III. Results and Discussions

A. Anthropic activities

According to the last National Census developed in Peru in 2017. The districts of San Jeronimo, Andahuaylas, and Talavera, had a population of 21 915, 43 560, and 19 251 inhabitants, respectively; in these districts, there is little coverage of the sewerage system by the public network. San Jerónimo had this service in 2,696 homes, Andahuaylas in 8,156 homes, and Talavera in 2,972 homes. The remaining families only had access to latrines of different types. This shows that domestic waste is generally dumped directly into the Chumbao River. The predominant economic activities in the study area are agriculture and cattle ranching and fishing, and aquaculture to a lesser extent. In terms of metal extraction, there are a few informal mining companies. The manufacturing, electricity, gas, and water sectors are not yet booming; activities such as construction and commerce are growing, and lodging, restaurants, and other services.

Water pollution is related to various activities, particularly agricultural and livestock activities. They cause pollution through runoff, as they flow over the surface of the ground dragging and dissolving substances that have been deposited in the soil. Thus, the main runoff pollutants are fertilizers, phytosanitary products, organic matter, and other toxic substances produced by livestock and certain other industrial activities [5].

One thousand forty cattle breeders were identified, and 56 of them were surveyed to find out the veterinary products they usually use in their activity. According to the DIA report, 3,871 heads of cattle were dewormed mostly with commercial anthelmintics, containing albendazole and mebendazole using ivermectin and other similar products. The control of flies and other ectoparasites was carried out with organophosphate and pyrethroid insecticides such as ectonil ® pour on, caravans over diazinon cypermethrin, karate zeon, arpon® g, and bifenthrin, among others. In the case of guinea pig breeding, 695 producers were found according to the DIA, and 54 of them were surveyed, who mentioned that they use organophosphate and pyrethroid insecticides such as fipronil and baygon to fumigate the area near their sheds and control flies, ticks, and pests. Regarding the cultivation of quinoa, 313 producers were found according to the DIA, and 52 of them were surveyed, which use pesticides such as Fitoklin, Oncol, Rotox, Cyperklin, Thiodan, Tifón, Campal, Ridomil, Silvacur, Sherpa, Cupravit, and Permethrin. For the cultivation of potatoes and corn, 849 producers were found according to the DIA, and 55 of these were surveyed. They use pesticides such as Fitoklin, Oncol, Karate Zeon, Lorpyfos, Rotox, Cyperklin, and Sherpa. Other human activities contribute to the contamination of the Chumbao River. It is the case of industrial activities which are not yet on a large scale downtown. Other sources of contamination are domestic and commercial waste that is discharged directly into the river.

The studied area is mostly used by agriculture, pasture, urbanization, and limited urban industry, especially in the identified sampling points. Different economic activities are carried out in human settlements, such as agricultural activities, mineral extraction, industry, commerce, and construction. They are the most important that are developed, in addition, there is an increase in population and urbanization in the surroundings of the cities, where the sources of water supply are. Anthropogenic activities are related to the contamination of aquatic ecosystems by the discharge of various chemical products from rural and urban activities. These products generate problems in the environment and a decrease in the availability of quality water [2], [6], [7].

B. Pesticide concentration

All the pesticides studied in the rainy and dry seasons were below the detection limits (<Dl). In the case of organochlorines and organophosphates, there were 19 and 25 active principles, respectively. The results obtained can be attributed to the time when the samples were collected and the rise of the water level in the river, which had a dilution effect on the pesticides. This does not correlate with the information obtained in the surveys where several agricultural and livestock chemicals were observed.

Pesticides used in agriculture reach the waters by entrainment and leaching. The dynamics of pesticides in the soil are very complex and depend on a series of factors that influence the mentioned processes. The substances sprayed on crops can be washed by rainwater and irrigation water. Then, it is transported to groundwater by leaching and to surface water by runoff. A phenomenon that is also influenced by the slope of the land; i.e., the volume of water falling to the ground and the topography of the cultivation area are two of the factors that play an important role in the risk of contamination of water resources by pesticides [8], [9].

Transport processes are also affected by the sorption properties of the soil, which are mainly determined by the content of organic matter, iron oxide and clay, ion exchange capacity, and pH. No less important are the physicochemical characteristics of pesticides; in general, the most water-soluble and persistent substances, i.e., those with the longest half-life, are the most easily transportable and represent the greatest risk of contamination. Organochlorine pesticides are resistant to biodegradation and accumulate in the environment [2], [10].

C. Physicochemical characteristics

In the present study, values below the maximum allowable limits were found for nickel and chromium (0.052 mg / L and 0.011 mg / L) [11]; levels of Fe and Br were also identified. The presence of iron in the water is attributed to soils formed by concretions of this mineral, while the presence of bromine correlates with iron. No maximum limits have been established for these elements in Peruvian regulations. Highland Rivers, dissolved oxygen should be ≤ 5 ppm, some values studied do not comply with this parameter, especially in the dry season. Dissolved oxygen values above 5 ppm are observed in other studies, influenced by atmospheric pressure, temperature, and total solids. The pH values increase slightly downstream. The permissible range is 6.5 to 9.0, the biochemical oxygen demand varies along with the sampling points, observing values above and below the maximum limit of 10 ppm [11].

TABLE III

PESTICIDE CONCENTRATION, PHYSICOCHEMICAL AND MICROBIOLOGICAL CHARACTERISTICS IN THE RAINY SEASON

Variable	P1L	P2L	P3L	P4L	P5L	P6L	P7L
a-BHC µg/L*	< 0.0032	< 0.0032	< 0.0032	< 0.0032	< 0.0032	< 0.0032	< 0.0032
a-Clordano µg/L*	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023
Aldrin µg/L*	< 0.0027	< 0.0027	< 0.0027	< 0.0027	< 0.0027	< 0.0027	< 0.0027
B-BHC µg/L*	< 0.0047	< 0.0047	< 0.0047	< 0.0047	< 0.0047	< 0.0047	< 0.0047
D-BHC µg/L*	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023
Dieldrin µg/L*	< 0.0026	< 0.0026	< 0.0026	< 0.0026	< 0.0026	< 0.0026	< 0.0026
Endosulfan I µg/L*	< 0.0022	< 0.0022	< 0.0022	< 0.0022	< 0.0022	< 0.0022	< 0.0022
Endosulfan II µg/L*	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023
Endosulfan sulfato µg/L*	< 0.0042	< 0.0042	< 0.0042	< 0.0042	< 0.0042	< 0.0042	< 0.0042
Endrin µg/L*	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023
Endrin Aldehído µg/L*	< 0.0115	< 0.0115	< 0.0115	< 0.0115	< 0.0115	< 0.0115	< 0.0115
g-BHC µg/L*	< 0.0027	< 0.0027	< 0.0027	< 0.0027	< 0.0027	< 0.0027	< 0.0027
g-Clordano µg/L*	< 0.0030	< 0.0030	< 0.0030	< 0.0030	< 0.0030	< 0.0030	< 0.0030
Heptacloro µg/L*	< 0.0034	< 0.0034	< 0.0034	< 0.0034	< 0.0034	< 0.0034	< 0.0034
Heptacloro Hepoxido µg/L*	< 0.0016	< 0.0016	< 0.0016	< 0.0016	< 0.0016	< 0.0016	< 0.0016
Metoxicloro µg/L*	< 0.0138	< 0.0138	< 0.0138	< 0.0138	< 0.0138	< 0.0138	< 0.0138
P, P'-DDD µg/L*	< 0.0030	< 0.0030	< 0.0030	< 0.0030	< 0.0030	< 0.0030	< 0.0030
P, P'-DDE µg/L*	< 0.0024	< 0.0024	< 0.0024	< 0.0024	< 0.0024	< 0.0024	< 0.0024
P, P'DDT. µg/L*	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Carbophenothion µg/L**	< 0.094	< 0.094	< 0.094	< 0.094	< 0.094	< 0.094	< 0.094
Chlorobenzilate µg/L**	< 0.089	< 0.089	< 0.089	< 0.089	< 0.089	< 0.089	< 0.089
Coumaphos µg/L**	< 0.114	< 0.114	< 0.114	< 0.114	< 0.114	< 0.114	< 0.114
Diallate µg/L**	< 0.089	< 0.089	< 0.089	< 0.089	< 0.089	< 0.089	< 0.089
Dimethoate µg/L**	< 0.079	< 0.079	< 0.079	< 0.079	< 0.079	< 0.079	< 0.079
Dinoseb µg/L**	< 0.131	< 0.131	< 0.131	< 0.131	< 0.131	< 0.131	< 0.131
Disulfoton µg/L**	< 0.082	< 0.082	< 0.082	< 0.082	< 0.082	< 0.082	< 0.082
EPN µg/L**	< 0.123	< 0.123	< 0.123	< 0.123	< 0.123	< 0.123	< 0.123
Ethion µg/L**	< 0.175	< 0.175	< 0.175	< 0.175	< 0.175	< 0.175	< 0.175
Famphur µg/L**	< 0.087	< 0.087	< 0.087	< 0.087	< 0.087	< 0.087	< 0.087
Fensulfothion µg/L**	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090
Fenthion µg/L**	< 0.078	< 0.078	< 0.078	< 0.078	< 0.078	< 0.078	< 0.078
Imidan µg/L**	< 0.168	< 0.168	< 0.168	< 0.168	< 0.168	< 0.168	< 0.168
Kepone µg/L**	< 0.099	< 0.099	< 0.099	< 0.099	< 0.099	< 0.099	< 0.099
Leptophos µg/L**	< 0.070	< 0.070	< 0.070	< 0.070	< 0.070	< 0.070	< 0.070
Malathion µg/L**	< 0.073	< 0.073	< 0.073	< 0.073	< 0.073	< 0.073	< 0.073
Methyl parathion µg/L**	< 0.094	< 0.094	< 0.094	< 0.094	< 0.094	< 0.094	< 0.094
Parathion µg/L**	< 0.085	< 0.085	< 0.085	< 0.085	< 0.085	< 0.085	< 0.085
Phorate µg/L**	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075
Phosalone µg/L**	< 0.115	< 0.115	< 0.115	< 0.115	< 0.115	< 0.115	< 0.115
Silvex µg/L**	< 0.159	< 0.159	< 0.159	< 0.159	< 0.159	< 0.159	< 0.159
Sulfotep µg/L**	< 0.068	< 0.068	< 0.068	< 0.068	< 0.068	< 0.068	< 0.068
Terbufos µg/L**	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075
Tetrachlorvinphos µg/L**	< 0.120	< 0.120	< 0.120	< 0.120	< 0.120	< 0.120	< 0.120
Thionazin µg/L**	< 0.069	< 0.069	< 0.069	< 0.069	< 0.069	< 0.069	< 0.069
Níckel mg Ni/L	< 0.052	< 0.052	< 0.052	< 0.052	< 0.052	< 0.052	< 0.052
Bromine mg Br/L	0.15	0.08	0.05	0.07	0.05	0.10[B]	0.07
Iron mg Fe/L	0.56	0.53	0.31	0.49	0.50	0.36[C]	0.61
Chrome ug Cr /L	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011
Dissolved oxygen mg O_2/L	4.79	4.87	4.82	4.90	4.57	6.40	4.86
pH	8.46	9.33	7.98	8.44	7.51	7.60	8.61
BDO mg O_2/L	2.71	2.11	9.88	28.37	58.45	91.13	115.34
Nitrates mg mgNO_3^-/L	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00
Phosphates mgPO_4^{-2}/L	0.05	0.17	1.31	1.64	1.52	1.87	1.02
Temperature °C	10.86	19.22	22.28	21.24	22.95	20.58	19.13
Turbidity FTU	0.20	17.57	28.77	15.40	62.40	37.97	24.33
Color Pt-Co	36.00	16.33	56.00	40.00	57.33	94.67	48.00
Dissolved Solids Totals mg/L	22.00	25.67	43.33	56.33	76.67	139.33	168.00
Conductivity uS/cm	44.67	51.33	86.33	108.33	154.33	277.67	337.00
Alkalinity mg$CaCO_3$/L	3.13	20.27	26.70	33.47	36.00	43.73	58.23
Hardness mg$CaCO_3$/L	6.97	44.07	80.80	101.37	109.10	100.67	200.80
Fecal Coliforms CFU/mL	25	150	2000	2000	2500	9500	3000
Total Coliforms CFU	0	0	1000	500	0	5000	0

Where: P: sampling points, E: dry season, *: organochlorine pesticides and **: organophosphate pesticides.

TABLE IV
PESTICIDE CONCENTRATION, PHYSICOCHEMICAL AND MICROBIOLOGICAL CHARACTERISTICS IN THE DRY SEASON

Variable	P1E	P2E	P3E	P4E	P5E	P6E	P7E
a-BHC µg/L*	< 0.0032	< 0.0032	< 0.0032	< 0.0032	< 0.0032	< 0.0032	< 0.0032
a-Clordano µg/L*	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023
Aldrin µg/L*	< 0.0027	< 0.0027	< 0.0027	< 0.0027	< 0.0027	< 0.0027	< 0.0027
B-BHC µg/L*	< 0.0047	< 0.0047	< 0.0047	< 0.0047	< 0.0047	< 0.0047	< 0.0047
D-BHC µg/L*	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023
Dieldrin µg/L*	< 0.0026	< 0.0026	< 0.0026	< 0.0026	< 0.0026	< 0.0026	< 0.0026
Endosulfan I µg/L*	< 0.0022	< 0.0022	< 0.0022	< 0.0022	< 0.0022	< 0.0022	< 0.0022
Endosulfan II µg/L*	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023
Endosulfan sulfato µg/L*	< 0.0042	< 0.0042	< 0.0042	< 0.0042	< 0.0042	< 0.0042	< 0.0042
Endrin µg/L*	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023	< 0.0023
Endrin Aldehído µg/L*	< 0.0115	< 0.0115	< 0.0115	< 0.0115	< 0.0115	< 0.0115	< 0.0115
g-BHC µg/L*	< 0.0027	< 0.0027	< 0.0027	< 0.0027	< 0.0027	< 0.0027	< 0.0027
g-Clordano µg/L*	< 0.0030	< 0.0030	< 0.0030	< 0.0030	< 0.0030	< 0.0030	< 0.0030
Heptacloro µg/L*	< 0.0034	< 0.0034	< 0.0034	< 0.0034	< 0.0034	< 0.0034	< 0.0034
Heptacloro Hepoxido µg/L*	< 0.0016	< 0.0016	< 0.0016	< 0.0016	< 0.0016	< 0.0016	< 0.0016
Metoxicloro µg/L*	< 0.0138	< 0.0138	< 0.0138	< 0.0138	< 0.0138	< 0.0138	< 0.0138
P, P'-DDD µg/L*	< 0.0030	< 0.0030	< 0.0030	< 0.0030	< 0.0030	< 0.0030	< 0.0030
P, P'-DDE µg/L*	< 0.0024	< 0.0024	< 0.0024	< 0.0024	< 0.0024	< 0.0024	< 0.0024
P, P'DDT. µg/L*	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Carbophenothion µg/L**	< 0.094	< 0.094	< 0.094	< 0.094	< 0.094	< 0.094	< 0.094
Chlorobenzilate µg/L**	< 0.089	< 0.089	< 0.089	< 0.089	< 0.089	< 0.089	< 0.089
Coumaphos µg/L**	< 0.114	< 0.114	< 0.114	< 0.114	< 0.114	< 0.114	< 0.114
Diallate µg/L**	< 0.089	< 0.089	< 0.089	< 0.089	< 0.089	< 0.089	< 0.089
Dimethoate µg/L**	< 0.079	< 0.079	< 0.079	< 0.079	< 0.079	< 0.079	< 0.079
Dinoseb µg/L**	< 0.131	< 0.131	< 0.131	< 0.131	< 0.131	< 0.131	< 0.131
Disulfoton µg/L**	< 0.082	< 0.082	< 0.082	< 0.082	< 0.082	< 0.082	< 0.082
EPN µg/L**	< 0.123	< 0.123	< 0.123	< 0.123	< 0.123	< 0.123	< 0.123
Ethion µg/L**	< 0.175	< 0.175	< 0.175	< 0.175	< 0.175	< 0.175	< 0.175
Famphur µg/L**	< 0.087	< 0.087	< 0.087	< 0.087	< 0.087	< 0.087	< 0.087
Fensulfothion µg/L**	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090	< 0.090
Fenthion µg/L**	< 0.078	< 0.078	< 0.078	< 0.078	< 0.078	< 0.078	< 0.078
Imidan µg/L**	< 0.168	< 0.168	< 0.168	< 0.168	< 0.168	< 0.168	< 0.168
Kepone µg/L**	< 0.099	< 0.099	< 0.099	< 0.099	< 0.099	< 0.099	< 0.099
Leptophos µg/L**	< 0.070	< 0.070	< 0.070	< 0.070	< 0.070	< 0.070	< 0.070
Malathion µg/L**	< 0.073	< 0.073	< 0.073	< 0.073	< 0.073	< 0.073	< 0.073
Methyl parathion µg/L**	< 0.094	< 0.094	< 0.094	< 0.094	< 0.094	< 0.094	< 0.094
Parathion µg/L**	< 0.085	< 0.085	< 0.085	< 0.085	< 0.085	< 0.085	< 0.085
Phorate µg/L**	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075
Phosalone µg/L**	< 0.115	< 0.115	< 0.115	< 0.115	< 0.115	< 0.115	< 0.115
Silvex µg/L**	< 0.159	< 0.159	< 0.159	< 0.159	< 0.159	< 0.159	< 0.159
Sulfotep µg/L**	< 0.068	< 0.068	< 0.068	< 0.068	< 0.068	< 0.068	< 0.068
Terbufos µg/L**	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075
Tetrachlorvinphos µg/L**	< 0.120	< 0.120	< 0.120	< 0.120	< 0.120	< 0.120	< 0.120
Thionazin µg/L**	< 0.069	< 0.069	< 0.069	< 0.069	< 0.069	< 0.069	< 0.069
Níckel mg Ni/L	< 0.052	< 0.052	< 0.052	< 0.052	< 0.052	< 0.052	< 0.052
Bromine mg Br/L	0.20	0.10	0.09	0.11	0.09	0.13	0.10
Iron mg Fe/L	0.60	0.59	0.37	0.53	0.58	0.39	0.69
Chrome ug Cr /L	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011
Dissolved oxygen mg O_2/L	7.75	8.54	5.18	8.03	2.21	5.11	7.91
pH	7.65	7.76	8.10	8.10	7.87	8.02	8.53
BOD mg O_2/L	0.00	39.67	185.67	51.00	145.33	47.33	6.67
Nitrates mg $mgNO_3^-$/L	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00
Phosphates $mgPO_4^{-2}$/L	0.05	1.49	0.91	1.69	1.70	2.07	0.62
Temperature °C	10.17	11.41	12.92	14.08	15.57	15.75	16.60
Turbidity FTU	4.27	11.43	23.70	29.43	66.07	99.90	143.53
Color Pt-Co	39.33	23.00	135.33	50.67	171.00	40.00	16.33
Dissolved Solids Totals mg/L	52.67	107.00	217.00	234.00	402.00	434.00	453.00
Conductivity uS/cm	105.33	214.00	434.33	468.00	803.67	868.67	905.67
Alkalinity $mgCaCO_3$/L	9.40	19.47	24.47	28.07	35.53	48.27	49.33
Hardness $mgCaCO_3$/L	20.33	42.30	74.17	85.73	107.63	112.60	170.13
Fecal Coliforms CFU/mL	14	325	25500	1100	54000	25500	400
Total Coliforms CFU	0.5	0	7000	250	20000	11500	70

Where: P: sampling points, E: dry season, *: organochlorine pesticides and **: organophosphate pesticides.

The basic character in some sampling points is due to the anthropic activities developed. Several quality indexes have been studied, considering these parameters [12], [13]. Water from the river throughout its entire course is used for crop irrigation. For vegetables, the maximum nitrate level should not exceed 100 ppm [11]. Nitrate concentrations in wastewater effluents can vary between 0 and 20 mg/L; when anthropogenic activities are present, nitrate values are normally below 1 mg/L [14]. The values found in the present study are below the detection limits.

Phosphates vary for the rainy and dry seasons, which are associated with the dissolution of phosphate rocks and minerals and anthropogenic sources such as discharges of domestic wastewater and residues from livestock and agricultural activities. Water temperature increases downstream of the river. The turbidity level also increases due to the natural erosion of the basin; this value also increases due to anthropic activity caused by industry or inorganic or organic domestic waste. The levels found are characteristic of rivers with high gradients and collected samples during rainy and dry seasons [15]. In category 3, for irrigation of vegetables and animal drinking, the maximum color value is 100 Pt / Co [11], with values above this indicator.

Total suspended solids are high in the dry season and low in the rainy season. The evaluation of this parameter constitutes an important indicator of the pollutant load, which affects the passage of light and limits the development of aquatic life. Therefore, it has a stimulating effect on the nitrification rate [14]. For the conservation of the aquatic environment, the maximum limit is 100 mg/L [11]. Some quantified values are above this parameter, indicating water pollution by non-native or native sources.

The points sampled comply with the Peruvian standard, which establishes a maximum value of 1000 µS / cm for conductivity [11], higher in the dry season and lower in the rainy season. This is due to the discharge of wastewater into the riverbed and the dragging of particulate material; similar temporal variations were reported by other authors [5], [15].

Alkalinity is high in the dry season and low in the rainy season. This variation is due to the concentration of carbonates, bicarbonates, and hydroxyl ions in the water [16]. In both seasons, it is appreciated that the values increase as the water follows its course. This condition may be associated with various factors such as the geology of the study area, the amount of atmospheric CO2 dissolved in the water, and the bacterial oxidation of organic matter. Also, the turbulence of the water that generates a change in the partial pressure of CO2 associated with the release of CO2 [17].

Water hardness is due to the content of calcium and magnesium ions. The results show low and high values during the rainy, and dry seasons respectively, the variations are associated with seasonality and lithological origin due to the high geological complexity of the study area [18]. Anthropic agricultural, livestock, swine, and fish farming affect the physicochemical properties of water streams [3].

Water sources are diminishing due to the anthropic activities taking place in the world. The analysis of the changes in water quality is necessary for the good management of this important resource. The results obtained indicate that in some places, the physicochemical characteristics of water are recovered due to the natural purification that occurs in surface water sources [19].

D. Microbiological characteristics

Fecal and total coliforms are considered indicators of contamination due to their simple, inexpensive, and rapid identification. Values during the rainy season were lower than those during the dry season. These variations are mainly because wastewater from domestic activities is discharged into the riverbed without any treatment and contributes to the high content of pathogenic microorganisms. This fact is also influenced by the dumping of domestic solid waste on the river banks [20]. In some cases, the values of thermotolerant coliforms greatly exceed the established minimum value of 2000 NMP/mL, for the conservation of the aquatic environment of rivers in the highlands or high Andes [11].

There is a great diversity of sources used for irrigation. Microbial contamination is evaluated to improve the level of knowledge and management for safe irrigation. Human fecal contamination was found in most of the types of irrigation water tested. Hepatitis E virus, polyomavirus, possible bacterial pathogens, such as Helicobacter pylori, Legionella spp. and Aeromonas spp. Giardia cysts and Cryptosporidium oocysts were not detected [21]. The present investigation could be complemented with current water management tools based on bacterial indicators. The results of pesticide concentration, physicochemical and microbiological characteristics in the Chumbao River are shown in Table 3 and Table 4.

E. Influence of anthropic activities on the water quality of the Chumbao river.

Multiple correlations of the variables were carried out, observing a positive behavior among them. A principal component analysis (PCA) was performed, in which the first 2 components were retained according to the Kaiser criterion (eigenvalues greater than 1), with which 96.55% of the variability of the original data could be explained.

The PCA clearly shows the degradation process of the water resource of the Chumbao River due to the discharge of wastewater from agricultural, commercial, domestic, and industrial activities. In Figure 2, the green circles show the stations located in the upper part of the Chumbao river valley before the urban area of the San Jeronimo district. These sampling points do not present significant contamination; the P1 in the rainy and dry season is below the true color restriction value (36.00 and 39.33 Pt-Co Units respectively), and at the same sampling point, the turbidity is below the maximum permissible limit for waters that can be purified with disinfection [11]. In the dry and rainy seasons, there are no high levels of contamination for the characteristics studied. There are no contaminating anthropic activities in the surroundings of the Chumbao River hydroelectric power plant, except for those dedicated to agriculture, such as potatoes, corn, quinoa, etc. In addition, livestock activities such as raising cattle, guinea pigs, and others were observed.

At P2, 5.56 km from the first sampling point (yellow in Figure 2), the river enters the most populated area of the San Jerónimo district. It presents an intermediate position in terms of contamination from agricultural activities and domestic wastewater. This point presents an important degree of contamination (high levels of BOD and true color) and shares some characteristics with sampling point P7E affected by the discharge of domestic wastewater. Sampling point P4E and black in color comprise the ones with the highest levels of contamination. This point is located near the Engineering Barracks in Curibamba, Andahuaylas. There are domestic, commercial, and industrial activities at this point. There are many businesses, and the municipal slaughterhouse of Andahuaylas is close to the point. In addition, the area is densely populated.

In Figure 2, the circles in red are the points with greater degradation of the water resource but less than P4E. These sampling points present low concentrations of DO and high values of the other physicochemical variables associated with component 1. It is caused by the alteration of the river with domestic, commercial, and industrial wastewater that causes an increase in pH, alkalinity, temperature, fecal coliforms, temperature, and fecal coliforms. The high values of true color, total dissolved solids, conductivity, hardness, and total coliforms in the points of the urban zone associated with component 2 result from the high content of organic matter in the domestic wastewater discharged in the districts of Andahuaylas and Talavera.

The presence of total and fecal coliforms in the sampling points studied is of concern. The values are above the healthy level, and these waters are used for irrigation in the districts of San Jeronimo, Andahuaylas, and Talavera. This concern arises because in Andahuaylas in 2019, 4,882 cases were recorded in children over 5 years of age and 4,401 cases in children under 5 years of age with acute diarrheal disease (EDA). Water is contaminated by human feces, such as drains, septic tanks, or latrines, which are especially dangerous. In addition, animal feces contain microorganisms capable of causing diarrheal disease [22]. According to WHO, about 1.87 million children die each year from causes related to diarrheal diseases, and approximately 88% of these deaths are associated with an unsafe water supply and poor sanitation and hygiene [23], [24].

In the 2017 water and sanitation sector diagnosis, it was noted that 3.4 million Peruvians do not have access to safe drinking water, and 8.1 million do not have sewerage. Only 47% of households have access to drinking water in urban areas and 1.7% in rural areas. Among the causes of these problems are operators with little support and serious economic problems, insufficient and unsustainable investments [25].

The State of the Chumbao River in the section studied, which includes the districts of San Jerónimo, Andahuaylas, and Talavera violates the rights of the inhabitants of these municipalities. Law No. 30588 of constitutional reform recognizes the right of access to water as a constitutional right in its article 7º-A, in which the State recognizes the right of every person to have progressive and universal access to drinking water. The State guarantees this right by prioritizing human consumption over other uses. The State promotes the sustainable management of water, which is recognized as an essential natural resource and constitutes a public good and patrimony of the Nation. It is inalienable and imprescriptible [26].

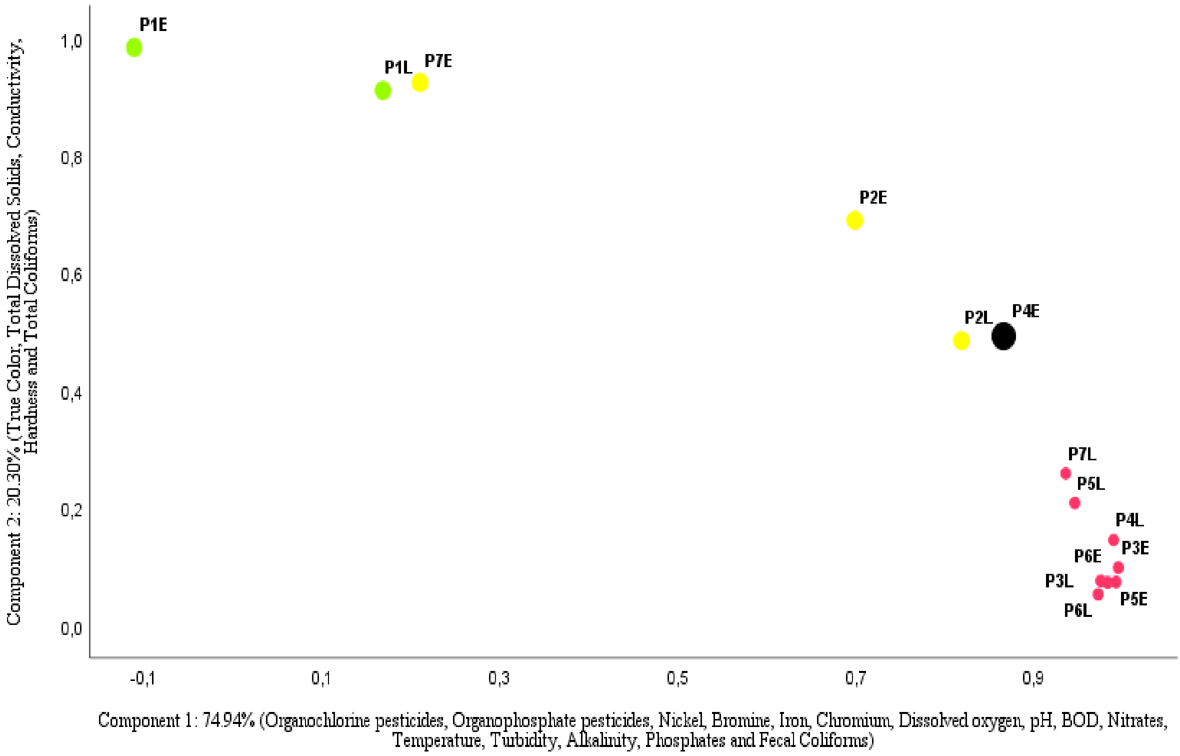

Fig. 2 Spatial distribution of the stations in the pollution gradient of components 1 and 2. Rio Chumbao, Peru.

IV. Conclusions

The influence of anthropic activities and the concentration of pesticides, physicochemical and microbiological characteristics in the Chumbao river, which belongs to the province of Andahuaylas, region of Apurímac, during 2019 was determined. The main anthropic activities were identified, emphasizing agricultural activities (raising cattle, raising guinea pigs, cultivating quinoa, potatoes, and corn), the most prevalent in the study area and closely related to the properties studied.

Significant concentration values of organochlorine and organophosphate pesticides have not been detected for the detection limits of the methodologies used. However, at a descriptive level, several products for veterinary and agricultural use have been identified, and they are present in the Chumbao river micro-basin. In the case of livestock activity, the frequent use of albendazole, mebendazole, and ivermectin as anthelmintics is observed for the control of flies and other ectoparasites. They use organophosphate and pyrethroid insecticides. In the case of quinoa, potato, and corn crops, various pesticides have been identified. It has not found control products for undergrowth. It was possible to determine the physicochemical and microbiological characteristics in the rainy and dry seasons in the Chumbao river. It has been observed that the competent authority above the environmental quality standards formulates many of the properties studied.

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