EVALUATION OF WATER QUALITY IN THE QUEBRADA EL SALADO THROUGH THE APPLICATION OF THE WATER QUALITY INDEX (ICA - NSF) (PARROQUIA EL VALLE, CANTÓN CUENCA, ECUADOR)

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ABSTRACT

The physical, chemical and microbiological parameters of the water in the El Salado stream were determined, taking into account nine parameters: turbidity, dissolved oxygen, BOD5, pH, nitrates, phosphates, fecal coliforms, total solids and temperature in order to compare with the regulations, after which the Water Quality Index of the National Sanitation Foundation (ICA - NSF) of the United States was calculated; For this, four monitoring campaigns were carried out between the months of February, March, April and May 2019; at four sampling points. The results obtained show that the water quality is within the range of Bad to Medium.

Keywords: environmental indicators, environmental pollution, water quality, water uses.

INTRODUCTION

The productive activity of man and the consumption of water by human populations generate wastewater and waste production, which constitute pollutants that undermine the quality of water in surface bodies (Mokoena & Mukhola, 2019). Sites that have been privileged with the availability of usable fresh water for different uses are in danger of limiting their potential due to contamination (Moloi *et al*., 2020; Bedla & Dacewicz, 2019).

Water quality, health and economic growth are mutually reinforcing and fundamental to achieving human well-being and sustainable development. Poverty and disease is a recurring binomial with a strong destructive power in society, but it is also difficult to tackle (Mensah & Casadevall, 2019; Hoyos *et al*., 2018). Generally, only the economic emphasis is prioritized and many times the actions and interventions are unsustainable, returning, repeatedly, to the same initial conditions (Di Minin *et al.*, 2017).

The effects caused by the contamination of water supply sources are related to the depletion of water resources and the decrease in their quality, as well as the loss of existing aquatic flora and fauna (Baldiris *et al*., 2017; Naidoo & Olaniran, 2014). When anthropogenic pollutants are dumped and the channel's self-purification level is exceeded (Abdel-Satar, *et al.*, 2017), the sources of water supply are threatened (Ugbebor & Oyinloye, 2017). Some authors estimate that by 2025, more than half of the earth's population will be affected by water scarcity ((Perez *et al*., 2018a; Mekonnen & Hoekstra, 2016).

The different bodies of surface water represent transcendental points for the operation and development of nature as well as for the human being, allowing a necessary supply for the maintenance of a system with a complex structure made up of human and environmental interactions (Malek *et al*., 2019; Seymour, 2016). The progressive deterioration of water sources caused by the different forms of anthropogenic emissions is a key point where preventive intervention is important to avoid serious problems with the resource and therefore its availability over a timeline (Brack *et al*., 2017).

The assessment of the state of the water resource is carried out including the analysis of physical, chemical and microbiological parameters, since currently degradation is constant and progressive (Bojarczuk *et al.*, 2018; Severiche *et al*., 2017a). The competent mechanism for determining the quality of a water effluent is the Water Quality Index (ICA), because in a simple way they present the degree of contamination with information requirements that are clearly based on the results of the parameters analyzed (Olsson *et al*., 2014).

The concern on the part of the competent public entities of the effluent has been manifested jointly with the discontent of the population for the state of the resources present in the stream, which has prompted to propose actions that are aimed at decisive points of recovery, conservation and management that seek to promote the development of communities and thereby improve the quality of life of people (Blumm & Wood, 2017). Therefore, in this work, the water quality of the El Salado stream located in the El Valle parish was determined, using the ICA-NSF Water Quality Index, initially presented by Brown in 1970 with the collaboration of the National Sanitation Foundation of the United States, which integrates nine parameters as a basis taking into account the need for applying the methodology to include more parameters to the initial proposal by the methodology as such (Pérez *et al*., 2018).

MATERIALS AND METHODS

Study Area

Throughout the basin of the El Salado gorge, agricultural activity is identified, which has been maintained over time since it is an ancestral activity. The demographic growth has presented a condition of forgetfulness of the agricultural activities, replacing by diverse commercial activities. The use of the creek is for irrigation of mixed short-term crops and grass. The carelessness marked by property dwellers and authorities has triggered significant problems for population development. The study area is between 2, 660 and 2,750 meters of altitude (Pérez, 2017).

The El Salado gorge is located in the Province of Azuay and belongs to the Cuenca canton. It is located in the southeast part of the canton, forming part of the hydrography of the El Valle parish; which in turn is bordering the urban limit of the city of Cuenca, at an approximate height of 2, 600 meters above sea level; its parish center is located 5 kilometers away from the city of Cuenca. The length of the gorge is 4 km until its union with the El Tasqui gorge, after that it is a contribution to the Paute River (Valle, 2015).

Sampling points: In the El Salado gorge, domestic discharges and the presence of domestic animals in the neighboring farms represent a very serious problem; the deterioration of the resource is due to the lack of riverside vegetation caused by the presence of cattle in its most. These activities generate an unfavorable environment for the ecosystem and its affected compartments from the water component (Valle, 2015).

Four sampling points were determined along the El Salado stream, as shown in Figure-1, in each sampling stage a single sample was taken at each point.

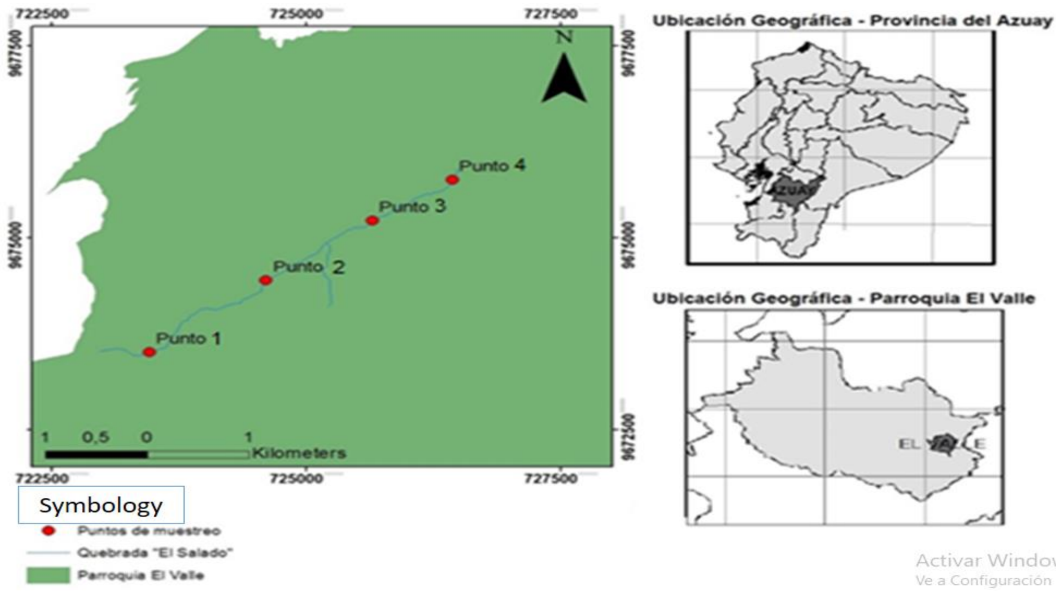

Figure-1. Sampling points
Source: Authors

Sampling

Sampling stages: 4 sampling stages were developed in the months of February, March, April and May 2019 in order to consider the variations of the physical-chemical and microbiological parameters in the transition between the dry and rainy period that develops in the locality.

Flow measurement: This factor represents a great importance in the monitoring of hydrographic basins. This allows a point of correlation to be given with the results of the analyses in order to rule out possible misuses outside the course of the effluent such as: recreation, domestic and agricultural use. To determine the flow, the effluent speed measured by the Global Water model FP111 propeller flow meter was taken into account, the result was expressed in meters per second, therefore, it was necessary to measure the cross-sectional area of the stream and integrate the data in the calculation and thus obtain the flow units, in addition to this, the cube method for the measurement of flows in effluents provided by the FAO was used (Perez *et al*., 2018b; Ordoñez & Peláez, 2013).

Equipment and materials: In order to obtain accurate measurements, the HACH C multi-parameter equipment, HACH 2199Q Turbidimeter, Global Water FP111 Windlass was used; the equipment was provided by the Environmental Engineering Laboratory of the Faculty of Chemical Sciences of the University of Cuenca. The Water Quality Laboratory located on the Balzay Campus provided the work infrastructure, as well as the supplies and equipment for analysis within the laboratory.

Collection and conservation of samples: To guarantee reliable results, a correct process of collection, treatment and transport of the samples until their analysis is necessary. In some process of the sampling chain they can undergo changes due to radiation conditions,

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temperature, etc., which reduces the percentage of reliability in the results of the analyzes (Viquez, 2016).

Determination of the ICA-NSF

The parameters that are measured are presented below with their respective units:

- Turbidity (NTU)
- Temperature (°C)
- Hydrogen potential (pH units)
- Biochemical Oxygen Demand in 5 days (mg/L)
- Nitrates (mg/L)
- Phosphates (mg/L)
- Total solids (mg/L)
- Dissolved oxygen (mg/L)
- Fecal coliforms (MPN/100 mL)
- Calculation of the water quality index of the NSF model

To perform the ICA calculation previously, it is necessary to obtain the analyzes of all the parameters contemplated in the development of the quality index. The variations that the result of the ICA represents give rise to decision-making since it more accurately reflects a change in the quality of the water body (Severiche *et al*., 2013; Landwehr & Denninger, 1970). The following formula is used to calculate the multiplicative index:

$$ICA_m = \sum_{i=1}^{9} (I_i * W_i)$$

Where:

- ICA_m: Water Quality Index.
- i: each of the quality parameters. Y
- Ii: subscript of parameter i; (it is between 0 and 100).
- w_i: Relative weights assigned to each parameter (Ii), and weighted between 0 and 1 such that the sum is equal to 1.

To obtain the values of the subindex "Ii", the value of the measurement provided by the different equipment and / or methodologies used is acquired. For each parameter there is a characteristic curve. The product value of the measurements is housed on the "x" axis, from where it is projected towards the curve that later on the "y" axis will give a value that corresponds to the subscript "Ii". Regarding the relative weights assigned for each parameter "w_i", Table-1 provides the values.

Table-1. Relative weights for each parameter of the ICA-NSF.

I	Parameter	w_i
1	Turbidity	0.08
2	Temperature	0.10
3	Hydrogenpotential	0.12
4	Biochemical oxygen demand in 5 days	0.10
5	Nitrates	0.10
6	Phosphates	0.10
7	Total solids	0.08
8	Dissolvedoxygen	0.17
9	Fecal coliforms	0.15

The effluent status classification is based on the numerical ranges presented in Table-2.

Table-2. Reference ranges for effluent status.

Range	Quality	General criteria
85 - 100	Excellent	Uncontaminated
70 - 84	Good	Acceptable
50 - 69	Half	Little polluted
30 - 49	Bad	Contaminated
0 - 29	Verybad	Highlypolluted

RESULTS AND DISCUSSIONS

Flow comparison: Flow was measured at each monitoring and at each sampling point, since it is considered important since it allows us to analyze an existing correlation between effluent quality and its respective flow (Nivelo, 2015). Within the sampling months, the change of season could be evidenced through the photographic record, since in the months of February and March higher flows are recorded, which is contrary in the next two months, making evident the lack of precipitation due to the global climate change.

The highest values recorded correspond to the data taken in monitoring 1 and 2 where there is a peak of 149.41 L / s corresponding to the point of MonayelCruce, on the other hand, the lowest value recorded is 64.87 L/s in monitoring 3 corresponding to the point of El Valle Centro, highlighting that the drastic drop in flow was exerted by a intake of a low pressure pump for irrigation of alfalfa on a predial slope to the creek.

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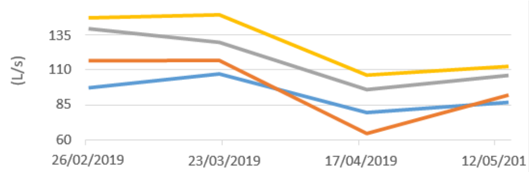

	26/02/2019	22/03/2019	18/04/2019	14/05/2019
P1 Victoria Alta	97,39	107,29	79,71	87,08
P2 El Valle Centro	116,72	116,94	64,87	92,19
P3 El Despacho	139,54	129,85	96,08	106,32
P4 Monay El Cruce	147,32	149,41	106,45	112,63

Figure-2. Comparison of the flows obtained in each of the samplings with the monitoring points
Source: Authors

Comparison of monitoring results: During the months of February and March, the presence of pronounced rains was obtained on certain days a week, while the month of April the pronunciation of rains were less than the previous months and the last month of sampling the amount of rainfall decreased dramatically. For the purposes of comparison with the regulations, the parameters measured in the points Barrio Victoria Alta (1), El Valle Centro (2), Barrio El Despacho (3), Monay El Cruce (4) that were related to the criteria contemplated in the Regulations. For the reason that the primary use is for pasture and alfalfa cultivation followed by livestock activity, Table-3 below shows the comparison results of each sample.

In monitoring 1 carried out on February 26, 2019, the concentration of Dissolved Oxygen does not meet the value given by the regulations, as well as in the case of Fecal Coliforms that have a too wide spectrum of non-compliance with the regulations. In campaign 2 carried out on March 22, 2019, in addition to non-compliance in Fecal Coliforms, the Dissolved Oxygen parameter is added. In monitoring 3 carried out on April 18, 2019, Fecal Coliforms in all its sampling points and the Dissolved Oxygen parameter in point number 4 do not comply with the provisions of the regulations, exceeding the values stipulated by current regulations. Monitoring 4 corresponding to May 14, 2019, the Fecal Coliform parameter does not comply in any of the sampling points.

ICA-NSF water quality index: Using the values obtained in the different tests either onsite or in the laboratory, calculations of the Water Quality Index were made for the El Salado stream. In monitoring number 1 it can be seen that at the point corresponding to the El Despacho area, the value of the ICA calculation is 48 (referential range), which indicates poor water quality at that point. At points 1 (Victoria Alta), 2 (El Valle) and 4 (MonayelCruce) the quality is average with values of 55, 50 and 50 respectively, these last two values are not too far from the value of point number 3. In Monitoring number 2 presented a low value of 49 from ICA-NSF at point number 3 (El Despacho). At points 1, 2 and 4 the water quality is average represented with values of 55, 55 and 50 respectively, highlighting that at point 4 (Monay El Cruce) the value is not far from the value of point 3.

In monitoring number 3 we have at point 4 corresponding to Monay EL Cruce a value of 44 that indicates poor water quality. At points 1, 2 and 3 the quality is medium, which indicates that there is moderate contamination. The last monitoring shows moderate contamination at the 4 points, since the values are within the medium quality range. ICA-NSF values were calculated manually using Excel.

A noticeable decline in water quality occurred at point 4 (Monay El Cruce) in April, otherwise it happens with point 2 (El Valle), which in the first monitoring shows a value of 50 corresponding to a medium quality with moderately polluted waters and increases its values until monitoring 3 where a value of 61 is obtained by calculating which is maintained until the fourth monitoring that corresponds to the month of May. Likewise, point number 3 corresponding to the El Despacho area, there is an increase in the water quality values, thus giving a change from poor to average quality throughout the monitoring time. In point 1 (Victoria Alta) the values indicate a decrease in the quality of the water in the months of March and April with respect to February and May, being within an average quality with moderately contaminated waters.

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Table-3. Comparison of monitoring results 1, 2, 3 and 4 with regulations.

Sampling Point	Parameter	Quality Criterion	Measurement Value Monitoring 1	Measurement Value Monitoring 2	Measurement Value Monitoring 3	Measurement Value Monitoring 4
1	Temperature (ºC)	15 max. 20 (+/- 3)	16.7	15.6	14.2	16.4
	Hydrogen Potential (pH units)	6.0-9.0	7.96	7.67	7.43	7.65
	Dissolved Oxygen (mg/L)	not less than 6 mg /L	8.00	7.34	6.53	7.95
	Fecal coliforms (MPN/100 mL)	<1000	7200	7200	7200	7200
	Total Solids (mg/L)	3000	1035	1660	1660	1668
2	Temperature (°C)	15 max. 20 (+/- 3)	16.2	16.1	16.5	16.8
	Hydrogen Potential (pH units)	6.0 - 9.0	8.00	7.45	7.24	7.95
	Dissolved Oxygen (mg/L)	not less than 6 mg /L	6.00	6.71	8.10	7.66
	Fecal coliforms (MPN/100 mL)	<1000	7200	7200	7200	7200
	Total Solids (mg/L)	3000	684	1753	1753	979
3	Temperature (°C)	15 max. 20 (+/- 3)	16.45	16.54	15.2	15.8
	Hydrogen Potential (pH units)	6.0-9.0	7.93	7.97	7.87	8.12
	Dissolved Oxygen (mg /L)	not less than 6 mg /L	5.00	4.78	7.16	8.13
	Fecal coliforms (MPN/100 mL)	<1000	7200	7200	7200	7200
	Total Solids (mg/L)	3000	756	1705	1705	983
4	Temperature (°C)	15 max. 20 (+/- 3)	17.05	17.05	16.1	16.0
	Hydrogen Potential (pH units)	6.0 - 9.0	7.65	7.65	6.79	7.59
	Dissolved Oxygen (mg/L)	not less than 6 mg /L	6.00	5.31	3.48	7.97
	Fecal coliforms (MPN/100 mL)	<1000	7200	7200	7200	7200
	Total Solids (mg/L)	3000	753	753	1453	767

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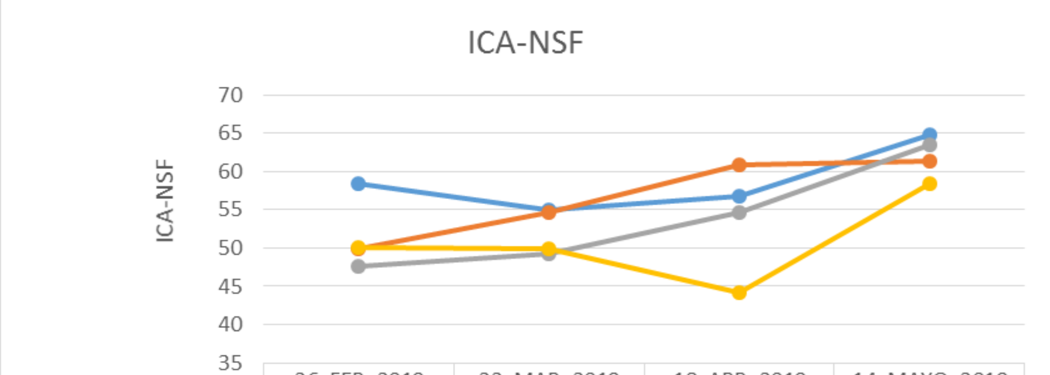

	26_FEB_2019	22_MAR_2019	18_ABR_2019	14_MAYO_2019
Vicoria Alta	58	55	57	65
El Valle	50	55	61	61
El Despacho	48	49	55	63
Monay El Cruce	50	50	44	58

Figure-3. Comparison of the ICA-NSF obtained in each of the monitoring
Source: Authors

Correlation between ICA-NSF and flow rates: Pearson's statistical correlation method (r) allows a better understanding of the relationship between the measured flow rates and the calculated Water Quality Indexes. In point 1 corresponding to the sector of the Victoria Alta neighborhood, the value of the Pearson's Correlation is r = -0.45 indicating a weak negative or inverse correlation (Severiche *et al.,* 2017b; Ortega, 2009), for the dates in which the samples were taken and ICA values were obtained as flow. For point 2 corresponding to the El Valle area, the value is r = - 0.82, having an inverse or negative linear correlation, equivalent to that as the flow increases the quality of the water in the stream decreases (Ortega, 2009). For the El Despacho area (point 3), the Pearson correlation has a value of r = - 0.76, recurring in an inverse or negative linear correlation, as the flow increases the quality of the water in the stream decreases (Valencia *et al.*, 2019; Ortega, 2009). In point four, the value of Pearson's correlation coefficient r = 0.011, which is considered a weak direct correlation, due to its proximity to 0, it can be said to be almost nil (Ortega, 2009). In this way, the variables are considered linearly independent.

CONCLUSIONS

The results of the experimental investigations contributed To understand the state of water quality in the studied area, the details are shown below: Monitoring 1 does not meet any of the sampling points regarding Fecal Coliforms with respect to the “Acceptable quality criteria for agricultural water”, in addition, in point 3 the dissolved oxygen does not meet the values established by the regulations regarding the "admissible Quality Criteria for the preservation of flora and fauna in fresh, cold or warm waters, and in marine and estuarine waters" thus giving the condition of contamination. For campaign 2 as well as 1 they do not meet any of the 4 sampling points in Fecal Coliforms with respect to the "Acceptable quality criteria for water for agricultural use", added to this in points 3 and 4, it does not meet the concentration of dissolved oxygen with respect to "admissible Quality Criteria for the preservation of flora and fauna in fresh, cold or warm waters, and in marine and estuary waters". The same scenario for monitoring 3 where the fecal coliform values do not meet at all sampling points, as well as at points 3 and 4 do not meet the values established by the regulations for the dissolved oxygen parameter. For the last monitoring sample, the parameter that does not meet at the four sampling points is fecal coliforms, thus giving a diagnosis of high contamination level.

REFERENCES

Abdel-Satar A. M., Ali M. H., Goher M. E. 2017. Indices of water quality and metal pollution of Nile River, Egypt. The Egyptian Journal of Aquatic Research. 43(1): 21-29.

Baldiris I., Acosta J., Martinez C., Sanchez J., Castro I., Severiche C. 2017. Multivariate analysis of surface water quality of the Bay of Cartagena (Colombia) period 2001-2017. International Journal of Chem Tech. 10(15): 421-432.

Bedla D., Dacewicz E. 2019. Data clustering analysis in the assessment of wastes using in the sewage filtration. Journal of Water and Land Development. (41): 31-36.

BLUMM M. C., WOOD M. C. 2017. No ordinary lawsuit: climate change, due process, and the public trust doctrine. Am. UL Rev. 67(1).

Bojarczuk A., Jelonkiewicz Ł., Lenart-Boroń A. 2018. The effect of anthropogenic and natural factors on the prevalence of physicochemical parameters of water and bacterial water quality indicators along the river Białka, southern Poland. Environmental Science and Pollution Research International. 25(10): 10102-10114.

Brack W., Dulio V., Ågerstrand M., Allan I., Altenburger R., Brinkmann M., Hernandez F. J. 2017. Towards the review of the European Union Water Framework Directive: recommendations for more efficient assessment and management of chemical contamination in European surface water resources. Science of the Total Environment. 576: 720-737.

Di Minin E., Soutullo A., Bartesaghi L., Rios M., Szephegyi M. N., Moilanen A. 2017. Integrating biodiversity, ecosystem services and socio-economic data to identify priority areas and landowners for conservation actions at the national scale. Biological Conservation. 206: 56-64.

Hoyos Chaverra M. A., Rodriguez Barrientos D. A. & Torres Quintero J. E. 2018. Evaluación Del Recurso Hídrico Superficial En La Subcuenca Hidrográfica Del Río Frío En El Departamento De Cundinamarca: Oferta, Demanda Y Calidad Del Agua. Revista De Investigación Agraria Y Ambiental. 9(1): 127-136.

Landwehr M., Denninger. 1970. Water Quality Index. EE.UU.

Malek A., Kahoul M., Bouguerra H. 2019. Groundwater's physicochemical and bacteriological assessment: Case study of well water in the region of Sedrata, North-East of Algeria. Journal of Water and Land Development. 41(1): 91-100.

MEKONNEN M. M., HOEKSTRA A. Y. 2016. Four billion people facing severe water scarcity. Science Advances. 2(2): e1500323.

Mensah J., Casadevall S. 2019. Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. Cogent Social Sciences. 5(1).

Mokoena M., Mukhola M. 2019. Current Effects of Cyanobacteria Toxin in Water Sources and Containers in the Hartbeespoort Dam Area, South Africa. Int. J. Environ. Res. Public Health. 16(22): 4468

Moloi M., Ozekeke O., Otomo P. 2020. Probabilistic health risk assessment of heavy metals at wastewater discharge points within the Vaal River Basin, South Africa. International Journal of Hygiene and Environmental Health. 224(113421).

Naidoo S., Olaniran A. O. 2014. Treated wastewater effluent as a source of microbial pollution of surface water resources. International journal of Environmental Research and Public Health. 11(1): 249-270.

Nivelo S. I. 2015. Monitoreo de la calidad del agua en San Cristóbal, Galápagos. Quito.

Olsson G., Carlsson B., Comas J., Copp J., Gernaey K. V., Ingildsen P., Steyer J. P. 2014. Instrumentation, control and automation in wastewater–from London 1973 to Narbonne 2013. Water Science and Technology. 69(7): 1373-1385.

Ordoñez G., Peláez T. 2013. Estudio del intercambio de agua superficial y agua. Cuenca.

Ortega L., Vidal L., Vilardy S. 2008. Análisis de la contaminación microbiológica (coliformes totales y fecales) en la Bahía de Santa Marta, Caribe Colombiano. Santa Marta.

Perez Ortega D. J., Segovia Ortega J. A., Cabrera Moncayo P. C., Delgado Vargas I. A. & MartinsPompêo M. L. 2018a. Uso del suelo y su influencia en la presión y degradación de los recursos hidricos en cuencas hidrográficas. Revista De Investigación Agraria Y Ambiental. 9(1): 41-57.

Perez Ortega D. J., Solarte J. G., Pantoja Díaz J. J. & Martins Pompêo M. L. 2018b. Dinámica Espacio-Temporal Del Uso Del Suelo Y Su Efecto Sobre La Degradación De Los Recursos Hídricos: Caso De La Cuenca Del Río Juqueri - Brasil. Revista De Investigación Agraria Y Ambiental. 9(1): 15-28.

Pérez J., Nardini A., Galindo A. 2018. Análisis comparativo de los índices de calidad del agua aplicados al río Ranchería, La Guajira-Colombia. Información Tecnológica. 29(3): 47-58.

Pérez S. 2017. Las empresas agropecuarias y la administración financiera. Revista Mexicana de Agronegocios. 40: 583-594.

Severiche C., Baldiris I., Acosta J., Bedoya E., Castro I., Pacheco H. 2017b. Multivariate Analysis of Water Quality in Rosario Islands National Park (Colombia). American Journal of Engineering Research. 6(6): 136-144.

Severiche C., Barretro A., Acevedo R. 2013. Efecto de las lluvias sobre la calidad del agua en la Ciénaga Grande de Santa Marta, Colombia. Avances: Investigación en Ingeniería. 10(1): 58-67.

Severiche C., Bedoya E., Vargas L., Marrugo Y. 2017a. Influence of the physicochemical composition of water on algae cover in an area of the Gulf of Morrosquillo, Colombian Caribbean. International Journal of ChemTech Research. 10(15): 371-378.

Seymour V. 2016. The Human-Nature Relationship and Its Impact on Health: A Critical Review. Frontiers in Public Health. 4(260).

Ugbebor J., Oyinloye A. 2017. Analysis of the water quality characteristics of intawaogba river. Asian Journal of Science and Technology. 8: 4072-4077.

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Valencia J., González J., Jimenez I., Molina G. 2019. Physico-chemical treatment of waste water contaminated with heavy metals in the industry of metallic coatings. Journal of Water and Land Development. (43, 22): 171-176.

Valle P. 2015. Plan de Desarrollo y Ordenamiento Territorial de la Parroquia El Valle. Cuenca.

Víquez C. 2016. Evaluación de la calidad del agua para consumo humano y propuesta de alternativas tendientes a su mejora, en la Comunidad de 4 Millas de Matina, Limón. Limón: Universidad Nacional: Escuela de Ciencias Ambientales.