Hydrogeochemical characterisation of the low Mandrare area, South Amboasary District

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ABSTRACT

The present study is interested in the mode of mineralization of groundwater distributed in the lower Mandrare zone. The latter, which is located in the extreme south of Madagascar, is administratively divided between five municipalities: South Amboasary, Tanandava, Ifotaka, Behara, and Sampoina. However, this zone presents interesting geological characteristics which influence both the underground flow mode, as well as the ionic exchanges which lead to the final mineralization of the studied waters.
By adopting a multidisciplinary study such as geology, hydrogeology, and hydrochemistry, the mineralization process is observed in a transversal way, connecting these three elements in order to explain the complexity of water mineralization measured (500 to +3000 µS/cm) on site, using a conductivity meter. However, more in-depth analyzes on major ions such as bicarbonate, chloride, sodium, calcium and also potassium, were carried out in an analytical laboratory before discovering that these are predominant in all the waters inventoried in the lower Mandrare area. The same is true for minor elements like nitrate and sulfate which seem to be in fairly high percentages in a few areas. The variation in the characteristics of the waters is quite different depending on their distance as well as the variation in the hydrostatic level allow them to be located on a grid of assessments in order to bring out the dominant facies in the area (sodium bicarbonate, etc.). These waters are technically easy to access, because even with a fairly variable general topography, the depth of the structures for any operation does not exceed twenty meters to find water. However, their hydrogeochemical characteristics reveal aspects that do not conform to potability, which requires a more complex intervention for their treatments.

Keywords*: Hydrogeochemistry, hydrogeology, semi-arid, mineralization, groundwater*

1. CONTEXT OF THE STUDY AREA

Amboasary Sud district, the area of investigation for this research, has specific characteristics that differentiate it from other districts of Madagascar. These characteristics are the result of several evolutionary processes in several areas, whether geological, biological, hydrological, hydrogeological, as well as the growth and the way of life on the human side which retracts into socio-economic and cultural aspects.

The composition and structure of the soil and subsoil are the first observable aspects of our study area. It results from a bedrock (plutonic) still observable in the North (Besairie H., 1944), if, under the effect of the climate and the pressure generated by a long weathering process, the detrital deposits have accumulated in forming stratigraphic layers of sedimentary formations. The sediments deposited on a geological time scale reveal the youngest rock on the surface. This quaternary generation, which is the most recent, favors the infiltration of precipitation water, leaving almost none on the surface (Besairie H., 1973).

Nonetheless, there is a permanent river (Mandrare) that crosses this district, giving hope to all life forms that depend on water for survival and development. However, only nearby areas benefit directly from this resource. For the others, recourse to other alternatives is required to have this scarce commodity in sufficient quality and quantity. As a result, several projects have followed one another in an attempt to exploit the resources available to serve the localities. Remember that this area has an annual rainfall deficit which makes it semi-arid (Garou J., 2012).

The extent of the Amboasary sedimentary basin is poor in surface water, the exploitation of groundwater has been strongly recommended by setting up wells and boreholes to extract this water in order to serve it to the population of this area. But by being often less sustainable, the exploitation of groundwater by vertical structures does not solve the water deficit both in terms of quantity and quality. Faced with recurring failures, the Malagasy government decides to launch a major project in 2017 to exploit the permanent Mandrare river by setting up a

pipeline for its delivery, and currently this structure remains functional and serves the town of Sampona with a prospect of extending the system, in order to increase the number beneficiaries.

However, the potential of groundwater remains significant to meet the water needs of our study area. But in reality, this potential remains ambiguous information if it is not associated with various factors influencing, namely the socio-economic aspect to understand the perception and the purchasing power of the population, the aspect climatological which indicates the quantity of recycled water in our considered system, the hydrological and hydrogeological aspect which informs the surface and underground flow mode with the determination of the available quantity from the water balance (Rakoto H., 2003). Finally, this study, although it is interested in these quantitative movements of water in the district of South Amboasary, its main objective lies on the highlighting of the qualitative aspect of any groundwater encountered on the basis of a hydrogeochemical study to have the dominant facies distributed in this zone.

1.1. Presentation of the study area

The South Amboasary District is located at the South East end of the Androy Region. It is administratively recognized as the third district located southwest of the Anosy region. It is the commune, on the eastern side, that separates the two interfering regions. But its characteristics correspond more to that of the Androy region, because if the east coast of the island[1] is renowned for its overabundance of water resources, our study area for its part, is experiencing a deficit in water on the one hand, but in addition, the underground reserves are naturally contaminated by mineralization due to the geological characteristics of the water table, because the taste which varies between brackish and salty reveals the strong presence of mineral salt which is released in dissolution in water which saturates the aquifer geological zone (Rabemanana V., 2002). In short, our study area is characterized by a generally dry appearance, a semi-arid zone briefly described by observing the water deficit that weighs on the societal life of the local population.

However, this district includes five municipalities[2] in total, each of which is concerned by this study. Indeed, this study covers a land area of 10,211 km²[3], but the distribution of the sampling points does not cover this totality, because they are based on the existing water points which make it possible to take samples for analysis.

The Mandrare river crosses the three communes of the study area and Mananara which is the tributary of Mandrare passes only through the commune of Behara. Note that no river crosses the town of Sampona which is in the southwest of the area.

[1] Madagascar is the fourth largest island in the world. It is located in about 400 km east of Africa separated by the Mozambique Channel. An island very rich in mining, biodiversity, cultural resources, and above all in "blue gold", but they are all under-exploited despite their high potential which could improve the way of life of its population.

[2] Ifotaka, Behara, Amboasary south, Sampona, and Tanandava south

[3] Total area of South Amboasary district. Represents about 35% of the territory of the Anosy region with an area of 29,024 km².

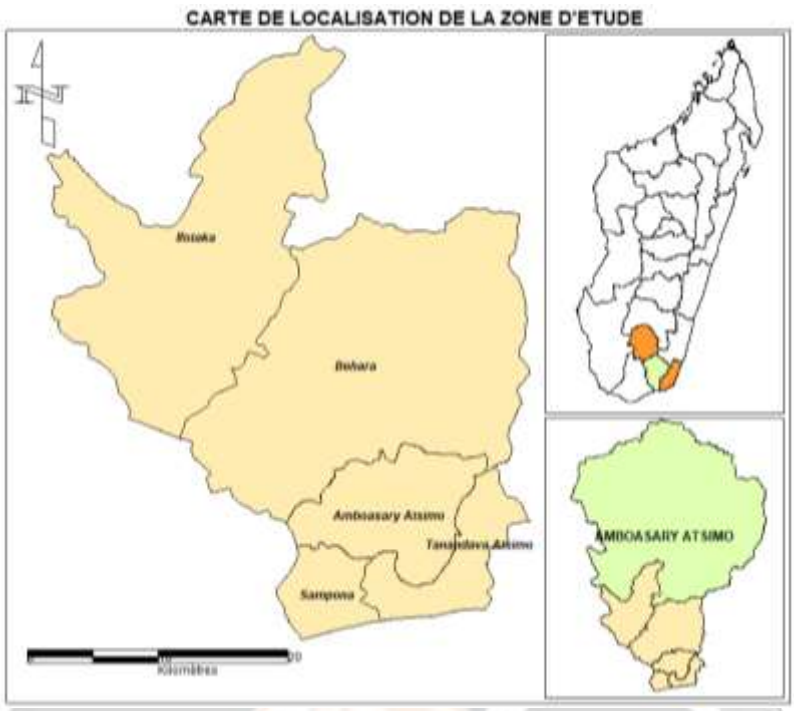

Fig 1: Location study area

For better precision, apart from its administrative affiliation delimited by the geographical limits of the territories, we can also locate our study area from its geographical coordinates. On this map, the district capital of Amboasary is located at 25 ° 02 ’7.17’ S, and 46 ° 23 ’0.33’ E. The main road that crosses the district is the National Road 13. This road crosses the district capital connecting Ambovombe and Taolagnaro. Paths in fairly poor condition connect all the administrative centers of the towns.

1.2. Climatic context

Due to its latitude close to the Tropic of Capricorn and protected from the humid trade winds by the relief, the area targeted by the project experiences a semi-arid climate. The region is tempered by a high thermal amplitude on the one hand, and by winds (from sea or land) on the other. The annual average temperature is around 23°C, with lows of 10°C and highs reaching 30°C.

The rainy season lasts for four months, from December to March, and concentrates 70% of the precipitation of the year. It is followed by eight months of dry season. The amount of annual precipitation reaches 545 mm at the eastern limit of the intervention area (Amboasary-Sud, average 2005-2015). Much of the rains fall in the form of intense events during the rainy season (cyclone). The drizzle of the dry season also constitutes a significant part of the total rainfall. Note that the region is also regularly affected by periods of drought.

The annual potential evapotranspiration (PET) greatly exceeds the total rainfall. It turns around 1’620 mm in Amboasary-Sud. The actual evapotranspiration (AET), impossible to calculate precisely, must reach 500 mm per year in Amboasary, depending on the quantities of water available. The AET thus represents about a third of the PET.

1.3. Geological context

In the southern part, the topographic slope is more and more marked towards the sea. In the littoral zone, made up of sandy dunes-oriented WNW-ESE by the action of sea currents, the slope plunges into the sea on the last kilometer of land (Battistini R., 1964). The western and eastern limits of the basin are marked by the notch of the Mandrare River.

The southern part is marked by the far-south basin which only began to form recently, during the Neogene (-20 million years ago), making it the most recent sedimentary basin of the island of Madagascar resting on the Precambrian base (Aurouze J., 1959). Continental Neogene formed by continental sediments with cross-stratified

soft sandstones and clays, clayey sandstone. The Quaternary formations consist of sands of aeolian origin and middle dunes of the Karimbolian. Calcareous crusts are also observable.

1.4. Hydrogeological context

The Amboasary region is drained by the Mandrare River. It is one of the rivers of the Great South which retains a residual flow during the dry season. Its watershed is located in volcanic soil located in the north with areas with high altitudes. The most frequently exploited water resource is the groundwater tables linked to the Mandrare River. This resource is exploited at the level of more or less old alluvial aquifers.

From a quantitative point of view, the flow rate provided by the wells seems very variable depending on the zones considered, which is probably related to the clay content of the sediments deposited by the river which influences their permeability (Rafenoarisoa., 2017). In terms of salinity, the influence of the sea is felt. There are probably saline inputs through the atmosphere.

North of Amboasary, the affluent of the Mandrare, the Mananara creates an area near Behara that is well irrigated with water with the presence of many canals, rice fields and well-developed alluvial aquifers. In the center of the village of Behara, built on a hill corresponding to a basement outcrop and dominating the alluvial plain, old wells collecting water from the basement have been abandoned due to very high mineralization. In this sector, the alluvial aquifers of Mananara and Mandrare should therefore be favored as water resource.

2. Methodologies

The methodological basis on which our intervention is based is the sampling of existing water points. Considering the costs of a linear meter of a borehole, which are quite expensive, resorting to new water points to serve as experimental observations remains exorbitant in financial terms. Nevertheless, reconnaissance and exploitation drilling campaigns have been carried out thanks to collaborations with local NGOs to serve as a reference for the variation in the characteristics of existing water points. Although some of the measurements are carried out on an occasional basis at the drawing point, the extracted water samples are transported to the analysis laboratory in order to determine their physicochemical characteristics. Once the analysis results have been taken out, they are transferred to the various processing software, namely Excel for recording databases and Aquachem for processing analysis results.

2.1. Inventory of existing water points

In total, 171 waters points, distributed in the five municipalities of Amboasary south, have been measured and sampled to find out their specific characteristics after they go to the laboratory for analysis. These water points are distributed in the study zone, are also different in their nature and in the type of infrastructure (well, borehole, river) that contains it. However, if this totality was considered in a punctual measurement of basic characteristic, such as the static level, the electrical conductivity as well as their hydrogen potentials (ph), only 78 water points among the inventoried existing waters carried out a more complex analysis which brings out a more precise result on their physicochemical characteristics. Let's see the summary of these water points in the first table below.

Among these 78 inventoried water points, 64 points are boreholes equipped or not with hand pump, 10 points are artisanal or modern wells, and 04 water collection points from the river.

Table 1. Distribution of inventoried water points in each municipality

Communes	Driling	Wells	Other sampling points	Total
Amboasary sud	40	05	01	46
Tanandava	15	02	01	18
Behara	05	01	02	08
Ifotaka	04	0	0	04
Sampoina	0	02	0	02
Total	64	10	04	78

Among the five municipalities that make up the southern Amboasary district, the capital has the most drinking water supply infrastructure. On the other hand, the commune of Sampoina has only two wells to serve the inhabitants. While a total of 78 water points were analyzed, 64 came from boreholes, 10 are from wells, and 4 were taken directly from the Mandrare and Mananara rivers. This distribution is best seen on a map that we will present in the following figure.

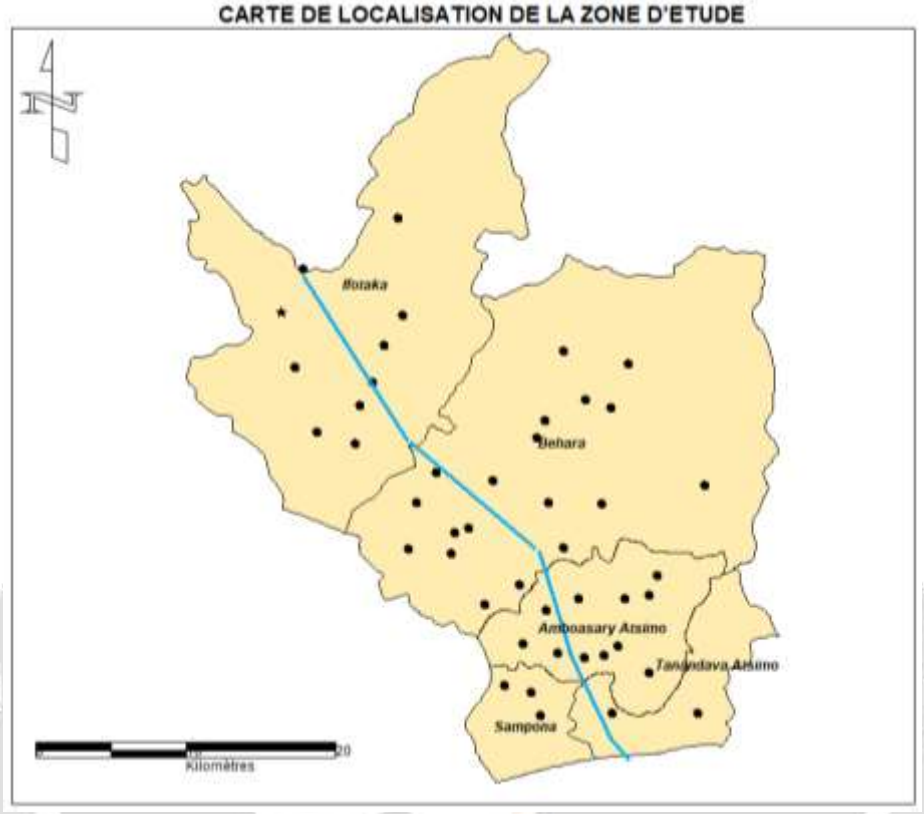

Fig2: Map showing the distribution of inventoried water points

Among these 78 inventoried water points, the southern Amboasary commune has the most inventoried water point which is 46, after come those of the Tanandava commune which is 18. For the rest, 8 water points are present in the municipality of Behara, 4 for the municipality of Ifotaka and 2 for Sampoina.

2.1. Sampling parameters and water analysis

During water point sampling, the hydrostatic level is measured first. The determination of the standard drinkability of water comes under two parameters, one is the physical parameters and the other is the chemical parameters.

The physical parameters can be analyzed in the field, which are electrical conductivity (EC), mineralization or dissolved salt content (TDS), hydrogen potential (pH), turbidity, and temperature. For the chemical parameters, they can only be analyzed at the level of a competent laboratory. The chemical parameters to be analyzed are: calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), ammonium (NH_4^{+}), total iron (Fe^{2+} ; Fe^{3+}), bicarbonates (HCO_3^{-}), chloride (Cl^{-}), sulfate (SO_4^{2-}), nitrite (NO_2^{-}), nitrate (NO_3^{2-}).

3. Results

The various studies carried out and the measurements of some physicochemical parameters in-situ and the laboratory analysis provide the physicochemical and chemical results of the water.

During the field investigation, seventy-eight (78) water points were measured and sampled, the following measurements were carried out: the hydrostatic level, the electrical conductivity, the mineralization, the potential in Hydrogen and the temperature. Then, the samples taken were analyzed at the competent

laboratory. These sample water points are targeted because of their strong representativeness of the aquifer including the Mandrare River, the Mananara River, wells and boreholes.

The results of field measurements or physicochemical parameters are classified according to the type of water and the extent of electrical conductivity, in order to understand these variations and the interconnection of water tables (Cf annexe1).

3.1. Hydrochemical water facies

The hydrochemical facies of the study area presents the proportion of the major elements of each of the water points analyzed. The Piper diagram provides a projection of the results for the entire study area and the Schoeller diagram those for the target municipality.

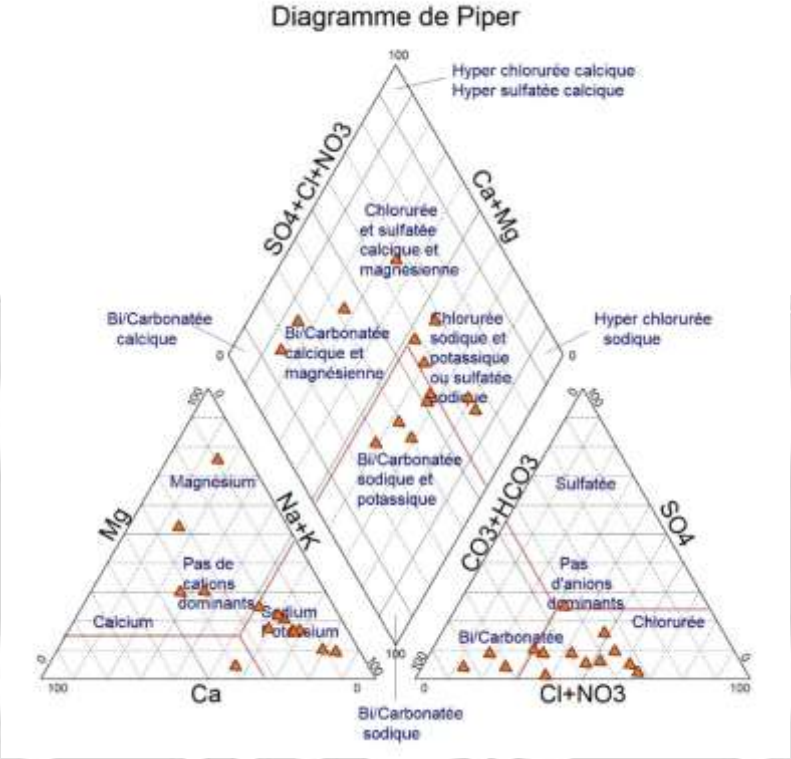

Fig3: Piper diagram of the waters of the study area

Following this Piper's diagram of the waters of the ensemble, the Schoeller diagrams of each intervention municipality below will confirm this hypothesis with the peak of one cation and one anion.

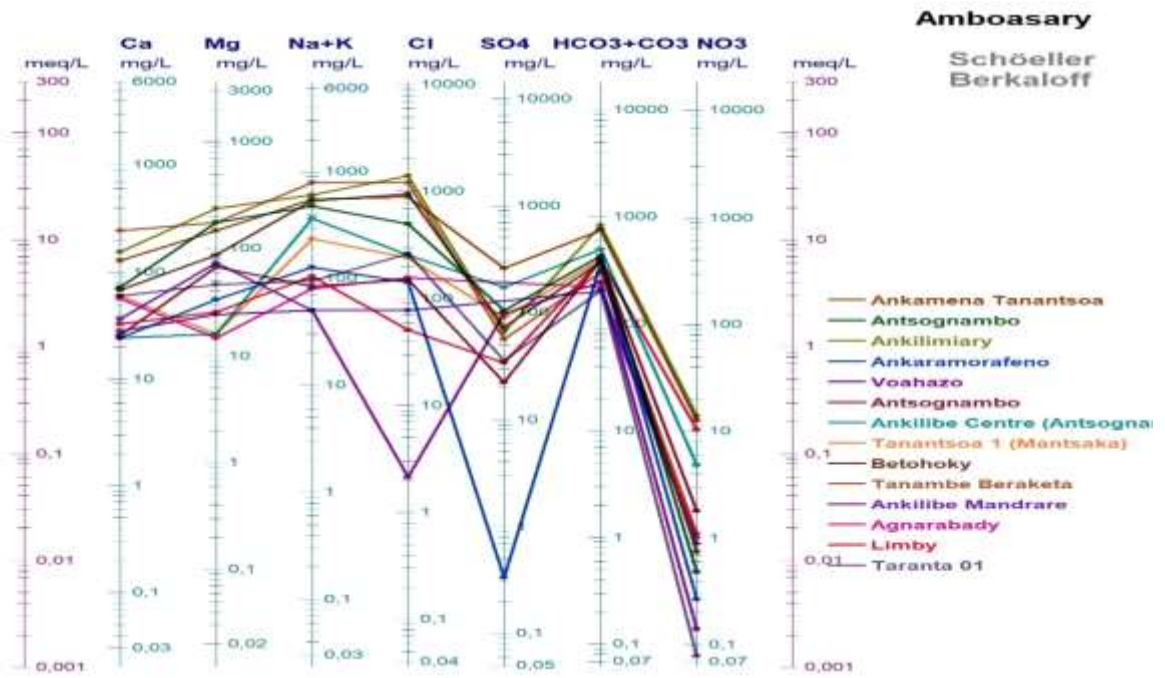

Fig4: Chemical facies of the waters of the municipality of Amboasary

According to the diagram in the figure above, $Na^{+}K^{+}$, Mg^{+}, Cl^{-}, et HCO_3^{-} ions are dominant in the waters of Amboasary commune. Four types of hydrochemical facies have been identified including the sodium bicarbonate facies, Magnesian bicarbonate facies, sodium chloride facies, and magnesian chloride facies. Ankaramorafeno's water point which has a very low sulphate value, and Voahazo which has a very low chlorine value as well.

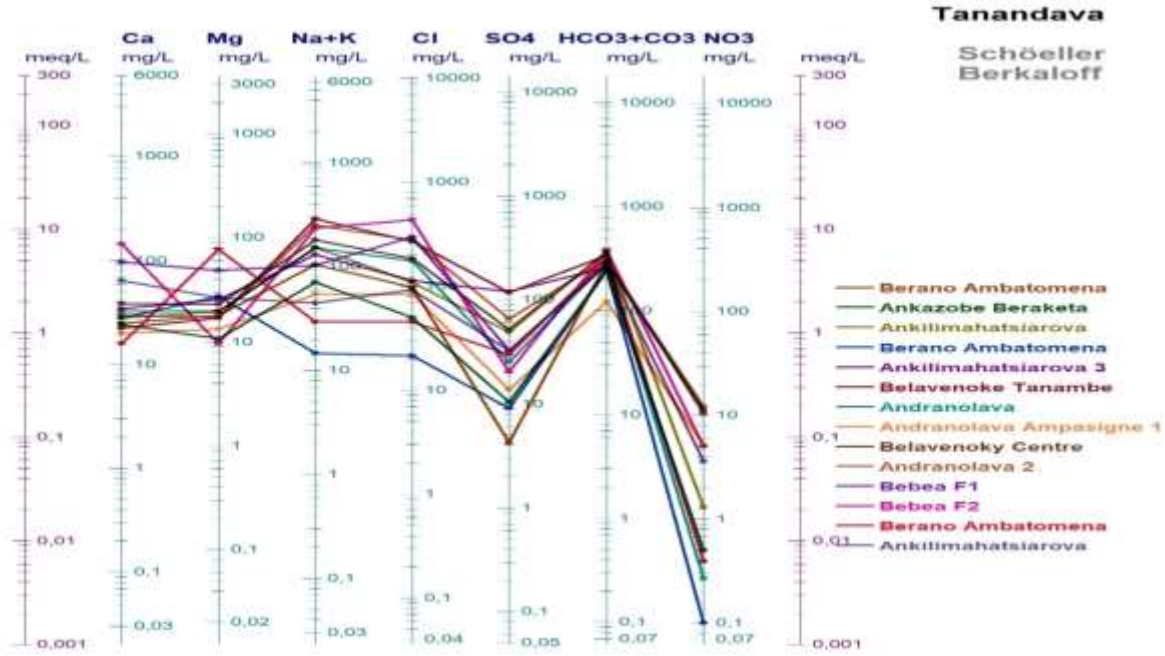

Fig5: Chemical facies of the waters of the municipality of Tanandava

The waters of the municipality of Tanandava are distributed in four facies including sodium bicarbonate, sodium chloride, and remarkable facies from a sampling point of Berano Ambatomena which is magnesian bicarbonate.

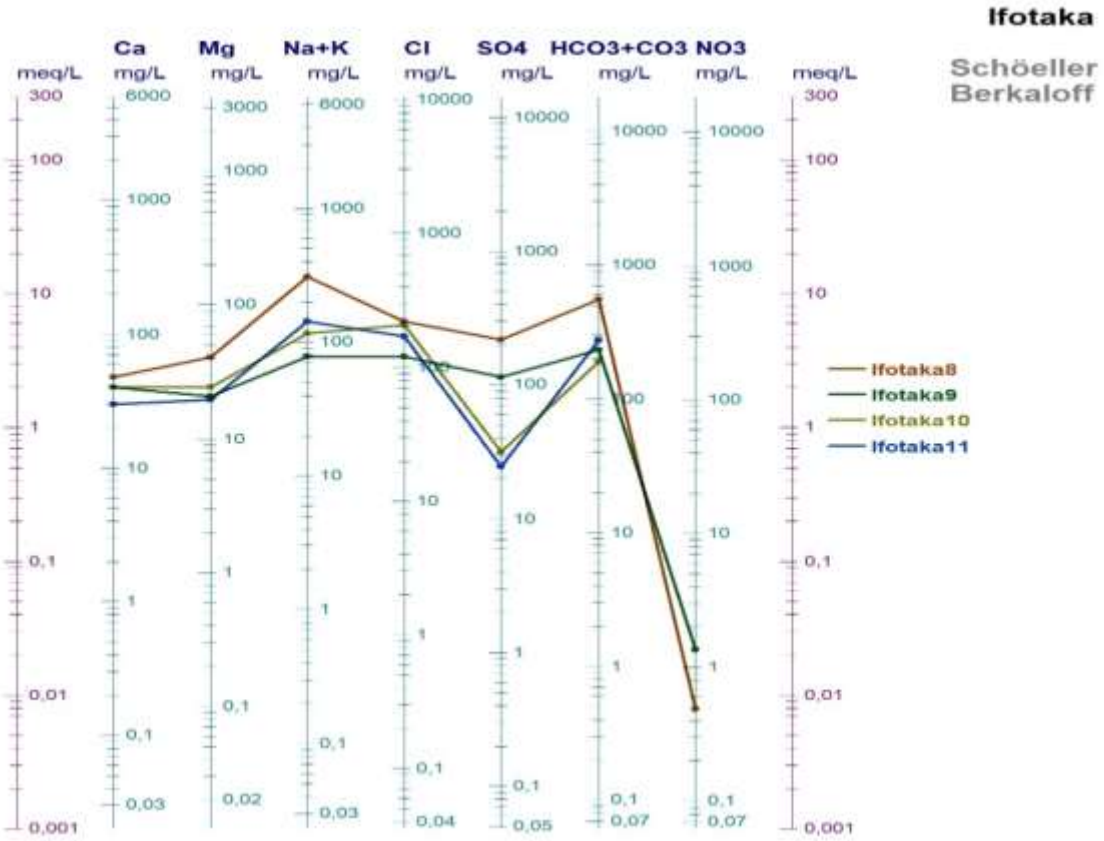

Fig6: Chemical facies of the waters of the municipality of Ifotaka

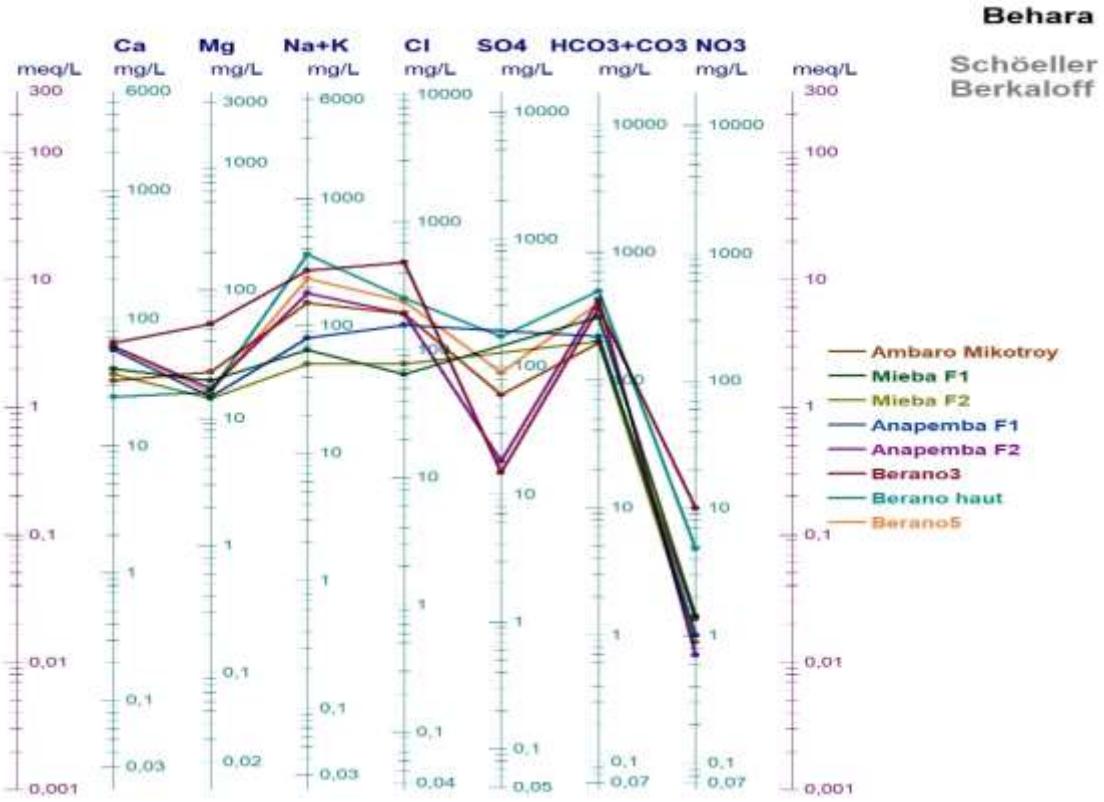

Fig7: Chemical facies of the waters of the municipality of Behara

The waters of the water sampling points of the commune of Ifotaka and Behara present the same facies whose ions are dominated by Na^+, Cl^-, et HCO_3^-. This means that we only have two facies, which are sodium bicarbonate and sodium chloride facies.

On the other hand, the facies of the municipality of Sampona have not been determined for lack of chemical analysis of the two samples taken.

From a general point of view, the sodium bicarbonate, sodium chloride and magnesium chloride facies dominate the study area. The Quaternary aquifer, in the North of the study area is dominated by the sodium bicarbonate chemical signature. But the southern part of the Mandrare river crossing the municipality of Amboasary, Tanandava which presents a signature of mixed facies. This zone is very heterogeneous, because it contains four hydrochemical facies, predominated by the sodium bicarbonate and sodium chloride type.

4. Discussions

During the study and sampling campaign phase, it is observed that the electrical conductivity of the study area varies from one water point to another (Rafenoarisoa., 2017). From a general point of view, these waters are classified among relatively well mineralized waters with high salinity waters, because the value of these electrical conductivities varies between 500 to more than 3000 µS / cm.

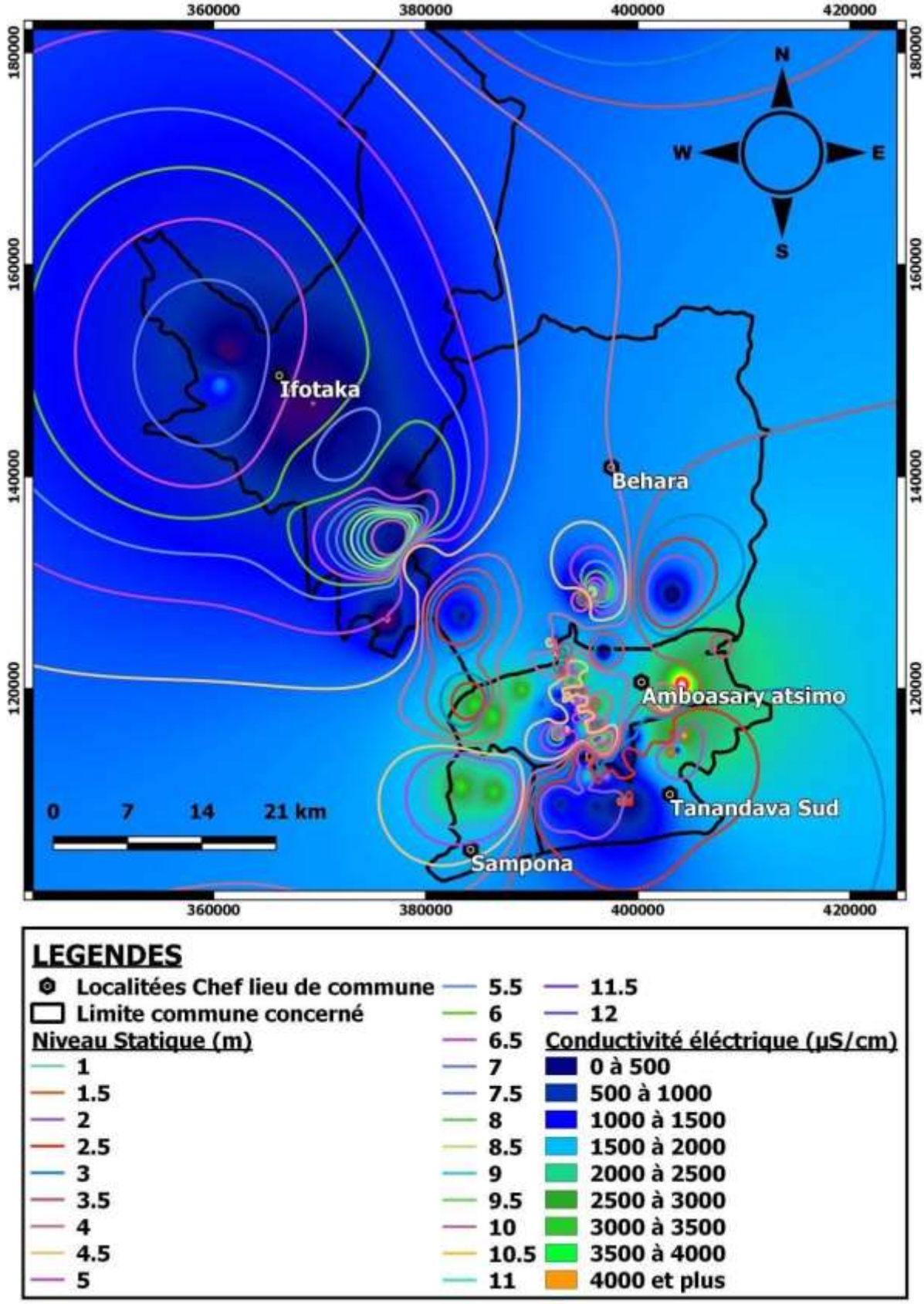

Fig8: Variation of electrical conductivity as a function of hydrostatic level

The location of the study area helps us understand that this chloride abundance is due to the infiltration of seawater into the water table (Guyot L., 2012). For the sodium concentration, the high levels can come from

leaching or percolation of salty soils as well as from the effect of marine salinity. These levels are probably attributed to different chemical mechanisms related to the base exchange which is influenced by pumping and direction of flow. Then, the intense evaporation in the coastal region favors the phenomenon of sea spray, the aquifer also can be enriched by this phenomenon.

5. Conclusion

The hydrogeochemistry study of the South Amboasary area focused on the comparative analysis of the mineral elements that make up the available water distributed in this district. Each water sample has different physicochemical characteristics.

The variation in water quality in this area has enabled us, according to the dominant mineral elements, to categorize these resources into four very distinct facies. The dominance of Na^+, Cl^-, et HCO_3^- ions highlights the dominance of the sodium bicarbonate, sodium chloride and magnesium chloride facies.

These facies result from the mineralogical composition of the soils and subsoils resulting from an alteration process and which are then interchanged with ions with the water which crosses them and which soak them for a sufficient period of time to the gradual accumulation of mineral elements in groundwater. The marine intrusion also contributes to the mineralization of these waters as well as the presence of a limestone formation which outcrops in some place.

While this study revealed the physicochemical characteristics of groundwater resources in the southern Amboasary district, this makes it possible to locate areas favorable to the establishment of a water point for a drinking water supply project. Indeed, each facies cover an area which represents the same characteristics, and when this variation is observed on a map, it facilitates the decision making on the best location of the water extraction structure to guarantee a better product, intended for human consumption.

However, we have seen that various areas with high conductivity are more favorable for human consumption. However, in the area outside the Mandrare River passage, the water catchment in this area risks being supplied with salt water which naturally remains unsuitable for drinking. Its operation, apart from the extraction, storage and distribution structure, requires another more specific structure to adjust the excess minerals that are associated with the raw water. For the municipality of Sampoina, the exploitation of underground water is not possible given the very high conductivity. So, two alternatives can be considered: the extension of the existing pipeline or resorting to specific treatments depending on the quality of the water (Andrifaliana N., 2019). However, the choice between these two variants is still based on a technical feasibility study associated with the total costs of its implementation.

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Annex1 : *The values of the analyzes and physicochemical measurements in situ and in the water laboratory*

Commune	Fokontany	Localité	Latitude S	Longitude E	Altitude	Profondeur équipée	Niveau piézométrique	Conductivité	Minéralisation	pH	Température	Calcium (Ca 2+)	Magnésium (Mg 2+)	Sodium (Na +)	Ammonium (NH4 +)	Fer total (Fe2+, Fe3+)	Bicarbonates (HCO3 -)	Chlorures (CL -)	Sulphate (SO4 2-)	Nitrites (NO2 -)	Nitrates (NO3 2-)
		Unité			m	m	m	µS/cm	ppm	--	°C	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
		Valeur admissible selon le norme OMS			-	-	-	3000	2000	--	--	200	50	--	0,5	0,5	--	250	250	0,1	50
Amboasary Sud	Ankamena Tanantsoa	Ankamena Tanantsoa	25° 0'46.00"	46°22'4.00"	22,8	4,22	1,45	3526	3426	7,29	20,2	128	148,23	544,98	0,47	0,45	756,4	893,18	259,82	0,09	12,7
	Ankamena Tanantsoa	Ankamena Tanantsoa	25° 0'46.60"	46°21'58.20"	17,7	5,5	5,4	2720	2619	7,11	20	112	116,64	302,82	0,1	0	414,8	681,6	156,61	0,19	0,31
	Antsognambo	Ankoboke	25° 3'13.52"	46°23'07.54"	19	9,23	6,49	3540	3278	6,73	20,2	121,6	6,32	377,3	0,44	0,4	549	504,5	26,23	0	5,71
	Antsognambo	Antsognambo 3	25° 3'13.60"	46°23'7.50"	13,6	10	5,4	3030	2806	7,03	20,1	72	174,96	474,5	0,97	0	1429,35	497	104,36	0,12	0,48
	Antsovela sama	Antsovela sama	25° 4'56.90"	46°28'56.90"	10,6	3	0,5	8740	8093	7,62	20,8	224	179,82	1636,84	1,4	0,1	751,52	2865,5	244,16	0,8	0,48
	Ankilimiary	Ankapoky	25° 0'34.31"	46°30'42.10"	21,4	12,2	4,7	5480	5074	7,12	20,1	154,4	240,33	610,31	1,86	3,2	829,6	1420	65,62	0,79	13,99
	Ankaramorafeno	Ankilibe	25° 4'44.20"	46°22'23.24"	14,9	4,22	3,77	849	788	7,53	20	24	33,53	126,6	0,84	0	372,1	142	0,33	0	0,27
	Voahazo	Andranomantigne	25° 6'14.46"	46°25'30.37"	15,3	5,9	2,9	978	904	7,77	20,3	28	24,3	49,97	0,02	0,25	244	2,13	97,18	0,01	0,14
	Ankilimiary	Taranty Ambany	25°02'21.61"	46°28'55.69"	14,6	10,1	4	1452	1283	8,05	20,1	56	24,3	226,19	0,02	0	335,5	306,72	55,03	0,48	2,4
	Ankaramorafeno	Agnahipoty	25°04'46.29"	46°22'12.53"	15,6	12,3	7,9	1432	1199	7,49	20	72	31,59	186,12	0	0	512,4	215,84	13,39	1,98	5,6
	Ankaramorafeno	Ankaramorafeno	25°04'04.4"	46°22'07.8"	11,2	8	4	707	655	7,21	25	80	12,15	38,75	0,03	0	439,2	58,22	42,01	0,1	0,5
	Antsognambo	Ankilimaro	25°02'54.4"	46°22'53.1"	13,4	5,4	2,2	1030	890	6,91	25	25,6	68,04	83,92	0,04	0	392,84	149,1	22,08	0,08	1,8
	Antsognambo	Ankilibe	25°03'38.10"	46°23'10.94"	13,4	5,4	2,2	744	691	7,6	25	40	15,55	102,03	0,04	0,15	280,6	109,34	22,86	0,1	4,2
	Ankilimiary	Taranty Antsirotsiro	25°00'50.22"	46°30'09.26"	21,7	6,3	3,5	721	670	7,79	29,5	22	15,8	108,29	0,04	0,05	207,4	134,4	16,72	0,04	4,83
	Ankaramorafeno	Belambo	25°04'32.42"	46°23'24.12"	18,1	11	4,7	2900	2685	7,56	30,2	28,8	32,08	628,69	0,33	0,01	688,08	418,9	443,4	0,5	0,31
	Ankaramorafeno	Ambahatry	25°04'48.29"	46°22'22.89"	16,8	14,5	4,95	1583	1468	7,74	20,2	48	40,34	307,74	1,06	0,03	553,88	220,1	219,36	0,12	0,49
	Antsognambo 5	Antsognambo 5	25°03'14.7"	46°23'02.4"	27	10,3	5,35	620	577	7,8	20	40	20,66	78,15	0	0	231,8	120,6	115,18	0	1,37
	Antsognambo 6	Antsognambo 6	25°03'10.3"	46°22'57.4"	14,6	9,9	3,5	882	817	7,39	20,6	40	24,3	115,34	0	0,8	189,1	205,9	31,57	0	0
	Antsognambo	Antsognambo Be Abobo1	25°03'54.2"	46°23'16.0"	19,7	13,85	5,9	954	887	7,64	20,2	30	19,44	142,76	0	0,15	274,5	170,4	24,73	0	0
	Antsognambo	Antsognambo Be Abobo2	25°04'0.30"	46°23'03.0"	18,2	13,85	5,11	915	850	7,26	20,1	31,2	22,36	199,96	0	0,1	274,5	184,6	143,97	0	0
	Ankilibe Centre (Antsognamb	Ankilibe Centre (Antsognambe	25°02'58.40"	46°22'55.0"	18,1	16	3,8	1376	1276	7,49	20,8	24	15,8	363,96	0	0,6	500,2	255,6	171,69	0,07	4,83
	Tanantsoa 1 (Mantsaka)	Tanantsoa 1 (Mantsaky)	25°00'14.00"	46°21'42.5"	23,1	13,4	4,2	1171	1084	7,44	20,1	60	15,8	235,16	0	0,8	402,6	241,4	89,62	0	0
	Tanantsoa 2 (Mantsaka)	Tanantsoa 2 (Mantsaky)	25°00'10.20"	46°21'44.8"	22	12	3,2	1084	1019	7,43	20,8	68	25,52	174,7	0	0,3	420,9	184,6	76,31	0	1,37
	Tanantsoa 3 (Mantsaka)	Tanantsoa3 (Mantsaky)	25°00'16.80"	46°21'47.05"	23,5	11,85	3,1	1096	1015	7,6	20	48	29,16	140,22	0	0,2	420,9	134,9	38,06	0	0,89
	Tanantsoa 4 (Mantsaka)	Tanantsoa 4 (Mantsaky)	25°00'16.60"	46°21'36.7"	26,8	13,8	4,8	3300	3056	7,28	20,3	154,4	93,31	420,82	0	1	353,8	951,4	97,9	0	0,66
	Tanantsoa 5 (Mantsaka)	Tanantsoa 5 (Mantsaky)	25°00'18.90"	46°21'43.1"	28,4	12,1	4,6	1350	1252	7,44	20,1	68	40,1	184,64	0	0	664,9	291,1	31,85	0	0,75
	Tanantsoa 6 (Mantsaka)	Tanantsoa 6 (Mantsaky)	25°00'10.50"	46°21'34.7"	26,8	13,8	4,7	3080	2852	7,54	20	100	79,22	443,89	0	0	420,9	795,2	115,18	0	1,24
	Agnarabady	Agnadabo	25°03'18.2"	46°28'03.2"	18,8	13,2	4,7	3280	3037	7,31	20	139,2	74,6	647,11	0	0	939,4	915,9	44,32	0	0,75
	Agnarabady	Ankilibe Mandrare	25°03'02.9"	46°23'03.2"	17,4	10	6	568	523	7,86	25	38	31,59	32,38	0	0,05	207,4	106,5	0	0	0,66
	Agnarabady	Mangaroa	25°03'38.48"	46°23'06.1"	13,8	13,8	4,5	574	532	7,36	25	20	9,72	112,78	0	0,15	280,6	92,3	0	0	0,71
	Ankaramorafeno	Ankaramorafeno	25°04'59.6"	46°22'37.7"	15,6	13,8	5,3	480	444	7,98	25	20	17,01	50,84	0	0	189,1	63,9	0	0	0,66
	Betohoky	Betohoky	25°01'25.4"	46°22'20.5"	21,3	5,2	2,5	3510	3250	7,39	25	68	87,48	529,17	0	0,6	378,2	951,4	73,31	0	0,75
	Tanambe Beraketa	Tanambe Beraketa	25°02'48.6"	46°22'50.1"	17	6,3	2,4	4470	4139	7,43	25	243,2	175,45	785,69	0	0,03	305	1212	55,59	0,12	1,11
	Mangaroa Beabobo	Mangaroa Beabobo	25°03'38.5"	46°23'06.2"	15,5	14	6,5	602	560	7,58	25	40	19,44	64,93	0	0	311,1	63,9	0	0	1,42
	Ankilibe Mandrare	Ankilibe Mandrare	25°02'58.4"	46°22'55.2"	18,1	16	12,2	613	567	7,61	29,5	36	74,12	50,6	0	0	201,3	78,1	0	0	0,89
	Agnarabady	Agnarabady(Animo 2)	25°03'03.3"	46°22'56.8"	16,5	9,65	3,55	719	666	7,62	30,2	56	14,58	80,83	0	0,04	219,6	156,2	0	0	1,02
	Tanantsoa 4 (Mantsaka)	Tanantsoa 4 (Mantsaka)	25°00'24.1"	46°21'50.5"	25,7	12,4	4,1	1181	1100	7,37	20	60	17,01	179,01	0,06	0,03	427	191,7	18,08	0	0,71
	Limby	Limby	25°03'22.9"	46°21'08.7"	17	8	3,9	784	727	7,75	25	32,8	25,27	104,94	0,05	0,15	395,25	51,12	33,87	0	10,45
	Ankamena	SPSM 1	25°03'22.9"	46°21'09.7"	16	9,1	4,6	3200	2963	7,93	20,8	32	21,87	504,36	0	0,25	561,2	552,38	32,58	0,07	49,71
	Ankamena	SPSM 2	25°02'53.5"	46°22'35.1"	21,4	13,6	4,7	2520	2333	7,52	20,2	64	54,43	269,67	0,18	0,15	366	487,12	14,72	1,56	9,97
	Ankamena	SPSM 3	25°02'51.2"	46°22'00.6"	10,3	13,1	4,7	1117	1039	7,56	20,1	56	15,55	123,12	0	0,01	278,16	149,1	56,23	0	0,12
	Tanambe 3	Tanambe 3	25°02'49.6"	46°22'50.6"	14,7	4,6	1,9	463	429	7,8	20	28,8	26,24	56,13	0,11	0	165,92	120,7	19,93	0	0,7
	Taranta 01	Taranta 01	25°00'35.3"	46°30'40.1"	23,6	8,15	2,3	1218	1131	7,61	25	59,2	46,66	94,3	0,04	0	204,96	262,7	35,56	0	0,08
	Taranta Tsirotsiro	Taranta Tsirotsiro	25°00'50.6"	46°30'8.7"	21,5	7,8	4,55	7090	6566	7,29	20	204,81	214,81	638,17	0,02	0	478,24	1633	128	0	3,77
	Taranta Ambenja	Taranta Ambenja	25°00'50.6"	46°30'8.7"	17,2	2,85	1,6	2760	2556	7,54	25	65,6	38,64	466,48	0,16	0	244	568	367,05	0	0,24
	Taranta Ambony	Taranta Ambony	25°02'46.7"	46°23'16.2"	16,3	4	2,8	3040	2843	8,13	20	33,6	98,17	545,77	0	0	990,64	568	101,64	0,07	1,87
	Taranta Ambany	Taranta Ambany	25°02'45.0"	46°22'48.5"	23,8	5,3	2,4	1095	1014	7,46	20	64	16,52	121,16	0,02	0,04	204,96	213	51,28	0,04	0,11
Tanandava	Berano Ambatomena	Andranolava	25° 6'50.14"	46°24'37.23"	13,4	5,4	3,2	695	645	7,47	20,8	24,8	17,98	104,5	0,06	0,3	287,92	98,69	4,23	0	12,1
	Ankazobe Beraketa	Ankazobe Beraketa	25°08'23.43"	46°25'41.28"	6,5	7	2	538	421	7,73	20	24	10,69	69,98	0,05	0	244	49,7	10,38	0,05	0,5
	Ankilimahatsiarova	Menagnara	25°08'26.6"	46°26'02.0"	6,7	6,75	1,5	981	864	7,67	25	28	19,44	152,56	0	0	372,1	109,34	48,84	0,68	1,3
	Berano Ambatomena	Ampasy Madrare	25°06'39.75"	46°24'10.81"	15,3	5,9	2,9	425	341	7,51	25	28	27,22	14,8	0,03	0,15	244	21,3	9,12	0,06	0,1
	Ankilimahatsiarova 3	Ankilimahatsiarova 3	25°08'26.70"	46°26'07.80"	8,6	10,75	3,05	761	707	7,84	23,3	34,4	25,27	130,56	0,07	0,3	262,3	113,6	119,84	0	0
	Belavenoke Tanambe	Belavenoke Tanambe (Ankoba	25°08'28.80"	46°26'02.70"	11	6,7	2,5	1283	1180	7,49	20,4	22,4	16,77	286,78	0	0	341,6	269,6	118,76	0	0
	Andranolava	Andranolava	25°06'42.5"	46°24'31.7"	14,17	8,4	2,1	974	902	7,26	20,5	32	19,44	149,92	0	0,25	292,8	177,5	25,29	0,01	0,27
	Andranolava Ampasigne 1	Andranolava Ampasigne 1	25°00'45.4"	46°24'28.2"	20	7,17	2,87	386	360	7,01	20,5	20	13,37	54,43	0	0,04	122	85,2	13,69	0	5,18
	Belavenoky Centre	Belavenoky Centre	25°08'22.8"	46°26'5.7"	5,4	6,75	2,45	1181	1090	7,73	20,6	38,4	22,84	180,9	0	0,4	366	184,6	52,15	0	0
	Andranolava 2	Andranolava 2	25°06'43.4"	46°24'24.2"	9,9	11,3	4,5	1206	1140	7,58	20,6	30	17,01	253,52	0	0,2	317,2	276,9	65,68	0	10,23
	Bebea	Bebea	25° 8'33.88"	46°24'9.48"	3,4	5	1,5	1311	1214	7,17	20,6	96	48,6	103,41	0,05	2	285,48	298,2	32,48	0,23	11,1
	Bebea	Bebea	25° 8'33.90"	46°25'9.70"	6,8	5,2	1,8	1750	1655	7,17	20,7	144	9,72	232,71	0,03	5	378,2	438,78	20,42	0,99	5
	Berano Ambatomena	Berano Ambatomena	25° 6'5.05"	46°25'54.70"	3,7	3,2	2,2	601	580	7,65	25	16	77,76	29,44	1,63	1,63	322,08	45,44	29,82	0,18	0,39
	Ankilimahatsiarova	Ankilimahatsiarova	25° 8'24.64"	46°26'11.07"	13,4	6	2	715	662	7,77	26	64	26,73	45	0	0,15	275,72	92,3	32,4	0,52	3,6
	Belavenoky	Ankivoky	25° 8'21.31"	46°25'32.72"	9,6	4,8	1,3	1500	1390	7,59	24	48	19,44	243,74	0,05	0	351,36	322,34	10,66	0,03	14,7
	Bedaro	Manda	25° 2'38.90"	46°19'58.40"	19,6	7,5	4,3	4800	4445	7,02	25	208	102,06	802,28	0,16	0	395,28	1564,8	193,16	0	0,48
	Belavenoky	Maharoa	25° 8'25.34"	46°26'04.03"	8	4,3	1	818	759	7,69	25	65,6	33,05	58,94	0,07	0,04	309,88	106,5	43,63	0,02	4,9
	Ankilimahatsiarova	Andranomasy	25° 8'15.39"	46°26'20.90"	8,1	6	2	1030	955	7,72	26	42,4	9,72	166,7	1,2	0,05	514,84	82,36	3,46	0,09	0,19
Ifotaka	Ifotaka8	Ifotaka	24°49'60.00"	46°10'6.90"	35	10,2	5,2	1583	1468	7,74	20,2	48	40,34	307,74	1,06	0,03	553,88	220,1	219,36	0,12	0,49
	Ifotaka9	Ifotaka	24°52'0.00"	46°13'4.30"	38	11	6,4	620	577	7,8	20	40	20,66	78,15	0	0	231,8	120,6	115,18	0	1,37
	Ifotaka10	Ifotaka	24°55'0.00"	46°12'50.00"	31	16,4	10,5	882	817	7,39	20,6	40	24,3	115,34	0	0,8	189,1	205,9	31,57	0	0
	Ifotaka11	Ifotaka	24°55'60.00"	46°14'2.30"	29	13	4,05	954	887	7,64	20,2	30	19,44	142,76	0	0,15	274,5	170,4	24,73	0	0
Behara	Ambaro Mikotroy	Tsionkarivo	24°58'52.30"	46°16'35.9"	22,7	5,3	2	1027	965	8,42	29	32	23,09	151,33	0	0,08	195,2	191,7	60,48	0,09	1,37
	Mieba F1	Mieba F1	24°57'46,08"	46°22'20,64"	10,0	-	1,7	700	340	9,16	27,2	40	14,6	64,93	0	0	311,1	63,9	0	0	1,42
	Mieba F2	Mieba F2	24°57'46,08"	46°22'22,8"	10,0	-	1,5	580	290	9,4	26,8	36	14,12	50,6	0	0	201,3	78,1	0	0	0,89
	Anapemba F1	Anapemba F1	24°57'48,96"	46°23'35,88"	10,0	-	2,1	760	370	9,1	26,8	56	14,58	80,83	0	0,04	219,6	156,2	0	0	1,02
	Anapemba F2	Anapemba F2	24°57'51,12"	46°23'35,88"	10,0	-	1,6	1124	548	9,3	28,5	60	17,01	179,01	0,06	0,03	427	191,7	18,08	0	0,71
	Berano	Berano Ambatomena	25° 7'0.00"	46°23'42.10"	8	7,5	1,6	2900	2200	7,52	20,2	64	54,43	269,67	0,18	0,15	366	487,12	14,72	1,56	9,97
	Berano4	Berano	25° 8'22.70"	46°26'0.55"	8	7,5	6,1	1354	1100	7,49	20,8	24	15,8	363,96	0	0,6	500,2	255,6	171,69	0,07	4,83
	Berano bas	Berano bas	25° 8'33.90"	46°25'9.70"E	7	5,2	1,8	1750	1250	7,44	20,1	60	15,8	235,16	0	0,8	402,6	241,4	89,62	0	0
Sampona	Sampona1	Sampona	25°11'34.97"	46°17'44.30"	5	10,7	6	3800													
	Sampona2	Sampona	25° 8'59.46"	46°18'45.27"	7	10	6	4487													