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Radiometric and chemical parameters in freshwater samples of Centro Experimental Aramar (CTMSP/Brazil) environmental monitoring programme

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The authors describe experimental results obtained with gamma spectrometry, alpha and beta gross counts, liquid scintillation and fluorometry techniques for the measurement of background radiation, and several other techniques for chemical parameters analysis in surface water samples, collected in Centro Experimental Aramar and surroundings, from 1988 to 2007. The estimated average background radiation concentrations in water samples in this region are low, related to the low level detection limits of the techniques, and the chemical parameters values are compared with the limits established by CONAMA (Comissão Nacional do Meio Ambiente / Brasil – a government agency responsible for Brazil's environmental protection). There are good water quality parameters, and low interference in the environment in Centro Experimental Aramar and region.

Keywords: Water samples; Water quality parameters; Gamma spectrometry; Environmental protection

Introduction

As industrialised countries strive to increase their standard of living, they affect the environment, sometimes irreversibly [1–3]. At present, in Brazil, a framework of institutions and laws governs the degree industry is permitted to affect the environment. These laws and their enforcement, although imperfect, have been beneficial to protecting and even improving the environment [4].

The Centro Tecnologico da Marinha (CTMSP) is a military research organisation, located in Sao Paulo city (Brazil), whose objectives are to set up nuclear and energy systems for Brazilian naval ship propulsion. These projects are being developed in Centro Experimental Aramar, situated at Ipero city (100 km from Sao Paulo). It is important to

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investigate background radiation concentrations and chemical parameters in water samples of the Centro Experimental Aramar and region because an industrial nuclear research programme is being assembled in this centre [5]. Therefore, surface water samples from environmental stations have been collected and analysed systematically, since 1988 (second semester), by using gamma spectrometry, alpha and beta gross counts, liquid scintillation and fluorometry techniques [6,7] and several other techniques for water chemical parameters analysis [8]. The main objective is to assess the water quality parameters and verify the possible interference in the environment. The measurements were performed in addition to the Environmental Monitoring Programme, carried out by the radioecological laboratory in this region [9].

This study provides a reference level for the purposes of water quality parameters analysis and comparative monitoring. Knowledge of radioactive concentrations and water chemical parameters is necessary to determine the quality parameters, background levels, transfer, dosimetry and environmental implications.

Materials and methods

The Radiation Protection and Environmental Control Department (CTMSP) has conducted an environmental monitoring programme through the Centro Experimental Aramar and region, an area defined by a 10 km radius. Tasks have included collecting and analysing soils, fish, grass, water, milk, harvest and air samples in 124 environmental stations, since 1988 [6,7,9]. Surface water samples were collected in 11 environmental stations, distributed on Ipanema river (five sample points: 1,2,3,4,8), Sorocaba river (four sample points: 5,6,7,9) and in Ferro stream (two sample points: 13,15), located in the vicinity of this nuclear research centre (see figure 1). Only point 7 is outside the radius circle. The UTM (Universal Transverse Mercator) location coordinates of the environmental stations for water sampling are:

(i) Ipanema river:
(1) {234738E,7406988N};(2){235051E,7409710N};(3){235179E,7409948N};
(4) {235290E,7412106N};(8){238303E,7403542N}.
(ii) Sorocaba river:
(5) {236449E,7413912N};(6){232708E,7413615N};(7){225895E,7415869N};
(9){242876E,7406164N}.
(iii) Ferro stream:
(13) {232597E,7411083N};(15){231720E,7409390N}.

The sample preparation methodologies are described in references [9,10]. The frequency of the collected and analysed samples has been different throughout the years, caused by technical conditions, but in general it was monthly [9].

The following techniques have been used for analysis: gamma spectrometry, alpha and beta gross counts, liquid scintillation and fluorometry measurements [8,9]. Gamma spectrometry was performed by using a 65 cm^3 Ge intrinsic detector with a relative efficiency of 25% and a resolution of 1.9 keV (FWHM) for the 1332 keV peak of ^{60}Co. This detector was coupled to a 4096 multichannel which was connected to a microcomputer. Spectra were analysed using the software Maestro/Egg Ortec. The energy efficiency curve was obtained by a set of gamma ray reference sources. The ^{238}U natural series' activity was estimated from 351.9 keV and

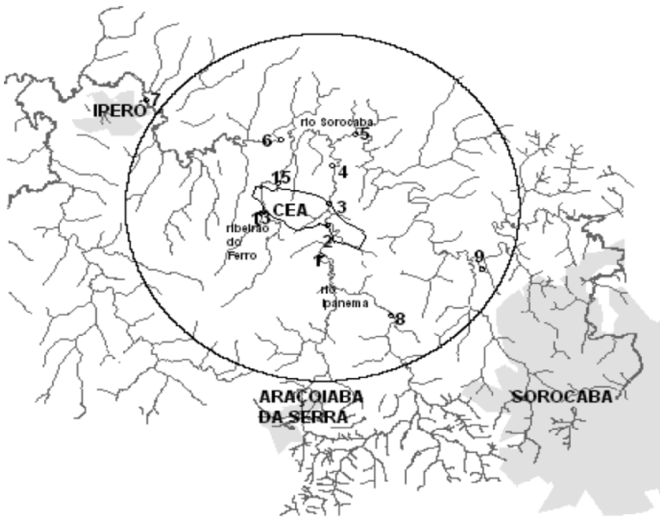

Figure 1. Location of Centro Experimental Aramar (CEA) and the region defined by the 10 km circle radius, the eleven water sampling points: 1,2,3,4,5,6,7,8,9,13 and 15, the main cities around: Sorocaba, Ipero and Araçoiaba da Serra, and the Sorocaba river (rio Sorocaba), Ipanema river (rio Ipanema), Ferro stream (ribeirão do Ferro).

609.3 keV gamma lines of ^{214}Pb and ^{214}Bi, respectively. The ^{232}Th natural series' activity was estimated from the ^{228}Ac emission at 911.1 keV. The samples were sealed and the measurements were made one month later to ensure equilibrium between the isotopes and their decaying products [11]. The gamma spectrometry system calibration has been periodically checked through the National Intercomparison Programme (PNI) for water sample analysis, conducted by the Secondary Standard Dosimetry Laboratory (IRD/CNEN/BRAZIL) [12].

Fluorometry measurements were made by using a digital fluorometry detector model 5015 and reference [8] describes the method of analysis.

Tritium counting was performed with a Beckmann (model LS-5801) liquid scintillation spectrometer, using polyethylene vials containing 10 ml of Ultima Gold XR (scintillation) and 1 ml of the distillate sample. The samples were counted for 100 minutes. The counting regions were selected by taking into account the quench level of the samples. Previously, the tritium spectrum was calibrated using Beckman/Spectrum Analysis software calibration, by measuring a set of ^{3}H standards ((761 $\pm$ 5%) dps: activity in 01/02/1991) with different levels of quenching (called #H number). The reproducibility counting efficiency is 1% [13].

Alpha and beta gross counts were performed in a Berthold LB-770-2 low level counter, containing ten proportional gas detectors. The efficiencies, previously determined, were 13% for alpha counting, by using a calibrated ^{230}Th alpha source, and 34% for beta counting, by using a calibrated ^{90}Sr beta source.

The techniques used to prepare and analyse the environmental samples were taken from the standards methods, described in detail in reference [8]. The chemical parameters analysed, the methods employed and the equipment used are listed below:

a) Flame Atomic Absorption Spectrometric method [8] [section 3111]: aluminium, soluble iron, total iron, manganese, zinc (Atomic Absorption Spectrophotometer – Hitachi-model Z-8100 polarised Zeeman);

b) Electrothermal Atomic Absorption Spectrometric method [8] [section 3113]: lead , copper, nickel, chromium (Atomic Absorption Spectrophotometer – Hitachi-model Z-8100 polarised Zeeman with graphite furnace);
c) Flame Emission Photometric method [8] [section 3500]: potassium, sodium (Micronal –model B262);
d) Electrometric method [8] [section 4500]: pH (Analion – model IA601);
e) Turbidity method [8] [section 2130]: turbidity;
f) Visual comparison method [8] [section 2120]: colour;
g) Titrimetric method [8] [section 4500]: ammonia, chloride, Biochemical Oxygen Demand (BOD), Dissolved oxygen (DO), orthophosphate, total phosphate, Chemical Oxygen Demand (COD) [section 5220] (Procyon – model Sa720);
h) Colorimetric method (Spectrophotometer) [8] [section4500]: nitrate, nitrite (Micronal – model B382);
i) Ion Selective Electrode method [8] [section 4500]: fluoride (Procyon – model Sa720);
j) Electrical Conductivity method [8] [section 2520]: electrical conductivity (Micronal – model B331).

Results and discussion

Table 1 shows the low level detection limits (LLD) related to the ^{214}Pb (^{238}U-series) and ^{228}Ac (^{232}Th-series) radionuclides, measured by the gamma spectrometry technique. These values are variables, because the analysis software and the preparation methodology changed throughout the years [9]. Nowadays, the ^{214}Pb LLD value is lower than 0.20 Bq/l and the ^{228}Ac LLD value is lower than 0.30 Bq/l in the water samples. The ^{214}Pb and ^{228}Ac concentrations obtained in all the samples were LLD values. Those values are in accordance with the data obtained in the pre-operational conditions [7], denoting a low natural radioactivity in Centro Experimental Aramar and region [13]. The measurements published in reference [14] state a contrasting situation: the values of ^{238}U and ^{232}Th concentrations obtained in the water of rivers near uranium mines were enhanced in comparison with concentrations measured in other rivers, indicating an increase of natural radioactivity.

The LLD value for tritium determination, by using the liquid scintillation technique, is 14.8 Bq/l [13]. Tritium activities (Bq/l) were measured in 14 surface water samples, in the period from 1990 to 1999 and the results obtained provided an average value of (25.9 ± 2.1) Bq/l. The results published in reference [15] indicate tritium activity levels between 0.6 Bq/l (LLD value) and 3.6 Bq/l, in rivers of different origin. In spite of this, both values are

Table 1. Low Level Detection limits (LLD) determined in surface water analysis in all environmental samples, by using gamma spectrometry technique (^{214}Pb and ^{228}Ac concentrations in Bq/l), fluorometry technique (U concentrations in Bq/l units) and alpha and beta gross counts technique (alpha and beta concentrations in Bq/l)

Year	^{214}Pb	^{228}Ac	U natural	Alpha counts	Beta counts
1988 *	0.27	0.48	0.025	0.13	0.10
1989 to 1991	0.37	0.48	0.13	0.13	0.10
1992 to 1995	0.40	0.50	0.13	0.13	0.10
1996 to 1998	0.20	0.30	0.13	0.13	0.10
1999 to 2007	0.20	0.30	0.005	0.13	0.10

* values were obtained in the pre-operational conditions [7].

compatible with the tritium limit concentration in drinking water of 740 Bq/l, recommended by the US Environmental Protection Agency (EPA) [16] and 100 Bq/l for waters intended for human consumption [15], thus confirming a low natural tritium radioactivity in Centro Experimental Aramar and region [13].

Uranium concentration results obtained by fluorometry analysis in all samples were LLD values, in agreement with the data obtained in the pre-operational conditions [7], and the data presented in a similar environmental monitoring programme [17]. Table 1 also shows these LLD values; and they are different, because the analysis software and the preparation methods changed throughout the years [5].

Table 1 also presents the LLD values for alpha and beta total counts monitored in these samples. Alpha and beta results obtained in the majority of the samples analysed were LLD values (more than 95%). By considering the complementary results (5%), the maximum and average values obtained were, respectively: 0.30 Bq/l and 0.20 Bq/l for alpha counts and 0.80 Bq/l and 0.40 Bq/l for beta counts. Additionally, the results obtained in surface water around a proposed uranium mining site, published in reference [18], are: alpha activity between 0.06 Bq/l and 0.13 Bq/l and beta activity between 0.14 Bq/l and 0.36 Bq/l, and the result of alpha activity in water, published in reference [19], indicates a value of 0.05 Bq/l. The limits suggested by the EPA [8] establish that if the average annual concentrations is less than 0.56 Bq/l (15 pCi/l) for alpha gross counts and less than 1.85 Bq/l (50 pCi/l) for beta gross counts, no further analysis is required. By taking into account these limits, the alpha and beta specific radioactive contaminants need not be identified in the water samples of the Aramar Environmental Monitoring Programme.

Tables 2–4 show the evaluated water quality chemical parameters, related to the sampling points, river location, average, maximum and minimum values and tolerable limit values defined by CONAMA [20].

Most of the water quality chemical parameters of the Ipanema river and Ferro stream are lower than the established limits suggested by CONAMA. The parameters pH, colour and turbidity are also in agreement with the CONAMA limits at all the sample points. Metal concentrations of copper, nickel and lead are very low. Aluminium concentrations were about 10% higher than CONAMA limits in some months, at all the sampling points. Ammonia, nitrate, sodium and BOD are in low concentrations and DO is in high concentrations in the Ipanema river and Ferro stream. The main human activities developed in this region are agricultural. Therefore, the water quality parameters of this river and stream can be considered good.

The turbidity, copper, nickel and lead parameters evaluated in the Sorocaba river are comparable with the CONAMA limits. The iron and aluminium concentrations are a little higher than the limits. The BOD, sodium and ammonia parameters are found in higher concentrations and DO in lower concentrations, in accordance with data obtained in reference [21]. This is probably caused by the higher volume of sewage added to the river every day. The COD concentration is approximately five times higher than the BOD concentration. It suggests that non-biodegradable materials, like soap, are added to the river too. Phosphate and ammonia concentrations were found to be higher than the CONAMA limits.

The variable aluminium levels found in the rivers and stream is explained by the fact that the area studied is a transition region between Seasonal Semideciduous Forest and Savannah Forest (Cerrado), where it is usual to find high concentrations of aluminium and iron [22,23]. Additionally, a now disused iron mine was established in this region in the past [21].

Another noteworthy finding is that fluoride concentrations were low in the two rivers and stream.

Table 2. Calculated water quality parameters of Ipanema river (maximum, minimum and average (avr) values). The CONAMA limits are also presented

IPANEMA RIVER

Parameters and units	Sample 8			Sample 1			Sample 2			Sample 3			Sample 4			CONAMA Limits
	Avr	Max	Min	Avr	Max	Min	Avr	Max	Min	Avr	Max	Min	Avr	Max	Min	
pH	6.84	7.13	6.6	6.7	7.07	6.34	6.85	7.1	6.58	6.88	7.21	6.64	6.92	7.18	6.72	6.0 to 9.0
Turbidity (FTU)	32.99	98.25	13	25.43	51.88	12.6	25.84	41.7	11.5	26.96	43.7	11.5	27.2	52.25	11.6	100
Colour (colour unit)	20.02	78	9	19.8	84.29	8.64	22.77	99.29	9.09	22.9	106.43	9	30.02	192.14	9	75
El.conductivity (μS/cm)	89.41	133.3	66.67	86.79	119	64.55	83.32	94.25	66.08	87.49	132.2	66.88	87.8	139.8	66.78	*
Copper (μg/l)	<3.87	12.3	<0.03	<4.2	16	<0.01	<4.21	8.4	<0.02	<3.65	10.9	<0.03	<3.85	10	<0.01	20
Nickel (μg/l)	<15.62	90	<1	<15.55	90	<1	<14.98	90	<1	<15.57	90	<1	<15.15	90	<1	25
Lead (μg/l)	<2.84	8.1	<0.15	<2.99	8	<0.15	<3.2	8.08	<0.15	<3.45	7.92	<0.15	<3.18	8.55	<0.15	30
Zinc (μg/l)	<18.19	29.09	<0.03	<19.12	31	<0.05	<18.68	30.27	<0.04	<19.08	30.64	<0.03	<17.88	27.27	<0.03	180
Chromium (μg/l)	<8.62	30	<1	<8.62	30	<1	<9.44	30	<1	<8.64	30	<1	<8.64	30	<1.09	*
Aluminium (mg/l)	<0.83	1.96	<0.2	<0.66	1.2	<0.2	<0.74	1.59	<0.21	<0.73	1.36	<0.18	<0.88	2.32	<0.26	0.1
Manganese (mg/l)	<0.14	0.18	<0.1	<0.13	0.28	<0.1	<0.11	0.14	<0.09	<0.12	0.16	<0.1	<0.12	0.2	<0.1	0.1
Soluble Iron (mg/l)	<0.27	0.35	<0.2	<0.33	0.49	<0.18	<0.36	0.52	<0.25	0.33	0.44	0.22	0.43	1.46	0.22	0.3
Total Iron (mg/l)	2.13	4.65	0.23	1.48	2.67	0.23	1.64	3.06	0.24	1.75	3.24	0.31	1.8	3.59	0.23	*
Nitrate (mg/l)	<0.42	0.7	<0.27	0.37	0.6	0.16	0.38	0.6	0.2	<0.36	0.6	<0.19	<0.38	0.6	<0.23	10
Nitrite (mg/l)	<0.03	0.17	<0.01	0.01	0.04	0.01	<0.01	0.03	<0.01	<0.01	0.03	<0.01	<0.01	0.03	<0.01	1
Ammonia (mg/l)	<0.08	0.21	<0.02	<0.07	0.13	<0.03	<0.06	0.13	<0.02	<0.07	0.13	<0.02	<0.07	0.21	<0.02	0.02
Fluoride (mg/l)	<0.13	<0.15	<0.12	<0.14	0.18	<0.12	<0.13	0.16	<0.12	<0.13	0.21	<0.12	<0.13	0.2	<0.12	1.4
Sodium (mg/l)	4.09	5.57	2.83	4.01	5.33	2.87	3.99	4.94	2.87	3.99	5.11	2.89	3.92	5.19	2.87	*
Potassium (mg/l)	3.45	5.45	1.99	3.36	5.18	2.07	3.37	5.28	2.04	3.44	5.28	2.06	3.36	5.12	2.02	*
Chloride (mg/l)	<2.42	4.22	<1.7	<2.15	3.64	<1.46	<2.19	3.63	<1.42	2.21	3.7	<1.48	<2.19	3.46	<1.55	250
Total solids (mg/l)	<103.1	174.6	<3.97	<95.37	146	<3.64	<94.29	118.36	<3.69	94.97	116	<3.71	100.45	134.5	<3.65	500
COD (mg/l)	<17.25	24.58	<9.46	<15.55	21.75	<9.33	<15.72	23.14	<8.46	16.03	24.8	<8.99	15.83	24	<8.58	*
BOD (mg/l)	<1.68	5.2	<1	<1.59	4.5	<1.05	<1.71	8.14	<0.93	1.65	7.14	<0.72	<1.54	5.29	<1	5
DO (mg/l)	6.2	6.96	5.07	5.92	6.59	4.85	7.13	7.98	6.2	6.87	8.04	6.2	7.05	7.94	6.1	5
Orthophosphate (mg/l)	<0.03	0.06	<0.01	<0.03	0.05	<0.01	<0.03	0.05	<0.01	0.03	0.05	<0.01	<0.03	0.05	<0.01	*
Total Phosphate (mg/l)	<0.03	0.06	<0.01	<0.03	0.07	<0.01	<0.04	0.19	<0.02	0.04	0.14	<0.02	<0.05	0.15	<0.02	0.025

*There are no established limits.

Table 3. Calculated water quality parameters of Sorocaba river (maximum, minimum and average (avr) values). The CONAMA limits are also presented

		Sample 9			Sample 5			Sample 6			Sample 7			CONAMA Limits
	Parameters and Units	Avr	Max	Min	Avr	Max	Min	Avr	Max	Min	Avr	Max	Min	
SOROCABA RIVER	pH	6.64	6.75	6.5	6.6	6.81	6.4	6.66	6.78	6.5	6.71	6.97	6.55	6.0 to 9.0
	Turbidity (FTU)	29.34	36.09	8.16	30.2	82.5	13.54	29.26	81.67	12.5	30.02	89.11	10.4	100
	Colour (colour units)	18.78	23.75	10.8	19.44	72.86	10.42	17.03	47.86	10.4	22.74	116.67	10.8	75
	El.Conductivity (μS/cm)	167.64	244.25	18.81	171.02	245.83	136.4	168.93	234.83	146.8	166.85	234.5	137.6	*
	Copper (μg/l)	<4.47	9.18	<0.01	<5.25	13.4	<0.03	<3.92	9.1	<0.01	<4.06	9.3	<0.01	20
	Nickel (μg/l)	<16.35	30	<1.33	<16	90	<0.14	<17.14	90	<1.6	<18.35	90	<1.91	25
	Lead (μg/l)	<4.36	13.2	<0.1	<3.93	10.94	<0.1	<3.94	11.33	<0.1	<3.65	10.5	<0.1	30
	Zinc (μg/l)	<18.76	27.1	<0.02	<18.34	27.45	<0.02	<18.2	28.64	<0.02	<19.54	33	<0.02	180
	Chromium (μg/l)	<9.17	10	<1.17	<8.24	20	<1.33	<8.07	20	<1.33	<9.17	30	<1.2	*
	Aluminium (mg/l)	1.28	2.43	0.25	<1.8	4.48	<0.46	1.47	2.61	0.45	<1.64	4.64	<0.44	0.1
	Manganese (mg/l)	<0.18	0.2	<0.13	<0.19	0.25	<0.14	0.18	0.22	0.13	<0.17	0.23	<0.1	0.1
	Soluble iron (mg/l)	0.27	0.4	0.14	<0.26	0.43	<0.17	<0.27	0.4	<0.19	0.3	0.5	0.2	0.3
	Total iron (mg/l)	2.04	2.46	0.16	2.48	4.54	0.12	2.35	5.57	0.16	2.12	3.53	0.18	*
	Nitrate (mg/l)	<0.68	5.67	<0.17	<0.48	2.74	<0.21	<0.34	0.55	<0.2	<0.39	0.61	<0.2	10
	Nitrite (mg/l)	<0.07	0.05	<0.01	0.24	2.59	0.01	<0.1	0.85	<0.01	<0.16	1.52	<0.01	1
	Ammonia (mg/l)	1.91	2.51	0.99	2	2.97	0.94	1.9	2.76	0.92	1.84	3.01	0.87	0.02
	Fluoride (mg/l)	0.91	1.81	0.45	0.79	1.31	0.29	0.8	1.29	0.37	0.86	1.36	0.35	1.4
	Sodium (mg/l)	15.39	23.29	9.8	13.52	23.45	4.93	13.76	22.16	9.55	13.92	23.69	9.62	*
	Potassium (mg/l)	5.14	8.64	2.88	4.96	7.79	2.9	4.86	7.39	2.8	4.83	7.54	2.94	*
	Chloride (mg/l)	10.18	13.2	7.96	10.05	13.4	7.19	9.61	13.2	7.1	9.51	13.5	7.24	250
	Total solids (mg/l)	<146.41	205.67	<28.53	<162.06	235.5	<24.64	<150.6	248.22	<25.2	<149.87	226.83	<23.42	500
	COD (mg/l)	31.4	51	10.32	26.59	40	9.15	25.39	51.2	9.47	23.84	33.6	7.79	*
	BOD (mg/l)	6.23	11.07	3.19	6.38	23	3.23	4.56	7.67	3.06	5	11	3.44	5
	DO (mg/l)	1.01	1.66	0.39	1.74	3.29	0.81	1.96	3.87	1.24	2.62	4.06	1.5	5
	Orthophosphate (mg/l)	<0.06	0.11	<0.02	<0.06	0.14	<0.02	<0.06	0.12	<0.02	<0.07	0.18	<0.02	*
	Total Phosphate (mg/l)	0.08	0.11	0.03	<0.08	0.17	<0.02	<0.08	0.18	<0.02	<0.19	1.62	<0.02	0.025

*There is no established limits.

Table 4. Calculated water quality parameters of Ferro stream (maximum, minimum and average (avr) values). The CONAMA limits are also presented

		Sample 13			Sample 15		CONAMA Limits
	Parameters and units	Avr	Max	Min	Avr	Max	Min	
FERRO STREAM	pH	7.23	7.4	6.95	7.16	7.3	7.1	6.0 to 9.0
	Turbidity (FTU)	7.97	14.75	4.7	9.56	11.6	6.6	100
	Colour (colour units)	13.64	19.58	6.36	11.81	12.9	10.8	75
	El. Conductivity (µS/cm)	156.79	217.4	124.9	156.97	184	134	*
	Copper (µg/l)	<3.49	8.3	<0.04	<2.3	3.6	<1.5	20
	Nickel (µg/l)	<16.13	90	<1	<2.17	4.2	.1.1	25
	Lead (µg/l)	<2.05	3.42	<1	<3.82	5.93	<1.7	30
	Zinc (µg/l)	<17.43	24.55	<0.02	<20	<20	<20	180
	Chromium (µg/l)	<8.46	<30	<1	<1	<1	<1	*
	Aluminium (mg/l)	<0.33	0.88	<0.14	<0.22	0.3	<0.2	0.1
	Manganese (mg/l)	<0.11	0.15	<0.09	<0.17	0.2	<0.1	0.1
	Soluble iron (mg/l)	0.27	0.51	0.13	<0.36	0.46	<0.3	0.3
	Total iron (mg/l)	0.84	1.4	0.6	0.82	0.9	0.8	*
	Nitrate (mg/l)	0.32	0.5	<0.2	<0.39	0.5	<0.3	10
	Nitrite (mg/l)	<0.01	0.02	<0.01	<0.01	0.01	<0.01	1
	Ammonia (mg/l)	<0.08	0.2	<0.02	<0.08	0.15	0.01	0.02
	Fluoride (mg/l)	<0.16	0.22	<0.12	<0.15	0.16	<0.2	1.4
	Sodium (mg/l)	5.28	7.5	4.15	5.54	5.7	5.3	*
	Potassium (mg/l)	4.14	5.68	2.47	4.81	5.72	4	*
	Chloride (mg/l)	<1.57	2.1	<1.3	<1.97	2.1	<1.7	250
	Total solids (mg/l)	<126.93	164.67	<6.32	<149.37	208.7	<113.4	500
	COD (mg/l)	<15.44	20.4	<6.86	<15.62	18.25	<14	*
	BOD (mg/l)	1.17	1.86	0.92	<1	<1	<1	5
	DO (mg/l)	7.4	8.42	6.49	7.23	7.7	7	5
	Orthophosphate (mg/l)	<0.04	0.06	<0.01	<0.05	0.06	<0.1	*
	Total Phosphate (mg/l)	<0.05	0.07	<0.03	<0.06	0.07	<0.1	0.025

* There is no established limit.

Those cited river and stream characteristics may be found in most rivers that pass near urban centres in a tropical area, and are influenced by the land use region [22,24].

Conclusions

The assessment of 11 environmental water sample points located at Centro Experimental Aramar and region, by taking into account the radioactive and the water quality chemical parameters, collected and measured in the period from 1988 to 2007, indicates accordance with values obtained in the pre-operational conditions and governmental suggested limits. We conclude that practically there are no changes in the water quality parameters in those sampling points analysed.

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