristic of the river was investigated.

Sampling and analysis: In each site, five to seven water samples were collected from mild river depth using the 1000 cc polyethylene bottles in April 2018. The sediments also were sampled. The water samples were taken to the laboratory immediately and reserved in a refrigerator at 4 °C until analysis. Laboratory analyses for water quality were carried out according to APHA [23]. (2012) in ISO 17025: 2005 certified laboratory.

The pH measured a pH meter, Electrical Conductivity (EC) by conductivity meter, the concentration of cations (Ca²⁺, Mg²⁺, Na⁺, and K⁺) and total dissolved solids (TDS) were determined by Atomic Absorption Spectrophotometry, The ions (CO₃²⁻, HCO₃⁻, Cl⁻ and SO₄²⁻) through standard titration methods As outlined by Guidelines for Laboratory Analysis of Soil and Water Samples [24].

Water quality classification: Water quality was classified for irrigation by the Wilcox method based on EC, sodium adsorption, and ratio (SAR) as outlined by Mahdavi [25]. Furthermore, due to the high carbonates content of geological calcareous parent materials, the river water's total hardness (TH) was evaluated. The SAR describes the relationship between soluble Na⁺ and soluble divalent cations (Ca²⁺ and Mg²⁺) [26].

All the ions are expressed in meq/L, SAR values are plotted against EC values (in µS/cm) (Table 2).

Statistical analysis: The data were statistically analyzed using SAS 6.12 for the variance of each variable, including the ANOVA (General Linear Models; GLM) procedure.

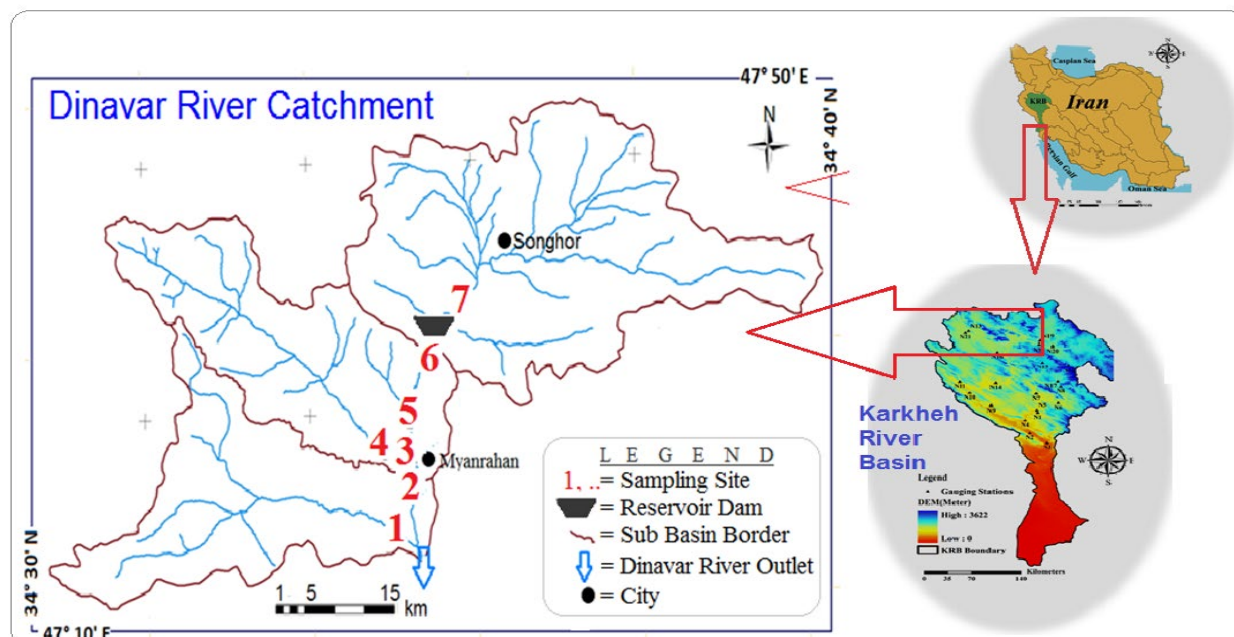


Figure 1) Geographic location of the study area in upper Karkheh River Basin (KRB), Iran

Table 1) Wilcox classification for irrigation water quality [22].

Factor	Value	Class	Quality
SAR	10<	S ₁ (Low)	Perfect
	18-10	S ₂ (Average)	Good
	26-18	S ₃ (High)	Average
	>26	S ₄ (Very high)	Bad
EC ($\mu\text{mhos/cm}$)	100-250	C ₁ (Low)	Perfect
	250-750	C ₂ (Average)	Good
	750-2250	C ₃ (High)	Average
	>2250	C ₄ (Very high)	Bad

Table 2) Schuler quality chart for drinking water [26].

Quality	Na ⁺ (mg/L)	Cl ⁻ (mg/L)	SO ₄ ²⁻ (mg/L)	TDS (mg/L)	TH (mg/L)
Good	<115	<175	<145	<500	<250
Acceptable	115-230	175-350	145-280	500-1000	250-500
Average	230-460	350-700	280-580	1000-2000	500-1000
Inappropriate	460-920	700-1400	580-11500	2000-4000	1000-2000
Completely inappropriate	920-1840	1400-2800	11500-2240	4000-8000	2000-4000
Non-potable	>1840	>2800	>2240	>8000	>4000

Findings and Discussion

The Selected Sits

Khedrabad: This site is located in the outlet of the Dinavar River close to Khedrabad village. The river bed comprises fine-grained materials with a gentle slope, braided forms of sediments. Field verification showed that most flood zone parts are used for annual cropping and improper sand and gravel harvesting, causing severe riverbank erosion in convex banks (Table 3). A meander with 23m radian and 112m length has caused meanders and riverside's failure and riverside accelerating flood hazards. This has

been accelerated by reducing base river flow due to constructed dam, pollutant concentration, and severe cropping activities in the river border. Farmer incentive for annual crop cultivation by movement and weak field monitoring should also be considered. Field survey indicated that about 210ha of bed and border of the river were dominated by Ta, contributing to sediment trapping and curtailing flow velocity and flood hazard.

A study by Richards [27] and Raghunath [28] showed that flexible stems and strong and deep root system of Ta cause high roughness

confidence and significantly reduce shear stress and river flow velocity.

Myanrahan: This site is located in the Dinavar plain, and it is the main straight and wide reach (width of up to 400 m). Due to gentle slope and deposited sediment, there are about 10 points for sand and gravel harvesting. However, field verification showed that the main sources of river degradation and pollution are improper open-pit sand and gravel, converting the river bed to irrigated lands, and disposing of rubbish and soiled waste. Furthermore, riverside and parts of flood beds are converted to irrigated areas promoting erosion, siltation, and water turbidity.

Shamar: This site is located in the upper part of Myanrahan, and its border and flood bed are converted to irrigation areas. The normal width of base flow is 14 m, while flood width is up to 91m. Field surveys showed that sever tillage practice in riverside and bank erosion are more considerable in this site (Table 3).

Zamani: The catchment of its site is mainly orchard, rain-fed, and rangeland in steep slope areas. River width in conjunction part is up to 230m. In this site, riverbank and flood beds are partly subjected to tillage practice and annual crop cultivation. In the down part of Zamani village, animal manure and domestic wastes cause river water contamination.

Shirkhan: It is located in hilly lands comprising fine-grained materials in bed and its catchment. There is no considerable riverbank erosion in it, while siltation and water turbidity sources of Dinavar River are mainly originated from site catchment due to improper tillage practice and surface mining activities.

Jamishan: This site is formed along the narrow valley in the mountainous lands. This site's river is more stable due to minimum land-use change and vegetation cover in bed and border, particularly *Sali* and *populous*, orchard and permanent grasses. Jamishan dam is built in the upper part of this site.

Shahgodar: It is located upstream of the Jamishan dam delivering urban waste to the reservoir dam (Table 3; Figure. 2).

Water Quality Trends

Water quality and statistical analyses are shown in Table 4. The average pH is 7.25, which varies among the seven sites. The average pH value in five sites (downstream sites) is significantly higher than that of upstream sites that are more closed to urban wastewater and sludge. The

lower pH value is due to concentrations of urban wastewater, while the neutral to alkaline pH condition is due to waste compounds that precipitate and deactivate [28, 29]. The average carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) are 17.5 and 358.2mg/L, respectively. Both of these water ions are significantly ($p < 0.05$) lower in the river downstream (including Khedrabad, Myanrahan, Zamani, and Shamar sits) than in the river upstream (Shirkhan, Jamishan, and Shahgodar). However, the higher carbonate content in upper sites is related to geological calcite and dolomite mineral contents. These minerals precipitate and dissolve in water, affecting other soil properties [29, 30]. Cl^- and SO_4^{2-} (chloride and sulfate salt contents) were 27.7 and 6.70mg/L, respectively. These variables were found in significantly higher levels in the Jamishan site (49.7 and 9.12mg/L for Jamisahn reservoir dam, respectively; Figure 2).

The water reserved in this dam is strongly affected by wastewater and runoff from the mountainous urban area. In this site, municipal sewage of Songhur city directly enters the river. The urbanization strongly elevated the surface water chloride content, particularly, in the most snow-affected areas that are most likely to use road salt [31]. The mean values of cations including Ca^{2+} , Mg^{2+} , Na^+ and K^+ were 78.55, 26.21, 22.72 and 8.73mg/L respectively. The ANOVA analysis also indicated that these values are almost significantly higher in the upper river sites than in other sites. Na^+ is a key factor affecting water quality. It is important to be investigated for its variations. As shown in Table 4, sodium ion levels are significantly lower in five sites than in Jamisahn and Shahgodar sites. The sodium ion levels in Shahgodar and Jamishan (reservoir dam) sites were two-fold and three-fold, respectively. This is due to the flow of wastewater from urban areas (Songhor) into rivers and dams (Table 4). These trends are not only hazardous for drinking water but also cause concerns about irrigation. The change of SAR, TDS, and TH trends was approximately the same as the sodium ion trend change. Using wastewater for irrigation purposes negatively influences the soil salinity status represented by electrical conductivity (EC) and sodium adsorption ratio (SAR) [32, 33].

The Suitability of Water Quality for Irrigation and Drinking Purposes

Irrigation: The suitability of water quality for irrigation was investigated based on EC and SAR

replicate different classes (according to Wilcox classes). Based on EC, there are good conditions in 5 sites, but the upper part (Jamishan and Shahgodar) falls within the average condition, mainly due to urban pollutants (Table 5). As shown in Table 4, sodium levels are significantly higher in the mentioned two sites than in other sites. Therefore, water quality class based on SAR is declined to bad conditions in these two sites. Among all cations, sodium level change indicates the high overall hazard of salinity for irrigation in the future. Apparently, due to the intrusion of complex salt components from rural, urban, and industrial areas, agricultural activities, and local tourism established close to the river drainage system.

Drinking: The calculated values for water quality based on Na%, Cl⁻, SO₄²⁻, TDS, and TH replicate showed good to acceptable levels (according to Schuler quality classes) of water for drinking use (Table 5).

However, there were some exceptions following the irrigation trend change. For example, the high total hardness in both of the water samples specifies the active geological calcareous containing higher amount of calcium magnesium in the upper catchment, which also affects TDS) [34]. The quality of water in the study

area to meet the drinking and irrigation standards was assessed using chemical indices. Although there was no important limitation for the Dinavar River to be used for drinking purposes, water quality in Jamishan and Shahgodar was lower due to TDS and TH. The results from analyzing all the water samples revealed that the characteristics and concentrations of the main physical and chemical parameters such as pH, EC, TDS, Na⁺, K⁺, Ca²⁺, Mg²⁺, Cl⁻, HCO₃⁻, CO₃²⁻ and SO₄²⁻ varied from the sites in the plain area to the sites in the mountainous areas. From an environmental degradation point of view, it can be concluded that there are important parameters or factors which exacerbate Dinavar River pollution. Thus, it is strongly recommended to monitor the water quality annually, particularly around the reservoir dam and urban areas.

Water quality vulnerability factors: To assess Dinavar River water quality vulnerability, the number of cations and anions in the sediments obtained from different contaminant sources was investigated. These sources include urban wastewater (for Jamishan and Shagodar sites), animal manure effluents, sediment from heavily-plowed fields, riverbank erosion, flood bed, rural sewage (Table 6).

Table 3) Field verification of dominant erosion feature, main water turbidity, and pollutant sources

Site name	Main erosion feature	Main activities in the river bed and border	Dominant water river consumption	Main sources of river pollution and degradation*									
				1	2	3	4	5	6	7	8	9	10
Khedrabad	RBE*	Crops cultivation,	irrigation	■	■	■	■	■	■	■		■	
Myanrahan	RR**	sand and gravel Harvesting from the river bed, crops cultivation	irrigation	■	■	■	■		■	■		■	
Shamar	RR**	Sever tillage practice + native plant removal	irrigation	■	■	■	■		■	■		■	
Zamani	RBE*	Crops cultivation,	irrigation	■	■	■	■						
Shirkhan	RBE*	Orchard with crops cultivation	irrigation	■	■	■	■			■			■
Jamishan	-	Orchard with Protection of native vegetation	irrigation + urban supply (future)			■	■	■	■		■		
Shahgodar	RBE*	Irrigated crops	irrigation	■	■	■	■		■	■			

*1 = tillage practice in riverbank and flood bed, 2= converting the river bed to irrigated lands, 3 = animal and domestic waste leachate, 4 = agricultural waste (poultry, livestock and crop residues), 5 = disposal of rubbish and soiled waste, 6 = local tourist waste, 7 = municipal and industrial wastewater, 8 = barrier construction, 9 = improper open-pit sand and gravel harvesting from river bed), 10 = nonagricultural activities (road, gas pip net, sub-soil harvesting). ** RBE= riverbank erosion, ***RR= riverbed scoring.

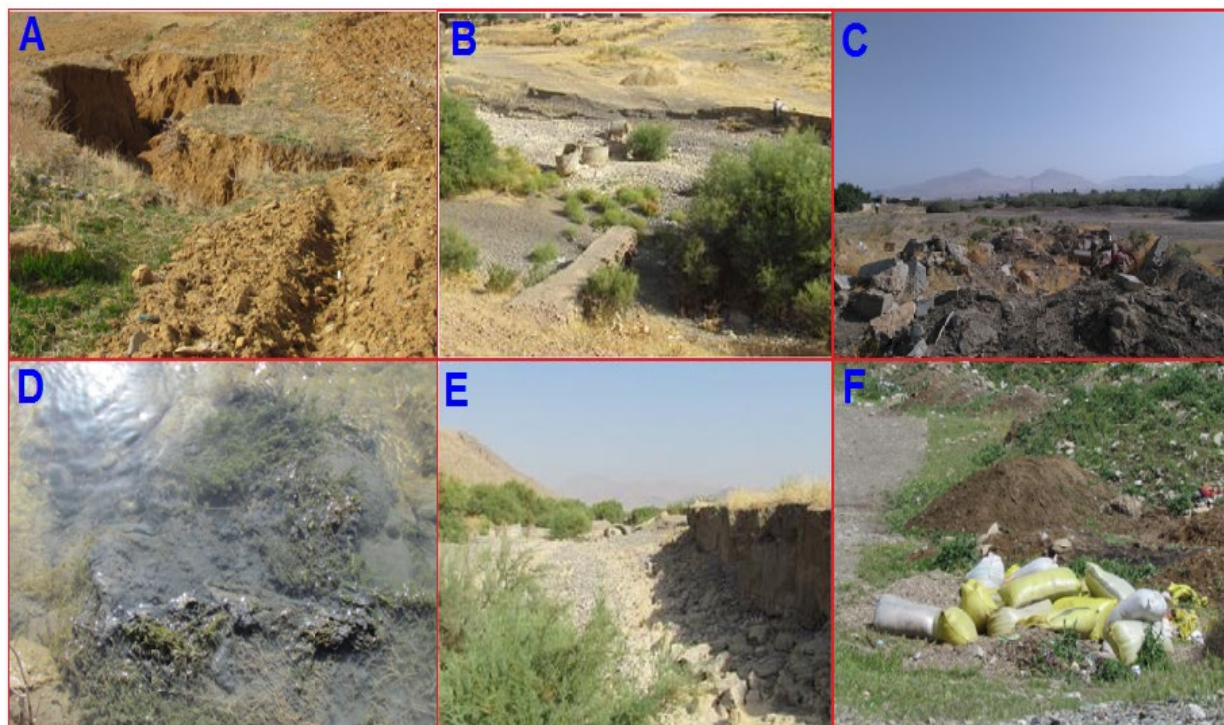


Figure 2) Types of river degradation and contamination; accelerated gully erosion through up-down the slope tillage in the upward river (A), bank erosion (B and E), disposal of rubbish and waste (C and F), domestic waste leachate (D)

Table 4) ANOVA of water quality variables in sampling sites of Dinavar River in Kermanshah, Iran

Water quality variable	Sites							P-value	Mean
	Khedrabad	Myanrahan	Shamar	Zamani	Shirkhan	Jamishan	Shahgodar		
pH	7.23 ^a	7.27 ^a	7.50 ^a	7.10 ^b	7.40 ^a	7.15 ^b	6.86 ^b	0.045	7.25
EC (dS/m)	0.43 ^{ab}	0.505 ^b	0.532 ^b	0.445 ^{ab}	0.530 ^b	1.16 ^a	1.40 ^a	0.004	0.58
CO ₃ ²⁻ (mg/L)	18.0 ^b	15 ^{ab}	18 ^b	12 ^b	24 ^a	11.80 ^b	24 ^a	0.003	17.5
HCO ₃ ⁻ (mg/L)	249.0 ^c	261.1 ^c	341.6 ^b	317.2 ^b	311.1 ^b	403.6 ^a	350.50 ^b	0.048	358.2
Cl ⁻ (mg/L)	17.40 ^c	17.4 ^c	23.07 ^b	17.7 ^c	28.4 ^b	49.7 ^a	24.8 ^b	0.023	27.7
SO ₄ ²⁻ (mg/L)	6.24 ^b	6.24 ^b	7.20 ^b	4.32 ^c	10.08 ^a	9.12 ^a	8.36 ^a	0.001	6.70
Ca ²⁺ (mg/L)	61.45 ^b	65.6 ^b	66.0 ^b	74.0 ^a	78.6 ^a	72.11 ^a	80.00 ^a	0.045	78.55
Mg ²⁺ (mg/L)	18.5 ^b	20.16 ^b	25.3 ^a	21.6 ^b	26.4 ^a	28.2 ^a	28.8 ^b	0.031	26.21
Na ⁺ (mg/L)	8.34 ^c	10.12 ^c	13.57 ^c	13.57 ^c	14.95 ^c	43.7 ^a	29.80 ^b	0.001	22.72
K ⁺ (mg/L)	1.56 ^c	1.56 ^c	2.44 ^c	1.17 ^c	2.34 ^c	31.67 ^a	4.3 ^b	0.001	8.73
CaSO ₄ (mg/L)	190.80 ^b	199.70 ^b	260.0 ^a	240.87 ^a	251.88 ^a	231.11 ^{ab}	253.10 ^a	0.044	227.33
SAR	0.19 ^b	0.18 ^b	0.27 ^b	0.25 ^b	0.26 ^b	0.71 ^a	0.76 ^a	0.001	0.38
TDS (mg/L)	180.0 ^c	195.30 ^c	241.0 ^b	220.62 ^b	244.76 ^b	658.5 ^a	476.20 ^{ab}	0.007	262.6
TH (mg/L)	236.0 ^b	248.0 ^b	305.0 ^a	275.0 ^{ab}	305.0 ^a	303.0 ^a	320.0 ^a	0.015	306

*Means with the same letters are not significantly different at pb0.05%. SAR = Sodium absorption ratio, TDS = Total dissolved solids, TH = Total hardness

Table 5) water classification for irrigation (Wilcox classes) and drinking (Schuler quality classes) purposes in different sites of Dinavar River

Water quality variable	Sites						
	Khedrabad	Myanrahan	Shamar	Zamani	Shirkhan	Jamishan	Shahgodar
EC (dS/m)	C ₂ (good)	C ₂ (good)	C ₂ (good)	C ₂ (good)	C ₂ (good)	C ₂ (good)	C ₃ (average)
SAR	S ₃ (average)	S ₃ (average)	S ₃ (average)	S ₃ (average)	S ₃ (average)	S ₃ (average)	S ₄ (bad)
Na ⁺ (ppm)	good	good	good	good	good	good	good
Cl ⁻ (ppm)	good	good	good	good	good	good	good
SO ₄ ²⁻ (ppm)	good	good	good	good	good	good	good
TDS (ppm)	good	good	good	good	good	good	acceptable
TH (ppm)	good	good	acceptable	good	acceptable	acceptable	acceptable

Table 6) ANOVA of fresh sediment quality in the sampled sites of Dinavar River in Kermanshah, Iran

Water quality variable	Major pollutant sources of fresh sediment						p-value
	Animal manure effluents	Sediments from heavily-plowed field	Riverbank erosion	Flood bed sediment	Rural sewage	Stable river banks	
pH	6.87 ^b	7.58 ^a	7.58 ^a	7.63 ^a	6.96 ^b	7.10 ^b	0.031
EC (dS/m)	3.47 ^a	1.20 ^{ab}	0.50 ^c	1.31 ^{ab}	1.53 ^{ab}	2.42 ^b	0.009
CO ₃ ²⁻ (mg/kg)	0.0	0.0	0.0	0.0	120	0.0	-
HCO ₃ ⁻ (ppm)	244.0 ^b	213.5 ^b	274.5 ^b	274.5 ^b	762.5 ^a	183 ^c	0.042
Cl ⁻ (ppm)	140 ^b	166.3 ^b	105 ^c	210 ^a	210 ^a	114 ^c	0.023
SO ₄ ²⁻ (ppm)	1829	0.0	0.0	0.0	0.0	1094	-
Ca ²⁺ (ppm)	64.0 ^c	168 ^b	96 ^c	160 ^b	240 ^a	89.93 ^c	0.087
Mg ²⁺ (ppm)	144 ^a	43.2 ^b	38.4 ^b	43.2 ^b	86.4 ^{ab}	12.88 ^c	0.003
Na ⁺ (ppm)	40.0 ^b	34.96 ^b	12.88 ^c	89.93 ^a	45.50 ^b	36.11 ^b	0.001
K ⁺ (ppm)	9.36 ^b	4.68 ^c	8.58 ^c	5.85 ^c	18.33 ^a	5.85 ^c	0.022
SAR	0.26 ^c	0.44 ^b	0.20 ^c	1.15 ^a	0.45 ^b	0.30 ^c	0.043

*Means with the same letters are not significantly different at pb of 0.05%.

Urban wastewater: Statistical analysis indicated that urban wastewater led to changes in pH, EC, sodium, SAR, TDS, and TH and, consequently, significant variations in water quality classes for drinking and irrigation purposes (Tables 4 and 5).

Animal manure effluents: Field surveys show that livestock manure is accumulated in a river or drainage system along the river, and finally enter the river by runoff and land flow. Some parts of this effluent precipitate in lateral fresh sediments. Sediment analysis shows that it can cause significant changes in water quality parameters, including pH, EC, Cl⁻, SO₄²⁻, and Mg²⁺ (Table 6).

Sediments from heavily-plowed fields: Much of the Shirkhan site's sediment is carried from nonpoint sources originated from hilly lands comprising fine-grained fractions. These areas along the river are subjected to land cover change and soil disturbance through up-down the slope tillage practice and improper nonagricultural activities. The pollutants carried from slope shoulders are blown into the drainage system by runoff. Like animal manure, the sediments containing these pollutants can reduce water quality (both drinking and agricultural). Therefore, the current influx of pollutants into the Dinavar River can have implications for drinking water, healthy crop production, and eutrophication.

Riverbank erosion: Degradation of the riverbank and its adjacent soil layers deplete the sequestered cations and ions released into the river water.

Flood bed sediment: As significant amounts of sediments in the river flood bed are capable of trapping suspended particles and pollutant

substances, they are mostly rich in cations and anions.

Rural sewage: The sediment affected by rural sewage is rich in chlorine, sulfate, calcium, and potassium.

Stable river banks: Sediment samples from stable rivers have approximately lower levels of ions and cations affecting water quality. This indicates that the river can filter and sink the suspended sediment and pollutants and consequently purify the surface water with plant cover and minimize erosion. Eutrophication has an important impact due to the overuse of chemical fertilizers, heavy tillage practices, and erosion in arable lands resulting in high concentrations of nitrate (NO₃⁻), phosphor, and cations ions in aquatic ecosystems including rivers, shallow lakes, and dams [16, 35]. The severity of eutrophication has posed damage to aquaculture and tourism. The direct input of rural sewage and leachate from agricultural wastes reduces the biological quality and dissolved oxygen [17, 35, 36]. Dinavar catchment geologically comprises calcareous parent materials. This condition provides the main water carbonate source, bicarbonate, magnesium, and calcium [37]. Hence, land-use change, intensive agricultural, and industrial activities combined with urban waste expansion and changing life patterns have exacerbated pollution in surface water [38]. Therefore, an integrated water management approach to reach sustainable water resources, optimal consumption, and quality control by the balanced allocation of agricultural, environmental, and industrial sectors seems essential [39]. Unfortunately, the increasing trend of land use/cover change and climate change has

exacerbated the crises caused by drought, one outcome of which is the decline of river water quality. The need for effective actions will be greater for urban rivers affected by extensive sources of pollution [40, 41]. Moreover, in Iran's mountainous catchment, the floods hazards and river overflow during winter will be accelerated mainly due to land use/cover change and subsequently increasing runoff coefficient and soil erosion hazard [42-44].

Conclusion

The water quality for irrigation and drinking proposes, and the factors affecting it were analyzed in the Dinavar River in Kermanshah, Iran. Seven river sites in plain, hilly, and mountainous areas along the river were selected. Water samples analysis based on pH, EC, cation, and ion showed perfect water quality. In contrast, the statistical analysis based on EC, SAR, TDS, and TH revealed that water quality in the upper Dinavar River is significantly affected by urban wastewater and pollutants. Consequently, the water quality for irrigation proposes was found to decline from good to average and from good to bad levels based on EC and SAR. Besides, the water quality for drinking purposes, similar to irrigation purposes, was found to decline from good to acceptable based on TDS and TH. This occurred mainly due to increased sodium ion, which was two-fold to three-fold due to the discharge of wastewater from urban areas (Songhor) into the river and reservoir dam. Water quality in the other five sites was at a good level for both drinking and irrigation purposes. This result revealed that the Dinavar River, with its significant effect on water quality, plays an important role in providing agricultural and environmental services. However, this unique resource is being degraded due to anthropogenic activities. Water quality threats are more severe in upper sites (Jamishan and Shahgodar sites) where are strongly contaminated by urban wastewater. In contrast, the hilly area of the Shirkhan site was faced heavy siltation water turbidity due to soil profile disturbance through tillage practices, land cover changes, and nonagricultural activities (open-mining, gas pipe, etc.). The other four sites in plain areas were mostly subjected to land use/cover change due to riverbank erosion, flood bed degradation, and local tourism disposal. Since the water resources for semi-arid rivers are finite and rapidly diminish, the

contamination sources of river water and the increasing demand for water highlight the necessity of developing a better water pollution control. Consequently, river degradation control and wastewater treatment and monitoring the siltation and pollutant resources at the catchment scale seem vital for Dinavar River management in the upper Karkheh river basin.

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