Research Article
Open Access
CrossMark

Seasonal variation of the water quality in an intermittent river perennified by hydraulic work: a case study of the Terra Nova river basin, Northeast Brazil

Abstract

The hydrographic basins inserted in the Brazilian semi-arid region tend to aridization and intermittency due to climatological and geological conditions, suffering great anthropic pressure and experiencing seasonal changes in water quality. The aim of this study was to analyze the seasonal variation of the water quality in an intermittent river perennified by hydraulic work: a case study of the Terra Nova river basin (TNRB), located in the state of Pernambuco, Brazil. Physical, chemical and biological parameters were analysed. Water samples were collected at eight sampling points in the TRNB, from 2009 to 2022, totaling 26 campaigns. The Water Quality Index (WQI) adapted by the Environmental Sanitation Technology Company of the State of São Paulo (CETESB) was applied. The results were evaluated spatially and temporally. It was observed that in most campaigns there was no water at the monitoring points, both in the rainy season (77.8%) and in the dry season (73.5%). During the sampling period the WQI ranged from Excellent (81) to Bad (24) in the TNRB. Point Q06 stood out from the others, presenting the only WQI classified as Excellent. With regard to seasonality, the dry season ranged from Excellent (81) to Bad (24), while in the rainy season it ranged from Good (78) to Bad (22). To improve water quality it is necessary to invest in basic sanitation in the TNRB municipalities, environmental recovery, environmental education and monitoring with the aim of mitigating conflicts and impacts.

Keywords: water resources, basin transposition, semiarid, impacts, WQI

Volume 8 Issue 2 - 2024

Érika Tavares Marques,[1] Cláudia Ricardo de Oliveira,[2] Hidaiane Fayga Caldas,[3] Ariane Silva Cardoso,[3] Jonathas Araújo,[3] Maria do Carmo Sobral[3]

[1]Post-Doctoral Program in Development and Environment, Universidade Federal de Pernambuco, Brazil
[2]Environmental Management, Universidade Federal do Vale do São Francisco, Brazil
[3]Civil Engineering, Universidade Federal de Pernambuco, Brazil

Correspondence: Érika Tavares Marques, Universidade Federal de Pernambuco, Av. Prof. Moraes Rego, 1235 - Cidade Universitária, Recife - PE, Brazil, 50670-901, Tel +55 (81) 2126-8000, Email erikatmbio@gmail.com

Received: April 01, 2024 | **Published:** April 18, 2024

Abbreviations: APAC, Pernambuco Water and Climate Agency; BOD, biochemical oxygen demand; CCME, Canadian Council of Ministers of the Environment; CETESB, Environmental Sanitation Technology Company of the State of São Paulo; CONAMA - National Environmental Council; DO, dissolved oxygen; IBAMA - Brazilian Institute of the Environment and Renewable Natural Resources; NSF, National Sanitation Foundation; PACUERA, Plan for Conservation and Use in Surrounding Reservoirs; SFRIP, São Francisco River Integration Project; TN, total nitrogen; TP, total phosphorus; TNRB, Terra Nova river basin; WQI, Water Quality Index

Introduction

Semi-arid regions have particularities in terms of water dynamics during the year. In terms of world classification, semiarid rivers are those with the lowest continuity indices, due to the interruption of connectivity between upstream and downstream, between the river course and the floodplain and/or adjacent riparian areas, the vertical discontinuity to groundwater and the temporal discontinuity by the influence of seasonality. Therefore, the intermittent and temporary stretches can be called discontinuous.[1]

Non-perennial rivers have attracted significant attention due to the progressive increase in water demand and pollution, river engineering side effects and climate change. The non-perennial rivers in semiarid regions cease to flow spatiotemporally along their course.[2] Scientific literature employs diverse terminology to hydrologically describe nonperennial rivers, such as ephemeral, intermittent, temporary, and dry rivers.[3,2]

The predominance of low rainfall and dry and hot climate for most of the year, makes the hydrography of the semiarid region fragile, being insufficient to maintain water levels in perennial rivers in the long periods of absence of rainfall, with the exception of the São Francisco River, which due to its hydrological characteristics, where its sources are outside the perimeter of droughts, enables it to be maintained throughout the year. Rainfall is normally poorly distributed and occurs irregularly, mainly due to peculiarities of its climatic characteristics, because the region has historically faced serious problems related to the scarcity of rainfall, which provides severe and prolonged drought in much of the region.[4]

Strong evaporation is another characteristic of such regions, a factor that has effects on water dynamics and exchanges between rivers, as well as on stagnant water or reduced velocity in the riverbed.[5,6] According to the Köppen-Geiger the climate classification is BSh (hot semi-arid climate - steppe) and the rainfall regime is marked by scarcity, marked spatial-temporal irregularity and long periods of drought, where most precipitation generally occurs in three months, with an annual average of less than 800 mm.[7]

In the Brazilian Northeastern semi-arid region, the temporal variability of precipitation often causes situations of water scarcity. In this scenario, reservoirs play an important role in flow regulation, making the excess flow of the rainy season compensate existing deficits during the dry season.[8] In semiarid regions at low latitudes, dams and the artificial year-round use of rivers make up the main source of water for domestic, industrial and agricultural consumption.[9] Water scarcity refers to the imbalance between the supply of water resources and demand.[10,11]

According to Cunha et al.[12] and Marengo, Torres and Alves[13] a higher frequency of severe droughts will likely make the Brazilian Northeast region more vulnerable to droughts in the near future. These projections suggest the occurrence of more frequent and intense droughts, in addition to a tendency towards desertification in the region. These conditions lead to an increase in evaporation from reservoirs and rivers, affecting irrigation and agriculture. Demonstrating, therefore, the growing need to mitigate the effects of drought and the development of initiatives that foster coexistence with the semi-arid region, such as the operation of the São Francisco River Integration Project (SFRIP), which aims to guarantee the water supply for the socioeconomic development of the states of the Northeast Brazil most vulnerable to droughts.[14]

Integration projects between basins are developed around the world, perhaps as the most controversial alternative due to its complex implications, in an attempt to solve this problem. The connection usually occurs to transfer water from a region that is abundant to another region that is scarce, causing social, economic and environmental impacts that must be fully considered in the elaboration of such a project to achieve the maximum benefits in the region.[15,16] That transposition implies a conflict between the management committee of the São Francisco waters and the Federal Government, since the central role of this committee, which is contrary to transposition, was disregarded.[17]

In Brazil, other experiences in transpositions between river basins have as an example the High Tietê-Baixada Santista and River Piracicaba-High Tietê Systems (Cantareira System), in São Paulo, in addition to the transposition of the Paraíba do Sul river, involving the states of Rio de Janeiro, São Paulo and Minas Gerais. In the Northeast, there is the Curema-Mãe d'Água System for the Várzeas de Souza, Paraíba (associated with the transposition of the São Francisco), and the transfer of the Paraguaçu River to supply the Metropolitan Region of Salvador.[18]

In this sense the São Francisco River Integration Project with the Northeast Northeastern Watersheds is a water infrastructure initiative. Two independent systems, called North Axis and East Axis, will collect water from the São Francisco between the Sobradinho and Itaparica dams, in the State of Pernambuco. Compounds canals, water pumping stations, small reservoirs and hydroelectric power plants for self-supply, these systems will meet to the supply needs of 390 municipalities of the semi-arid region, the Agreste region of Pernambuco and the Metropolitan Region of Fortaleza. The benefited river basins are the following: the Jaguaribe River, in Ceará; from the Piranhas-Açu river, in Paraíba and Rio Grande from North; the Apodi river, in Rio Grande do Norte; the Paraíba river, in Paraíba; the Moxotó, Terra Nova and Brígida rivers, in Pernambuco, in the São Francisco river basin.[19]

In arid and semi-arid areas freshwater resources are very limited, and their deficiency has become a critical apprehension worldwide. According to Trajano et al.,[20] a strategic tool for territorial management is the management of water resources and for these purposes, the hydrographic basins, as they are catchment areas of water and various anthropic activities, are adopted as physical units of recognition, characterization and evaluation. Monitoring water resources quality is a basic requirement to ensure its sustainability.

Materials and methods

The Terra Nova River, tributary of the São Francisco River, located in the semi-arid region of Pernambuco, has a length of 40 km, with its sources located on the boundary of the State of Ceará. Its fluvial regime is intermittent throughout its course. The study area is located between 7º 40'20" and 8º 36'57" South latitude, and 38º 47'04" and 39º 35' 58" West longitude.

According to the Pernambuco Water and Climate Agency (APAC, n.d.),[21] the Terra Nova river basin has an area of 4,887.71 km², which corresponds to 4.97% of the state's area. The basin's drainage area involves 12 municipalities, of which 3 are fully located in the basin (Cedro, Salgueiro and Terra Nova), 2 have headquarters within the basin (Serrita and Verdejante) and 7 are partially situated (Belém do São Francisco, Cabrobó, Carnaubeira da Penha, Mirandiba, Orocó, São José do Belmonte and Parnamirim).

According to the Köppen's classification, the region has a hot semi-arid climate (BSh). The rainfall of the Brazilian semi-arid region is marked by space-time variability, which, associated with low annual totals over the region, results in the frequent occurrence of days without rain, that is, dry spells, and consequently, in "drought" events.[22] The wet period comprises the months of March to June, with an average annual precipitation of 568 mm. The dry period, with little or no precipitation, runs from July to February.[23]

The present study analyses the seasonal variation of nine water quality variables (pH, turbidity, biochemical oxygen demand, total phosphorus, total nitrogen, water temperature, chlorophill-a, total solids and thermotolerant coliforms) from 8 sampling points in a watershed located in the Brazilian semiarid from 2009 to 2022, totalling 26 campaigns Table 1,2 & Figure 1.

Table 1 Identification and localization of the sampling points monitored in the TNRB during the study period

SP	County	Place	Water Body	Fuse	Altitude (m)	UTM Coordinates (m)	
						E	N
Q05	Cabrobó	Terra Nova reservoir (Projected)	Lentic	24L	366	461034.8	9086220
Q06	Terra Nova	Terra Nova reservoir - axis of the dam	Lentic	24L	367	458862	9090348
Q07	Terra Nova	Terra Nova River - upstream of the dam	Lotic	24L	363	458862	9090348
Q08	Cabrobó	Serra do Livramento reservoir	Lentic	24M	413	464964	9091402
Q09	Sertânia	Mangueira reservoir	Lentic	24M	413	475406	9091402
Q10	Sertânia	Negreiro reservoir	Lentic	24M	499	481021	9106263
Q11	Sertânia	Milagres reservoir	Lentic	24L	515	492599.3	9127011
Q12	Jati	Jati Reservoir	Lentic	24M	482	498.935	9.148.052

Source: CMT ENGENHARIA AMBIENTAL (2016)[24]

Citation: Marques ET, de Oliveira CR, Caldas HF, et al. Seasonal variation of the water quality in an intermittent river perennified by hydraulic work: a case study of the Terra Nova river basin, Northeast Brazil. *Int J Hydro.* 2024;8(2):55–63. DOI: 10.15406/ijh.2024.08.00375

Table 2 Data from the monitoring campaigns and the respective dates, years and seasons

Campaign	Data	Year	Season
1	March to April	2009	rainy
2	July to August	2009	dry
3	February to March	2010	rainy
4	May to June	2010	dry
5	October to November	2010	dry
6	February to March	2011	rainy
7	May to July	2011	dry
8	August to September	2011	dry
9	October to November	2011	dry
10	January to March	2012	rainy
11	April to May	2012	rainy
12	July to August	2012	dry
13	November	2012	dry
14	January to March	2013	rainy
15	September to October	2013	dry
16	February to April	2014	rainy
17	August to October	2014	dry
18	February to May	2015	rainy
19	August to October	2015	dry
20	April to June	2016	dry
21	August to November	2016	rainy
22	March to June	2017	dry
23	August to December	2017	dry
24	September to December	2018	dry
25	March to June	2019	dry
26	November to February	2020	dry

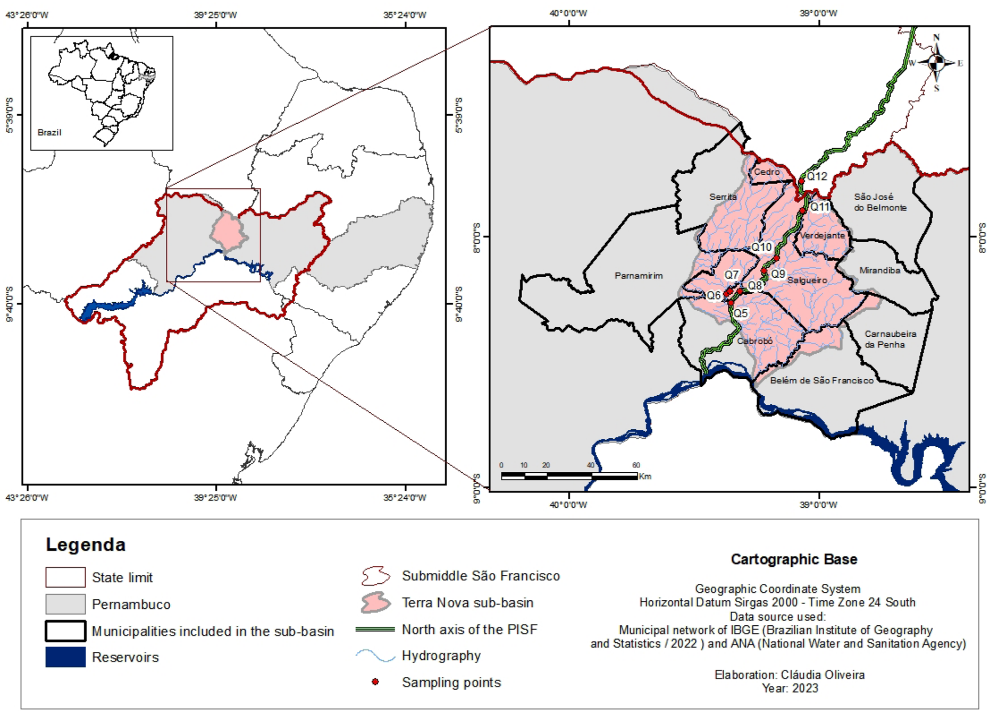

Figure 1 Sampling points in the TNRB.

Source: Cláudia Oliveira.

The average annual precipitation in the region ranges from 500 to 1,100 mm, with great irregularity in the interannual rainfall regime, which presents a standard deviation greater than 40% in relation to annual averages, estimated at 579 mm. The rains are poorly distributed throughout the year, due to a short rainy season, generally between March and July, and an extended period with little rain, in the rest of the months of the year.[24]

The physical-chemical and microbiological parameters were analyzed in 26 monitoring campaigns. These data were obtained from the SFRIP water quality monitoring reports (Basic Environmental Plan - PBA 22), provided as a conditional of the Brazilian Institute of the Environment by the Ministry of Regional Development (MDR) in the period between 2009 and 2022. The parameters (pH, Temperature, Turbidity, Electrical Conductivity, Salinity, Dissolved Oxygen, Total Dissolved Solids) were obtained by reading the Horiba multiparameter probe model U-53G/10 serial number 6DNOKJ76.

Anthropogenic action, either in concentrated form (domestic waste, organic contamination, industrial, heavy metals) or diffused (agricultural pesticides), contributes to the introduction of compounds into water, affecting its quality. Therefore, the way man uses, occupies, and manages the soil in the basin has a direct impact on water quality.[24]

The conceptual terms of water quality are not exclusively linked to its state of purity, but to its physical, chemical and biological characteristics. Monitoring these characteristics is essential for obtaining information related to environmental conditions, especially in watersheds, serving as a subsidy for decision-making aimed, above all, at the conservation and sustainable use of water.[25]

The physical and chemical parameters of water play a significant role in classifying and assessing water quality. It is the basic duty of every individual to conserve water resources.[26]

The need for greater knowledge and control of temporal and spatial variability led to the development of water quality indices.[27] Currently, several methodologies can be used to monitor watercourses. Among them, the Water Quality Index (WQI) stands out, developed by the National Sanitation Foundation (NSF, 2010)[28] and the WQI that was adapted by the Company of Environmental Sanitation Technology of the State of São Paulo (CETESB).

The calculation of the WQI is composed of physical-chemical and microbiological parameters, which mainly reflect the contamination of water bodies caused by the release of domestic sewage, and the standards used in the development of this index are related to the quality of water for public supply purposes.[29] In this context, the evaluation of physical, chemical and biological characteristics, mainly with regard to water quality, aims to gather a large amount of information in a way that allows prompt interpretation and recognition of trends over time and space. However, a high number of parameters makes it difficult to analyze and disseminate the quality of the water body, especially for a lay public.[30]

Due to this fact, the WQI have been incorporated and applied in the monitoring of water quality, in the last decades in different parts of the world. The index is a mathematical tool used to transform several parameters into a single magnitude, which represents the level of water quality. The use of an WQI is practical and is a driving guideline, as any water quality monitoring program generates a large number of analytical data that need to be presented in a synthetic format, so that they describe and represent in an understandable and meaningful way the current status and trends in water quality.[31–33]

Although the classification of water quality depends on its destination (irrigation, human consumption, industrial use, etc.), it is always important to have information on its composition as complete as possible, both in terms of the number of the analyzed parameters and in relation to the spatial and temporal coverage of the monitoring frequency.[34] Like any tool, the use of a WQI has advantages and disadvantages. Among the advantages, obtaining water quality from several parameters with different units in a single number that is easier to understand and be used by government authorities in making decisions about the use, destination and treatment of water. Likewise, its determination easily allows obtaining information on the temporal nature and spatial evolution of water quality in a given basin, as well as the comparison between different basins. The fact that some information is "lost" in the process of calculating the index stands out, for example, the presence of high levels of a certain pollutant, going unnoticed when the indicator assumes many parameters for its determination.[34]

The WQI is calculated by the weighted production of water qualities corresponding to the variables that make up the index (Table 3). The following Equation 1 is used:

$$\text{IQA}=\prod_{i=1}^{n} q_i^{w_i} \qquad \text{Equation 1}$$

where:

WQI: Water Quality Index, a number between 0 and 100;

qi: quality of the ith parameter, a number between 0 and 100, obtained from the respective "average quality variation curve", depending on its concentration or measurement and,

wi: weight corresponding to the ith parameter, a number between 0 and 1, assigned in due to its importance for the global conformation of quality, being that Equation 2:

$$\sum_{i=1}^{n} w_i = 1 \qquad \text{Equation 2}$$

on what:

n: number of variables included in the WQI calculation.

From the calculation carried out, the quality of the raw water can be determined, which is indicated by the WQI, varying on a scale from 0 to 100, represented in Table 4. If the value of any of the nine variables is not available, the WQI calculation is unfeasible.

Table 3 Parameters used to calculate the WQI

Parameter	Unit	Weight (wi)	Maximum Value Allowed by CONAMA Resolution 357/2005 for watercourses Class 2
Dissolved Oxygen (DO)	$mg.L^{-1}$	0.17	> 5 $mg.L^{-1}$
Thermotolerant coliforms	NMP.100 mL^{-1}	0.15	1000 NMP.100 mL^{-1}
pH	-	0.12	6.0 a 9.0
Biochemical oxygen demand (BOD)	$mg.L^{-1}$	0.10	5 $mg.L^{-1}$
Water Temperature	°C	0,10	40 °C
Total Nitrogen (TN)	$mg.L^{-1}$	0.10	1.27 mg/L for lentic environments and 2.18 mg/L for lotic environments
Total Phosphorus (TP)	$mg.L^{-1}$	0.10	0.03 $mg.L^{-1}$
Turbidity	UNT	0.08	100 UNT
Total Solids	$mg.L^{-1}$	0.08	

Source: CETESB (2017)[35]

Table 4 Classification of water quality according to the adapted WQI.

Value	Classes
80 ≤ WQI ≤100	Excellent
52 ≤ WQI <80	Good
37 ≤ WQI <52	Acceptable
20 ≤ WQI < 37	Bad
0 ≤ WQI < 20	Very Bad

Source: CETESB (2017).[35]

Initially, the data referring to the parameters and watersheds related to the water quality indicators were organized in spreadsheets in Excel. Subsequently, descriptive statistical analyzes were carried out to verify the differences between the statistics of the water quality variables according to the years 2009 and 2022. To analyze the rainfall, a correlation analysis was performed between the years and between the dry and rainy seasons. The boxplot graphics were made in SPSS v. 20 to identify the spatial and temporal differences of the variables under study.

Results

During the dry season, the water temperature ranged from 22.35°C to 30.88°C, while in the rainy season it ranged from 25.08°C to 31.8°C. According to the data collection platform PCD Salgueiro (APAC 2009-2022),[36] in the period between 2009 and 2022, the average annual precipitation was 533.14 mm, varying between 230.9 mm and 839.0 mm (Table 5).

Table 5 Annual variation of rainfall in the TNRB during the study period

Year	Average annual rainfall (mm)	Average monthly rainfall (mm)
2009	771.2	24.88
2010	504.9	42.08
2011	494.6	41.22
2012	230.9	19.24
2013	386.3	32.19
2014	529.1	44.09
2015	494.6	41.22
2016	378.8	31.57
2017	331.8	27.65
2018	756.4	63.03
2019	511.2	42.6
2020	686	57.17
2021	549.2	45.77
2022	839	69.92

According to Silva[37] the frequency of rainfall below the historical average has intensified in the Basins of the North Axis of the Transposition of the São Francisco River, especially after the 1990s. Which is indicative of the trend towards an increase in drought events in the region, which coincides with the increase in the frequency of El Niño and the influence of SST anomalies on precipitation variability.

According to the Plan for Conservation and Use in Surrounding Reservoirs (PACUERA) of the Terra Nova river basin,[24] as all the existing rivers in the basins and thalwegs affluent to the reservoirs in question are temporary or intermittent, it can be considered that the proposal for framing the water bodies is constituted by the five reservoirs: Terra Nova (Q05, Q06, and Q07), Serra do Livramento (Q08), Mangueira (Q09), Negreiros (Q10) and Milagres (Q11), all members of the Terra Nova river basin, is the same as the transposed water of the São Francisco River, that is, class "2".

In certain campaigns, the parameters Thermotolerant Coliforms, pH, BOD, total nitrogen, total phosphorus, turbidity and total dissolved solids showed values above the maximum limit allowed by the National Environmental Council - CONAMA Resolution 357[38] for Class 2 rivers (Table 6).

Table 6 Seasonal variation of parameters monitored in the TNRB

Parameter	Unit	Dry	Rainy
Thermotolerant Coliforms	NMP / 100 mL-¹	1.8 – 28,000	1.8 – 130,000
pH	-	4.11 – 9.23	7.22 – 8.42
BOD	mg.L-¹	0.68 – 42.00	1.00 – 24.30
Total Nitrogen	mg.L-1	0.18 – 5.00	0.50 – 29.12
Total Phosphorus	mg.L-¹	0.10 – 4.32	0.08 – 0.70
Water Temperature	°C	22.35 – 30.88	25.08 – 31.80
Turbidity	NTU	0.84 – 832.00	0.02 – 112.90
TDS	mg.L-¹	43.00 – 1,961.00	34.00 – 812.00
TSS	mg.L-¹	2.67 – 627.00	13.33 – 428.00
Dissolved Oxygen	mg.L-¹	3.00 – 17.00	2.00-10.00

In the dry season, thermotolerant coliforms ranged from 1.8 to 28,000 MPN / 100 mL-¹ and during the rainy season, ranged from 1.8 to 130,000 MPN / 100 mL-¹.

The WQI classes of each sampling point can be seen in Table 7. It is noteworthy that the dry class, despite not being an index of water quality, means that there was no water at the time of collection. Therefore, it was not possible to evaluate the WQI. Another category Not Calculated is due to parameters with a value lower than the quantification limit of the analysis equipment (<LQ) or not detected value (ND).

Table 7 Spatial analysis of water quality in the TNRB

Geral	Q05	Q06	Q07	Q08	Q09	Q10	Q11	Q12	Total	%
Excellent	0	1	0	0	0	0	0	0	1	0.48
Good	1	8	3	2	0	0	0	0	14	6.73
Acceptable	0	4	6	0	0	0	0	0	10	4.81
Bad	0	2	7	0	0	0	0	0	9	4.33
Very bad	0	0	0	0	0	0	0	0	0	0
Dry	21	6	6	23	23	25	26	26	156	75
Not Calculated	4	5	4	1	3	1	0	0	18	8.65
Total	26	26	26	26	26	26	26	26	208	100

In the TNRB, the WQI of point Q06 varied between Excellent (81) and Bad (24), having stood out from the others during the 7th monitoring campaign (dry period). Eight samples were classified as Good class. Four in the Acceptable class. Two in Bad. In 6 campaigns the point was dry and in 5 it was not possible to calculate the WQI.

At point Q07, the WQI varied from Good (70) to Bad (22) during the sampling period. Three samples were classified as Good, 6 as Acceptable and 7 as Bad. In 6 campaigns the point was dry and in 4 it was not possible to calculate the WQI.

Point Q08 only had water in two campaigns and the WQI remained in the Good class (77-72). In the other campaigns the point remained dry.

At point Q09 there was only water during campaigns 24, 25 and 26, but it was not possible to calculate the WQI due to the phosphorus having a value below the limit of quantification.

At point Q10 there was only water during campaign 26, but it was not possible to calculate the WQI due to the thermotolerant coliforms, which presented a value below the quantification limit.

At points Q11 and Q12 it was not possible to calculate the WQI, as there was no water in any of the 26 monitoring campaigns (Figure 2).

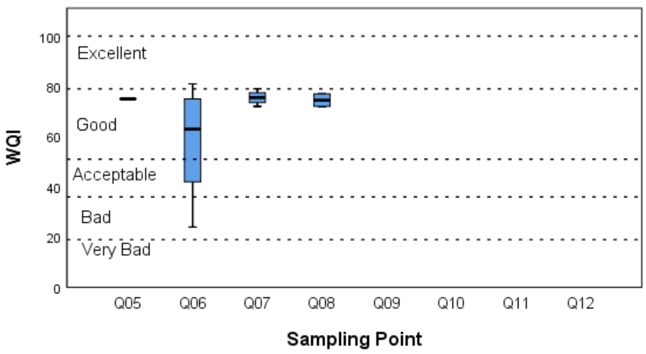

Figure 2 Spatial variation of WQI in TNRB during the sampling period.

Even in periods considered historically rainy, there were campaigns in which there was no water at the monitored points (Table 8). Only in the 20th campaign did the projected Terra Nova reservoir (Q05) reach 100% of its capacity.

Table 8 Seasonal variation in water quality in the TNRB

WQI	Rainy		Dry	
	N	%	N	%
Excellent	0	0	1	0.7
Good	7	9.7	7	5.1
Acceptable	4	5.6	6	4.4
Bad	4	5.6	5	3.7
Very Bad	0	0	0	0
Without water	56	77.8	100	73.5
Not Calculated	1	1.4	17	12.5
Total	72	100	136	100

In the dry period, the WQI in the TNRB ranged from Excellent (81) to Bad (24) and during the rainy season it ranged from Good (78) to Bad (22) (Figure 3). There was no data normality according to the Shapiro-Wilk test.

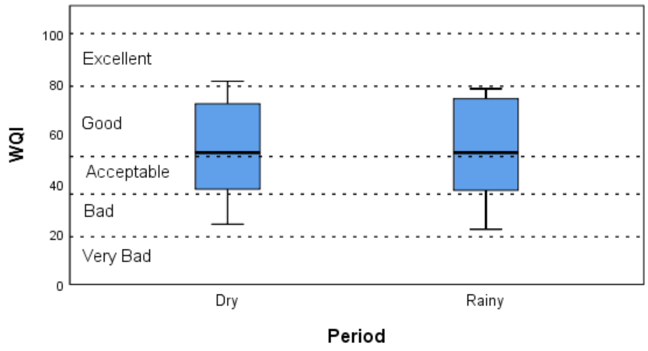

Figure 3 Seasonal variation of the WQI in TNRB during the sampling period.

During the TNRB monitoring, the following anthropogenic impacts were identified around the monitored points by the field team (Table 9).

Table 9 Anthropogenic activities developed in the TNRB

Point	Local	Anthropogenic activities
Q05	Terra Nova (projected) Reservoir	Presence of grazing animals.
Q06	Terra Nova Reservoir – dam axis	Pier, private pumps collection, human occupation, pasture animals, power transmission lines, agricultural activities on the reservoir bed, animal husbandry, animal watering, artisanal fishing, rural properties, human supply, fish mortality, fish salting, release of raw sewage and presence of odor.
Q07	Terra Nova river – downstream of the Terra Nova reservoir	Human occupation, pasture animals, presence of a bank of rooted floating and submerged macrophytes, fish mortality, discharge of sewage and presence of odor, dumping of solid urban and construction waste, presence of grazing animals, pig farming on the banks of the river, presence of oily waste, wet passage, power transmission lines and effluent discharge.
Q08	Serra do Livramento reservoir	Presence of grazing animals.
Q09	Mangueira reservoir	Human occupation. Presence of grazing animals.
Q10	Negreiro reservoir	Presence of grazing animals.
Q11	Milagres reservoir	As there was no water at this point during the 26 campaigns, no anthropogenic activities were mentioned.
Q12	Jati reservoir	As there was no water at this point during the 26 campaigns, no anthropogenic activities were mentioned.

Discussion

A possible positive impact related to the project is represented by the urban supply with better water quality, which results in potential impacts on improving the population's health and, possibly, lower costs related to water treatment. Another potential positive impact of the transposition is related to the prospect that the exogenous water made available in the region will help to boost the regional economy, mainly due to the reduction of restrictions on the further development/expansion of certain activities dependent on the input water for their implementation. Notably, irrigated agriculture is one of these activities; to a lesser extent the industry.[39]

Negative impacts involve not only interventions in the receiving basins regarding aquatic biology and river drainage but also changes in sociocultural relations. Even before the works began, for example, the resettlement of populations that lived around the project and the land regularization around the canals, which was paralyzed by the Federal Public Ministry. The Ministry of National Integration cites 38 socio-environmental programs[40] provided for the Brazilian Institute of the Environment and Renewable Natural Resources - IBAMA's conditions for implementing the transposition.

From 2010 onwards, a new period of drought began in the semi-arid Northeast, a period that was characterized by its severity and long duration.[41,42] This long drought period caused a series of negative impacts for the entire semi-arid region. Problems in urban supply, severe reduction in the stored volume in many reservoirs in the region, lack of water for irrigation and reduced harvests from rainfed agriculture are some of the negative consequences.[39]

Changes in the natural dynamics of ecosystems due to human action can be observed in several river basins, reflecting the need for integrated studies that include an understanding of the basic functioning of these basins.[43]

A very aggravating problem in the semi-arid region is the deficiency in basic sanitation in the region, especially in relation to sewage treatment, which is almost non-existent for the most part, which sometimes ends up being dumped directly into waterways. Another fact that must be considered is the diffuse pollution generated by agriculture. These factors have the potential to significantly harm the functioning of the transposition as a provider of water for human supply, a project of high cost and value, which cannot be neglected.[4]

The lack of sanitation has several negative impacts on the population health. In addition to harming individual health, increases public and private health spending on treating diseases. The World Health Organization (WHO) states that the main objective of sanitation is to promote human health, as many diseases can spread due to the absence of this service. Poor water quality, inadequate waste disposal, poor waste disposal and polluted environments are a result of the lack of sanitation and crucial factors for the spread of diseases.[44]

One of the great challenges of Brazilian sanitation is to develop sanitation programs in isolated communities that require independent solutions and different strategies that respect the natural and social identity of the place.[45] Basic sanitation is a protective factor for life quality and its precariousness or non-existence compromises public health, social well-being and degrades the environment. For the environment, it represents the end of polluted sewage being released directly into water sources such as rivers, groundwater, wells, ground, etc.[46]

The various studies carried out in the context of the transposition have shown that the surrounding areas of the reservoirs are either already occupied by human populations or will attract new contingents, indicating the need to develop actions that make the use and conservation of these water sources compatible. The land use analysis around the projected reservoirs demonstrated the existence of several communities in their vicinity and the possibility of various conflicts over water use, mainly by the closest population that did not benefit from supply infrastructure or granted use for irrigation.[4] Given this reality, the Environmental Program present in The Environmental Plan for Conservation and Use of the Reservoir Surroundings (PACUERA) of the Terra Nova reservoir includes Environmental Education activities, environmental recovery and environmental monitoring with the aim of mitigating conflicts and impacts.

Furthermore, it is necessary to consider the impacts of the new scenarios proposed with irrigated agriculture from the transposition waters, notably with regard to soil salinization, which can destroy not only the structure of the soil profile, but also its compaction and so on, make agricultural activities unfeasible.[47]

Conclusion

It was observed that in most campaigns there was no water at the monitoring points, both in the rainy season (77.8%) and in the dry season (73.5%). During the sampling period the WQI ranged from Excellent (81) to Bad (24) in the TNRB. Point Q06 stood out from the others, presenting the only WQI classified as Excellent. With regard to seasonality, the dry season ranged from Excellent (81) to Bad (24), while in the rainy season it ranged from Good (78) to Bad (22). It is necessary to invest in basic sanitation in the TNRB municipalities, environmental recovery, promote environmental education and monitoring with the aim of mitigating conflicts and impacts and improve water quality.

Acknowledgments

The authors thank the Ministry of Integration and Regional Development for making data available. This work was carried out with the support of the Coordination for the Improvement of Higher Education Personnel – Brazil (CAPES) – Financing Code 001.

Conflicts of interest

The authors have no conflicts of interest to declare.

References

1. Grill G, Lehner B, Thieme M, et al. Mapping the world's free-flowing rivers. *Nature*. 2019;569)7755):215–221.
2. Vidal-Abarca MR, Gómez R, Sánchez-Montoya MM, et al. Defining dry rivers as the most extreme type of non-perennial fluvial ecosystems. *Sustainability*. 2020;12(17):7202.
3. López E, Reynaldo Patiño, María L Vázquez-Sauceda, et al. Water quality and ecological risk assessment of intermittent streamflow through mining and urban areas of San Marcos River sub-basin. Mexico. *Environ Nanotechnol Monit Manag*. 2020;14:100369.
4. Silva FJ. Alcileia Sales, Higor Barbosa.. Impacts of climate change on the hydrology of the semi-arid region of Pernambuco: Scenarios and perspectives for the Terra Nova Basin-PE. *Journal of Hyperspectral Remote Sensing*. 2022;12(4):176–183.
5. Murgulet D, Murgulet V, Spalt N, et al. Impact of hydrological alterations on river-groundwater exchange and water quality in a semi-arid area: Nueces River, Texas. *Sci Total Environ*. 2016;572:595–607.
6. Xue Ying, Jinxi Song, Yan Zhang, et al. Nitrate Pollution and Preliminary Source Identification of Surface Water in a Semi-Arid River Basin, Using Isotopic and Hydrochemical Approaches. *Water.* 2016;8(8):328.
7. EMBRAPA SEMIÁRIDO. *Precipitação e evaporação*. 2021.
8. Fonseca-Neto GC, Simone Rosa Da Silva, Marcos Antonio Barbosa Da Silva Junior, et al. XXIV SIMPÓSIO BRASILEIRO DE RECURSOS HÍDRICOS. *Abordagem hidro-social de reservatórios no semiárido Pernambucano: estudo de caso do reservatório Nilo Coelho no rio Terra Nova*. 2021. Anais... Belo Horizonte, 21 a 26 de novembro de 2021.

9. Andrade EM, Lúcia De FP Araújo, Morsyleide F Rosa, et al. Seleção dos indicadores da qualidade das águas superficiais pelo emprego da análise multivariada. *Engenharia Agrícola*. 2007;27:683–690.
10. Rijsberman FR. Water scarcity: Fact or fiction? *Agric Water Manag.* 2006;80(1–3):5–22.
11. Ibáñez C, Caiola N. *Impacts of Water Scarcity and Drought on Iberian Aquatic Ecosystems*. In: Drought in Arid and Semi-Arid Regions; Springer: Dordrecht. The Netherlands. 2013;169–184.
12. Cunha APMA, Tomasella J, Ribeiro-Neto GG, et al. Changes in the spatial-temporal patterns of droughts in the Brazilian Northeast. *Atmospheric Science Letters*. 2018;19(10):1–8.
13. Marengo JA, Torres RR, Alves LM. Drought in Northeast Brazil -past. present. and future. *Theoretical and Applied Climatology*. 2016;129(3–4):1189–1200.
14. IPEA. *Transposição do rio São Francisco:* análise de oportunidade do projeto. Rio de Janeiro: IPEA. 2011.
15. Gupta J, Van Der Zaag P. Interbasin water transfers and integrated water resources management: Where engineering. science and politics interlock. *Physics and Chemistry of the Earth*. 2008;33(1–2):28–40.
16. Zhuang W. Eco-environmental impact of inter-basin water transfer projects: a review. Environ Sci Pollut Res Int. 2016;23(13):12867–12879.
17. Pires APN. Estrutura e objetivos da transposição do rio São Francisco: versões de uma mesma história. *Geousp – Espaço e Tempo (Online).* 2019;23(1):182–197.
18. Azevedo LGT de, Ruben La Laina Porto, Arisvaldo Vieira, et al. Série Água Brasil: Transferência de Água entre Bacias Hidrográficas. 1. ed. Brasília: Banco Mundial, 2005. p. 93.
19. Ecology Brasil. Ministério de Integração Nacional. *Projeto de Integração do Rio São Francisco com Bacias Hidrográficas do Nordeste Setentrional.* Estudos de Impacto Ambiental (EIA). Ecology Brasil, Agrar Consultoria e Estudos Técnicos e JP Meio Ambiente, julho de 2004.
20. Trajano SRRS, Spadotto CA, Holler WA, et al. Análise Morfométrica de Bacia Hidrográfica. Subsídio à Gestão Territorial Estudo de caso no Alto e Médio Mamanguape. *Boletim de Pesquisa e Desenvolvimento*. 2012;1:1–34.
21. APAC - Pernambuco Water and Climate Agency. *Water Basins – Terra Nova River*. [s.d.] 2023.
22. Correia RC. A região Semiárida Brasileira. In: Voltolini. T.V. (Org.). *Produção de caprinos e ovinos no semiárido*. Petrolina-PE: Embrapa Semiárido. 2011;1:21–48.
23. ANA – Agência Nacional de Águas. "Anexo E". In: *Reservatórios do Semiárido Brasileiro*: hidrologia. balanço hídrico e operação. Org. por Conejo. J.G.L.. 1 ed. ANA. Brasília-DF. 2017a.
24. CMT Engenharia Ambiental. *Plano de Conservação e Uso do Entorno dos Reservatórios Artificiais (PACUERA) PBA-14*. Diagnóstico Socioambiental Sub-bacia Terra Nova. CMT ENGENHARIA AMBIENTAL Engenharia. 2016. p. 475.
25. Abreu CHM, Cunha AC. Qualidade da Água em Ecossistemas Aquáticos Tropicais Sob Impactos Ambientais no Baixo Rio Jari-AP: Revisão Descritiva. *Biota Amazônia*.2015;5(2):119131.
26. Yap CK, Ismail A, Tan SG. et al. The impact of anthropogenic activities on heavy metal (Cd. Cu. Pb and Zn) pollution: Comparison of the metal levels in green-lipped mussel *Perna viridis* (Linnaeus) and in the sediment from a high activity site at Kg. Pasir Puteh and a relatively low activity site at Pasir Panjang. *Pertanika Journal of Tropical Agricultural Science.* 2004;27(1):73–78.
27. Almeida MB, Schwarzbold A. Avaliação sazonal da qualidade das águas do Arroio da Cria Montenegro. RS com aplicação de um índice de qualidade de água (IQA). *Revista Brasileira de Recursos Hídricos*. 2003;8(01):81–97.
28. NSF – National Sanitation Foundation. *Water Quality Index (WQI).* 2010.
29. CETESB - Companhia de Tecnologia de Saneamento Ambiental. *Variáveis de Qualidade da água.* São Paulo. 2009.
30. Silveira ACB. *Estudo de Caso da Implantação do Sistema Separador Absoluto de Esgoto em Sub-bacias do Sistema Marangá, Município do Rio de Janeiro, sob uma Perspectiva de Saúde Ambiental*. Dissertação (mestrado) – Pontifícia Universidade Católica do Rio de Janeiro, Departamento de Engenharia Civil e Ambiental, Programa de Pós-Graduação em Engenharia Urbana e Ambiental, 2018. p. 100.
31. Sánchez E, Manuel F Colmenarejo, Juan Vicente, et al. Use of the water quality index and dissolved oxygen deficit as simple indicators of watersheds pollution. *Ecological Indicators*. 2007;7(2):315–328.
32. CCME. Canadian Council of Ministers of the Environment. *Canadian Water Quality Guidelines for the Protection of Aquatic Life: CCME Water Quality Index 1.0, technical report.* In: CANADIAN Environmental Quality Guidelines, 1999, Winnipeg. . [s.l.]: Environment Canada, 2001.
33. Ferreira LM, Ide CN. *Avaliação comparativa da sensibilidade do IQA-NSF, IQA-Smith e IQA-Horton, aplicados ao Rio Miranda, MS*. In: Congresso Brasileiro de Engenharia Sanitária E Ambiental, 21., 2001, João Pessoa. [Anais...] João Pessoa: ABES, 2001.
34. Espejo L. Application of water quality indices and analysis of the surface water quality monitoring network in semiarid North-Central Chile. *Environ Monit Assess*. 2012;184:5571–5588.
35. CETESB - Companhia de Tecnologia de Saneamento Ambiental. 2017. *Apêndice D*. 2003.
36. APAC – Agência Pernambucana de Águas e Clima. 2009-2022. Monitoramento Pluviométrico. 2003.
37. Silva ERAC. *Análise da dinâmica climática em bacias semiáridas no Eixo Norte do Projeto de Transposição do Rio São Francisco: contribuições para o cumprimento dos Objetivos do Desenvolvimento Sustentável*. 2020. Tese (Doutorado em Desenvolvimento e Meio Ambiente) – Universidade Federal de Pernambuco, Recife, 2020.
38. Brasil. *Resolução CONAMA 357, de 17 de março de 2005*. Conselho Nacional de Meio Ambiente. 2010.
39. IPEA – Instituto de Pesquisa Econômica Aplicada. *Texto para Discussão.* Instituto de Pesquisa Econômica Aplicada.- Brasília: Rio de Janeiro : Ipea. 2022. p. 74.
40. Brasil. *Ministério da Integração Nacional.* Atlas Nordeste Abastecimento Urbano de Água 2006. 2015.
41. Viana JP. *Ações do governo federal na área de influência do Projeto de Integração do Rio São Francisco com Bacias Hidrográficas do Nordeste Setentrional: uma avaliação dos investimentos nos municípios do plano de ação.* Brasília: Ipea, maio 2014. (Texto para Discussão, n. 1965).
42. Gondim J. A seca atual no semiárido nordestino: impactos sobre os recursos hídricos. *Parcerias Estratégicas*. 2017;22(44):277–300.
43. Vasco AN, Britto FB, Pereira APS, et al. Avaliação espacial e temporal da qualidade da água na sub-bacia do Rio Poxim. Sergipe. Brasil. *Ambiente & Água*. 2011;6(1):118–130.
44. Siqueira MS, Rosa Roger dos Santos, Bordin Ronaldo, et al. Internações por doenças relacionadas ao saneamento ambiental inadequado na rede pública de saúde da região metropolitana de Porto Alegre. Rio Grande do Sul. Brazil, 2010-2014. *Epidemiol. Serv. Saúde*. 2017;26(4):795–806.

45. Hosoi C. Comunidades isoladas exigem um saneamento sob medida. *Revista DAE*. 2011;187 Ed:4–12.
46. Arruda LPS. *Pernambuco: agravos à saúde relacionados à falta de saneamento.* Luanna Pryscilla Simões Arruda. Monografia (Bacharelado em Saúde Coletiva) Vitória de Santo Antão: UFPE. 2019. p. 35.
47. Pires APN. Estrutura e objetivos da transposição do rio São Francisco: versões de uma mesma história. *Geousp – Espaço e Tempo (Online).* 2019;23(1):182–197.

Citation: Marques ET, de Oliveira CR, Caldas HF, et al. Seasonal variation of the water quality in an intermittent river perennified by hydraulic work: a case study of the Terra Nova river basin, Northeast Brazil. *Int J Hydro.* 2024;8(2):55–63. DOI: 10.15406/ijh.2024.08.00375