GEOCIÊNCIAS:

A história da terra

2

Luis Ricardo Fernandes da Costa
(Organizador)

Atena Editora
Ano 2022

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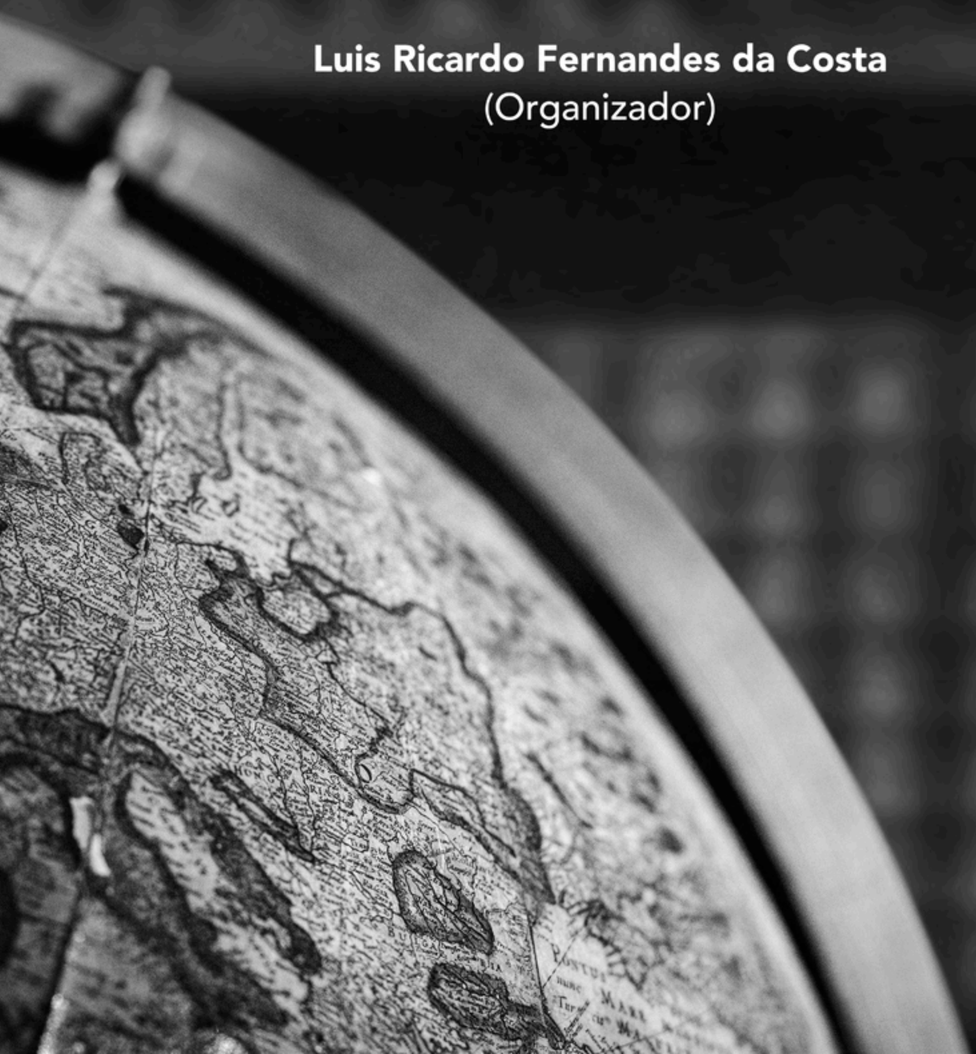

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CIÊNCIAS EXATAS E DA TERRA E ENGENHARIAS

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APRESENTAÇÃO

É com muito prazer que apresentamos a obra “Geociências: a história da Terra 2”, que apresenta uma série de seis artigos com diferentes abordagens e metodologias que dão prosseguimento as discussões do livro anterior.

A obra é composta por trabalhos voltados para as geociências e que abordam diferentes metodologias, desde análises de qualidade de água, passando pela importância de fontes de energias renováveis, além do planejamento ambiental e suas diferentes aplicações para o meio ambiente.

Como destaque, cabe ressaltar a aplicabilidade em diferentes contextos e realidades no Brasil e no exterior, além das experiências voltadas a consolidação do ensino de geociências a nível nacional, como é abordado ao longo do livro.

Diante dos desafios e atual conjuntura da ciência brasileira, a presente obra é uma possibilidade e esforço de divulgação de trabalhos em diferentes escalas e com a qualidade a nível Brasil, mesmo com os percalços e desafios da pesquisa cotidiana.

Convidamos a todos os leitores a percorrer pelo sumário e conferir o novo volume para essa coleção, com possibilidades de expansão e disseminação nos próximos trabalhos da área.

Luis Ricardo Fernandes da Costa

SUMÁRIO

CAPÍTULO 1

DETERIORATION OF WATER QUALITY IN THE NHARTANDA VALLEY AQUIFER, CITY OF TETE – MOZAMBIQUE

Data de aceite: 01/02/2022

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ABSTRACT: Groundwater is more protected than surface water. This is due to the filtering capacity exerted by the soil and by the unsaturated area of the aquifers. However, there are hydrophilic substances that can compromise the water quality of these sources. The deterioration of groundwater quality can be caused by human activities or natural processes, the action of both factors being more frequent. In this perspective, this study aims to evaluate the water quality of the Nhartanda Valley aquifer system. In this evaluation some organoleptic, physico-chemical and biological parameters were performed using a portable multiparameter for In Situ analysis, a UV-Visible spectrophotometer for chemicals and 3M™ Petrifilm™ plates to inoculate and perform biological analysis. The results obtained in 03 analyzes each, show that the water quality of the Nhartanda aquifer system is affected and is deteriorating by human activity (urban, domestic, agricultural and livestock, among others) and natural (saline intrusion and mineral dissolution). This time, joint actions must be carried out as a way of conserving and protecting this main public source of water supply to the Municipality of Tete.

KEYWORDS: Groundwater, Deterioration, Nhartanda Valley, Tete and Mozambique.

DETERIORIZAÇAO DA QUALIDADE DA ÁGUA DO AQUÍFERO NO VALE NHARTANDA, CIDADE DE TETE - MOÇAMBIQUE

RESUMO: As águas subterrâneas são mais protegidas do que as águas superficiais. Isso se deve à capacidade filtrante exercida pelo solo e pela área insaturada dos aquíferos. No entanto, existem substâncias hidrofílicas que podem comprometer a qualidade da água dessas fontes. A deterioração da qualidade das águas subterrâneas pode ser causada por atividades humanas ou processos naturais, sendo a ação de ambos os fatores mais frequente. Nesta perspectiva, este estudo tem como objetivo avaliar a qualidade da água do sistema aquífero do Vale do Nhartanda. Nesta avaliação alguns parâmetros organolépticos, físico-químicos e biológicos foram realizados utilizando um multiparâmetro portátil para análise In Situ, um espectrofotômetro UV-Visível para parâmetros químicos e placas 3M™ Petrifilm™ para inocular e realizar análises biológicas. Os resultados obtidos em 03 análises cada, mostram que a qualidade da água do sistema aquífero de Nhartanda é afetada e está se deteriorando pela atividade humana (urbana, doméstica, agrícola e pecuária, entre outras) e natural (intrusão salina e dissolução mineral). Desta feita, devem ser realizadas ações conjuntas como forma de conservar e proteger esta principal fonte pública de abastecimento de água ao Município de Tete.

PALAVRAS-CHAVE: Água Subterrânea,

Deterioração, Vale de Nhartanda, Tete e Moçambique.

1 | INTRODUCTION

This work aims to evaluate the quality of groundwater in the Nhartanda Valley Aquifer System, Tete City. This study is a fundamental tool to support water management, especially in this region where the precious liquid is “scarce and limited” for the community. Water scarcity in many countries and/or cities with high population concentration has become an impediment to development and, in many cases, an obstacle to their own livelihoods. The use of water resources presupposes carrying out sample studies to assess its quality. In this way, it is crucial to know the environmental factors, both natural and human that, directly or indirectly, affect the quality of the water and, with this, base the direction of the investments necessary to raise the quality levels of the same. For this purpose, analyses of organoleptic, physico-chemical and biological parameters were carried out in the Nhartanda Aquifer System and the results were compared with the potability standard established by the Ministry of National Health and the WHO, since this water is sometimes consumed still in raw form.

2 | STUDY AREA – NHARTANDA VALLEY

The Nhartanda Valley (Fig. 1c) is located in Southern Africa, more specifically in the Central region of Mozambique (Fig. 3.1a), in the southern part of Tete City (Fig.3.1b), homonymous province. It is a fluvial plain of the Zambezi River, with NW/SE orientation, in an area of 6.76 km^2, corresponding to 2.2% of the surface of the City of Tete, which is approximately 314 km^2. This valley has a length of 6.45 km and a maximum and minimum width of 1.4 km and 0.47 km respectively.

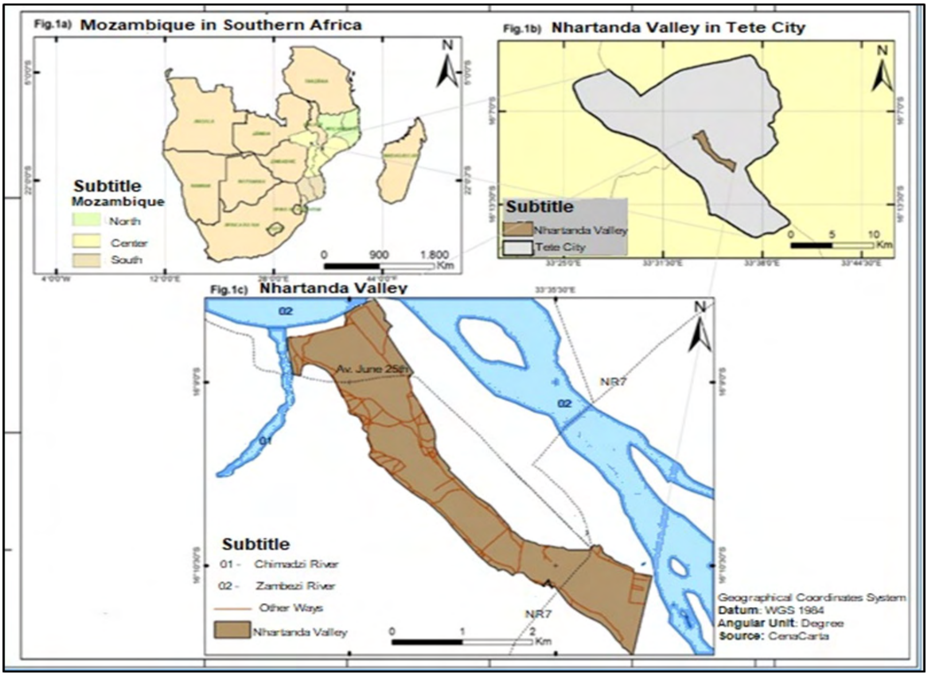


Figure 1: Location of the Nhartanda Valley.

The Nhartanda Valley consists of Phanerozoic sedimentary formations (sandstones) from the Lower Zambezi and presents a flat relief, with altitudes between 125m-130m, resulting from the evolution of one of the anastomosed systems of the Zambezi River.

Nhartanda is located in the middle section of the Lower Zambezi and in the Mozambique North climate region, dominated by a Tropical Dry climate and alluvial soils (fine, medium and coarse sand). This aquifer is intergranular, free and isotropic, subordinate to the Zambezi River, with flows greater than 200m^3/h and “insignificant” lowering (less than 2 meters) (MUCHANGOS, 1999 & COBA, 2012, 2013). The depth of the static (S.L.) and dynamic (D.L.) water levels range from 4.8m to 7.7m and from 9.2m to 19m, respectively. The estimated recharge is 6 000 000 m^3/year, with ~4% of runoff, ~12% of precipitation and hills and ~84% of the Zambezi River and the hydraulic conductivity is greater than 86 m/day (WE CONSULT, 2016).

Furthermore, the physical-geographical characteristics of Nhartanda favour the development of various activities (agricultural and livestock and areas of human occupation, which include residential areas, service provision, ceramic craft factories and others) (Fig. 2).

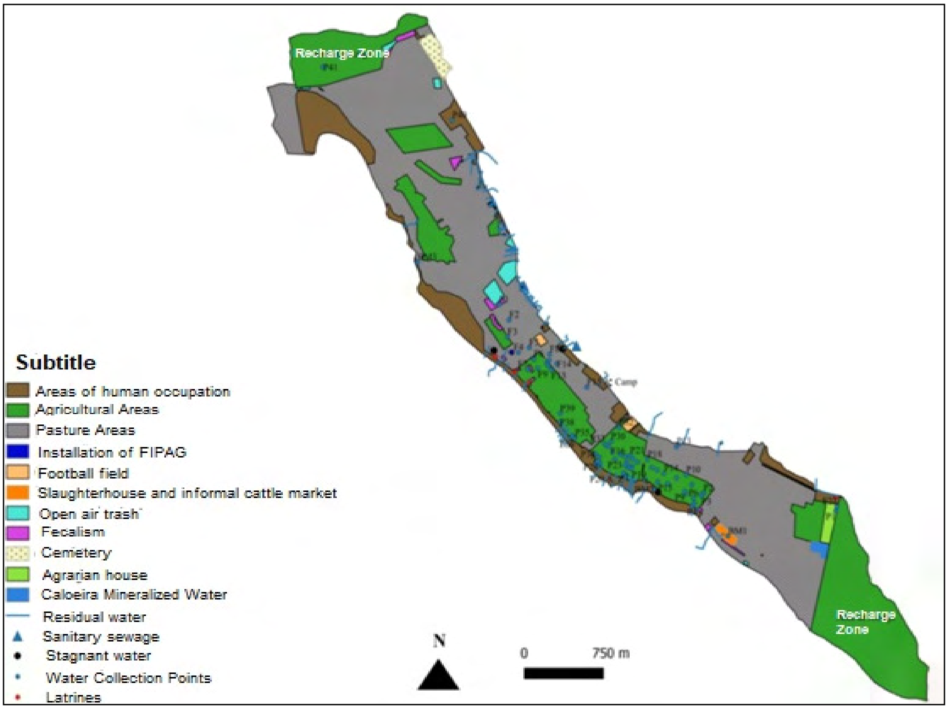


Figure 2: Land occupation in the Nhartanda Valley.

The entire area of the valley is subject to sources of pollution and/or contamination (punctual and diffuse), associated with the lack of basic sanitation in the City of Tete in general, which, in a certain way, influence its environmental and water quality in particular.

3 | OBJECTIVES

3.1 General

- Assess the groundwater quality of the Nhartanda Valley Aquifer System, Tete City;

3.2 Specifics

- Present the physical-geographic characteristics of the Nhartanda Valley;
- Identify the factors that contribute to the deterioration of the water quality of the Nhartanda Valley aquifer system;
- Propose strategies to safeguard the water quality of the Nhartanda Valley.

4 | METHODOLOGIES

The study was carried out in different stages. To materialize the purposes of each phase, a set of carefully selected methods and techniques were applied.

In a first phase, a survey of past works of characterization and investigation of the study area was carried out, which allowed for a better understanding of it.

The second phase included field surveys, through recognition of the study area. At this stage, in addition to the registration of 67 water catchment points (26 holes and 41 wells and 26 water points selected for sampling, 11 wells and 15 holes) and potential sources of pollution/contamination with the aid of the GPS receiver Garmin 64s, the measurement of the depth of the wells and the water table and the mapping of the use and occupation of the land were also carried out.

The third phase consisted of office work, which included the application of a set of Geo-technologies (Google Earth/Pro and Qgis 2.14 and ArcGis 10.3, GPSVisualizer) which allowed the integration and compilation of cartographic data.

Finally, the natural characteristics of the water were determined for each georeferenced and selected sampling point, carried out in two different ways: (i) "*In Situ*", some organoleptic characteristics (taste and odor) and physico-chemical properties were determined such as temperature (T ºC), pH, electrical conductivity (EC), turbidity (NTU) and total dissolved solids (TDS), using a portable multiparametric meter brand HANNA model HI 9829 (ii) laboratory analysis to determine the chemical and biological properties. For these, at each sampling point, approximately 1L of water was collected, with equipment and appropriate and previously sanitized containers, packed in coolers and transported to the laboratory (fig. 3).

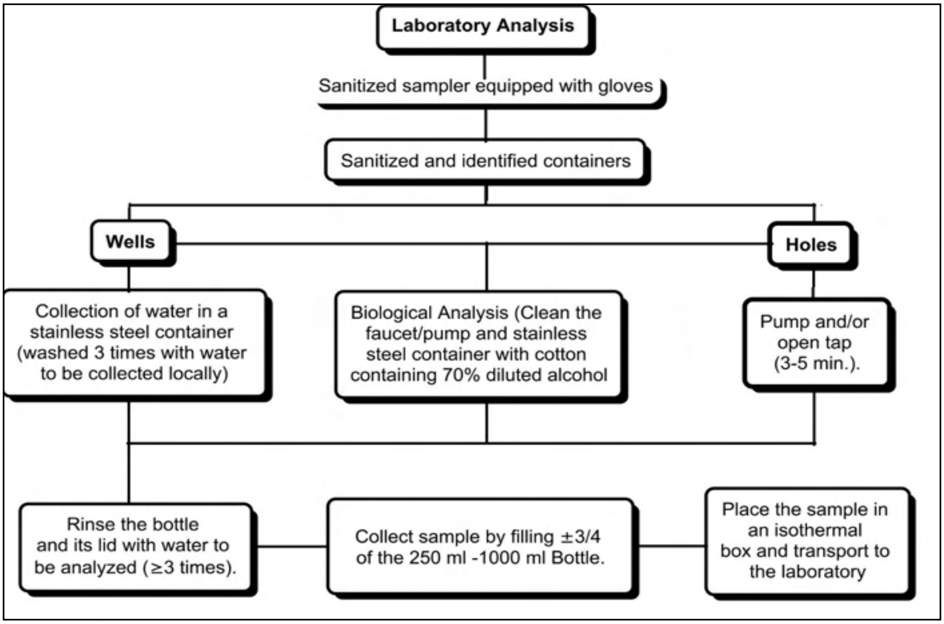


Figure 3: Sample collection, packaging and transport process.

In the laboratory, some chemical and biological parameters were determined, previously selected in accordance with the existing conditions in the Laboratory of the Water Supply Investment and Heritage Fund (FIPAG), City of Tete, and with the proper care in order to preserve the properties of the samples (fig.4).

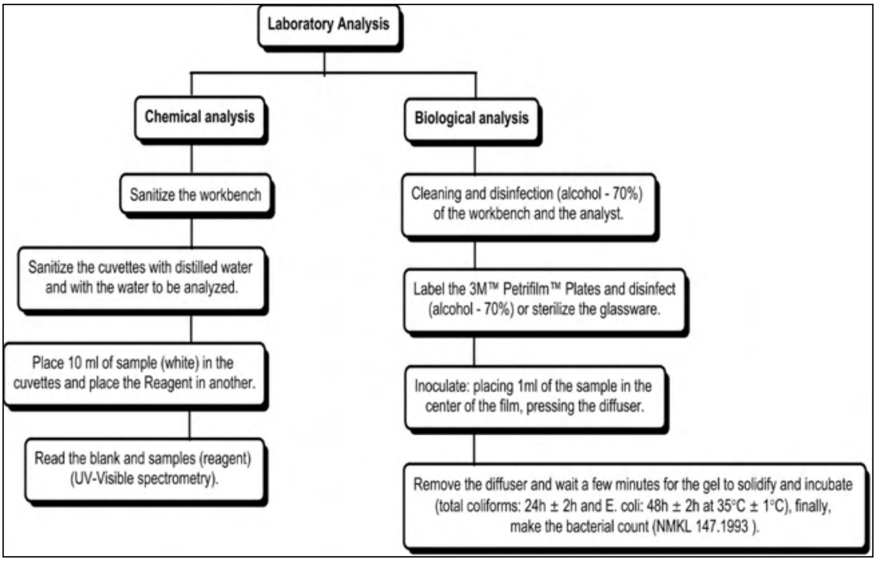


Figure 4: Laboratory procedures for chemical and biological analysis of water.

With the exception of salinity, which was obtained by a Hach portable multiparameter, model HQ 14d, the remaining parameters such as alkalinity, total hardness and content of the elements of chloride, calcium, nitrate, nitrite, ammonia, total iron and manganese were obtained by UV-Visible Spectrophotometry, using a multiparameter Bench Photometer, brand HANNA, model HI 83200.

All laboratory work was carried out with the utmost care and precision as possible so as not to influence/change the results obtained, as well as protecting the analyst through the use of adequate protection means (gloves, masks, gowns, glasses). The laboratory analyzes (chemical and biological), associated with “In Situ” allowed to characterize and evaluate the water quality of the Nhartanda Valley aquifer system.

5 I RESULTS AND DISCUSSION

Water quality is a determining factor for the health of the human population. For SILVA, HORA & OLIVEIRA (2017), for the analysis of water quality, a set of characteristics, usually measurable, of a nature where their characteristics must be kept within certain limits, which are represented by standards, guiding values, must be observed, water quality, sediment and biot. The averages of the results obtained in "In Situ" and laboratory analyses of the raw water samples collected in wells (P) and boreholes (F) and/or hand pumps (B) of Nhartanda Valley are presented below.

5.1 Physico-chemical and organoleptic parameters

The physico-chemical and organoleptic parameters refer to indirect measurements of elements present in water, which may or may not be toxic to the environment and man (CNA, 2007). Within these, the following were considered (Tab.1).

	Color	Taste	Odor
	<15 uH (Hazen units)	salty	Iron in holes and clay in wells
MAV	<15 uH	Odorless	Insipid

Table 1: Organoleptic parameters.

It is important to note here that the color measurement was carried out about 10 years ago. The lack of a photometer or colorimeter makes the evaluation of this parameter based on macroscopic observation.

Although Taste and Odor can be used as an indicator or warning sign for the occurrence of unwanted substances, its assessment is quite subjective, which makes it difficult to establish admissible limit values (MAV) for these organoleptic characteristics.

5.2 Physical-chemical parameters

Generally in groundwater, the temperature is conditioned by the materials through which it circulates, that is, by the geothermal degree, but due to the reduced depth of the Nhartanda aquifer, this is strongly influenced by the atmospheric temperature (Table 2).

The high turbidity (except B_1 and B_3) is observed in the rainy season, favoured by the intense agricultural activity that promotes the removal/erosion of the soil. This situation contributes to high levels of CE and TDS (except B_1, P_{20} and P_{31}) (Tab.2).

	T° C	**Turbidity (NTU)**	**EC (µS/cm)**	**TDS (mg/l)**	**Alkalinity (mg/l)**	**Total hardness (mg/l of $CaCO_3$)**
	Orthothermals Hypothermals	5,1-40 Wells; 2,1- 32,1 Holes	601-3090 Wells; 724-2408 Holes	300-1200	135-250 Wells 150-400 Holes	150-320
MAV		5 NTU	50-2000	1000		500
	Salinity (%)	Chlorides (ml/g)	Calcium (mg/l)	Manganese	Total Iron (mg/l)	Nitrite
	0,2 - 1,2	120 – 475	20-120	0,003-0,02	0,2 – > 1,04	1,8-15,7
MAV	<0,5%	250	50	0.1	0,3	0,3

	Ammonia (mg/l)		pH			
	0,14-0,91		7.14 -7.99			
MAV	1,5		6.5 e 8.5			

Table 2: Results of the analysis of the Nhartanda Valley's physico-chemical parameters.

The water from the Nhartanda Valley aquifer system has a total hardness with values between 105 and 320 mg/L of $CaCO_3$ and is classified as moderately hard, hard and very hard water. The total hardness results will be related to the brackish water mixture (except P_{11}, P_{13}, P_{18}, P_{41}, F_1 and F_3, with records in F_{18}, F_{22} and B_1.) from the Valley water – sandstone water interaction. This healthiness can also be related to high temperature throughout the year (causing water evaporation and salt concentrations), which can contribute to high salinity. Other factors such as over exploitation (which allows the saline wedge to advance) and the dissolution of calcite, halite, dolomite and gypsum, not only contribute to the salinization of the aquifer, but also to the high levels of Chlorides (except B_1, P_4, P_{11}, P_{13}, P_{18}, P_{20}, P_{31}, P_{38}, P_{40} and P_{41}) and Calcium (F_8, F_9, F_{10}, F_{12}, F_{14}, F_{18}, F_{22}, P_{13}, P_{22}, P_{31}, P_{38}, P_{40} and P_{41}) (Tab.2).

Iron and manganese cations, metallic elements abundant in nature, through water infiltration through soil and rocks, are dissolved and become part of groundwater (FEITOSA & FILHO, 2010). In Nhartanda, the Fe contents far exceed those of Mn and the majority (61.5%) exceeds the MAV. The highest total Fe value is found in boreholes and exceeds 1.04mg/l and is associated with: (i) water residence time in interrupted or obstructed boreholes; (ii) nature and care of machines and accessories, as well as introduction of iron-bacteria during drilling; (iii) obsolescence and/or lack of sanitation in the materials that make up the holes (Tab.2).

As for the nitrogenous species (Nitrates, Nitrites and Ammonia), which constitute the occurrence of nitrogen in water, it is important to refer to the concentration of nitrates and nitrites in which some samples exceed the MAV's (LIMA, 2010). With the exception of water from F_3, F_6, F_8, F_{10}, B_1 and B_3 as well as that of P_1, P_{11}, P_{40} and P_{41}, the NO_3^- contents in the Nhartanda Valley groundwater are higher than the MAV. These high levels are strongly associated with the leaching process, from soils with fertilizers and fertilizers applied in agricultural activities and also to urban effluents and human excreta. Nitrite contents, in turn, are related to those of nitrates in the waters, and vary between 1.8 and 15.7 mg/L, in the waters of wells and wells in the Nhartanda Valley. In both boreholes and wells, the NO_2^- content exceeds the MAV, indicating serious pollution/contamination problems in the Nhartanda Valley (Table 2).

5.3 Biological parameters

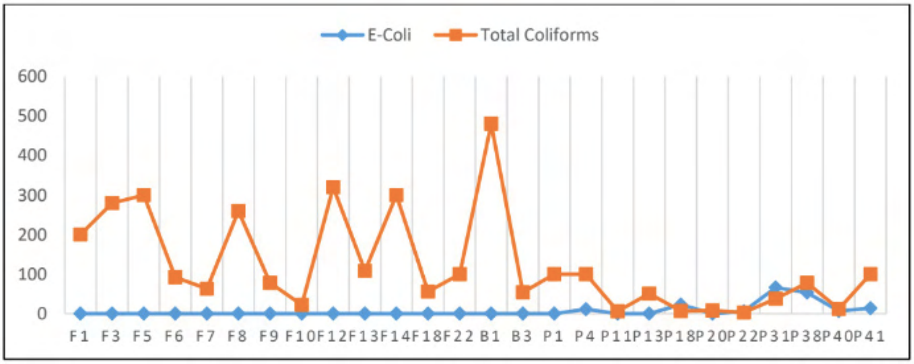
The biological parameters of water result from the relationship between aquatic organisms and the environment in which they occur and allow the detection of potential pollutants/contaminants not identifiable through physical-chemical and organoleptic characteristics.

Water for human consumption cannot contain pathogenic microorganisms and must be free of bacteria that indicate faecal contamination. This is possible to assess through the presence of coliforms (because of the ease of detecting and quantifying), in which the bacterium Escherichia coli is one of the main indicators (FUNASA, 2006).

The detection and quantification of all pathogenic microorganisms potentially present in water is arduous, time-consuming and costly, as it involves the preparation of different culture media and it is not always possible to obtain positive results or to confirm the presence of the microorganisms. These difficulties result from the fact that certain organisms are intolerant and others tolerant, depending on their ability to survive in new environmental conditions (FUNASA, 2014).

Therefore, easily identifiable organisms were selected for the Nhartanda Valley, whose occurrence in the water is correlated with the presence of pathogenic organisms – called indicator organisms (Escherichia coli and total coliforms). Bacterial counting was also carried out.

Graph 1 shows that groundwater in the Nhartanda Valley contains bacteria, whose amounts (43 – 1 000 000 CFU - colony forming units) and nature vary considerably with location and environmental conditions.



Graph 1: E-Coli and total Coliforms.

The holes are free of E-Coli, unlike the wells (except P_1, P_{11}, P_{13} and P_{20}) which have quantities ranging from 6 (P_{22}) to 66 (P_{31}). Total coliforms occur in both borehole and well water, with greater amounts in the latter. With the exception of water from holes F_6, F_7, F_9, F_{10}, F_{18}, B_3, P_{11}, P_{13}, P_{18}, P_{20}, P_{22} P_{31}, P_{38} and P_{40}, the remaining sampling points have quantities greater than 100 Colony Forming Units (CFU) of total coliforms.

The values of the organoleptic and physico-chemical parameters, associated with the biological ones, indicate that the water is polluted and may be contaminated. This deterioration can be caused by several factors (fig. 5).

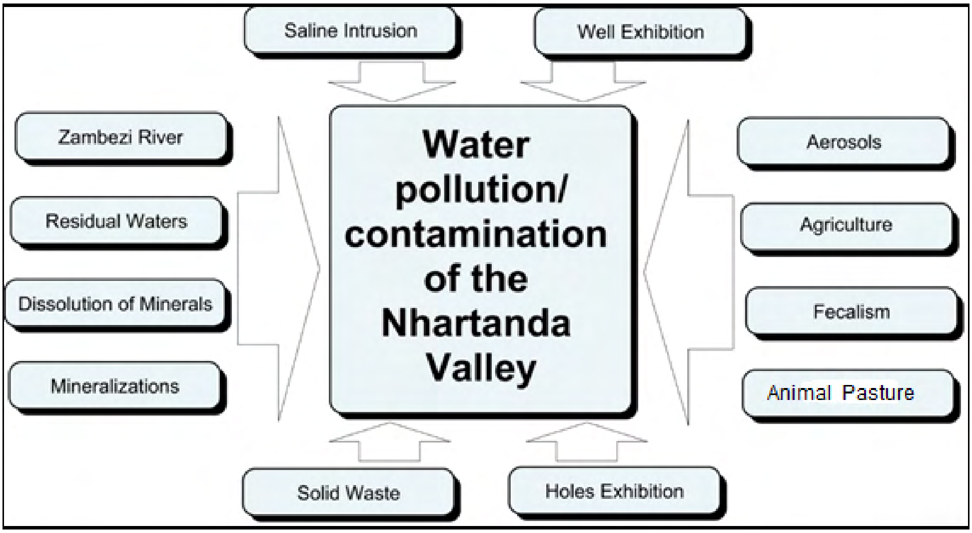


Figure 5: Factors of water quality deterioration in Nhartanda.

The Nhartanda Valley aquifer system is infested by various sources of pollution/point and/or diffuse contamination, both natural and those that are the result of human action that, directly or indirectly, greatly affect the quality of the water. Hence, a set of actions must be carried out in order to preserve that hydro-treasure of Tete City. Among these actions we can cite Environmental Education as its salvation.

CONCLUSION

The Nhartanda Valley aquifer system has a high vulnerability and susceptibility to pollutants and/or contaminants. This situation, combined with the physical characteristics of the aquifer and the local natural conditions, allow a large part of pollutants/contaminants (bacteria, viruses and other substances) to easily reach the aquifer causing several analyzed parameters to be above the MAV, thus creating a "*Water stress*".

The presence of potentially polluting/contaminant activities along the Valley and adjacent areas, associated with pollution of the Zambezi River, agriculture and livestock, waste disposal and the practice of open defecation, proximity to pits and latrines and inadequate construction of wells as well as the lack of protection of the wells also contribute to the degradation of the water quality.

Given this scenario, a set of actions are needed in order to protect the Nhartanda Valley's groundwater and, consequently, public health. These actions should be joint, involving the Municipality of Tete City, the Provincial Directorate of Public Works, Housing and Water Resources of Tete, Ara Zambeze, FIPAG, Residents of adjacent areas and Civil Society, starting with the socio-environmental awareness of all stakeholders and involving them in all activities to protect that source.

Finally, this shows that it is very important to understand that groundwater is not an invulnerable and inexhaustible source and that its pollution/contamination poses serious risks to the existence of life.

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