Cultivos Tropicales, 2021, vol. 42, no. 3, e01
ISSN impreso: 0258-5936
ISSN digital: 1819-4087

julio-septiembre
Ministerio de Educación Superior. Cuba
Instituto Nacional de Ciencias Agrícolas

http://ediciones.inca.edu.cu

Original Article

Chemical and agronomic characterization of Tapaste river water, located at the source of the Almendares-Vento Basin

Yenisei Hernández-Baranda[1*]

Pedro Rodríguez-Hernández[2]

Mirella Peña-Icart[3]

Yanitza Meriño-Hernández[4]

Reneé Pérez-Pérez[1]

Loreilys Ortega-García[1]

[1]Instituto Nacional de Ciencias Agrícolas (INCA), carretera San José-Tapaste, km 3½, Gaveta Postal 1, San José de las Lajas, Mayabeque, Cuba. CP 32 700

[2]Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA). CP 520 038.

[3]Instituto de Ciencia y Tecnología de Materiales. Universidad de La Habana. CP 10 400.

[4]Departamento de Producción Agrícola. Universidad de Granma. CP 85 100

[*]Author for correspondence: yeniseihernandezbaranda@gmail.com

ABSTRACT

The scarcity and deterioration of fresh water is one of the most alarming problems facing humanity today. As a solution strategy, different competent administrations, such as UNESCO and the Royal Legislative Decree of Spain, have proposed the reuse of wastewater. Cuba is not exempt from these problems and its national water policy promotes the application of this practice. For this reason, the objective of this work was to characterize and evaluate the quality of Tapaste river waters, located in the upper part of Almendares-Vento Basin source. To carry out the study, a monitoring network was established in the river's passage through the urban area of Tapaste town. The values of the evaluated indicators were compared with those established by FAO, WHO and the Ministry of the Environment and Climate Change Strategy of British Columbia government for use in agriculture, domestic and conservation of aquatic life respectively. As main results, it was found that the quality of the Tapaste river water is not appropriate for any of the three uses evaluated, because the concentration of Cd, alkalinity and BOD_5 exceed the established limits and in the most contaminated points it is exceeded up to 17, 11 and 22 times for Cd, alkalinity and BOD_5, respectively. The pollution observed is a consequence of the level of water stagnation and the continuous discharges of urban waste, which vary with the sampling site.

Key words: agriculture, water quality, biological conservation, family consumption, water reuse

INTRODUCTION

The quality loss of groundwater and surface water, as well as the scarcity of this resource, is one of the most alarming environmental problems facing humanity [1,2]. In addition, numerous studies predict increases in the intensity, duration and spatial extent of droughts, changes in precipitation patterns, and glaciers decline, all as a consequence of climate change. Therefore, fresh water is one of the most vulnerable resources to this natural phenomenon [3].

In Cuba, there have also been serious drought problems in recent periods, which may considerably affect the harvests in the coming years [4]. In addition, eutrophication of lakes and increased metal content in aquifer areas have been observed, due to the discharge of insufficiently treated industrial and livestock waste [5]. Almendares river is the most important body of surface water in the Cuban capital, a reflection of poorly used anthropic practices that affect its vitality. Different studies show the current deteriorated quality of this ecosystem, mainly due to high levels of organic matter, heavy metals and other pollutants [6–8]. However, evaluations carried out at its source are very scarce and, therefore, the information about the chemical composition of the water since its inception is insufficient.

The problem of water scarcity and pollution is even greater if one considers that agriculture uses 70 % of the fresh water available. As a solution strategy, different administrations have proposed the reuse of wastewater in agriculture [9]. In Cuba, wastewater is practically not reused, but given the drought problems that the country has presented and the convenience of giving it a productive use, different researchers promote this practice implementation [4].

However, the need to implement them in a safe way for the environment requires prior studies to evaluate their quality. Almendares River is born in Tapaste town, San José de las Lajas, Mayabeque, where it begins an intermittent course and the agricultural and urban activities carried out in the place can modify the chemical composition of water. For this reason, the objective of this work was to characterize the Tapaste River water and evaluate its quality for potential use in agriculture, family consumption and biological conservation of aquatic life.

MATERIALS AND METHODS

Four water samples were collected in the intermittent river that passes through Tapaste town, which corresponds to the source of the Almendares-Vento basin. The sampling was carried out on August 11, 2015, corresponding to a rainy period in Cuba. The sampled points were located at 23º02'53”of North Latitude and 82°13'23” West Longitude (Point I), 23º02'42 ”of North Latitude and 82°13'29” West Longitude (Point II), 23º02'13 ”of North Latitude and 82°13'52 ”West Longitude (Point III) and 23º01'88” North Latitude and 82°14'36 ”West Longitude (Point IV) (Figure 1). The samples were collected following established sampling and preservation procedures [10].

Figure 1. Sampling points in Tapaste River, San José de las Lajas, Mayabeque

At the sampling site, the pH and electrical conductivity were measured and samples were conserved and stored according to requirements of subsequent analyzes. PH and electrical conductivity were measured in triplicate, using an Orion Star^{TM} A325 portable multiparameter meter. Then the laboratory analyzes were carried out in the Department of Biochemistry and Plant Physiology of the National Institute of Agricultural Sciences. Alkalinity was determined by potentiometric titration with 0.1N H2SO4. Total residues (TR), fixed residues (FR) and volatile residues (VR) were evaluated by gravimetry, through drying in an oven and muffle (HERON mod HD-150). For this last analysis, successive heating times of 20 minutes were carried out until reaching constant weight. The biochemical oxygen demand (BOD_5) was also determined by the respirometric method through the OxiTop (WTW mod IS-12) and the content of Ca, Na, K, Mg, Cu, Pb, Cd, Mn by atomic absorption spectrophotometry. (Analytic Jena novAA 350). The procedures for these analyzes are described in the Water Analysis Manual [(10)].

The agronomic water quality was evaluated by calculating the sodium adsorption ratio (SAR), hardness in French hydrometric degrees (°F) and Kelly index, as shown in equations 1, 2 and 3, respectively. The results were processed by factor analysis. The indicators that present differences between points will be analyzed according to Duncan's Multiple Range Comparison test with $p \leq 0.05$ %, using the SPSS Statistics program v22 for Windows.

RESULTS AND DISCUSSION

The water quality was evaluated in the four sampled points, according to the criteria established by FAO [(11)], WHO [(12)] and the Ministry of Environment and Climate Change Strategy of the government of British Columbia [(13)], for their use in agriculture, domestic and conservation of aquatic life, respectively. The quality evaluation for agricultural use was carried out on the basis of the following categories: salinity, infiltration problems and toxicity [(11)]. The electrical conductivity (EC) in points I, III and IV was lower than the upper limits established by FAO and, therefore, they do not represent a problem of soil salinization (Table 1). In contrast, point II is in the established range of “Increasing problem” of salinization (0.75-3 dS m^{-1}), which means that it can have detrimental effects on sensitive crops.

Cultivos Tropicales, 2021, vol. 42, no. 3, e01
ISSN impreso: 0258-5936
ISSN digital: 1819-4087

julio-septiembre
Ministerio de Educación Superior. Cuba
Instituto Nacional de Ciencias Agrícolas
http://ediciones.inca.edu.cu

Table 1. Parameters that characterize the chemical water composition at the sampled points and the reference values established by FAO, WHO and the Ministry of the Environment and Climate Change Strategy of the government of British Columbia

Indicators	P- I	P- II	P- III	P- IV	Agriculture use 11	Domestic use 12	Aquatic life 13
pH SE (0.11)	7.78 a	7.69 a	7.77 a	7.74 a	6.5-8.4	6.5-9.5	6.5-9
EC dSm^{-1} SE (0.008)	0.545 d	0.961 a	0.672 b	0.626 c	0.7	-	-
Ca meq L^{-1} SE (0.05)	1.10 d	1.95 a	1.70 b	1.48 c	0-20	2.49-7.49	-
Mg meq L^{-1} SE (0.005)	0.088 b	0.187 a	0.092 b	0.086 b	0-5	-	-
Na $meqL^{-1}$ SE (0.01)	1.20 c	1.93 a	1.31 b	1.16 d	3	8.7	-
K mgL^{-1} SE (0.4)	11.0 c	32.9 a	16.0 b	16.2 b	0-2	-	-
Zn mgL^{-1} SE (0.01)	0 b	0.09 a	0.04 ab	0 b	2	3	0.03
Cd mgL^{-1} SE (0.005)	0.110 c	0.130 b	0.153 a	0.167 a	0.01	0.003	0.002
Mn mg L^{-1} SE (0.03)	0.37 a	0.10 b	0 b	0 b	0.2	0.4	-
Pb mg L^{-1}	0	0	0	0	5	0.01	0.007
SAR **SE** (0.03)	1.56 b	1.86 a	1.39 c	1.31 c	0-3	-	-
Alkalinity meq L^{-1} SE (0.2)	8.43 d	16.83 a	12.27 b	10.40 c	1.5	-	-

The letters compare the four points in an indicator according to Duncan p≤0.5. Standard error (SE)

The comparative analysis of the Sodium Adsorption Ratio (SAR), with the FAO limits, reflected that the river water did not present problems of sodification and infiltration in the soil (Table 1). However, these problems are due, among other factors, to the combination of the effects associated with the sodium and salinity of the water.

The simultaneous evaluation of the SAR and EC indicators in the FAO diagram (1985) showed that the water from the four points presents problems of slight or moderate reduction in the infiltration rate in the soil. For these reasons, its use is recommended without neglecting the possible effects in crops that demand a high content of this resource.

The pH and concentration of most of elements (Table 1) were lower than the maximum permissible limits, so they do not represent a risk of toxicity for plants, domestic use and the conservation of aquatic life. Among the indicators that did not comply with what was established is the concentration of Cd, which exceeded by an average of 14, 47 and 70 times the acceptability criteria for use in agriculture, domestic use and conservation of aquatic life, respectively.

It is important to point out that Cd is one of the heavy metals that has attracted the most attention in the sciences of soil, plants and living beings; in general, due to its high toxicity, mobility and bioaccumulative power. The levels found in the water from the source of the Almendares River not only affect its usefulness, but also show alarming problems of contamination. Given its accumulation capacity, it is highly probable that the concentrations in sediments and living organisms that develop in this environment are higher than those determined in water. In the 1940s, Cd contamination in the Jinzu River and in rice cultivation became apparent when more than 100 people in Japan died from Cd toxicity [(14)]. These events should be a cause for concern and alarm for other countries in similar environmental situations.

Since the pH, at all the points sampled, is below 8.3, the alkalinity is almost entirely due to bicarbonate ions. This is another of the indicators that exceeded the limit for use in agriculture (Table 1) and exceeded the usual range of bicarbonate ion concentration in irrigation water (0-10 meq L^{-1}). Bicarbonate, even at very low concentrations, is a problem, especially when fruit crops are sprinkled during periods of very low humidity (Hr <30 %) and high evaporation. Under these conditions, white deposits form on fruits and leaves that are not washed away by subsequent irrigation and reduce their marketability.

According to the chemical characterization carried out, the river water is classified as of the sodium calcium bicarbonate type. It is attributed that Ca and alkalinity owe their content in the water to its interaction with Cojímar formation rocks, which consist of soft calcareous marls and on occasions, harden into compact limestone [(15)].

The concentrations of elements such as Ca, Mg, Na and K showed an almost similar trend in their course through sampling points (Figure 2). Point II presented the highest concentration values for four elements. Point III followed in order, except for Mg, and I and IV points showed the lowest values, which corresponds to the behavior of EC. The elements Ca, Mg and K are within the range of usual concentrations defined by FAO for irrigation water. Limit values are not established for these elements, but rather certain relationships that must be met between them and Na, in order to maintain the desired balance. The elements Ca and Na are in almost a similar proportion, higher than Mg and comply with the relationship established by FAO so that Ca can counteract the dispersant effects of Na in the soil and its toxicity in crops.

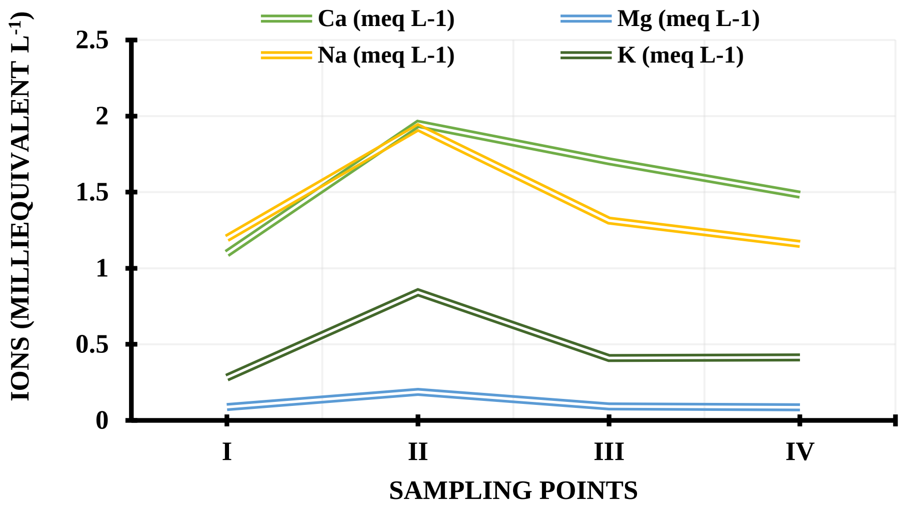

Figure 2. Behavior of the elements Ca, Mg, Na and K in their course through the sampled points

The concentrations of Ca, Mg and K elements were lower than those determined ones by another researcher in his study of the water quality in different wells near the sampling site (16). However, river water showed higher Na concentration values than well water. These differences are due to the fact that groundwater, as it passes through the soil, acquires a higher content of nutrients and elements present in rocks and minerals. Na does not seem to be a characteristic element of the place lithology and its higher concentration in surface waters could be due to waste discharges.

The highest values of total residue (TR), fixed residue (FR) and volatile residue (VR) (Table 2) were obtained in point II.

Table 2. Agronomic water quality parameters and indicators at the sampled points

	P-I	P-II	P-III	P-IV
TR mg L^{-1} SE (121)	858 ab	1094 a	636 b	517 b
FR mg L^{-1} SE (51)	394 b	627 a	388 b	280 b
VR mg L^{-1} SE (99)	464 a	467 a	248 a	237 a
Hardness (°F) SE (1)	24 d	43 a	36 b	31 c
KI (%) SE (1)	46 b	48 b	55 a	54 a

These data confirm the results obtained for alkalinity, metal concentration and BOD_5 (Figure 3). The high alkalinity, as well as the total residue values above 1000 mg L^{-1}, indicates that the analyzed waters have a tendency to form incrustations.

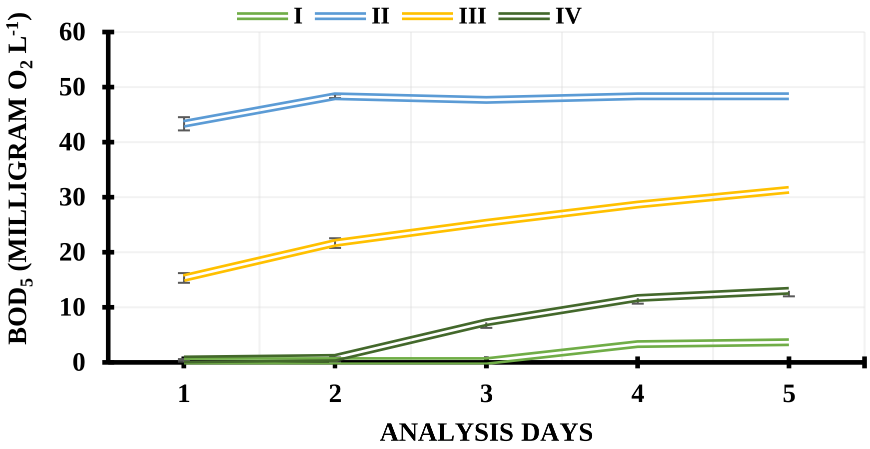

Figure 3. Evolution of BOD_5 during the analysis period

The tendency to chemical precipitation of $CaCO_3$ was predicted using the Langelier saturation index [(11)]. The results indicated that the waters of points I, II, III and IV presented $CaCO_3$ saturation indices of 0.18; 0.69; 0.67 and 0.44, respectively. This aspect can be a limitation, especially in fertigation, because the flow of water is obstructed and, in addition, it contributes to soil alkalization. The increase in pH enhances a waste of nutrients, due to their low availability in values higher than 8.0. One of the possible mechanisms to minimize these effects is to adjust the pH to 7.0 in the irrigation water and in this way the saturation index becomes negative and, therefore, the carbonate should not precipitate.

According to the hardness values in French hydrometric degrees (°F), the waters of I and IV points are considered moderately hard and points II and III correspond to hard waters. The Kelly index (KI) is one of indicators that define the appropriate proportions of Ca, Mg and Na ions and its value greater than 35 % indicates that the waters of the four points are suitable for irrigation (Table 2) [(17)].

The BOD_5 values are higher than the limits established in the Water Quality and Discharge Control Standard AG-CC-01 for waters that are destined for public supply (2 mg O_2 L^{-1}) and the preservation of fauna and flora (5 mg O_2 L^{-1}) [(18)]. Points II and III even exceed the limit (10 mg O_2 L^{-1}) for use as irrigation water for food crops, including those root crops that are consumed raw and crops where the edible portion is in direct contact with the water [(19)]. Therefore, due to the high content of organic matter, waters of the different points are not suitable for the mentioned uses. It is important to note that in I and IV points the lowest values of this variable were reached, since they correspond to the entrance and the river exit through the town. This result indicates that the contamination is caused by urban residual discharges and animal husbandry residues.

CONCLUSIONS

- The chemical composition of Tapaste River water, San José de las Lajas, Mayabeque, reflects formation characteristics to which it belongs and also the negative impact it receives from urban wastewater discharges.
- The highest values of EC, SAR, TR, FR, alkalinity, hardness and concentrations of Ca, Mg, Na, K, Zn, were found in point II, which coincidentally is the one that receives greater discharges of domestic and animal husbandry waste.
- The high contents of Cd in the water of four points qualify it not suitable for irrigation, domestic use and conservation of aquatic life and represent an alarming environmental problem. Also the high bicarbonate contents represent a problem for its use in agriculture given the tendency to form incrustations.
- The pollutant organic load classified the water in the four points as not suitable for domestic use and conservation of aquatic life and in II and III points; it is not suitable for use in agriculture.

RECOMMENDATIONS

For the reasons stated, the need for a systematic sampling is suggested to confirm the contamination level and obtain definitive conclusions about the environmental quality of the river under study.

BIBLIOGRAPHY

1. Restrepo Gutiérrez E, Zárate Yepes CA. El mínimo vital de agua potable en la jurisprudencia de la Corte Constitucional colombiana. Opinión Jurídica. 2016;15(29):123–40.
2. Zhou X, Lei K, Khu S-T, Meng W. Spatial flow analysis of water pollution in eco-natural systems. Ecological Indicators. 2016;69:310–7.
3. Guppy L, Anderson K. Global Water Crisis: the facts. Hamilton, Canadá: United Nations University Institute for Water, Environment and Health; 2017 p. 16.

4. Díaz Duque JA. El agua en Cuba: un desafío a la sostenibilidad. Ingeniería Hidráulica y Ambiental. 2018;39(2):46–59.
5. Sanchez BLM, Rivero AEG, Chávez ES. Carga contaminante dispuesta en cuenca Ariguanabo, provincia Artemisa, Cuba. Revista Cubana de Ingeniería. 2016;7(2):55–63.
6. Díaz Rizo O, Rudnikas AG, Lavin Pérez RD, Arencibia Carballo G. XRF analysis of sediments from Nuevitas Bay (Cuba): assessment of current heavy metal contamination. 2014;
7. Argota Pérez G, Argota Coello H, Iannacone J. Bioaccumulative exposure to heavy metals in *Gambusia punctata* and *Gambusia puncticulata* from the ecosystem of Almendares, Havana-Cuba. The Biologist (Lima). 2016;14(2):339–50.
8. Santana JL, Massone CG, Valdés M, Vazquez R, Lima LA, Olivares-Rieumont S. Occurrence and source appraisal of polycyclic aromatic hydrocarbons (PAHs) in surface waters of the Almendares River, Cuba. Archives of environmental contamination and toxicology. 2015;69(2):143–52.
9. WWAP (United Nations World Water Assessment Programme)/UN-Water. 2018. The United Nations World Water Development Report 2018: Nature- Based Solutions for Water. Paris, Francia: UNESCO; 2018. 139 p.
10. L Nollet LM, P de Geldes LS. Handbook of Water Analysis. 3ra ed. London, England: CRC press; 2014. 979 p.
11. Ayers RS, Westcot DW. Water quality for agriculture. FAO Irrigation and drainage paper. Vol. 1. Rome, Italy: Rome: Food and Agriculture Organization of the United Nations; 1985. 174 p.
12. Organization WH. Guías para la calidad del agua de consumo humano. 4ta ed. Perú: Ginebra; 2018. 606 p.
13. Ministry of Environment and Climate Change Strategy. British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife and Agriculture: Summary Report. [Internet]. 2019 Aug [cited 25/05/2021] p. 39. Available from: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/water-quality-guidelines/approved-water-quality-guidelines
14. Ogawa T, Kobayashi E, Okubo Y, Suwazono Y, Kido T, Nogawa K. Relationship among prevalence of patients with Itai-itai disease, prevalence of abnormal urinary findings, and cadmium concentrations in rice of individual hamlets in the Jinzu River

basin, Toyama prefecture of Japan. International Journal of Environmental Health Research. 2004;14(4):243–52.

15. Bermúdez PJ. Las Formaciones Geológicas de Cuba. Geología Cubana. 1ra ed. Cuba: Instituto Cubano de Recursos Minerales; 1961. 177 p.
16. Dell'Amico-Rodriguez JM, Morales-Guevara D, Calana-Naranjo JM. Monitoreo de la calidad del agua para riego de fuentes de abasto subterraneas en la parte alta del nacimiento de la cuenca Almendares-Vento. Cultivos Tropicales. 2011;32(4):49–59.
17. Loera-Alvarado LA, Torres-Aquino M, Martínez-Montoya JF, Cisneros-Almazán R, Martínez-Hernández J de J. Calidad del agua de escorrentía para uso agrícola captada en bordos de almacenamiento. Ecosistemas y recursos agropecuarios. 2019;6(17):283–95.
18. Secretaría de estado de medio ambiente y recursos naturales. Norma de Calidad de Agua y Control de Descargas AG CC 01. Santo Domingo, República Dominicana; 2001 p. 52.
19. Alcalde-Sanz L, Gawlik BM. Minimum quality requirements for water reuse in agricultural irrigation and aquifer recharge. Towards a legal instrument on water reuse at EU level. 2017; 57 p. ISBN: 978-92-79-77175-0, doi: 10.2760/804116.