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SURFACE WATER ANALYSIS IN EL ASTILLERO

SURFACE WATER QUALITY AND SAFETY ASSESSMENT IN THE VILLAGE OF EL ASTILLERO ACCORDING TO WORLD HEALTH ORGANISATION GUIDELINES

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CASA CONGO | El Astillero, Rivas Nicaragua.

Dedicated to Huibregt Heyt

(1930 - 2018)

Contents

Abstract

Water is one of the most important resources on our planets as it sustains life itself. Safe and clean water is one of the basic rights any human should have access to. Together with Casa Congo, a study was conducted regarding the water quality and safety in the village of El Astillero, Rivas in Nicaragua. The water of the wells was analysed, as well as of the river Rio Escalante and of the grey water outlets of several households. The parameters measured were pH, Dissolved Oxygen, Electric Conductivity, Total Dissolved Solids, Nitrate, Phosphate, Ammonia and Water Hardness. The wells' water was contaminated with nitrate (66 ppm on average) in a concentration 16 ppm higher than the recommended threshold according to the World Health Organisation. The river Rio Escalante was found to be in a hypertrophic state with 15 ppm of PO4 on average and with explosive growth of algal species. The grey water measured revealed presence of Coliform bacteria in the water in 100% of the samples. These results suggest that measures must be taken in order to improve the water's quality. The groundwater of the wells in El Astillero is not safe for people due to the high nitrate content above the guidelines set by the World Health Organisation. The river Rio Escalante's trophic state can be improved through awareness raising and education in the community and reduction of fertilizer use from farmers. Concerning the grey water, the village of El Astillero requires a sewage system, water collection and depuration infrastructure to prevent the exposure of people and animals from hazardous bacteria in this contaminated water. In conclusion, Casa Congo could be of support by initiating informative events with the community and advice regarding possible improvements and remediation measures, with the future goal of a safe supply of water for the community.

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1. Introduction

Water is one of the most important resources on our planets as it sustains life itself. Safe and clean water is one of the basic rights any human should have access to. One of the most effective ways of securing this right is sound water quality management. I followed an MSc in Environmental Sciences and Water quality, because I am determined to help grant access to safe and clean water to all those who have this right denied. This project with Casa Congo, will be the start of working towards my dream.

Casa Congo is a NGO managed by locals with the goal to empower and improve the life quality of the people in the village and in the area. In collaboration with Casa Congo, I intend to perform a general water quality analysis in the village of El Astillero **(fig.1)**, in order to assess the quality and safety of the water. This preliminary water quality analysis will help advice on the improved water treatment infrastructure required by the local inhabitants of El Astillero. Therefore, this project will focus on assessing the potability and safety of the water sources present in the village, as well as providing insight over the eutrophication and contamination of the surface waters.

In the village of El Astillero, Nicaragua, wells provide the villagers with water for drinking, cooking and everyday use. Residual water of the houses in the area is expelled directly on the road, exposing people and animals to potential contamination. In addition, the grey water can leech further into the soil and runoff into the ocean and contaminate the environment. Thus, an investigation is done regarding the water quality state of the river Rio Escalante situated north of the village.

This report shows the outcome of the surface water assessment that took place from November 2019 until January 2020.

During this research three questions are considered:

1- What is the water quality and safety state of the groundwater?

2- What is the water quality of the river Rio Escalante?

3- How many grey water spills are present in the village and where?

1.1 Study Area

Figure 1. El Astillero (Nicaragua), area of interest. Casa Congo is indicated in the centre of the village. North of the village the river Rio Escalante. South of the village the water tank infrastructure is indicated by a grey pinpoint. Snapshot taken from google earth imagery and map resources.com.

2. Materials and Methods

2.1 Data Collection

-**pH** and **EC** are measured with the pH-EC meter EC-3587 from *RoHS* (fig.2). The instrument is calibrated before use with the two point calibration method. Also, measurements are taken at the location marked with the Garmin 64s GPS.

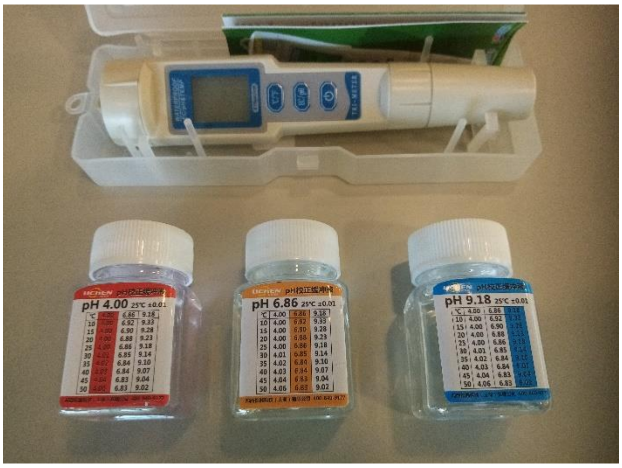

Figure 1 pH meter and buffer solutions (pH 4-6.86-9.18).

-**Water Hardness, Phosphates, Nitrates and Ammonia** are measured with test strips from *Precision Lab Europe* (fig.3).

Figure 3 Nutrient strips for nitrate, phosphate, ammonia and water hardness.

- **Dissolved Oxygen** is measured with DO Meter AR 8010 Smart Sensor from *Intell Instruments^{TM}* Pro (fig.4). This instrument is calibrated with a two point calibration method. Measurements are taken three times per sample and the average will be considered.

Figure 4 Oxygen meter.

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-**Total Dissolved Solids** (TDS) are measured with a TDS stick developed by *Original Xiaomi TDS Water Tester Pen*.

-**Water Turbidity** is measured with a digital Turbidity meter (0-200 NTU).

-**Total Coliforms** are measured through test kits from La Motte Europe (fig.5).

Also a statistic analysis of the data collected is performed with Sigmaplot.

Figure 5 Total coliform test.

2.2 Setup

As the wells are an important source of water for the villagers, the safety of this water is assessed first. This is done through investigating the presence of Nutrients and Total Coliforms as well as measurements of the pH, Dissolved Oxygen (DO), Water Hardness, Total Dissolved Solids (TDS) and temperature **(tab.1)**. The values of these parameters provide a general overview of the situation and the quality of the water. Once the water quality is assessed, improvements to the infrastructures are suggested to Casa Congo. The NGO will then be able to take on board this advice for furthering their mission of providing safe and clean water to the community.

As mentioned previously, the grey-water outlets running directly onto the road are also a health hazard. The presence of Ammonia Phosphates and Nitrates from these outlets is analysed. This is done so as to investigate the presence of potential contaminants in the grey waters and the risk of exposure to these contaminants to the people and animals. Based on the results, a suggestion for a collection and treatment infrastructure of the grey water is considered.

The water quality state of the river Rio Escalante is assessed. This river has a significant catchment area. Thus, an overview of its water quality state can indicate the impact of nutrient pollution in the area of interest. All proposed solutions will be made bearing in mind what resources are available to the inhabitants of El Astillero.

Table 1. Water quality parameters and safety range assessment. ND Refers to Non Determined.

Parameters	Offhand	Measurement unit	Materials required	Safe Range / Assessment Criteria
pH	pH		pH-EC meter	5-7 Neutrality
Electric Conductivity	EC	µS/cm	pH-EC meter	ND
Water Hardness	WH	ppm 0-500	Field Strips	ND
Dissolved Oxygen	DO	mg/l	Oxygen meter	Saturation 100%
Total Dissolved Solids	TDS	ppm	TDS meter	ND
Nitrate	NO3	ppm 0-500	Field strips	Oligotrophic Mesotrophic Eutrophic
Phosphate	PO4	ppm 0-100	Field strips	Oligotrophic Mesotrophic Eutrophic
Ammonia	NH3	ppm 0-6	Field strips	≤ 3 ppm
Total Coliform	TC	Present/ Absent	TC test	Absence

3. Results

The results obtained are described for the three sources of freshwater analysed, the wells, the grey waters and the river Escalante.

3.1 Wells

In the village of El Astillero 60 Wells were geographically marked with a Garmin 64s GPS and measured for water quality parameters. The data collected from the wells is analysed with QGIS and with Sigmaplot. Results of the wells analysis are considered for each parameter. The spatial distribution of the wells shows a dense cluster in the north side of the village. Instead, in the central-south side of the village wells measured are located along the road **(fig.2)**.

Figure 6. Wells sampled in the village of El Astillero. GPS location taken with Garmin64s. Bing aerial Image

The overview table **(tab.2)** shows on average a Neutral pH value (6.9) and low Dissolved Oxygen value (3.21 mg/l) characteristic of groundwater.

Also, ammonia measured in the form of NH3 is measured in 2 wells in concentration above 6 ppm **(appendix A)** which are not in use. The water is hard, with on average 125 ppm contained in the groundwater **(tab2)**.

Table 2. Overview of the parameters measured in the Wells in the Village of El Astillero.

	Depth (m)	DO3 (mg/L)	pH	TDS (ppm)	EC (µS/cm)	NO3 (ppm)	PO4 (ppm)	NH3 (ppm)	WH (ppm)
Average	9.91	3.21	6.95	1202	2260	66.54	16.25	0.23	125.87
Max	22	7.75	8.41	7455	15320	500	35	6	350
Min	2	0.8	6.1	147	115	0	0	0	80
St.Deviation	5.4	1.52	0.47	1287	2359	129.68	8.71	1.15	33.59

3.1.1 Salinity

The salinity of the groundwater in El Astillero in the dry season (November-December 2019) is measured in the wells present in the community. The data obtained was then interpolated to gain an overview of the groundwater quality in this area.

The water salinity is quantified through the measurement of two parameters, the Electric Conductivity (EC) and the Total Dissolved Solids (TDS). The strength of measuring two parameters lies in the confirmation of a similar result through two different measuring methodologies. Indeed, there is a relationship between EC and TDS and a regression can be considered between the two parameters (*Hubert E. & Wolkersdorfer C., 2015.*). Results from the regression, obtained with the data of the wells' samples, show a strong positive linear relationship with a correlation of r = 0.98 **(appendix E)**

The Salinity expressed as Electric Conductivity (EC) of the groundwater resulted in 2260 µS/cm on average. The maximum value measured was 15320 µS/cm and the minimum 115 µS/cm.

The frequency distribution of the EC samples revealed that 55% were measured between 1000 and 2000 µS/cm, 25% had EC values between 2000 µS/cm and 3000 µS/cm, 1% had values of 4000 µS/cm, 2% had values of 6000 µS/cm and 1% had values above 15000 µS/cm **(tab.3).**

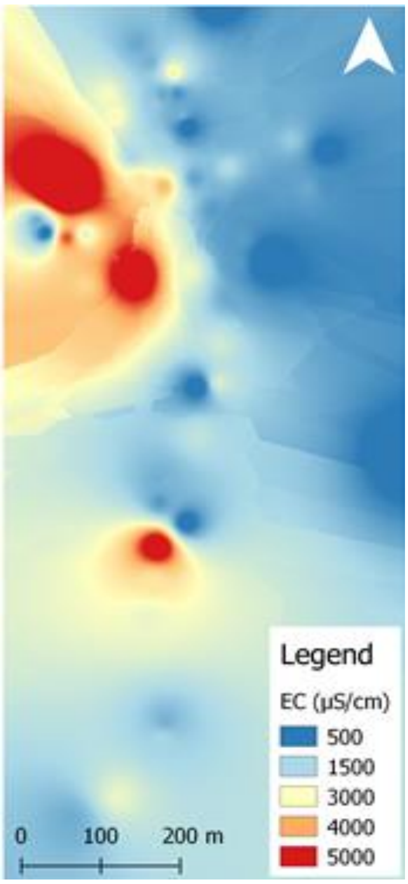

Figure 7. Electric Conductivity Inverse Weighted Interpolation (IDW). Spatial analysis of the wells measurement points.

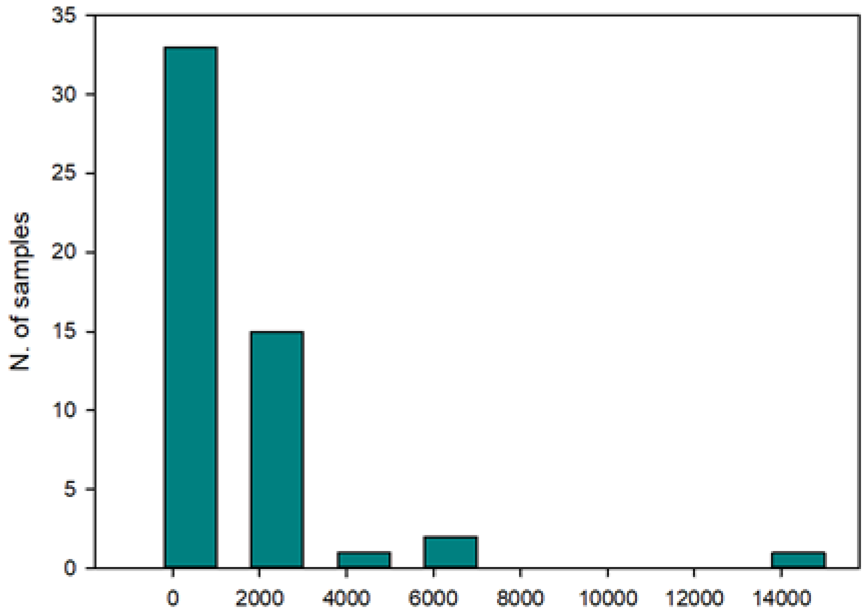

Figure 8. Frequency distribution of the Electric Conductivity measured samples of the wells.

3.1.2 Nutrients

Nitrate (NO_3) and phosphate (PO_4) are the two critical nutrients that determine the ecological balance of a water body. Indeed, excessive levels of NO_3 as well as PO_4 cause eutrophication of the environment in which they are present. High nutrients concentration in a water body can have catastrophic outcomes for the ecosystem. For instance, when this nutrients reach a threshold concentration in the water column, some algal species increase their growth exponentially in a short amount of time, harming greatly the equilibrium of the ecosystem. This process is known as a Bloom. This Blooms cause anoxia (low oxygen levels) in the water and increases stress for all aerobes, ultimately leading to death of those organisms (Callejas L. et al., 2015) *(Cuellar-Martinez et al., 2018).*

Nitrate

Nitrate expressed as NO3 contained in the groundwater 66.5 ppm on average. The minimum value measured was 10 ppm and the maximum measured was 500 ppm.

The interpolation of the data, obtained, show high levels of Nitrate in the groundwater in the North west area. Indeed, in the area closest to the sea and in the core of the village a pocket of high concentration of NO3 is identified, with an interpolated value of 250 ppm (**fig.9**).

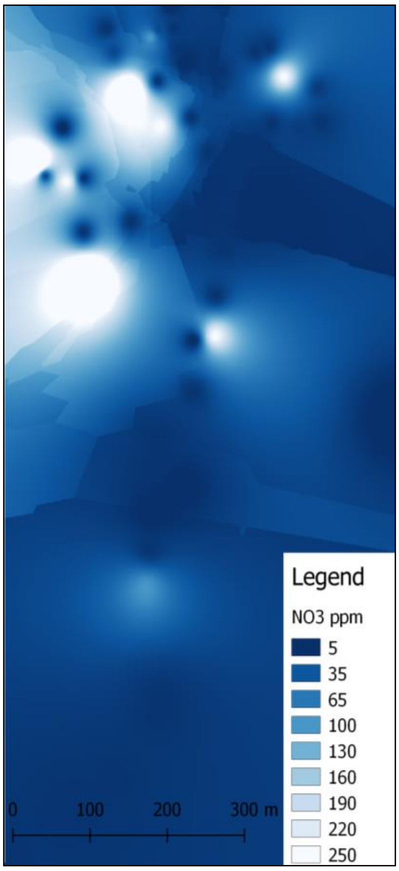

Figure 9. Nitrate Inverse Weighted Distance Interpolation (IDW). Spatial analysis of the wells measurement points.

The frequency distribution of the samples location revealed that 55% of the samples contained 10 ppm of NO3, 8% contained 250 ppm, 7% contained 25 ppm, 5% contained 500 ppm and 2% for individually 0 ppm, 15 ppm, 50 ppm and 100 ppm **(fig.10)**. Also, 15% of the sampling locations could not be measured due to the wells being sealed and not in use.

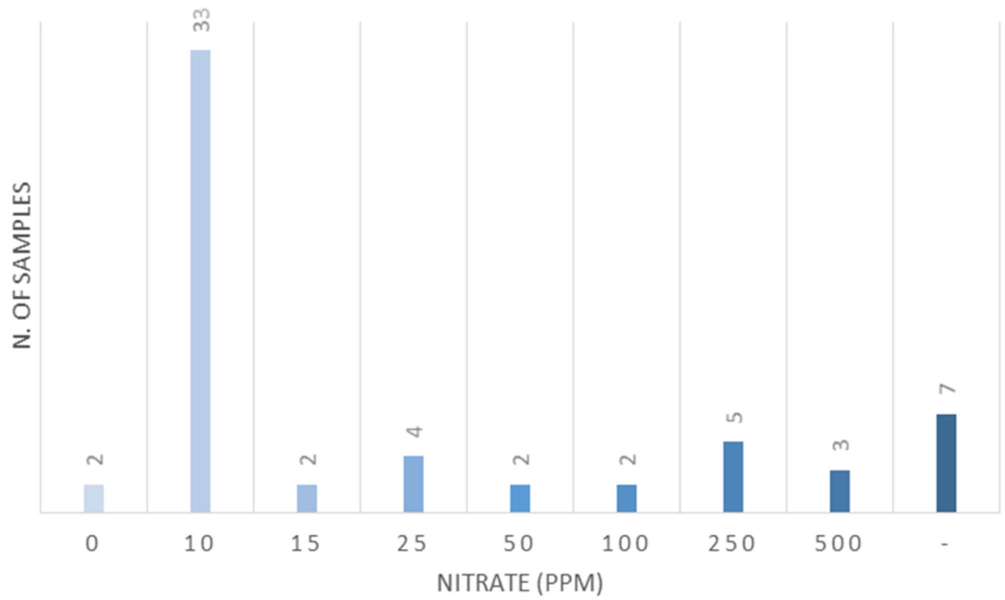

Figure 10. Frequency distribution of Nitrate samples.

Phosphate

Phosphate content expressed as PO_4 in the dry season (November-December 2019) in the groundwater amounts to 16.25 ppm on average **(tab.2).** Also, some wells showed high values in isolated points in the central and south areas of the village. The minimum value registered is 0 ppm and the Maximum is 35 ppm **(tab.2)**.

The spatial analysis of the Phosphate reveals presence of phosphate overall in the area on average 16.25 ppm **(tab.2)**. Furthermore, the spatial analysis reveals in the North West area of El Astillero a pocket with high concentration of 25 ppm **(fig.11)**.

The frequency distribution reveals that 55% of the samples contain 10 ppm of PO_4, 28.3% contain 25 ppm, 13% could not be measured, 6% contained 15 ppm, 2% contained 35 ppm and 5 ppm each and 1% did not contain any phosphate **(fig.12)**. The 13% of samples could not be measured due to the wells being sealed and not in use.

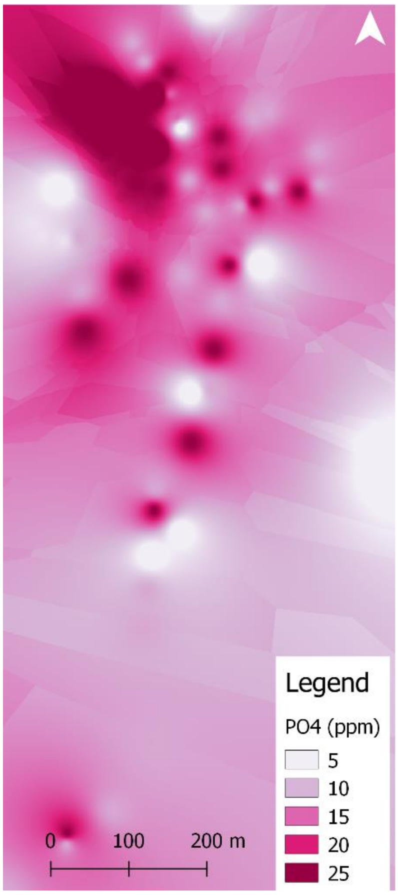

Figure 11 Phosphate Inverse Distance Weighted interpolation (IDW). Spatial analysis of the Wells measurement points.

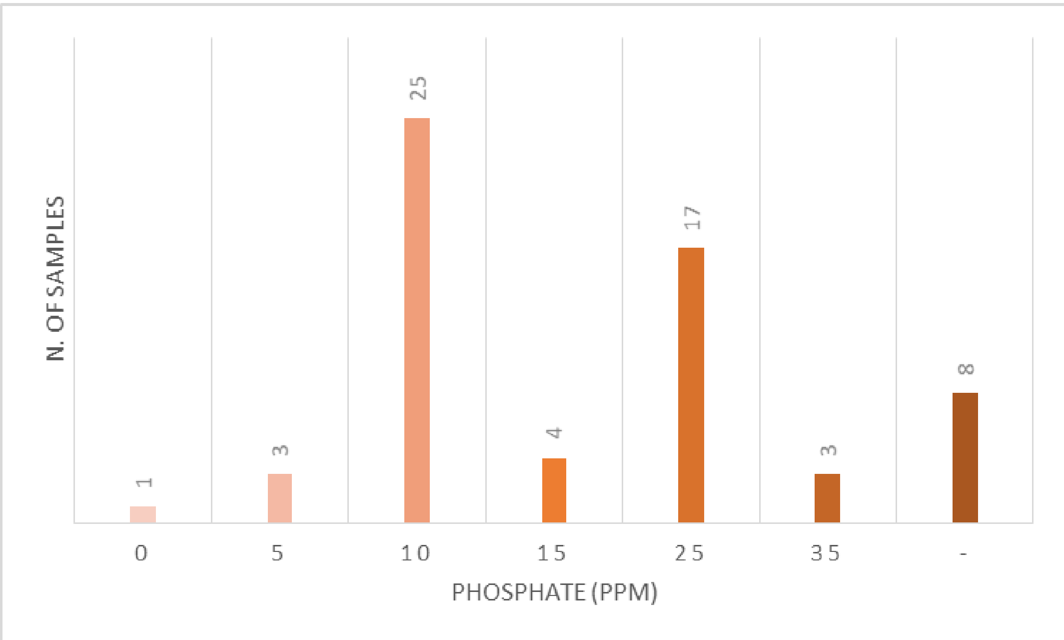

Figure 12. Frequency distribution of Phosphate samples

3.2 Rio Escalante

The River Rio Escalante plays a fundamental role for the ecosystem and the community of El Astillero. Indeed, the River Escalante is the river with the largest catchment area in this Region. The Rio Escalante also plays a geographical-political role as the border between the Nicaraguan Region of Carazo and Rivas.

Sampling locations in the dry season of January 2020, were registered with a Garmin 64s for the GPS location **(fig.13)**. Consequently, a spatial analysis for the parameters measured is performed.

The table overview **(tab.3)** shows good values on average for pH (8.1) and Dissolved Oxygen (8.1 mg/l).

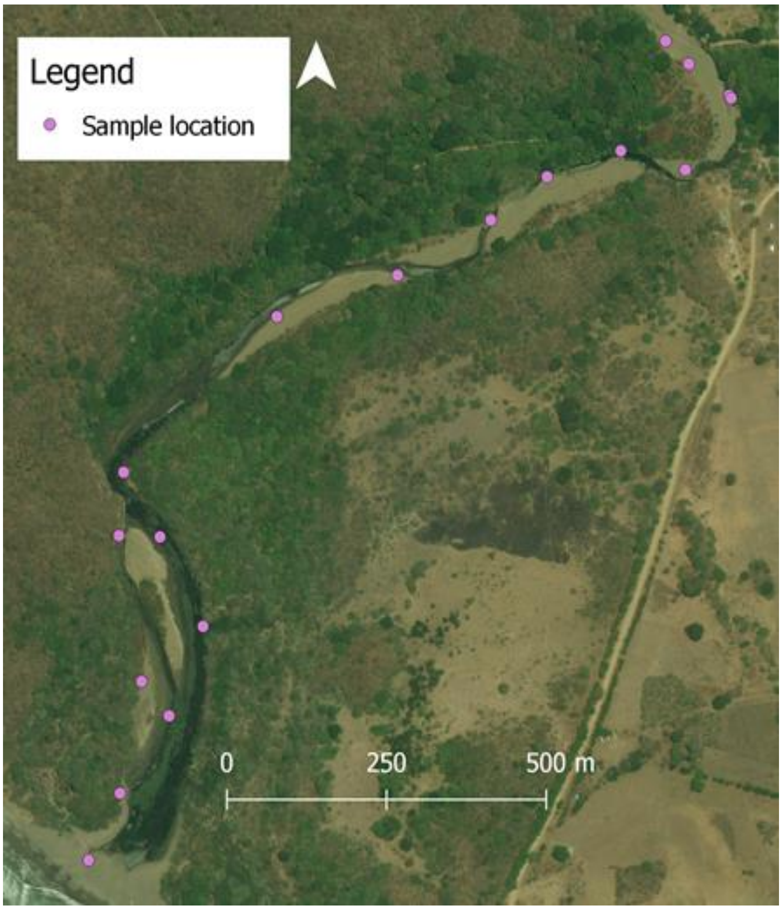

Figure 13. Sample location in the river Rio Escalante. GPS points taken with Garmin 64s. Bing aerial Image

Table 3. Rio Escalante parameters overview

	DO (mg/l)	EC (uS/cm)	TDS (ppm)	pH	NO3 (ppm)	PO4 (ppm)
Average	8.10	3485	2449	8.11	12	15
Max	8.90	6410	4580	8.80	50	50
Min	5.50	668	337	7.25	0	0
ST.Dev	0.86	2315	1689	0.40	14	14

3.2.1 Salinity

The Water's EC in the Rio escalante is 2450 µS/cm on average. The maximum value measured is 6410 µS/cm and the minimum value measured is 680 µS/cm. The spatial analysis of the river Rio Escalante show an increasing EC gradient from the Cangrejal area to the estuary (Bocana).

In the Cangrejal (starting sampling area) the water is fresh showing values around 500 µS/cm. In the middle section the water's EC changes abruptly to higher values from light brackish between 800 µS/cm and 1700 µS/cm. The last trait at the delta (Bocana) displays medium brackish water, EC up to 6000 µS/cm **(fig.14)**.

The frequency distribution chart **(fig.17)**, indicates that 31% of the samples show EC values between 0 and 1000 µS/cm, 6% between 1000 – 2000 µS/cm, 26% between 3000 – 4000 µS/cm, 16% between 5000 – 6000 µS/cm and 21% between 6000 – 7000 µS/cm.

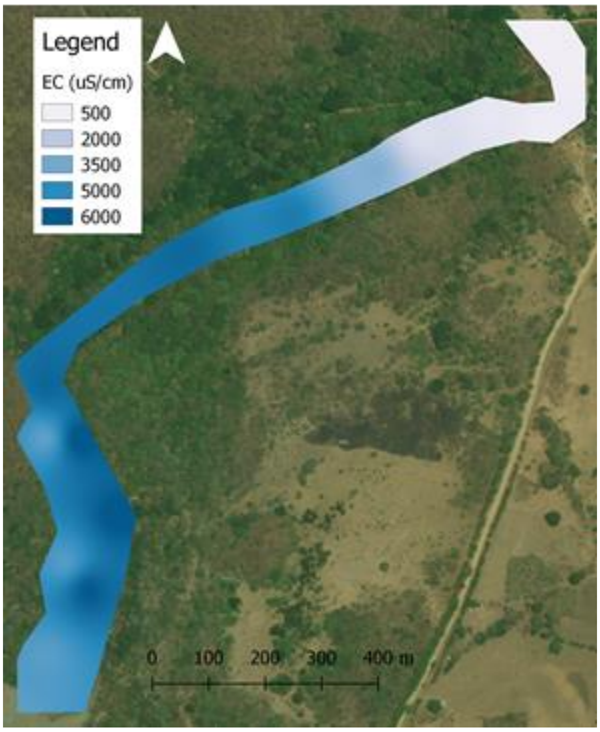

Figure 14. Electric Conductivity Inverse Distance Weighted Interpolation (IDW). Spatial analysis of the Rio Escalante sampled points. Bing aerial Image

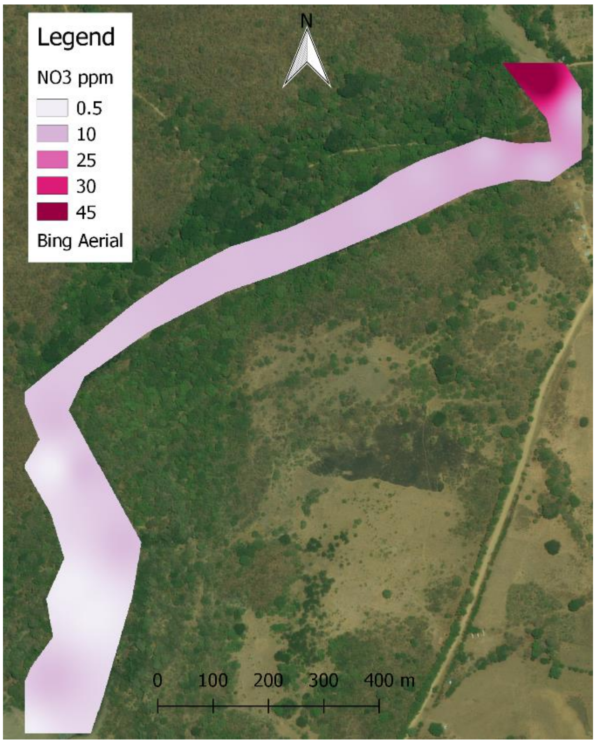

Figure 15. Nitrate Inverse Distance Weighted Interpolation (IDW). Spatial analysis of the Rio Escalante sampled points. Bing aerial Image

2.2.2 Nitrate

The Nitrate in the river measured as NO3 in the Rio escalante during the dry season (January 2020), contained 12 ppm on average.

The minimum value measured was 0 ppm and the maximum concentration spike point (45ppm) is measured in the Cangrejal area, where some cattle animals few meters upstream from the measurement points were drinking and bathing in the river **(fig.15)**.

The frequency distribution graph **(fig.17)** shows that 68% of the samples contain between 10 - 20 ppm of NO3, 22% contain between 0 – 10 ppm and 11% contain between 50 – 60 ppm.

3.2.3 Phosphate

The Phosphate expressed as PO4 contained 15 ppm on average in the river. The maximum value measured is 50 ppm and the lowest is 0 ppm **(tab.3)**.

In one of the locations a sudden spike in phosphate is measured (50 ppm), in correspondence to local people washing their clothes in the river **(fig.16)**.

The frequency chart **(fig.17)** shows that 26% of the samples contain between 0 – 10 ppm of PO4, 37% contain between 10 – 20 ppm, 21% contain between 20 -30 ppm, 10% contain between 30 – 40 ppm and 6% contain between 50 and 60 ppm.

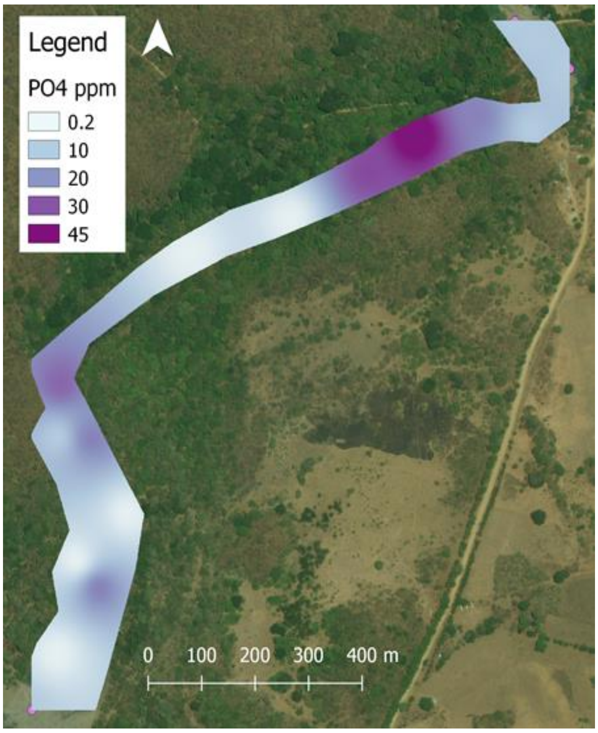

Figure 16. Phosphate Inverse Distance Weighted Interpolation (IDW). Spatial analysis of the Rio Escalante sampled points. Bing aerial Image

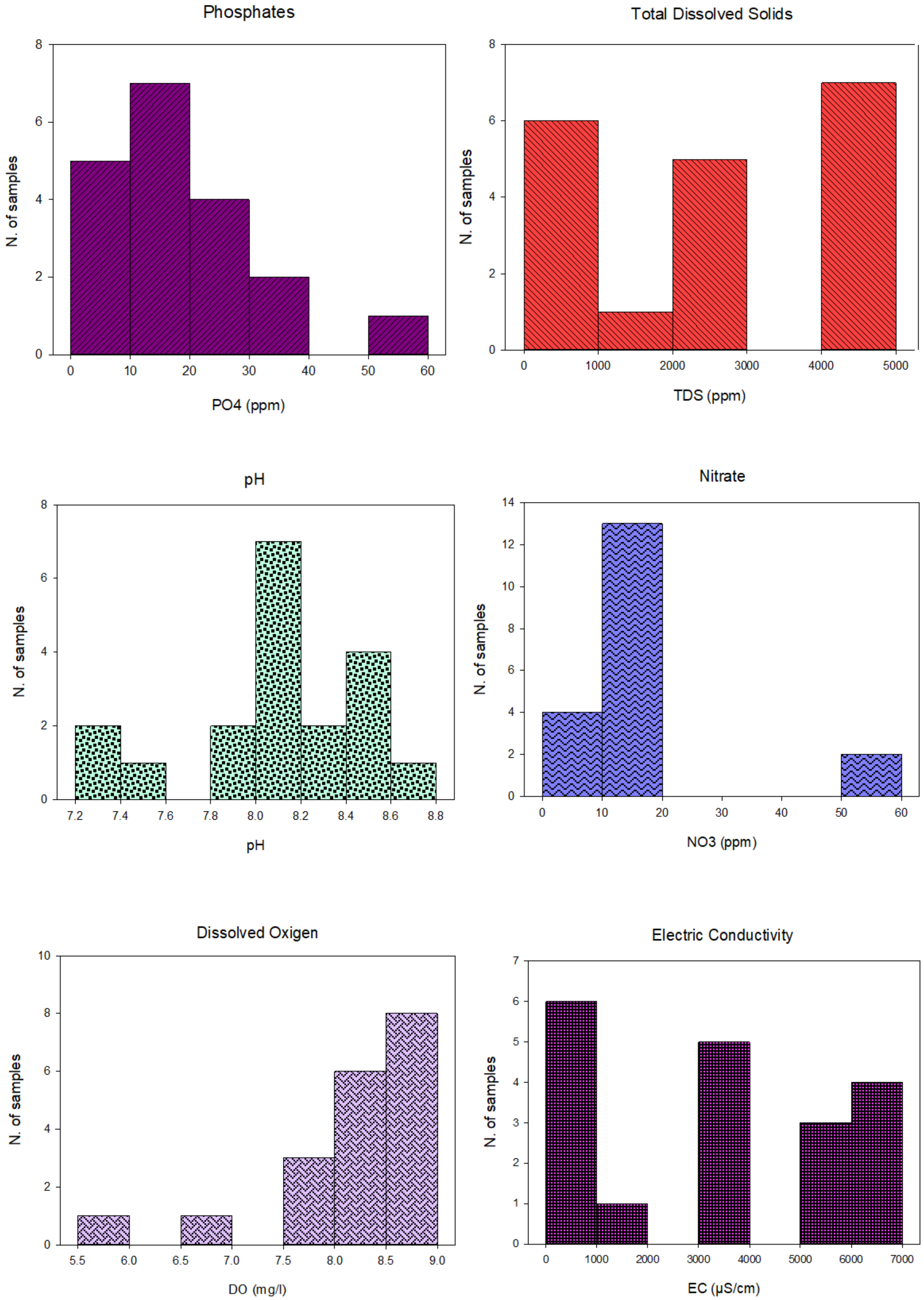

Figure 17. Frequency distribution of the parameters measured in the river Rio Escalante

3.3 Grey Water

Concerning the grey water 10 samples were tested with the Total Coliform test kit from "*La Motte Europe Ltd*.". The test tubes have nutrients inside that allow Coliform bacteria to grow in the tubes over a 48h period. Also, if the sample collected is contaminated, the coliform bacteria's growth causes the pH to drop, an indicator to turn the water yellow and the bacteria's metabolism will cause a gas layer to form on top of the water surface.

Then, the GPS locations where a grey water spill was found are marked with the Garmin 64s, then 10 locations are chosen evenly distributed around the village for the Total Coliform presence test **(fig18)**. Finally, 100% of the samples tested, revealed Total Coliform contamination in the grey water **(appendix D).**

Figure 18. Grey water spill locations are labelled in red and in yellow the tested samples that revealed to be contaminated by Total Coliform.

4. Discussion

In the groundwater of El Astillero, the water quality parameter values for pH, Dissolved Oxygen, Salinity and ammonia, were within range according to the guidelines of the World Health Organisation (WHO, 2017).

The nutrients levels for both phosphate and nitrate are above the recommended guidelines for water quality of 50 mg/l for nitrate (measured on average 66 mg/l, **see tab.2**) and 10 mg/l for phosphate (16 mg/l measured, see **tab.2**). Phosphate levels in the water are not concerning for people's health (WHO). Instead, the water presents high levels of Nitrate above 50 ppm in some wells **(appendix A)**, which indicate a contamination in the groundwater (WHO, 2017). Additionally, high concentration of Nitrate in groundwater is concerning for people's health. Nitrate in water with low DO values (3.2 mg/l on average in the wells) can speciate to Nitrite, a highly toxic compound that is harmful to infants and pregnant women at concentrations higher that 3 mg/l in the water (WHO, 2017). Furthermore, high concentrations of Nitrate and Nitrite in water are known to cause adverse health effects, like affecting the carrying capacity of oxygen for the haemoglobin (nitrite), inhibition of the thyroid gland activity (nitrate), vitamin A deficiency (nitrate) and production of nitrosamines which are known to be carcinogenic compounds (nitrates and nitrites) (WHO, 2017). Such high levels are very likely to be caused by seepage of the ground dug toilets in the village and by runoff of fertilizers into the soil and ultimately into the aquifer.

Concerning the river Rio Escalante the water quality parameters values for pH and Dissolved Oxygen **(tab.3)** were within a safe range, according to the Trophic State Index (TSI) *(USF Water Institute, 2018), (Carlson R.E. 1997)***.**

The river Rio Escalante contains on average 15 mg/l of phosphate **(tab.3)**. Thus, this river is in a compromised ecological state, according to *(Carlson R.E., 1997)* the Trophic State Index (TSI) indicates a Hypereutrophic environment **(appendix C)**. Besides, a Hypereutrophic environment for a water body is harmful due to the decompensation of the natural ecological equilibrium. Thus, regular occurring natural phenomenon in this trophic state are amplified by magnitude and intensity *(Cuellar-Martinez et al., 2018) (Ger, Kemal A et al 2014)*. For instance, when a certain threshold of limiting nutrients (Phosphorus and Nitrogen) is reached in the water, an explosive growth of algae occurs. Such phenomenon is called bloom and when potentially harmful species reproduce in such an explosive fashion, this phenomenon takes the name of Harmful Algae Bloom *(Carpenter S. R., 2005) (Ger, Kemal A et al 2014).* Harmful Algae Blooms (HAB) are detrimental events due to the ecological degradation of the water, such as bad odours, anoxic conditions, animal kills (fish, turtle) and ultimately leading to intoxication of people *(Cuellar-Martinez et al., 2018).* Additionally, in this area HAB events have been registered starting from the year 2005 up to 2018 (Callejas L. et al., 2015) *(Cuellar-Martinez et al., 2018).* Indeed, the responsible for this HAB is the dinoflagellate "*phaeocystis",* which secretes a toxin that can be accumulated in shellfish that feeds upon those algae *(Callejas L. et al., 2015).* Consequently, shellfish accumulates the saxitoxins present in the dinoflagellate causing 50 cases of Paralytic Shellfish Poisoning (PSP) in Nicaragua *(Callejas L. et al., 2015)*. Correspondingly, between 1970 and 2007, more than 7000 cases of PSP intoxication were registered in Latin America and the Caribbean region (LAC), with 119 human fatalities *(Callejas L. et al., 2015).*

Thus, to prevent and improve the ecological situation in the Rio escalante is to improve and shelter the animals and community in the area of El Astillero. Hence, it is important to tackle the sources of nutrient pollution such as cattle farming areas, agricultural areas and the clothes washing locations. Through workshops and information events with the community it is possible to identify those sources and control their input into the Rio Escalante.

Concerning the grey waters 28 locations were found where contaminated water was spilling directly on the road **(fig.18).** Also, 100% of the samples tested revealed Total Coliform contamination in this water spill locations. Coliform contamination poses a threat to every person and animal that comes in contact with puddles created by the identified spills (*Temple, K. L et al. 1982*). Indeed, cows, pigs and chickens that regularly drink this water are infected by the bacteria, which can then be transmitted to humans through consumption of animal products *(Hameed, K. G. A, 2007) (Anette M. Hammerum, Ole E. Heuer, 2009).* For instance, "*Escherichia coli"* bacteria transmitted through animals can develop antimicrobial resistance posing an additional threat to infected patients *(Anette M. Hammerum, Ole E. Heuer, 2009).* In conclusion, it is of the utmost importance for the village of El Astillero to make available a sewage system, a grey water collection and depuration infrastructure.

5. Conclusion

The wells' water of El Astillero is contaminated with high concentration of nitrate. This groundwater should not be used for drinking and cooking purposes because it can be harmful for human health. Infants and pregnant women are the most vulnerable subjects and should avoid any use of this nitrate contaminated water.

The river Rio Escalante is in a hypereutrophic state according to the Trophic State Index. This is a worrying situation for the ecosystem and the people of the community. Indeed, toxic algae events have been registered in the area before and many cases of Paralytic Shellfish Poisoning happened. However, measures can be taken to improve the situation. On one hand, through informative lectures/workshops in the community about the environmental impact of detergent used directly in the water. On the other hand, the fertilizer use of farmers should be reduced to tackle the nutrient pollution at its source and to improve the river quality in the future.

In conclusion, it is of paramount importance to provide a sewage system, a grey water collection and depuration infrastructure to the village. Undeniably, this infrastructure can guarantee an improvement in the groundwater of El Astillero by preventing seepage of contaminated water in the aquifer. Furthermore, a sewer infrastructure does not expose animals and people to dangerous bacteria that can pose a health threat to the community.

These measures are suggested with a future vision of obtaining an equilibrium state between man and nature, so that the community of El Astillero under the guidance of Casa Congo can live in harmony with the ecosystem and the nature and sustain themselves with clean and safe water.

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7. Appendix

A. Well samples data

Wells	Depth (m)	DO (mg/l)	pH	EC (µS/cm)	TDS (ppm)	NO3 (ppm)	PO4 (ppm)	NH3 (ppm)	WH (ppm)
P1	-	6.8	7.8	1040	475	50	10	0	125
P2	3	2.35	6.74	1150	550	50	10	0	125
P3	8	2.9	6.7	1050	516	25	35	0	125
P4	7	3	6.36	1500	549	100	25	0	125
P5	15	2.25	6.75	3030	1550	25	25	0	125
P6	6	1.4	6.7	2830	1430	10	35	0	125
P7	6	4	7.6	1660	835	500	25	0	125
P8	8	1.8	6.6	1600	681	10	35	0	125
P9	15	3.6	6.6	3940	2350	250	25	0	125
P10	11	3	6.7	3300	1860	250	25	0	125
P11	6	6.4	8.41	1130	560	500	5	0	80
P12	7	5.6	7.8	3500	2040	10	10	0	125
P13	-	2.68	6.9	7850	4580	10	25	0	125
P14	10	1.85	6.7	850	403	10	25	0	125
P15	10	1.9	7.65	3200	1830	0	25	6	350
P16	15	-	-	-	-	-	-	-	-
P17	12	1	6.6	740	337	10	15	0	125
P18	10	1.42	6.6	1200	591	10	15	0	125
P19	10	-	-	-	-	-	-	-	-
P20	17	4.1	6.8	1160	573	10	25	0	125
P21	15	4.57	6.9	1790	850	25	25	0	125
P22	12	3.14	6.8	1240	583	10	10	0	125
P23	18	3.15	6.9	1070	526	10	10	0	125
P24	13	4.43	7	1510	756	250	15	0	125
P25	13	3.83	7	1060	522	15	25	0	125
P26	17	1.85	6.6	740	356	10	10	0	125
P27	-	4.4	6.8	930	452	10	10	0	125
P28	13	2.3	6.6	850	419	10	25	0	125
P29	13	5.5	7	870	426	10	10	0	125
P30	7	7.75	6.7	880	432	10	10	0	125
P31	5	2.1	6.6	1000	490	10	10	0	125
P32	-	3.5	7	1250	619	10	10	0	125
P33	5	2.3	6.97	1090	419	10	10	0	125
P34	7	3.03	6.75	2710	1430	10	10	0	125
P35	16	4	6.9	1060	521	10	10	0	125

P36	16	3.16	6.8	910	438	10	15	0	125
P37	15	-	-	-	-	-	-	-	-
P38	-	-	-	-	-	-	-	-	-
P39	15	2.85	6.78	900	441	10	25	0	125
P40	14	4	6.9	2220	1140	10	25	0	125
P41	18	0.8	6.1	2330	1200	250	10	0	125
P42	7	-	-	-	-	-	-	-	-
P43	16	4.35	6.9	2020	1010	10	25	0	125
P44	-	-	-	-	-	-	-	-	-
P45	3	2.35	7.8	3700	2200	500	25	0	125
P46	3	-	-	-	-	25	5	0	80
P47	3	6.1	8.2	4930	3160	250	5	0	80
P48	3	6.66	8.16	2500	1300	10	10	0	80
P49	3	5	7.3	15320	7455	-	-	-	-
P50	3	0.85	7.6	7170	4700	0	0	6	125
P51	4	2.6	6.27	3250	1840	10	10	0	125
P52	3	2,35	6,95	2610	1380	100	10	0	125
P53	22	2.35	6.95	2610	1380	10	10	0	125
P54	5	2.75	6.84	2770	1470	10	10	0	125
P55	12	2.15	6.75	1090	545	10	25	0	125
P56	7	1.81	6.75	1160	572	10	10	0	125
P57	2	1.9	6.6	1340	670	10	10	0	125
P58	3	4	7.1	1170	579	10	10	0	125
P59	4	2.4	6.75	1660	840	10	10	0	125
P60	22	2.75	7.2	115	147	15	10	0	125

B. River Rio Escalante Samples data

River location	DO (mg/l)	EC (µS/cm)	TDS (ppm)	pH	NO3 (ppm)	PO4 (ppm)
RE1	7.6	668	338	8.1	50	10
RE2	7.8	680	337	8.1	50	10
RE3	6.5	690	510	7.9	10	10
RE4	5.5	670	357	7.25	10	10
RE5	8.6	940	534	7.58	10	25
RE6	8.76	730	406	7.26	10	10
RE7	8.1	1170	1200	7.86	10	50
RE8	7.5	3190	2150	8.4	10	35
RE9	8.5	5260	4060	8.19	10	0
RE10	8.4	5750	4100	8.19	10	0
RE11	8.6	5810	4040	8.21	10	30
RE12	8.4	3820	2540	8.8	0	10
RE13	8.3	6410	4460	8.17	10	25
RE14	8.6	6360	4420	8.2	10	0
RE15 WB	8	3990	2680	8.5	0	0
RE15I	8.9	6160	4540	8.24	10	25
RE16	8.4	6140	4580	8.18	0	25
RE17 WB	8.6	3930	2660	8.5	10	0
RE18 WB	8.9	3850	2610	8.5	0	10

C. Rio Escalante Hypereutrophic state

Figure19. Pictures showing the hypereutrophic state of the river Rio escalante. Algae overgrowth can be seen from the distinct green coloration of the water body.

D. Grey Waters

Figure 20. Total Coliform samples taken at T_0, start of the incubation time. The last sample on the right is the control. Numbers refer to the geographic marked location point in the GPS map. Test kits from "La Motte Ltd."

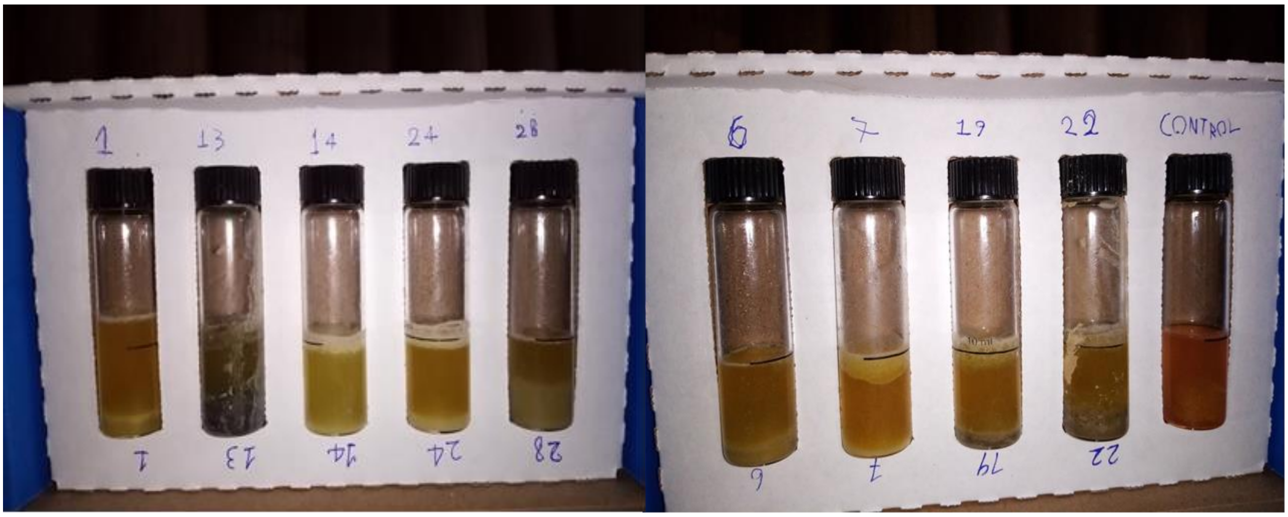

Figure 21. Total Coliform samples at T_f, the end of the incubation period of 48 hrs, all samples show a change in pH indicated by the yellow coloration and a gas layer on the water surface as sign of Coliform presence. Test kits from "La Motte Ltd."

E. Electric Conductivity and Total Dissolved Solids

Electric Conductivity (EC) and Total Dissolved Solids (TDS) are two parameters that can measure the Salinity of the water. EC is measured in micro-Siemens per centimetre (µS/cm and TDS in parts per million (ppm). According to *(Hubert E. & Wolkersdorfer C., 2015.)* there is a relationship between the two parameters and a conversion factor can be calculated. Thus, to test the reliability and precision of the instruments used for the EC (pH-EC meter EC-3587 from *RoHS)* and TDS (*Original Xiaomi TDS Water Tester Pen*.) measurements. Therefore the relationship between the two parameters is tested in Sigmaplot, with the data obtained from the wells water of El Astillero.

Results from the regression, obtained with the data of the wells' samples n = 60, show a strong positive linear relationship with a correlation of r = 0.98 **(fig.20)**. The correlation factor is on average 0.52.

Concluding, since the data obtained from the regression and the conversion factor show similar results to *(Hube.rt E. & Wolkersdorfer C., 2015.),* which leads to the indication that both instruments provide reliable readings of their respective parameter of EC and TDS.

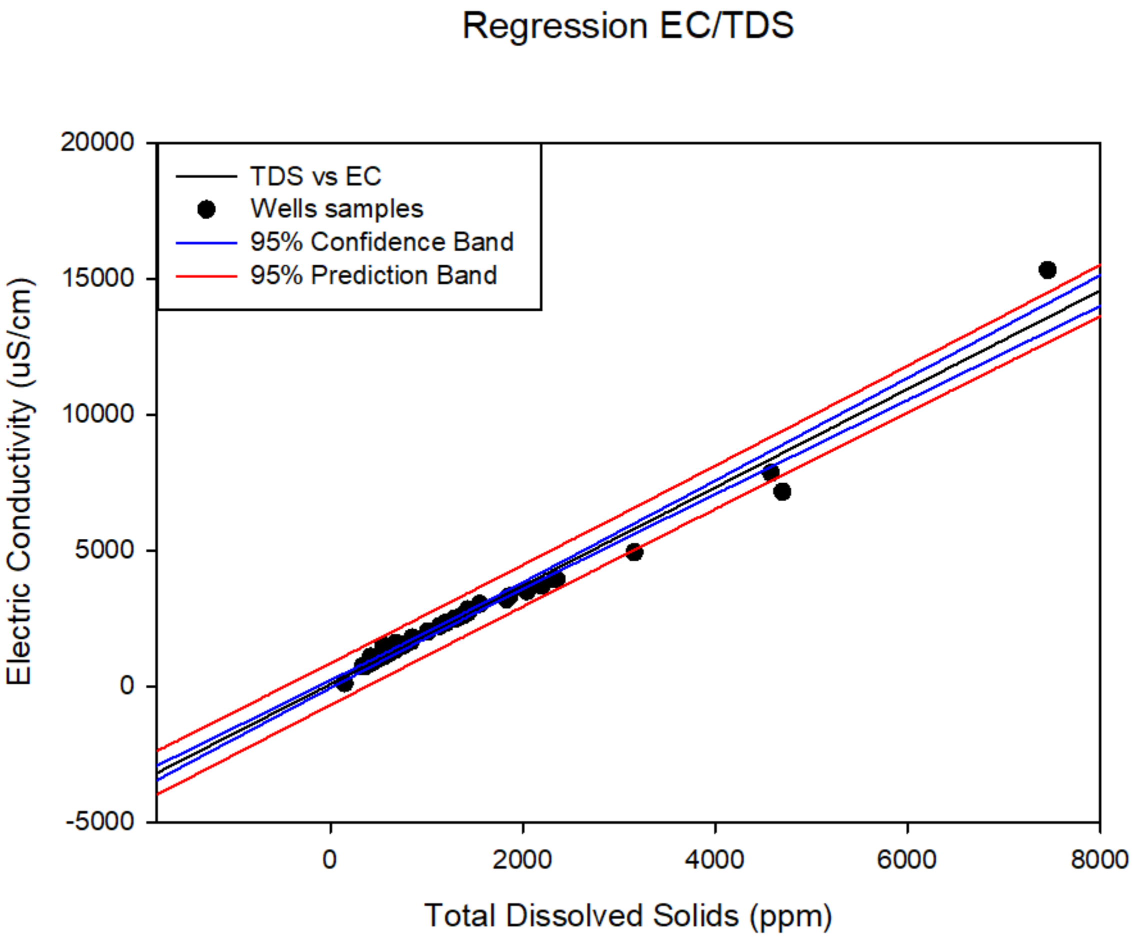

Figure 20. Regression EC/TDS for the wells samples data n=60