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Articles

Water quality for agriculture use in Jequetepeque middle river basin, Peru

Calidad de agua de uso agrícola en la cuenca media del río Jequetepeque, Perú

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Abstract

This research had the main objective to determine water quality for agriculture use in Jequetepeque middle basin river, Peru. Six sampling stations were located (Puente Kuntur Wasi bridge, La Monica sector, La

Capilla sector, Yatahual village, El Pongo village, and Yonan bridge). The physical-chemical, bacteriological parameters and SAR index were determined. The water quality in the study area was found within the Water Quality Standards by Supreme Decree N°004-2017-MINAM, according to Category 3: vegetable irrigation and animal drink, and D1: vegetable irrigation, it used without restrictions for different crops. It is important for bacteriological assessment, the average values of thermotolerant coliforms exceeded water quality (1 000 NMP/100 ml) and indicating low organic pollution as a consequence of the contributions or discharges of domestic origin. The SAR index was found values lower than 3, therefore it is not limiting for agricultural activity. It is of great importance to carry out water quality studies of all the river basins in the country, especially the determination of the quality of water for irrigation due to the potential effect on human health and ecosystems.

Keywords: Water quality, Jequetepeque River, SAR index.

Resumen

La presente investigación tuvo como principal objetivo determinar la calidad del agua de uso agrícola en la cuenca media del río Jequetepeque, Perú. Se ubicaron seis estaciones de muestreo estación (Puente Kuntur Wasi, Sector La Mónica, Sector La Capilla, Cacerío Yatahual, Cacerío El Pongo y Puente Yonan) en la cuenca media del río Jequetepeque. Se determinaron parámetros físico-químicos, bacteriológicos e índice RAS. La calidad del agua en la zona de estudio se encontró dentro de los Estándares de Calidad de Agua, D.S. N°004-2017-MINAM, Categoría 3: Riego de vegetales y bebida de animales, y D1: Riego de vegetales, por lo que el agua puede ser usada sin restricciones para uso agrícola. Es importante indicar, en referencia a la evaluación bacteriológica, que los valores promedios de coliformes termotolerantes superaron los Estándares de Calidad de Agua (1000 NMP/100 ml), debido a las aportaciones o vertimientos de origen doméstico. En el índice de RAS se encontraron valores menores a tres; en consecuencia, no es limitante el uso del agua para la actividad agrícola. Es de gran importancia realizar estudios de calidad de agua de todas las cuencas hidrográficas en el país, en especial para determinar la calidad del agua para riego por el potencial efecto sobre la salud humana y los ecosistemas.

Palabras clave: calidad de agua, cuenca Jequetepeque, índice RAS.

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Introduction

Water resources play a vital role in economic, agriculture, industry activity, and finally sustainable development. The availability and quality of water, surface or underground, has deteriorated due to the increase in the population, urbanization, and industrialization (Tyagi, Sharma, Singh, & Dobhal, 2013), in this sense the availability and quality of water are indicators used to calculate the environmental sustainability index that considers the ability countries to protect the environment in the coming decades (Balmaseda & García, 2013). The water resource is subject to the pressure of an increasingly hydric demand in quantity and quality water-related to social, political, and environmental aspects (Roldan, Díaz, Pérez, & Moreno, 2010), it is necessary to have timely sources information regarding water quality to achieve the integrated management water resource (Bermejillo *et al*., 2012).

The physicochemical and biological water characteristics vary due to anthropogenic pollution, coupled with natural and artificial processes; make its physicochemical and biological properties vary widely from section to section throughout the basin river (Sutadian, Muttil, Yilmaz, & Perera, 2016). Due to high water demand, it is relevant to determine its quality water for human consumption, agricultural, industrial use, aquaculture, and biodiversity conservation, as well as its use for recreation and aesthetics (Rivera, Encina, Palma, & Mejias, 2009).

Consequently, it is important to keep in mind the resources; water quality has closely related to social well-being and economic population development, which well-being depends on it the current and future generations (Ocampo-Duque, Osorio, Piamba, Schuhmacker, & Domingo, 2013). Ecosystems balance of various water sources belong environmental services. They will allow the integrated water resources management; which includes control and water management, and its uses in agricultural, forestry, livestock, and industrial activities for the control and minimization of pollution effluents water quality is closely related to social well-being and economic population development, which well-being depends on it the current and future generations (Pawar, 2013; Gyawali, Techato, Yuangyai, & Musikavong, 2013).

Sutadian *et al*. (2016) and Medeiros *et al*. (2017) (cited in Pérez, Nardini, & Galindo, 2018), affirmed quality water is one of the most important issues in water management resources and its classification is based on the purity degree and pollution. It could be the assessment from the physicochemical and biological characteristics Rangeti, DzwairoBarratt, & Otieno, 2015, cited in Pérez *et al*., 2018). Due to the various factors and parameters that affect water quality, the final evaluation makes it complex. In this sense, it was necessary to use water quality indicators, which are a very useful tool for monitoring, control, and water resources management. Different countries use quality indices, which vary widely according to current regulations or provisions that have to do with government policies.

Studies carried out in Mexico at Amajac River presented values higher than the Mexican standard, of the water quality index (I.C.A.), as well the results found by Álvarez, Panta, Ayala, and Acosta (2008), for values of soluble solids, total solids and dissolved oxygen, and total and fecal coliforms most likely number. Likewise, studies carried out in the Santa Cruz River (RSC), Sonora-Mexico, in the dry season, the parameters assessing reported with very high concentrations, except pH (referred to the Mexican standard). Unlike the above, the concentrations found for nitrites, and sediment presence considered between into standard values, of good water quality in the Santa Cruz River, Sonora (Posada, Roldán, & Ramírez, 2000). Sarabia-Meléndez, Cisneros-Almazán, Aceves-De-Alba, Durán-García, and Castro-Larragoitia (2011) found that there are two most important parameters in the water quality determining for agricultural use; the electrical conductivity (EC) and Sodium Adsorption Ratio Index (SAR), it is possible to establish a classification of water for agricultural use, according to Salinity Laboratory standards of United States.

Studies carried out in Colombia in 2000, it was determined the physicochemical and biological parameters evaluated in the Piedras Blancas-Antioquia basin presented low fluctuations throughout the basin under study, with exception of electrical conductivity parameter and total solids, whose variations were related to the evaluation period, due to high rainfall during the study execution period (Solís, Israel, Nubes, Castillo, & Meraz, 2011).

In Chile, Peña (1993) stated water quality for agricultural use has been restricted due to the amount of boron, presented especially in the Altiplanic region ("Norte Grande"), where water frequently exceeds high boron levels as 5.0 mg/l, mainly affecting crops sensitive like citrus plants, which are affected by 0.3 mg/l concentrations. Likewise, in the "Norte Chico" area, it is affected by boron content in water with values close to 1.5 mg/l, which to because high limitations the resource use.

Reinaudi, Grégoire, Rosiére, Nadal and Viñuela (1998) carried out of water quality study for irrigation in Central Region hothouses of La Pampa-Argentina found total arsenic concentration was higher than allowed by World Health Organization (WHO). Likewise, Báez (1999), in Buenos Aires, indicated the more important problems associated with irrigation quality water are soil salinization and sodification because it causes a deterioration of properties soil, although some crops such as *Triticum aestivum* "wheat" produced acceptable yields even with relatively high salinity levels.

In Peru, the National Strategy for Management Water Resources establishes protection water quality of resources, necessary implementation mechanisms for hydrographic protection basins and aquifers is relevant. It has been determined that water quality is mainly affected by mining tailings effluents discharge, containing heavy metals, which are evacuated directly without any treatment into hydrographic basins, some of them being basins with great problems. Due to reversing the difficulty of effect and negative impact on water bodies, these are Mantaro, Rímac, Santa, and Ilo river basins, among others, which present great chemical pollution cause loss biodiversity and ecosystems deterioration (INRENA, 2003). In La Libertad Region, the basins with the greatest deterioration or pollution are the Moche and Jequetepeque rivers, presenting bioaccumulation of mining-metallurgical pollutants and sediments. The indiscriminate agrochemicals use causes loss of trophic chains, biodiversity and decrease the productive capacity of agricultural soils of Moche and Jequetepeque valleys (Juarez, 2006).

There are large-scale agricultural projects for developing countries, but unfortunately, they lack adequate management of irrigation projects, bringing negative consequences on communities, whose primary objective was to achieve sustainable development from an economic, social, and environmental perspective. The complex environmental interactions processes and development of irrigation and drainage systems, present high difficulty in predicting types of impact and/or changes in nature. However, currently, with strategic, economic, and environmental detailed studies, it could be handled and controlled different interactions of human activities, agricultural areas, and water resources used in different activities, avoiding possible negative impacts produced in the development zone.

It is necessary to know the situational status of the Jequetepeque river basin, with emphasis on the middle part, evaluating supply and water demand, the water quality of hydrological events, which results will allow have basic information in making decisions about authorities at different levels and propose integrated management of

Jequetepeque river basin. Likewise, determine impacts generated by activities carried out that affect water quality for agricultural use, with a long-term approach, which guarantees a complete and holistic vision of meaning agricultural activities associated with water quality to contribute to integrated water quality management for agricultural use in middle Jequetepeque river basin, Peru.

Materials and methods

Study area

Jequetepeque river borns in a small lagoon located at "Cerro Agopití" foot, Cajamarca province, at 07° 20' S.L. and 78° 21' W.L., 4 000 meters above sea level; basin river runs about 150 km from east to west. About 4 000 meters above sea level, collects on its way drainage more than 30 secondary rivers, streams, and minor streams and it is stored in the "Gallito Ciego" dam. The main tributaries of the Jequetepeque river extend between 600 and 2500 meters above sea level.

Jequetepeque River is the result of Puclush and Magdalena confluence rivers, the same ones that join at height of Llallan town, at an approximate of 710 elevation meters downstream; receives contributions from Pallac river on the right bank and Chausis stream on the left bank. The hydrographic system of the Puclush sub-basin contributes the greatest amount of water to the Jequetepeque river due to rainfall in the upper part and the presence of lagoons, shrubby tree vegetation, and pastures. Magdalena River borns at Huacrarucro heights, initially it receives contributions from Choten and Naranjo rivers on the right bank and the Asunción River on the left bank. It takes the name Magdalena River at Choropampa height with an approximate elevation of 1600 meters above sea level; its main tributaries on the right bank are La Viña, Chetillano, and Llaminchan, and San Pablo rivers; on the left bank it has following Chonta, Huertas and Contumaza tributaries rivers.

Sampling

Sampling corresponded in seasonal periods changes, flood and low water, whose sampling frequency was twice a month in each sampling station, according to established in Resolution N°010-2016-National Water Authority: National Protocol quality monitoring of Surface Water Resources (ANA, 2016). The study comprised a sampling period (December 2018 to May 2019), following international standards (GEMS, 1987). Six sampling stations were selected (Table 1 and Figure 1), per standards established by Global Environmental Monitoring System (GEMS, 1987). Portable equipment used in the present investigation were HI 991300 multiparameter equipment (HANNA brand), pH meter, electrical conductivity (EC), total dissolved solids (TDS) and temperature; HI 9829 multiparameter equipment (HANNA brand), pH, mV, ORP, DO, EC, TDS, resistivity, salinity, temperature, atmospheric pressure, and turbidity meter.

Table 1. Georeferencing and altitude of sampling stations located in middle Jequetepeque river basin, Peru.

Sampling stations	**Coordinates UTM**		**Altitude (m.a.s.l.)**
	East	**North**	
E-1 (Kurtur Wasi bridge)	7°13′ 23″ S	78° 50′ 51″ W	837
E-2 (La Mónica sector)	7°13′ 39″ S	78° 54′ 04″ W	759
E-3 (La Capilla sector)	7°12′ 16″ S	78° 56′ 21″ W	689
E-4 (Yatahual village)	7°10′ 03″ S	79° 01′ 17″ W	596
E-5 (El Pongo village)	7°12′ 22″ S	79° 02′ 52″ W	552
E-6 (Yonan bridge)	7°15′ 17″ S	79° 06′ 03″ W	448

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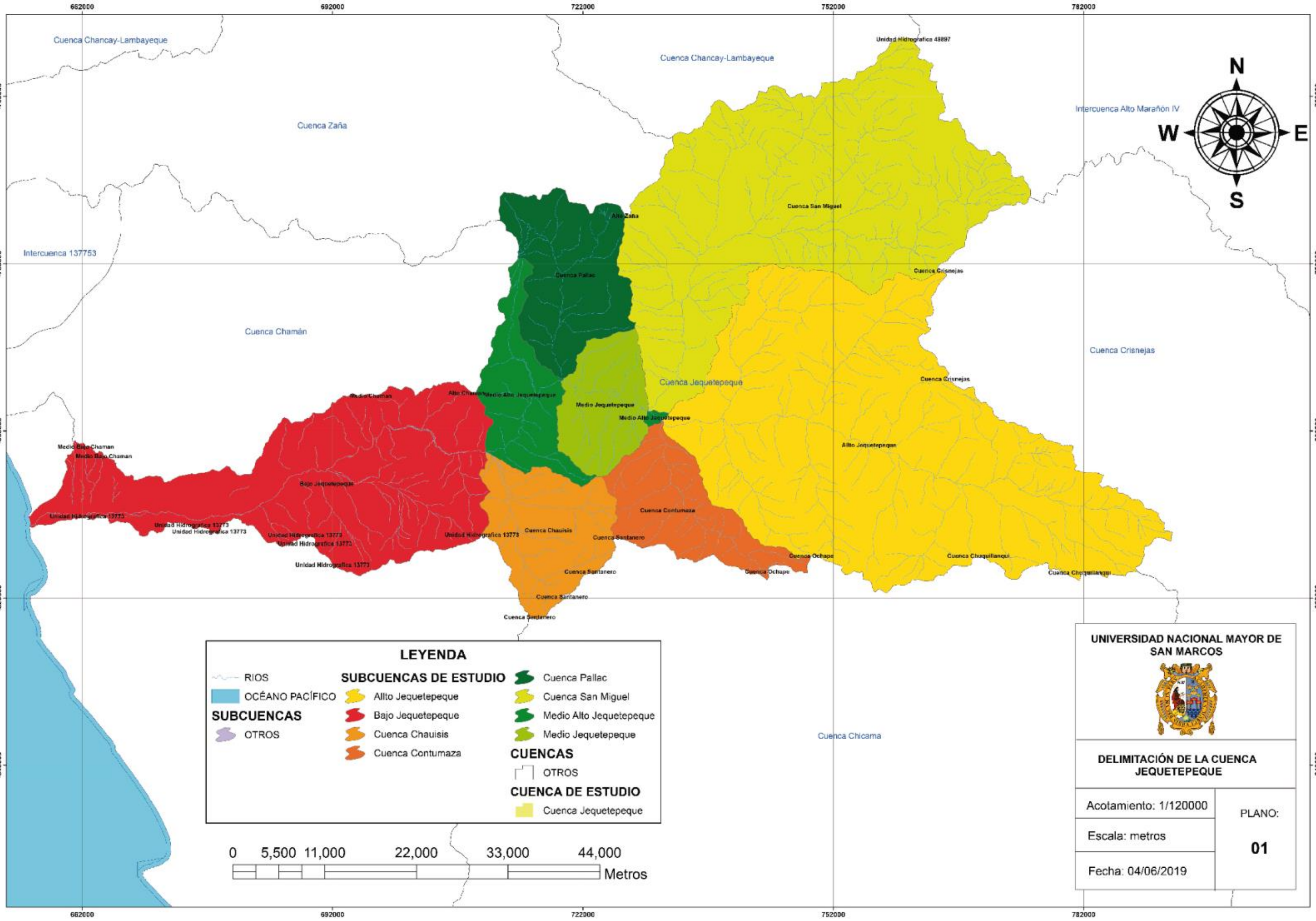


Figure 1. Delimitation of middle Jequetepeque river basin, Peru.

From a statistical point of view, this investigation has a longitudinal type with a trend design (Hernández, Fernández, & Baptista, 2010). The information corresponding to water availability (supply and demand) of the Jequetepeque river basin is registered in the database by application test for multivariate normality and bivalent normal distribution. This investigation was necessary to use a coefficient nonparametric correlation like Spearman's and Wilcoxon's bivalent distribution test (Hines & Montgomery, 1996). This is due to the fact there is a relationship between water volumes through which it flows in hydrological basins and water quality, so much that in flood times, higher concentrations of total dissolved solids could be found and also a greater possibility of dilution or contaminants concentration such as heavy metals.

Wilcoxon statistical analysis is a non-parametric test used when comparing the mean range of two related samples and determining if there are differences between them. It uses as an alternative to the Student's t-test when the normality of these samples cannot be assumed. It is a nonparametric comparison test of two related samples and therefore does not need a specific distribution. In the case of basin volumes, as the Jequetepeque basin. It is very irregular for this reason of the dependent variable is used rather. It is used to compare two related measurements and determine if the difference between them is due to chance or not (in the latter case, the difference is statistically significant).

Spearman's coefficient correlation (rho) use to evaluate the association between two variables that have ordinal categories. The coefficient can vary from -1 to +1. Spearman's rho interpretation agrees on values close to 1; indicate a strong and positive correlation. Values close to −1 indicate a strong and negative correlation. Values close to zero indicate there is no linear correlation. There may be another type of correlation, but not linear.

Physical-chemical parameters evaluated according to APHA-AWWA-WEF (2012) and bacteriological (NMP/100 ml) standards, whose methods for each parameter evaluated detailed in Table 2, for agricultural use, Category 3: Vegetable irrigation and animal drink, and D1: Vegetable irrigation according to D.S. N°004-2017-MINAM; SAR index was also determined (Ayers & Westcot, 1987; Rashidi & Seilsepour, 2011).

Table 2. Physical-chemical and bacteriological parameters to assessing water quality

Physical-chemical and bacteriological parameters	Methods	Year
Temperature	Standard Methods for the analysis of water and wastewater, 22 ND edition. SM 2550 B	2012
Hydrogen potential (pH)	Standard Methods for the analysis of water and wastewater, 22 ND edition. SM 4500-H+ -B	2012
Conductivity (CE)	Standard Methods for the analysis of water and wastewater, 22 ND edition. SM 2510 B	2012
Total dissolved solids (TDS)	Standard Methods for the analysis of water and wastewater, 22 ND edition. SM 2540 C	2012
Carbonate (CO_3)	Standard Methods for the analysis of water and wastewater, 22 ND edition. SM 2320 B	2012
Bicarbonate (HCO_3)	Standard Methods for the analysis of water and wastewater, 22 ND edition. SM 2320 B	2012

Chlorides (Cl^{-1})	Standard Methods for the analysis of water and wastewater, 22 ND edition. SM 4500-Cl- -B	2012
Dissolved oxygen (O_2)	Standard Methods for the analysis of water and wastewater, 22 ND edition. SM 5210 B	2012
Biochemical oxygen demand (BOD_5)	Standard Methods for the analysis of water and wastewater, 22 ND edition. SM 5210 B	2012
Total coliforms (NMP/100 ml)	Standard Methods for the examination of water and wastewater APHA, AWWA, WEF	2012
Thermotolerant coliforms (NMP/100 ml)	Standard Methods for the examination of water and wastewater APHA, AWWA, WEF	2012
Chemical parameters	**Methods**	**Year**
Calcium (Ca^{+2})	Calcium. EDTA Titrimetric Method. 3500-Ca B. APHA-AWWA-WEF. 23rd Edition.	2017
Magnesium (Mg^{+2})	Magnesium. Calculation Method. 3500-Mg B. APHA-AWWA-WEF. 23rd Edition.	2017
Sodium (Na^{+1})	Metals by Flame Atomic Absorption Spectrometry. Direct Air-Acetylene	2017

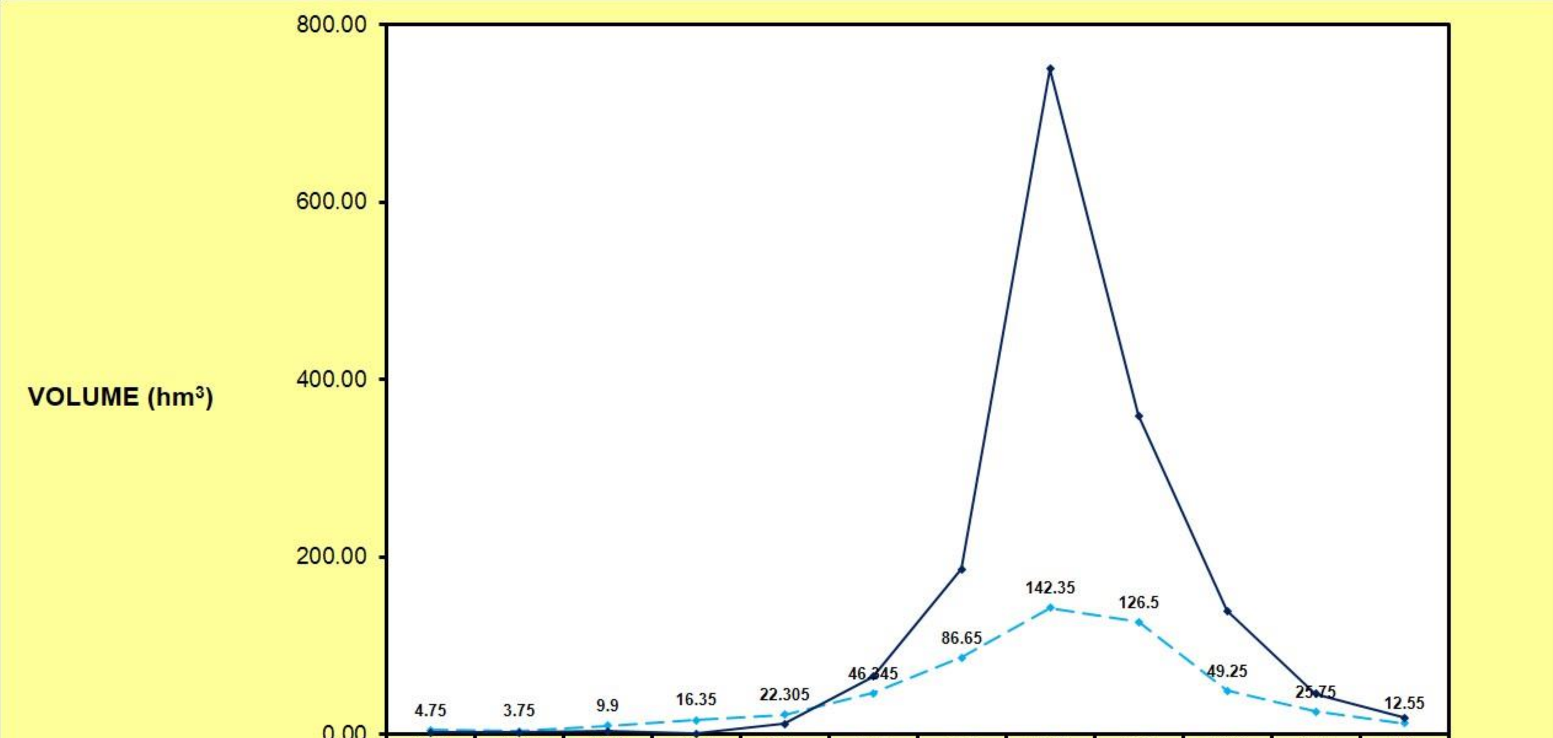
	Flame Method. 3111 B. APHA-AWWA-WEF. 23rd Edition.	
Lead (Pb)	SMEWW-APHA-AWWA-WEF Part 3111 B, 23rd Ed. 2017 Metals by Flame Atomic Absorption Spectrometry. Direct Air-Acetylene Flame Method	2017
Cadmium (Cd)	SMEWW-APHA-AWWA-WEF Part 3111 B, 23rd Ed. 2017 Metals by Flame Atomic Absorption Spectrometry. Direct Nitrous Oxide-Acetylene Flame Method	2017

Water the agricultural used is evaluated for potential risk, because can be considered potentially dangerous, if they present high salt concentrations, which is harmful and it is evident when waters irrigate agricultural soils, making soils become saline and consequently lose their productivity (FAO, 2002). When evaporation occurs, the percentage of water retention in soil decreases, and consequently soil humidity is lower, salt elimination does not take place, then the soil becomes saline and there is loss of water. If water irrigation has salt concentration (initial) and this is within permissible limits being able to reach higher soil salinity due to water evaporation. On the other hand, salt concentration can reach a limited value of solubility, and consequently salts precipitate. This is determined by the presence of calcium and magnesium cations, sodium anion (chlorides), which are not in equilibrium and have a direct relationship with the pH, altering the initial concentrations. That is when calcium salts have low solubility and what happens is sodium concentrations increase in soil water, as well as percentage exchangeable sodium anion (Romero, 2013).

Sodium Adsorption Ratio Index (SAR) assess is to adjusted Sodium Absorption Ratio Index (Adjusted SAR), Residual Sodium Carbonate, Water Hardness, calcium (Ca + 2), and magnesium (Mg + 2) cations evaluated concerning water quality for agricultural use (Ayers & Westcot, 1987; Rashidi & Seilsepour, 2011). Parameters to be evaluated Environmental Quality Standards for water category III-Vegetables irrigation and animal drink described in Supreme Decree N° 004-2017-MINAM be taken into account (MINAM, 2017).

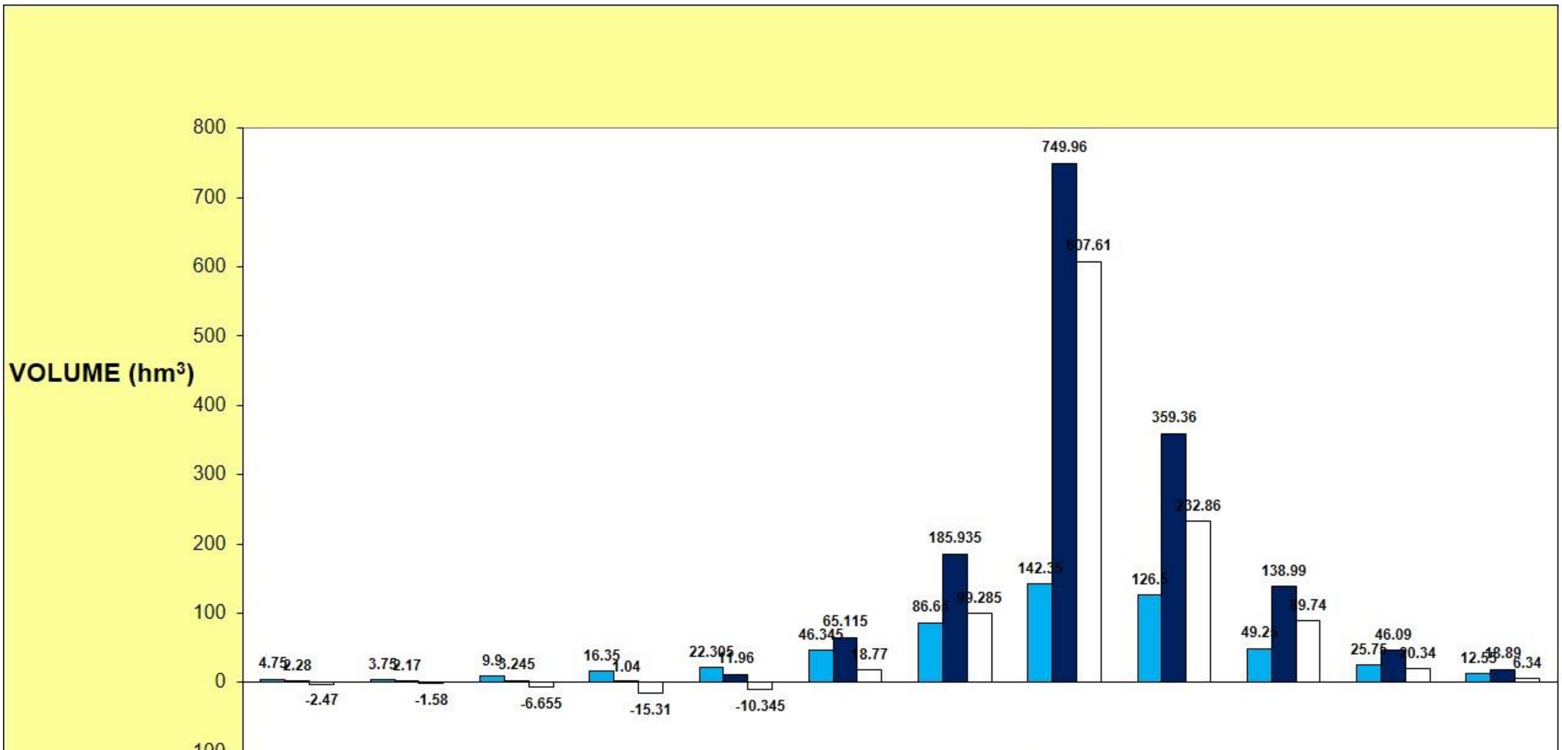
Results and discussion

Water balance of Jequetepeque basin was carried out with data from the 2017-2018 year, it was carried out because ENSO (El Niño Southern Oscillation) occurred in the area study under the main demand is for agricultural use, the contribution of seasonal rains is used and it is complemented with irrigation in the dry season as can be seen. There was greater supply and demand water during February, March, and April months (Figure 2), which has been decreasing since from May to July months. Having a greater supply at 75 % persistence with 749.96 hm^3 and a real supply of 142.35 hm^3 during March 2018. Likewise, in Figure 3, it can be seen that it was presented that executed offer 749.96 hm^3 exceeded the scheduled offer of 142.35 hm^3, making a differential 607.61 hm^3 (Figure 3) for the 2017-2018 water year. About highest programmed gross demand was 129.8029319 hm^3 and executed 111.1599072 hm^3 (Figure 4) for all uses occurred on February month while highest differential occurred on December month (32.66550747 hm^3) and on March (34.49521828 hm^3), respectively (Figure 5).



	AGO.	SET.	OCT.	NOV.	DIC.	ENE.	FEB.	MAR.	ABR.	MAY.	JUN.	JUL.
OFERTA AL 75 % PERSISTENCIA (hm3)	4.75	3.75	9.9	16.35	22.305	46.345	86.65	142.35	126.5	49.25	25.75	12.55
OFERTA REAL (hm3)	2.28	2.17	3.245	1.04	11.96	65.115	185.935	749.96	359.36	138.99	46.09	18.89

Figure 2. Real water supply at 75 % persistence in Jequetepeque river basin, Peru (August 2017-July 2018).



	AGOSTO	SETIEMBRE	OCTUBRE	NOVIEMBRE	DICIEMBRE	ENERO	FEBRERO	MARZO	ABRIL	MAYO	JUNIO	JULIO
OFERTA PROGRAMADA (hm3)	4.75	3.75	9.9	16.35	22.305	46.345	86.65	142.35	126.5	49.25	25.75	12.55
OFERTA EJECUTADA (hm3)	2.28	2.17	3.245	1.04	11.96	65.115	185.935	749.96	359.36	138.99	46.09	18.89
DIFERENCIA OFERTA (hm3)	-2.47	-1.58	-6.655	-15.31	-10.345	18.77	99.285	607.61	232.86	89.74	20.34	6.34

Figure 3. Water supply programmed and executed and it's differential in Jequetepeque river basin, Peru (August 2017-July 2018).

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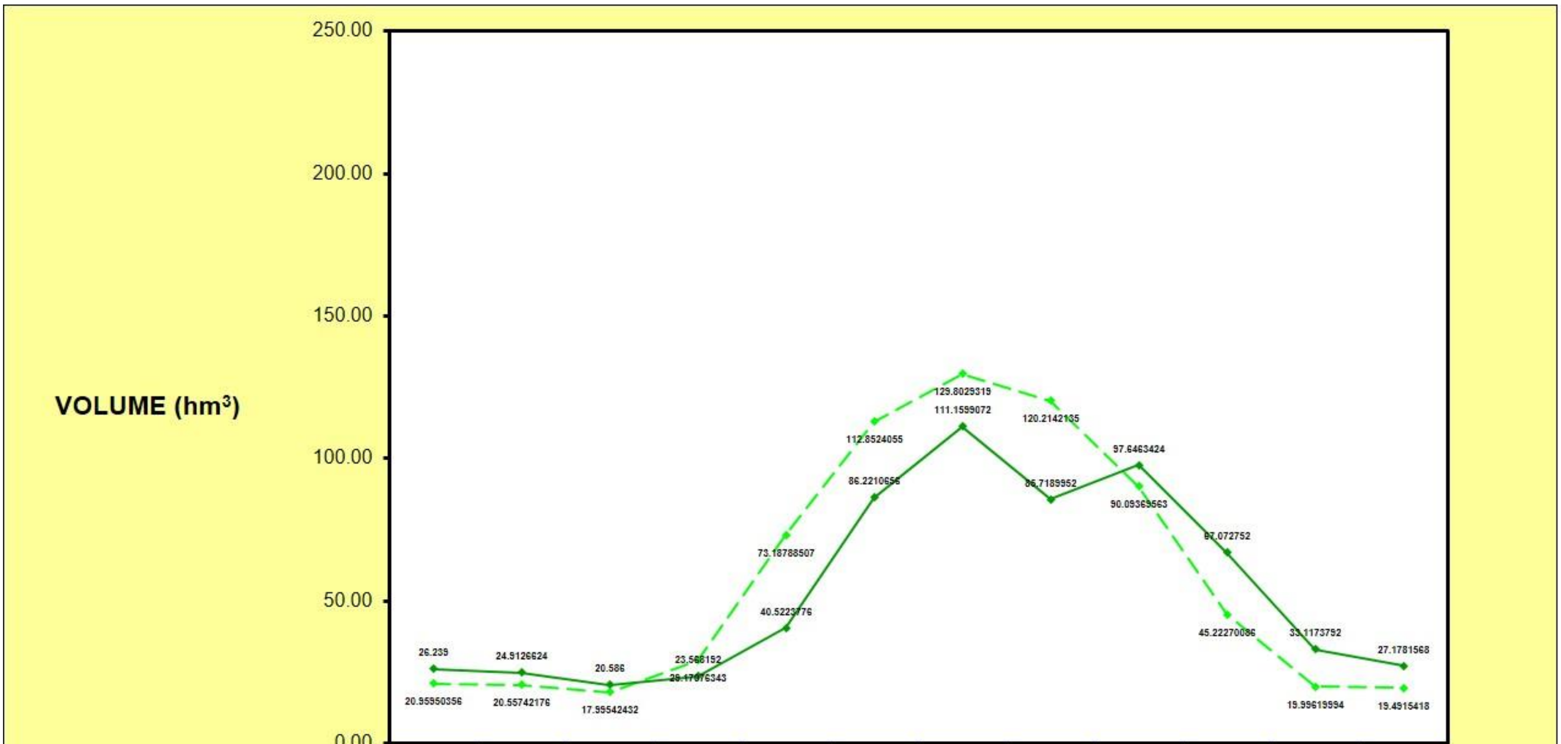
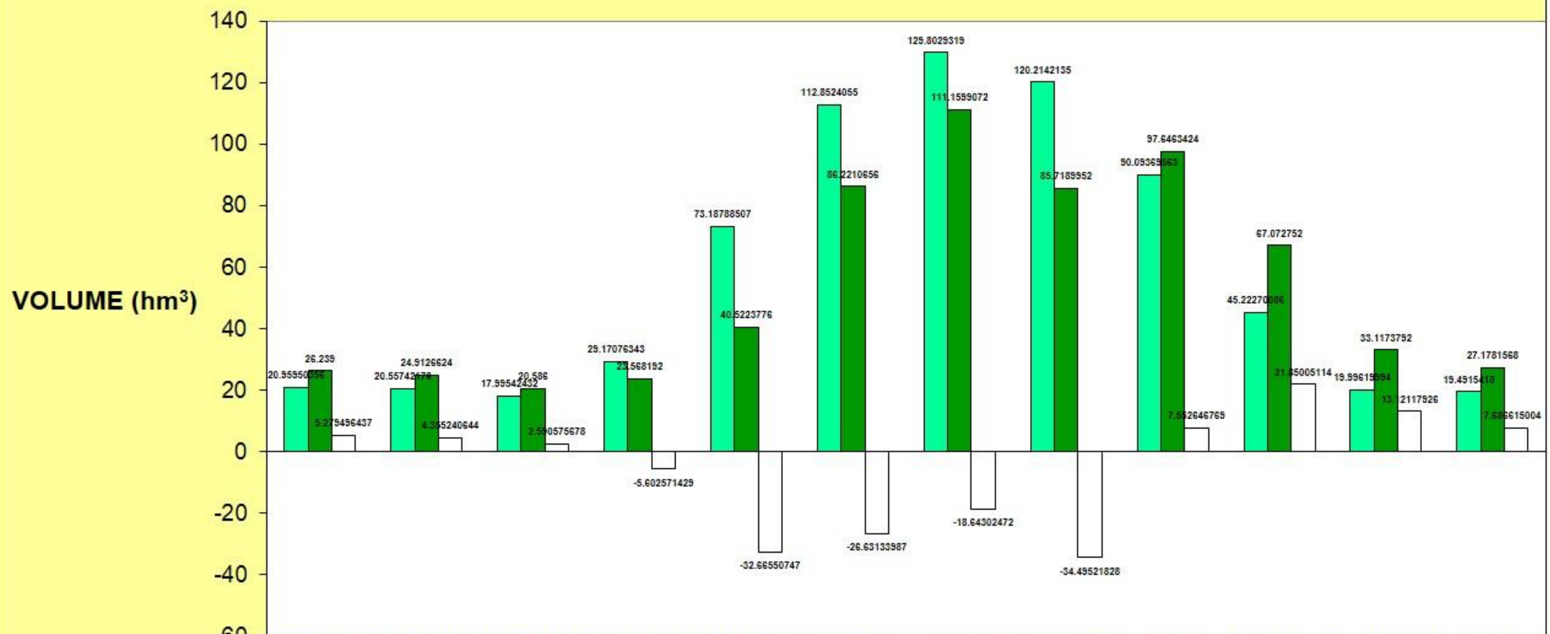


	AGO.	SET.	OCT.	NOV.	DIC.	ENE.	FEB.	MAR.	ABR.	MAY.	JUN.	JUL.
DEMANDA TODOS USOS PROG. (hm3)	20.95950356	20.55742176	17.99542432	29.17076343	73.18788507	112.8524055	129.8029319	120.2142135	90.09369563	45.22270086	19.99619994	19.4915418
DEMANDA TODOS USOS EJEC. (hm3)	26.239	24.9126624	20.586	23.568192	40.5223776	86.2210656	111.1599072	85.7189952	97.6463424	67.072752	33.1173792	27.1781568

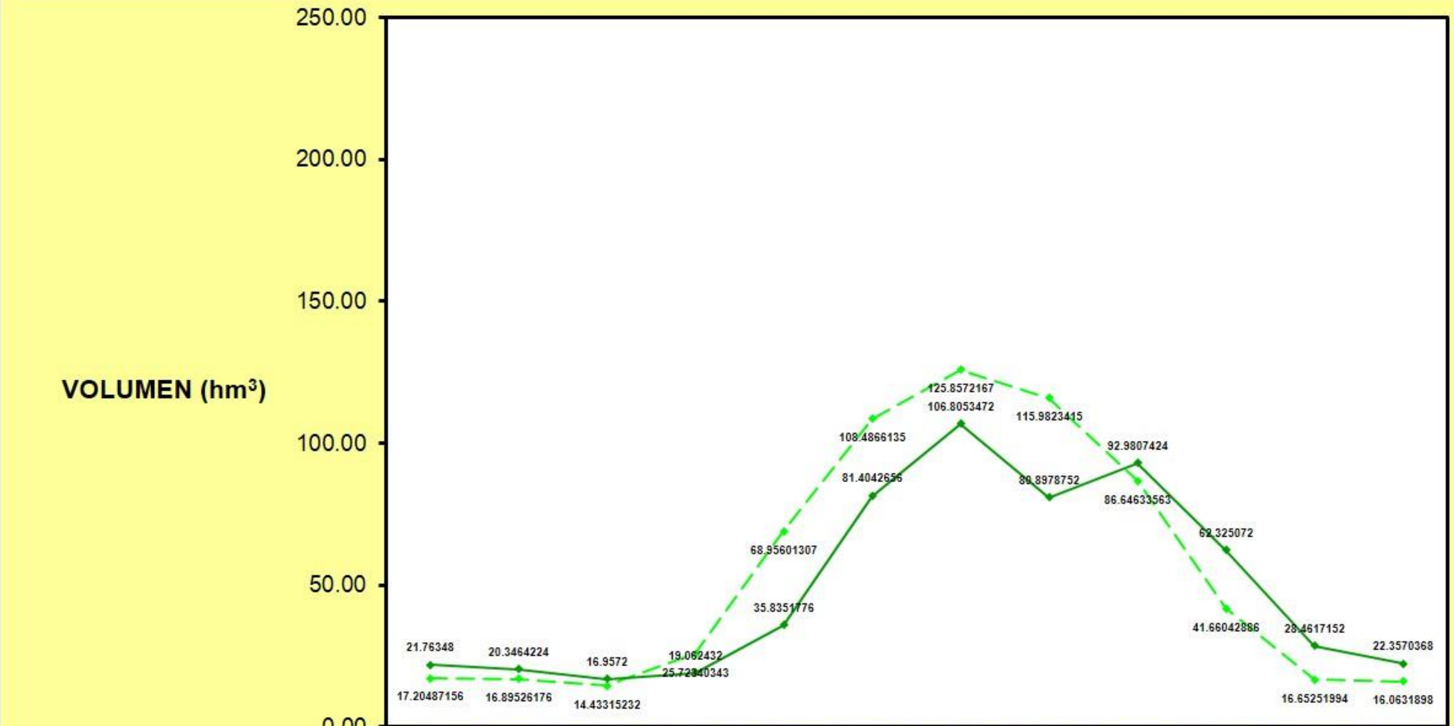
Figure 4. Gross demand programmed and executed in Jequetepeque river basin, Peru (August 2017-July 2018).



	AGOSTO	SETIEMBRE	OCTUBRE	NOVIEMBRE	DICIEMBRE	ENERO	FEBRERO	MARZO	ABRIL	MAYO	JUNIO	JULIO
DEMANDA TODOS USOS PROG. (hm3)	20.95950356	20.55742176	17.99542432	29.17076343	73.18788507	112.8524055	129.8029319	120.2142135	90.09369563	45.22270086	19.99619994	19.4915418
DEMANDA TODOS USOS EJEC. (hm3)	26.239	24.9126624	20.586	23.568192	40.5223776	86.2210656	111.1599072	85.7189952	97.6463424	67.072752	33.1173792	27.1781568
DIFERENCIA (hm3)	5.279496437	4.355240644	2.590575678	-5.602571429	-32.66550747	-26.63133987	-18.64302472	-34.49521828	7.552646769	21.85005114	13.12117926	7.686615004

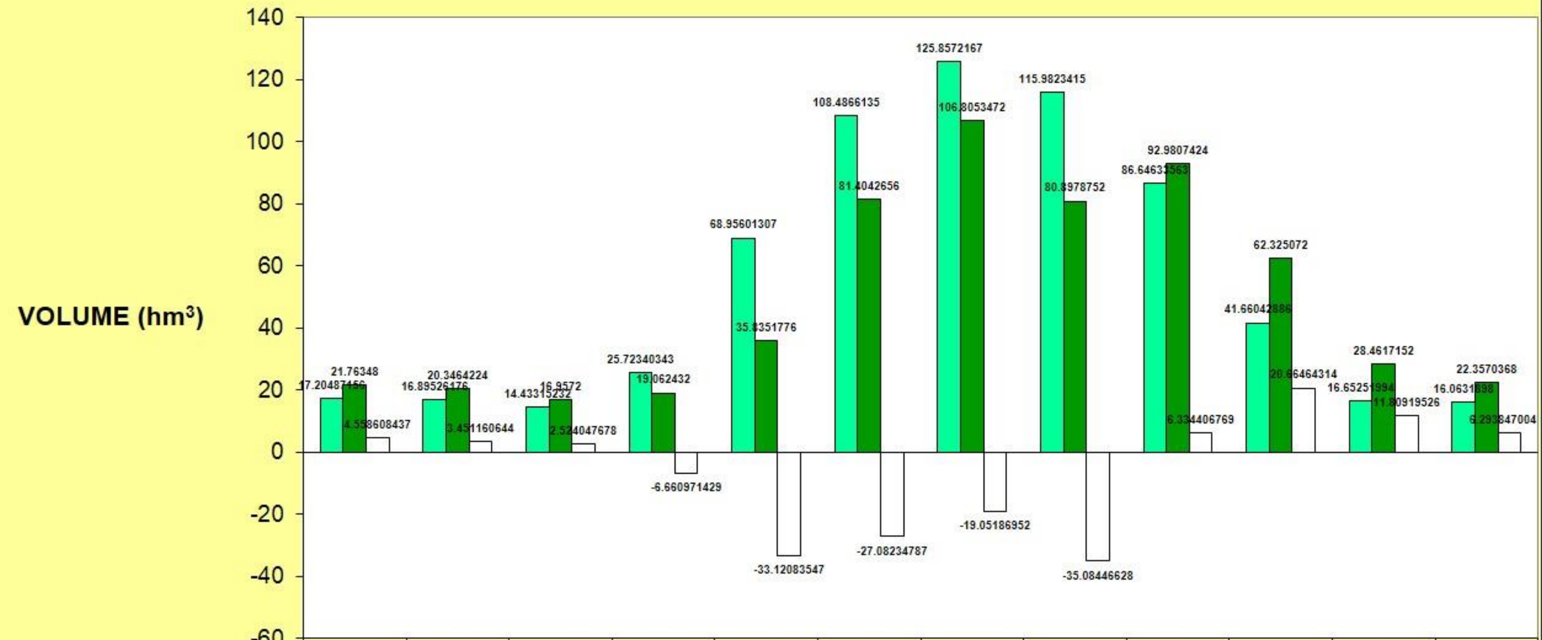
Figure 5. Scheduled and executed gross demand and its differential in Jequetepeque river basin, Peru (August 2017-July 2018)

The highest agricultural demand (Figure 6) was in February month, be programmed 125.8572167 hm^3 and executed 106.8053472 hm^3, while the highest differential occurred in March month with 35.08446628 hm^3 and 33.12083547 hm^3 in December, respectively (Figure 7).



	AGO.	SET.	OCT.	NOV.	DIC.	ENE.	FEB.	MAR.	ABR.	MAY.	JUN.	JUL.
DEMANDA USO AGRICOLA PROG. (hm3)	17.2048716	16.8952618	14.4331523	25.7234034	68.9560131	108.486613	125.857217	115.982341	86.6463356	41.6604289	16.6525199	16.0631898
DEMANDA USO AGRICOLA EJEC. (hm3)	21.76348	20.3464224	16.9572	19.062432	35.8351776	81.4042656	106.805347	80.8978752	92.9807424	62.325072	28.4617152	22.3570368

Figure 6. Agricultural demand programmed and executed in Jequetepeque river basin, Peru (August 2017-July 2018).



	AGOSTO	SETIEMBRE	OCTUBRE	NOVIEMBRE	DICIEMBRE	ENERO	FEBRERO	MARZO	ABRIL	MAYO	JUNIO	JULIO
DEMANDA USO AGRICOLA PROG. (hm3)	17.20487156	16.89526176	14.43315232	25.72340343	68.95601307	108.4866135	125.8572167	115.9823415	86.64633563	41.66042886	16.65251994	16.0631898
DEMANDA USO AGRICOLA EJEC. (hm3)	21.76348	20.3464224	16.9572	19.062432	35.8351776	81.4042656	106.8053472	80.8978752	92.9807424	62.325072	28.4617152	22.3570368
DIFERENCIA (hm3)	4.558608437	3.451160644	2.524047678	-6.660971429	-33.12083547	-27.08234787	-19.05186952	-35.08446628	6.334406769	20.66464314	11.80919526	6.293847004

Figure 7. Programmed and executed agricultural demand and its differential in Jequetepeque river basin, Peru (August 2017-July 2018).

The hypergeometric approximation distribution is presented as the Poisson approximation to the binomial distribution. In this section, we will consider the normal approximation to the binomial distribution. Since the binomial is a discrete probability distribution, this may seem counterintuitive; however, it is involved in a limit process, keeping the p of the binomial fixed and leaving n ∞. It is known as the DeMoivre-Laplace approximation.

To determine bivalent normality, it is necessary to evaluate the relationship between water supply and demand, if both variables followed a normal distribution. If they were bivalent normal distribution (Table 3, Table 6, Table 9), it was necessary to use Pearson's correlation which indicated that there was no bivalent normal distribution and in this case, it was necessary to use a non-parametric correlation coefficient like Spearman's. When it was evaluated using Spearman correlation (Table 4, Table 7, Table 10), two variables were found that are very strongly related because their value was $P < 0.05$. Likewise, Wilcoxon bivalent distribution test (Table 5, Table 8, Table 11), the asymptotic significance of 0.638 and 0.53 was found for supply and demand hydric respectively (Table 6 and Table 7) in Jequetepeque river basin 2017-2018 year.

Table 3. Multivariate normality test relation to water supply in Jequetepeque river basin during the 2017-2018 year.

Henze-Zirkler = 1.520446	Chi2(1) = 13.256	Prob > chi2 = 0.0003
Doornik-Hansen	Chi2(4) = 37.525	Prob > chi2 = 0.0000

Table 4. Spearman's rank correlation, stats (rho p) pw to water supply in Jequetepeque river basin during the 2017-2018 year.

Spearman's rank correlation, stats (rho p) pw	
Object numbers	12
Spearman's rho	0.9161
Ho test: Program to run if they are independent variables	
Prob > |t|	0.0000

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Table 5. Range test with Wilcoxon signs for related samples according to water supply in Jequetepeque river basin during the 2017-2018 year.

Data	**Results**
Total number	12
Contrast statistic	60.000
Standard error	12.748
Standardized contrast statistic	1.647
Asymptotic significance (bilateral test)	0.099

Table 6. Multivariate normality test with gross demand in Jequetepeque river basin during the 2017-2018 year.

Henze-Zirkler = 0.8018365	Chi2(1)= 4.479	Prob>chi2 = 0.0343
Doornik-Hansen	Chi2(4)= 8.533	Prob>chi2 = 0.0739

Table 7*.* Spearman's rank correlation, stats (rho p) pw about gross demand in Jequetepeque river basin during the 2017-2018 year.

Spearman's rank correlation, stats (rho p) pw	
Object numbers	12
Spearman's rho	0.8392
Ho test: Program to run if they are independent variables	

Prob > |t|	0.0006

Table 8. Range test with Wilcoxon sign for related samples according to gross demand in Jequetepeque river basin during the 2017-2018 year.

Data	Results
Total number	12
Contrast statistic	33.000
Standard error	12.748
Standardized contrast statistic	-0.471
Asymptotic significance (bilateral test)	0.638

Table 9. Multivariate normality test about agricultural demand in Jequetepeque river basin during the 2017-2018 year.

Henze-Zirkler = 0.8085096	Chi2(1) = 4.563	Prob > chi2 = 0.0327
Doornik-Hansen	Chi2(4) = 8.554	Prob > chi2 = 0.0733

Table 10. Spearman's rank correlation, stats (rho p) pw about agricultural demand in Jequetepeque river basin during the 2017-2018 year.

Spearman's rank correlation, stats (rho p) pw	
Object numbers	12

Spearman's rho	0.8392
Ho test: Program to run if they are independent variables	
Prob > |t|	0.0006

Table 11. Range test with Wilcoxon sign for related samples according to agricultural demand in Jequetepeque river basin during the 2017-2018 year.

Data	Results
Total number	12
Contrast statistic	31.000
Standard error	12.748
Standardized contrast statistic	-0.628
Asymptotic significance (bilateral test)	0.530

Water quality is affected by diverse factors like land use, industrial and agricultural production. Do not adequate treatment give before discharged back into water bodies and amount water in rivers and lakes since its purification capacity depends on it. Water quality is a widely used term, however, scientific evaluation is quite important and this solution is a basic strategy in development foundations for resources water management (Parparov, Hambrigh, Hakanson, & Ostapenia, 2006). There are many physical-chemical and microbiological factors that allow us to know whether certain water bodies are contaminated or not. This means that if there is an alteration in established parameters, pollution occurs, although the foreign substance present in water does not imply be contaminated, unless there is an impact on a living being or material (Bonet & Ricardo, 2011; Guerrero, 2014).

The irrigation quality water is very important to reduce the problem of the total concentration of soluble salts present in water, meanwhile higher quantity salts are present lower in water quality (Guerrero, 2016). Factors that influence water quality are pH, presence [calcium (Ca^{+2}) and magnesium (Mg^{+2})] and electrical conductivity (Palancar, 2006; Cortés-Jiménez, Troyo-Diéguez, & Murillo-Amador, 2009; Lingaswamy & Saxena, 2015).

Physico-chemical and bacteriological parameters were evaluated in six sampling stations in the Jequetepeque river. These parameters were temperature (t), hydrogen potential (pH), electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), biochemical oxygen demand (BOD_5), calcium (Ca^{+2}), magnesium (Mg^{+2}), sodium (Na^{+1}), carbonates (CO_3^{-2}), bicarbonates (HCO_3^{-1}), chlorides (Cl^{-1}) and including lead (Pb) and cadmium (Cd), total and thermotolerant coliforms (NMP/100 ml) (Figure 8, Figure 9, Figure 10). These results compared with water quality standards, according to ECA D.S. N° 004-2017-MINAM and European Union's Environmental Quality Standards (EQS) (UE, 2013).

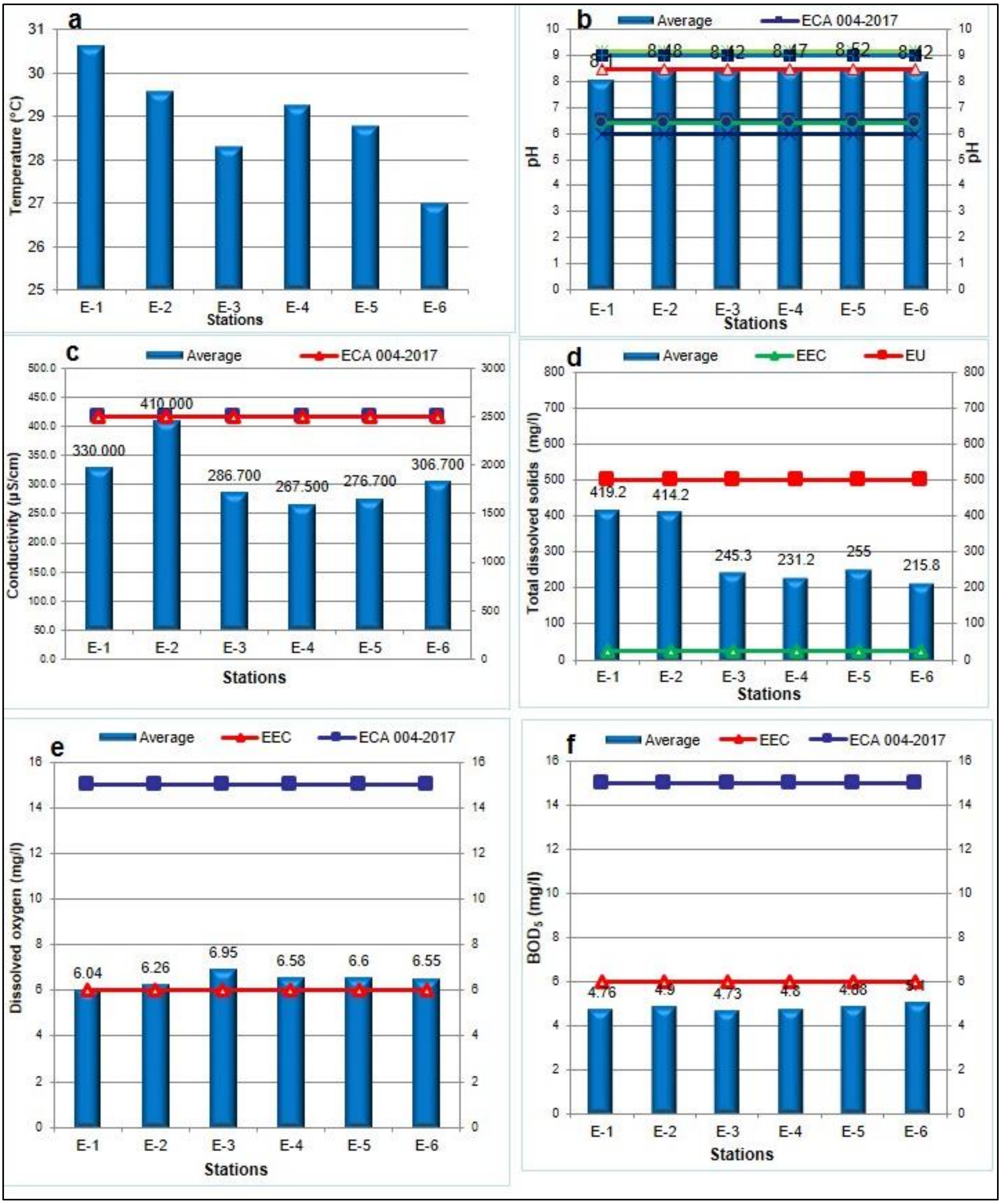

Figure 8. Physical-chemical parameters assessing: temperature (a), pH (b), conductivity (c), total dissolved solids (d), dissolved oxygen (e), biochemical oxygen demand (f) in middle Jequetepeque river

basin, Peru.ECA= Environmental Water Quality Standards-Peru (D.S. N°004-2017-MINAM).EEC= European Economic Community (Directive 2008/105/CE of European Parliament and Council on December 16, 2008).EU= European Union-2013 (Directive 2013/39/UE of European Parliament and Council on August 12, 2013).

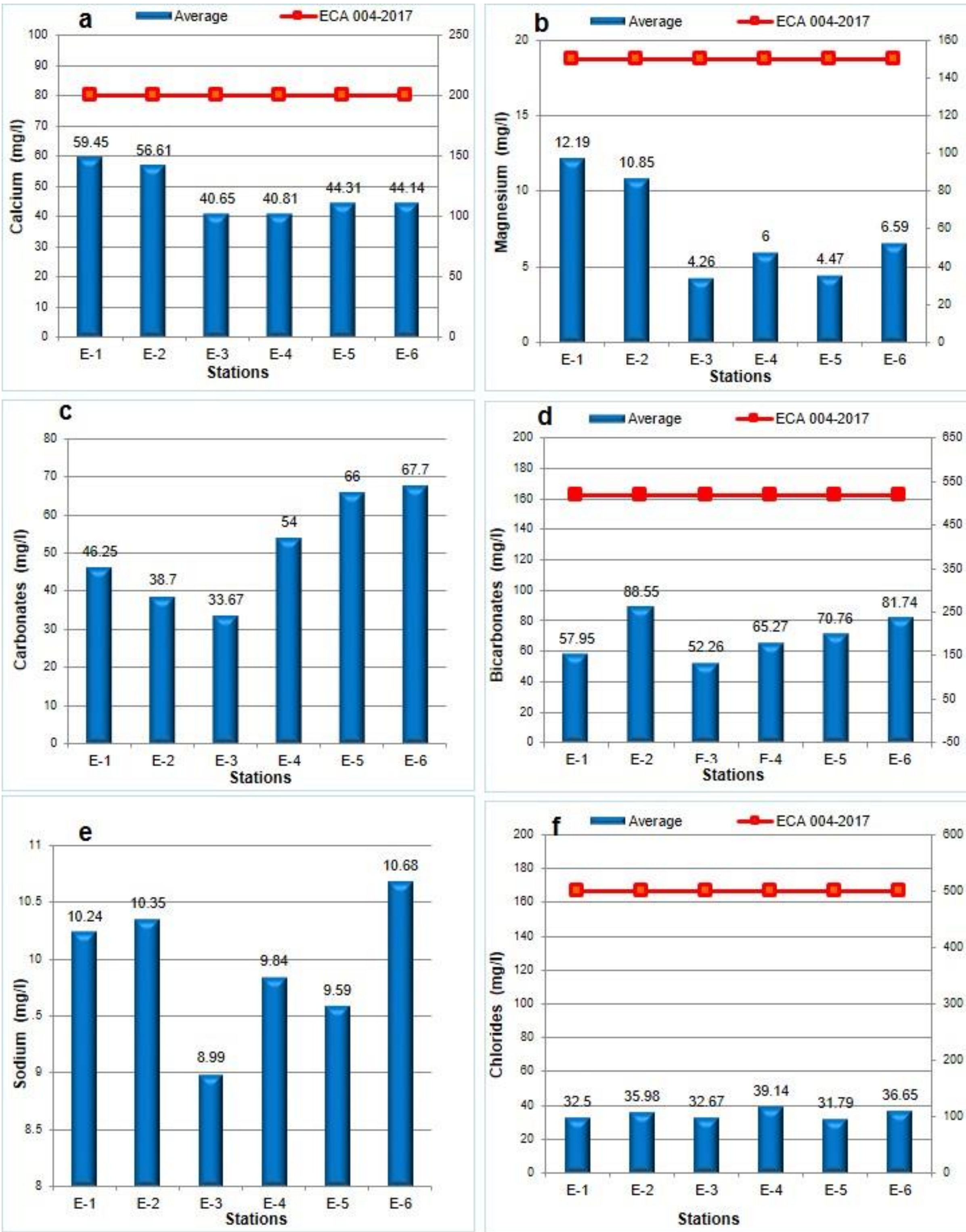

Figure 9. Chemical parameters assessing: calcium (a), magnesium (b), carbonates (c), bicarbonates (d), sodium (e), and chlorides (f) in

Jequetepeque river middle basin, Peru. ECA = Environmental Water Quality Standards-Peru (D.S. N°004-2017-MINAM).

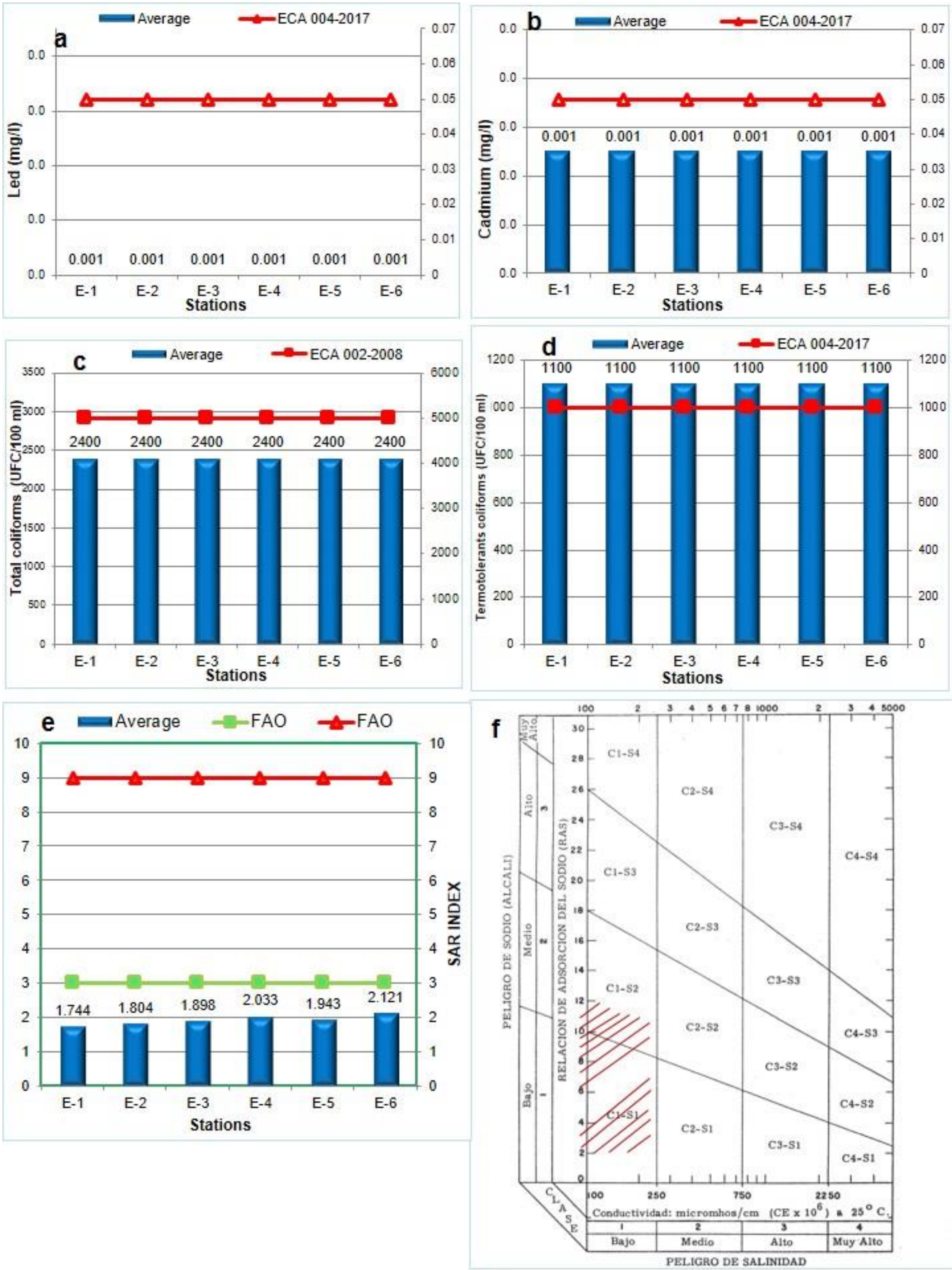

Figure 10. Chemical and bacteriological parameters assessing: lead (a), cadmium (b), total coliforms (c), thermotolerant coliforms (d),

and determination of SAR index and its diagram (e, f) in middle Jequetepeque river basin, Peru.ECA= Environmental Water Quality Standards-Peru (D.S. N°002-2008-MINAM).ECA= Environmental Water Quality Standards-Peru (D.S. N°004-2017-MINAM).FAO= Food and Agriculture Organization of the United Nations (FAO). Soil erosion (2019).

All evaluated parameters were within Water Quality Standard values, except bacteriological parameters (total and thermotolerant coliforms), which exceeded ECA D.S. N°004-2017-MINAM. Which is not equivalent to European Union standards (UE, 2013). There is no equivalence in any case.

Castañé, Topolián, Cordero and Salibián (2003), cited by Salas (2014), classify Hg, As, Cr, Pb, Ni and Zn as metals with greatest toxicological and ecotoxicological effect in aquatic environments, while Prieto, González, Román y Prieto (2009) consider Hg, Cd, As, Cr, Tl and Pb, toxic as well. It is pertinent to mention that copper ($Cu^{1,2}$) is an essential element, required by plants and animals, however, copper in high concentrations has cytotoxic effects (Gaete, Aránguiz, Cienfuegos, & Tejos, 2007). While other metals mentioned above do not have metabolic functions like copper so they are not biodegraded and bioaccumulate in tissues and could affect the central nervous system and/or become carcinogenic. The average lead value (Pb) found in all monitoring stations in the middle Jequetepeque river basin was 0.005 mg/l (Figure 10a). Lead does not found in bodies of water naturally, it comes from pollution by lead arsenate and other salts, especially from mining effluents. Lead bioaccumulates in bones, could cause damage to the central nervous system. Long-term consumption of lead-contaminated water has lethal effects.

Cadmium average value found at all monitoring stations in the middle Jequetepeque river basin was 0.001 mg/L (Figure 10b). Cadmium is a metallic element soluble in water like chlorides, nitrates, and sulfates, uncommon in natural waters. In addition to causing nausea and vomiting, it bioaccumulates in the liver, pancreas, thyroid, and kidneys, is considered a carcinogenic element. Its presence in water usually comes from pollution with residues of the electroplating industry. Buenfil-Rojas and Flores-Cuevas (2007) affirms pollution of Hondo River by heavy metals (As, Cd, Pb, and Hg) comes from sugar mills, such as pesticides use and fertilizers, as well as direct sewage discharges at different points of riverbank and small industry waste.

Determination of total coliforms (Figure 10c) has do not been considered in the Peruvian regulations, Category 3: Irrigation of vegetables and animal drink. D1: Irrigation of Vegetables (D.S. N° 004-2017-MINAM) (MINAM, 2017), whose parameter was considered in D.S. N° 002-2008-MINAM (MINAM, 2008); however currently aforementioned supreme decree has been repealed. However, thermotolerant coliforms (Figure 10d) in six monitoring stations exceeded the standard value (1000 CFU/100 ml), according to Category 3: Irrigation of vegetables and animal drink. D1: Irrigation of Vegetables (D.S. N° 004-2017-MINAM).

Temperature, total dissolved solids, as well as organic matter, directly related to survival and proliferation rates of microorganisms, including total and fecal coliforms, latter associated with pathogenic bacteria. It is pertinent to mention in the study area there are small populated centers, whose domestic effluents discharge directly into the Jequetepeque river basin, as a consequence, it was found thermotolerant coliforms (Figure 10d), exceeded quality standards (ECA) for agricultural use (D.S. N°004-2017-MINAM). However, studies carried out by Lessard and Sieburth (1983), Rozen and Belkin (2001), and Cabral (2010) affirmed temperature is not related to survival and proliferation of microorganisms as demonstrated by Davies and Evison (1991), at not find significant differences in the survival rate of *Salmonella montevideo* subjected to 5, 15 and 25°C temperatures.

SAR index is used in sodium absorption relationship (Can-Chulim, Ramírez-Ayala, Ortega-Escobar, Trejo-López, & Cruz-Díaz, 2008), which expresses the relationship between sodium ions to calcium and magnesium cations. Figure 10e observed the lowest value (1.744) found in Kuntur Wasi bridge station (E-1), while the highest average value (2.121) was found in Yonan bridge station (E-6). Values found in all stations were less than 3, according to FAO normative (Ayers & Westcot, 1987), there is no restriction for agricultural water use (Figure 10f). Likewise, studies carried out on water quality irrigation in "Sierra Norte" Puebla (Mexico), found average values of 1.0 for sodium absorption ratio in the relation between sodium ions to calcium and magnesium cations (SAR), concluding it is optimal for agricultural use (Can-Chulim, Ortega-Escobar, Sánchez-Bernal, & Cruz-Crespo, 2014).

However, it is relevant to mention agricultural constantly contributes different types of pollutants (salts, pesticides, and fertilizers from irrigation, among others), so this sector requires to assessment water use considering other aspects, in addition, specific quantitative analyses (Söderbaum & Tortajada, 2011). Return waters (runoff and percolation waters) due to their high salinity and nutrient content can produce a negative environmental impact on the water bodies (surface or underground) that receive them, conditioning water quality rivers and aquifers both for irrigation and other uses (Thayalakumaran, Bethune, & Mcmahon, 2007).

Conclusions

Water quality of middle Jequetepeque River basin found within Category 3: Irrigation of vegetables and animal drink. D1: Irrigation of Vegetables, according to quality standards ECA D.S. N°004-2017-MINAM can use without restrictions for different crops in the study area. Using Spearman's nonparametric correlation coefficient $P<0.05$ was found. Likewise, with Wilcoxon bivalent distribution test, the asymptotic significance of 0.638 and 0.53 was found.

The sodium absorption index (SAR) was found to be less than 3, which indicates that it is not limiting for agricultural activity, it can be used without restrictions for the different crops in the study area.

Quality water in the middle Jequetepeque river basin has moderately altered by contributions or discharges of domestic effluents throughout the basin. However, it is important to indicate average values of thermotolerant coliforms exceeded the Environmental Quality Standards (D.S. N° 004-2017-MINAM) (MINAM, 2017).

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