









Evaluation of the physical, chemical and microbiological parameters of the drinking water at the city of Caraz during the period August 2017-January 2018

[Evaluación de los parámetros físicos, químicos y microbiológicos del agua potable de la ciudad de Caraz durante el período agosto 2017-enero 2018]

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Resumen

El objetivo de la presente investigación fue evaluar los principales parámetros fisicoquímicos y microbiológicos del agua potable en la ciudad de Caraz, ubicada en la provincia de Huaylas, departamento de Áncash, durante el periodo comprendido entre agosto de 2017 y enero de 2018. Para ello se tomaron muestras en cuatro puntos de la ciudad, desde el reservorio de abastecimiento hasta la red de distribución domiciliaria. Se analizaron 23 parámetros físicos, químicos y microbiológicos: color, conductividad, sólidos totales disueltos, sólidos totales en suspensión, temperatura, turbiedad, cloro residual, cloruros, dureza total, fluoruros, nitratos, oxígeno disuelto, pH, sulfatos, arsénico, cadmio, cobre, hierro, manganeso, mercurio, plomo, coliformes totales y coliformes fecales. En la determinación de los parámetros indicados, se emplearon métodos de análisis químicos estandarizados para cada uno de ellos. Algunos análisis se realizaron en el mismo lugar (in situ) y otros en el laboratorio de química como en el de calidad ambiental de la UNASAM. Los resultados obtenidos fueron contrastados con los límites máximos permisibles (LPM) del Reglamento de la Calidad del Agua para Consumo Humano (MINSA, 2010). De los 23 parámetros evaluados, 20 se encontraron por debajo de los LMP (límite máximo permisible), con excepción del mercurio y los coliformes totales y fecales, cuya certidumbre dada por el método utilizado no permitió afirmar que los valores obtenidos se encuentren dentro del LMP.

Palabras clave: Agua potable, calidad del agua potable, Parámetros fisicoquímicos, microbiológicos.

Abstract

The objective of the present investigation was to evaluate the main physicochemical and microbiological parameters of drinking water in the city of Caraz, located in the province of Huaylas, department of Ancash, during the period between August 2017 and January 2018. For this purpose, samples were taken at four points in the city, from the supply reservoir to the home distribution network. Twenty-three physical, chemical and microbiological parameters were analyzed: color, conductivity, total dissolved solids, total suspended solids, temperature, turbidity, residual chlorine, chlorides, total hardness, fluorides, nitrates, dissolved oxygen, pH, sulfates, arsenic, cadmium, copper, iron, manganese, mercury, lead, total coliforms and fecal coliforms. In determining the indicated parameters, standardized chemical analysis methods were used for each of them. Some analyzes were carried out in the same place (in situ) and others in the

chemistry laboratory as well as in the environmental quality laboratory of UNASAM. The results obtained were contrasted with the maximum permissible limits (MPL) of the Regulation of Water Quality for Human Consumption (MINSA, 2010). Of the 23 parameters evaluated, 20 were below the MPL (maximum permissible limit), with the exception of mercury and total and fecal coliforms, whose certainty given by the method used did not allow us to affirm that the values obtained are within the MPL.

Keywords: Drinking water, water quality, physicochemical parameters, microbiological parameters.

1. Introduction

Water is essential for life, and a sufficient, safe and accessible supply must be available for all normal domestic uses, including drinking water (WHO, 2011). The study of water, according to Voet and Pratt (2009), from the biochemical point of view, requires observing the physical properties of water, its powers as a solvent and its chemical behavior; that is, the nature of the acids and bases present; Virtually all biological molecules act in response to the physical and chemical properties of the water that surrounds them.

Water travels through rocks and soils as part of its hydrological cycle; Due to its high solvent power, the concentration of substances dissolved in the water varies depending on the geographical location and the season of the year (Neira, 2006). Peru, due to its mineralogical nature due to the presence of the Andes and its economy dependent on the extractive activity of minerals, generates conditions for the dispersion of metals, which even reaches drinking water (Villena, 2018).

According to Borbolla et al. (2003), treated water, also called purified or drinking water, is that which has received a physicochemical treatment, conditioning it for human consumption, without the risk of causing any disease due to pathogenic microorganisms or chemical substances that affect the health of the population. On the other hand, the most common danger in relation to drinking water is its contamination, direct or indirect, due to the action of wastewater, human and animal excreta, and physicochemical and environmental factors (Marchand, 2022).

Drinking water treatment plants can provide safe water for human consumption, but its quality can be altered during its passage through the water distribution system with the possibility of physical, chemical, and mainly microbiological quality deterioration (Amézquita et al., 2014). In such a way that, the water in several places is much safer than others, being necessary, that it still has to be boiled or filtered and stored in a safe way to drink (Carrasco, 2013).

Achieving water systems with optimal quality, quantity, and continuity for the entire population is the result of a process that requires increased quality control at all levels and components, such as infrastructure work, the social component, and the subsequent administration of services (Mejía et al., 2016). Water quality is determined by comparing the physical and chemical characteristics of a water sample, with water quality norms or standards, which are based on acceptable toxicity levels to protect people's health (Pradillo, 2016).

On the other hand, to correctly interpret the water analysis, one must know and understand what the physicochemical parameters are (García, 2013). In order to facilitate the interpretation of physical, chemical and microbiological data, environmental agencies, universities and institutes resort to quality indices, which, through a mathematical expression, which represents all the valued parameters, evaluate the water resource (Samboni et al, 2007).

According to Neira (2006), hard waters, waters with high calcium and magnesium content, are associated with catchment basins of sedimentary rocks such as limestone or chalk, and soft waters, are waters with low calcium and magnesium content, usually have been in contact with impermeable rocks such as granite.

In the present investigation, the quality of drinking water in the city of Caraz was determined and evaluated, for which four strategically located sampling points were taken. The analyzes of the samples were carried out using standardized methods proposed by the APHA, AWWA and WCPF. The results obtained were contrasted with the maximum permissible values in the Regulation of Water Quality for Human Consumption (MINSA, 2010).

2. Materials and Methods

2.1 Materials

The materials used were provided by the chemistry laboratory and the environmental quality laboratory, both from UNASAM, following the security protocols established for these cases in order to guarantee the chain of custody of the samples.



Figure 1. Research team of the investigation

2.2 Methods of analysis

The analytical methods used to determine the physical, chemical and microbiological parameters are shown in Table 1.

Table 1: Methods to determine the physical, chemical and microbiological parameters

Parameter	Method	Unit
Colour	E. Merck 015	TCU
electrical conductivity	APHA 2510 B-Version 2012	$\mu\text{S/cm}$
dissolved totals Solids	Gravimetric	mg/L
totals Solids in suspension	Gravimetric	mg/L

Temperature	APHA 2550 B	°C
Turbidity	APHA 2130 B	NTU
Free residual Chlorine	Colorimetric-DPD	mg/L Cl ₂
Chlorides	APHA 4500-Cl-B	mg/L Cl ⁻
Total hardness	APHA 2340 c	mg/L CaCO ₃
Fluorides	Alizarine complexone	mg/L F ⁻
Nitrates	Nitrospectral	mg/L NO ₃ ⁻
Dissolved oxygen	APHA 4500-OG	mg/L O ₂
pH	APHA 4500-H*B-2012	pH
Sulphates	Bario sulfato, turbidimetric	mg/L SO ₄ ⁼
total arsenic	DIN-38 405	mg/L As
total Cadmium	Derivé de cation	mg/L Cd
Total copper	Colorimetric-Cuprizona	mg/L Cu
Total iron	Colorimetric. Triazina	mg/L Fe
total Manganese	Formaldoxina	mg/L Mn
total Mercury	Cetone de Michler	mg/L Hg
Total Lead	Colorimetric-PAR	mg/L Pb
faecal Coliforms	APHA 9222 D	UFC/mL
total Coliforms	APHA 9222 B	UFC/mL

TCU: True Color Unit

NTU: Nephelometric Turbidity Unit

CFU/mL: Colony Forming Unit per milliliter

2.3 Procedure

2.3.1 Recognition of the study area

The geographical conditions of the land and the facilities of the water treatment plant were recognized, as well as the location of the sampling points, knowledge of the needs for equipment and materials additional to those of the laboratory, measurement of transport times between the laboratories and the place where the samples are taken in order to guarantee the chain of custody of the samples.

2.3.2 Sampling points

The sampling carried out in the present work was of the non-probabilistic type, the conveniently chosen samples were made considering representative points based on the distance with respect to the place of initiation of the distribution of drinking water, that is, the water reservoir of the city, dividing it in four areas and considering a sample in each of them.

The samples for the analysis were: Point 1 that corresponds to sample 1 (M1): at the outlet of the drinking water reservoir, Point 2 corresponds to sample 2 (M2), in the Municipality of Caraz, Point 3 corresponds to the sample 3 (M3), at the intersection between Av. Luzuriaga with Av. 9 de Octubre and Point 4 that corresponds to sample 4 (M4), on Av. 20 de Enero.

2.3.3 Collection and storage of samples

The collection of the samples was carried out in strict compliance with the protocols established for these cases that allow their conservation and inalterability and avoid breaking the chain of custody.

The samples taken were carried out in two seasons, dry season and precipitation, considering that these factors have an influence on the measurement of the parameters considered.

According to Directorial Resolution No. 160-2015/DIGESA/SA, which approves the "Protocol of procedures for taking samples, preservation, conservation, transport, storage and reception of water for human consumption": containers, one liter of capacity, for sample taking, were made of polyethylene with previously sterilized and labeled safety lids. The first sample was taken in the dry season on October 4, 2017 and the second sample in the rainy season on January 31, 2018, which were placed in a cooler for transfer to the UNASAM laboratories. The samples were stored at a temperature of 4°C.



Figure 2. Sampling of the research

2.3.4 On-site analysis

The electrical conductivity, dissolved oxygen, pH and temperature analyzes were carried out in situ, considering that these parameters vary over time.

2.3.5 Analysis in the chemistry laboratory

The concentration of total dissolved solids and total solids in suspension were made in the UNASAM chemistry laboratory.

2.3.6 Analysis in the environmental quality laboratory

The color, free residual chlorine, chlorides, total hardness, fluorides, nitrates, sulfates, turbidity, total arsenic, total cadmium, total copper, total iron, total manganese, total mercury, total lead, fecal and total coliforms, were carried out. in the Environmental Quality laboratory of the Faculty of Environmental Sciences of UNASAM.

2.3.7 Contrasting results

Finally, the results of the analyzes carried out in each of the laboratories to which the samples were sent, as well as those obtained in the in situ analyzes were processed, contrasting them with the maximum limits allowed according to the Water Quality Regulation. for Human Consumption (MINSa, 2010).

2.3.8 Statistical analysis

The results obtained were statistically processed, determining the mean and standard deviation, which are shown in the results tables.

3. Results

3.1 Dry season

The results of the measurement of the physical, chemical and microbiological parameters in the dry season are shown in tables 2, 3 and 4, which indicates that the concentrations of metals are within the limits established by the norm given in DS N°031-2010-SA, with the exception of mercury; In this case, the instrument has a limitation due to the fact that its lower detection limit is 0.025 mg/l, determining values lower than this limit in all the samples; therefore, there is no certainty that the mercury analyzed is above or below the MPL of 0.001 mg/l established in the standard.

The turbidity determined in the dry season was 0.54 UNT, being said value below the MPL.

Table 2: Results of the physical parameters of the water at the sampling points in the dry season on October 4, 2017.

Parameter	Unit	M1	M2	M3	M4	Average	Standard deviation	Value DS N°031-2010-SA
Colour	TCU	< 0,5	< 0,5	< 0,5	< 0,5	<0,5	0,000	15
electrical conductivity	µS/cm	37	45,2	45,7	41	42,23	4,071	250
dissolved totals Solids	mg/L	25	23	27	26	25,25	1,708	1000
totals Solids in suspension	mg/L	< 1	< 1	< 1	< 1	<1	0,000	---
Temperature	°C	14	16,6	18,1	15,2	15,98	1,771	---
Turbidity	UNT	0,61	0,5	0,54	0,41	0,515	0,083	5

Note: UNT (Nephelometric Turbidity Unit), TCU (True Color Unit)

Table 3: Results of the chemical parameters of the water at the sampling points in the dry season on October 4, 2017.

Parameter	Unit	M1	M2	M3	M4	Average	Standard deviation	Value DS N°031-2010-SA
Free residual Chlorine	mg/L Cl ₂	0,25	0,25	0,25	0,25	0,25	0,000	0,5-5
Chlorides	mg/L Cl ⁻	5	5	5	5	5	0,000	250
Total hardness	mg/L CaCO ₃	29	30	30	30	29,75	0,500	500
Fluorides	mg/L F	< 0,10	< 0,10	< 0,10	< 0,10	<0,10	0,000	1 000
Nitrates	mg/L NO ₃ ⁻	1	1,8	1,3	1	1,275	0,377	50,00
Dissolved oxygen	Ppm	3,14	3,62	3,53	3,21	3,375	0,236	---
pH	pH	6,3	7,17	7,08	6,97	6,88	0,395	6,5-8,5
Sulphates	mg/L SO ₄ ⁻²	< 25	< 25	< 25	< 25	<25	0,000	250
total arsenic	mg/L As	< 0,010	< 0,010	< 0,010	< 0,010	<0,010	0,000	0,010
total Cadmium	mg/L Cd	< 0,002	< 0,002	< 0,002	< 0,002	<0,002	0,000	0,003
Total copper	mg/L Cu	< 0,02	< 0,02	< 0,02	< 0,02	<0,02	0,000	2,0
Total iron	mg/L Fe	0,045	0,037	0,056	0,224	0,045	0,089	0,3

total Manganese	mg/L Mn	< 0,010	< 0,010	< 0,010	< 0,010	<0,010	0,000	0,4
total Mercury	mg/L Hg	< 0,025	< 0,025	< 0,025	< 0,025	<0,025	0,000	0,001
Total Lead	mg/L Pb	< 0,010	< 0,010	< 0,010	< 0,010	<0,010	0,000	0,010

Table 4: Results of the microbiological parameters at the sampling points in the dry season on October 4, 2017

Parameter	Unit	M1	M2	M3	M4	Average	Standard deviation	Value DS N°031-2010-SA
total Coliforms	UFC/mL	< 1	5	< 1	< 1	2	2,0	0
faecal Coliforms	UFC/mL	<1	5	<1	<1	2	2,0	0.00

Notes: CFU/mL (Colony Forming Unit per milliliter)

3.2 Rainy season

The results of the measurement of the physical, chemical and microbiological parameters in the rainy season are shown in tables 5, 6 and 7, that in the free residual chlorine content an average content of 0.33 mg/L has been found in samples taken in both study periods. This content is less than the minimum amount necessary to guarantee effective disinfection of the water. The pH value found varies between 6.97 and 7.40 both in the dry season and in the rainy season. The turbidity determined in the rainy season was 0.74 UNT, these values being below the MPL.

Table 5: Results of the physical parameters of the water at the sampling points in the rainy season on January 31, 2018

Parameter	Unit	M1	M2	M3	M4	Average	Standard deviation	Value DS N°031-2010-SA
Colour	TCU	< 0,5	< 0,5	< 0,5	< 0,5	<0,5	0,000	15
electrical conductivity	µS/cm	151,3	98,6	98,8	98,8	111,9	26,284	250
dissolved totals Solids	mg/L	19,5	13,5	19	25	19,25	4,699	1000
totals Solids in suspension	mg/L	< 1	< 1	< 1	< 1	<1	0,000	---
Temperature	°C	14,7	17,5	16,2	19,7	17,03	2,119	---
Turbidity	UNT	0,96	0,69	0,68	0,64	0,743	0,147	5

Table 6: Results of the chemical parameters at the sampling points in the rainy season on January 31, 2018

Parameter	Unit	M1	M2	M3	M4	Average	Standard deviation	Value DS N°031-2010-SA
Free residual Chlorine	mg/L Cl ₂	0,2	0,3	0,5	0,4	0,35	0,129	0,5-5
Chlorides	mg/L Cl ⁻	3	4	3	3	3,25	0,500	250
Total hardness	mg/L CaCO ₃	20	19	18	--	14,25	1,000	500

Fluorides	mg/L F	< 0,10	< 0,10	< 0,10	< 0,10	<0,10	0,000	1
Nitrates	mg/L NO ₃ ⁻	< 1,0	< 1,0	< 1,0	< 1,0	<1,0	0,000	50
Dissolved oxygen	Ppm	3,26	3,02	3,02	2,92	3,055	0,145	---
pH	pH	7,52	7,61	7,6	7,4	7,533	0,097	6,5-8,5
Sulphates	mg/L SO ₄ ⁻²	< 25	< 25	< 25	< 25	<25	0,000	250
total arsenic	mg/L As	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	0,000	0,01
total Cadmium	mg/L Cd	< 0,002	< 0,002	< 0,002	< 0,002	< 0,002	0,000	0,003
Total copper	mg/L Cu	< 0,02	< 0,02	< 0,02	< 0,02	< 0,02	0,000	2
Total iron	mg/L Fe	0,075	0,032	0,029	0,067	0,051	0,024	0,3
total Manganese	mg/L Mn	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	0,000	0,4
total Mercury	mg/L Hg	< 0,025	< 0,025	< 0,025	< 0,025	< 0,025	0,000	0,001
Total Lead	mg/L Pb	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	0,000	0,01

The coliform content in the dry season and precipitation indicated in table 7, values less than 1 were found, not having the certainty that these values comply with the MPL of 0.00 established by the standard. In the city of Bagua, the total coliforms in 26 of the 110 samples they represent did not comply with the MPL (Hoyos and Gamarra, 2018). The average values found in times of drought and precipitation for the case of iron were 0.065 mg of dissolved Fe per liter, found within the MPL.

Table 7: Results of the microbiological parameters at the sampling points in the rainy season on January 31, 2018

Parameter	Unit	M1	M2	M3	M4	Average	Standard deviation	Value DS N°031-2010-SA
total Coliforms	UFC/mL	< 1	< 1	< 1	< 1	<1	0	0
faecal Coliforms	UFC/mL	< 1	< 1	< 1	< 1	<1	0	0.00

3.3 Percentage comparison of the physical and chemical parameters with respect to the MPL established by Supreme Decree No. 031-2010-SA, in the dry season and in the rainy season

Figures 3 and 4 show the graphs in which the physical and chemical parameters are compared in percentage terms, with respect to the MPL. Regarding the physical parameters, Supreme Decree No. 031-2010-SA does not establish a maximum limit for both temperature and total suspended solids, which is why it does not appear in the figure. In relation to the chemical parameters, due to the detection limit of the instrument used in the analysis of mercury, there was no specific value for this element, in this sense it has not been considered in the graph of figure 4. For the same reason, it has not been considered. microbiological parameters were plotted.

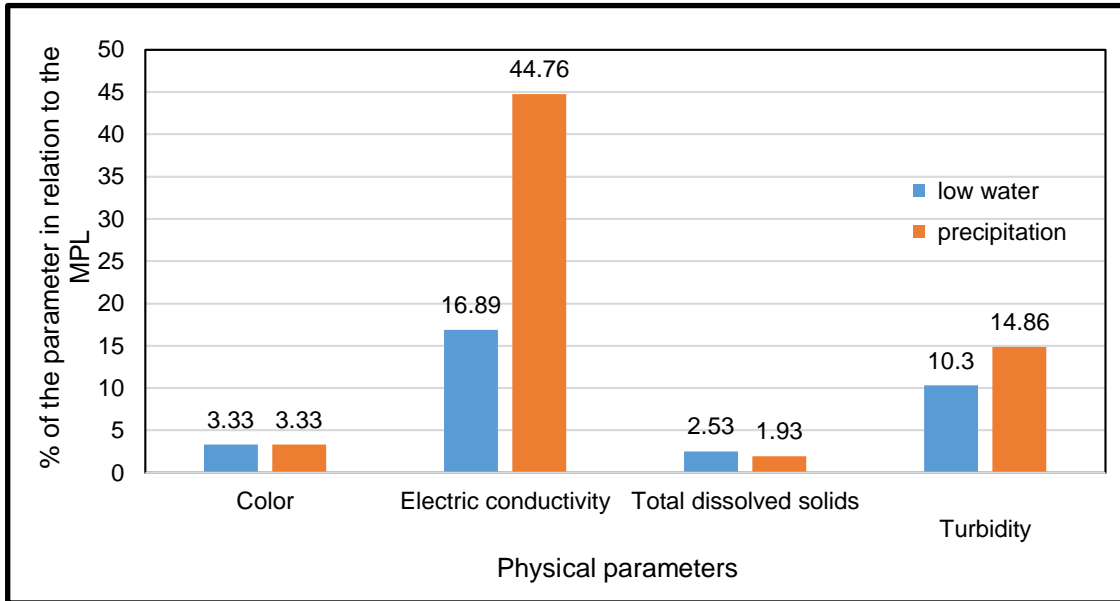


Figure 3: Percentage comparison of physical parameters with respect to MPL

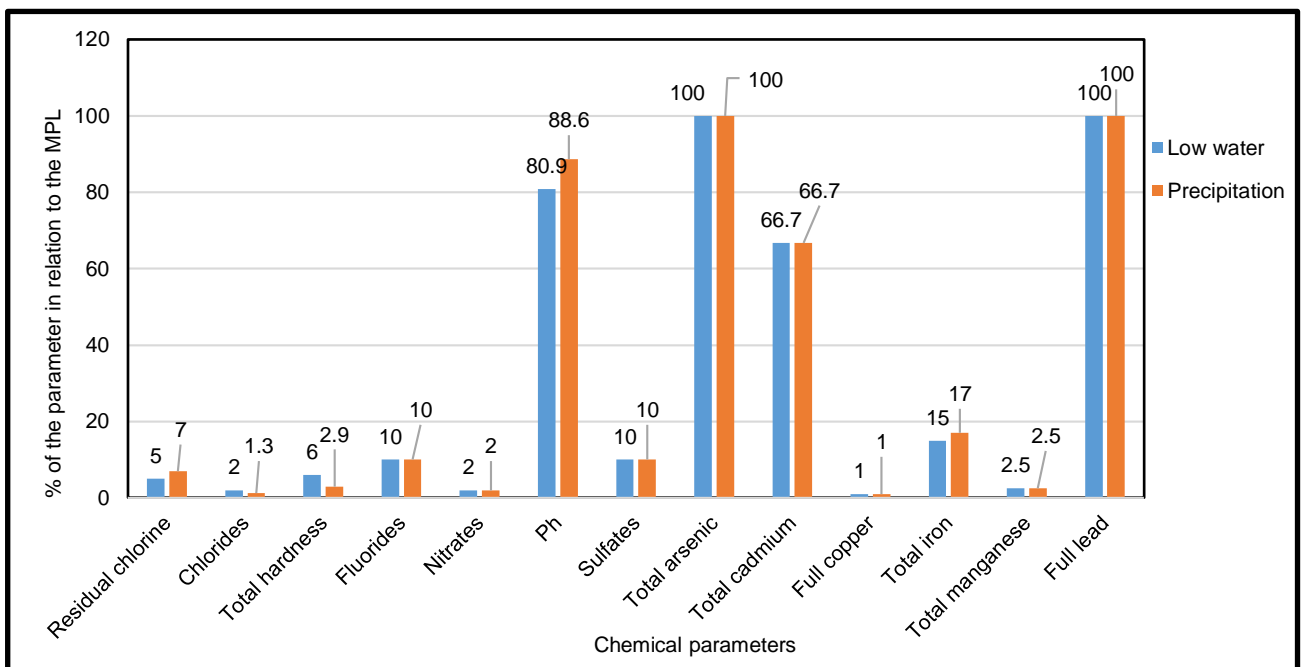


Figure 4: Percentage comparison of chemical parameters with respect to MPL

4. Conclusions

- In the home distribution network of drinking water in the city of Caraz, the six physical parameters that were evaluated all have values below the maximum limits allowed by the national standard (MINSA, 2010), both in dry season and in summer. rainfall.
- Of the fifteen chemical parameters evaluated, fourteen have values below the maximum limits allowed by the national standard (MINSA, 2010), minus mercury, both in the dry season and in rainfall.
- Regarding the concentration of mercury, it was determined that all the samples did not exceed the lower level of the instrument used of 0.025 mg/L. This limitation did not make it possible to determine with certainty whether this parameter complies with the MPL, which, according to the standard, establishes a maximum value of 0.001mg/L.
- The contents found of total and fecal coliforms, both in the dry season and in the precipitation season, were values less than 1, not having the certainty that these values comply with the MLP of 0.00 established by the standard, due to the limitations of the instrument used in its determination.

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