Ausa river: a study-case towards the comprehension of natural processes and anthropic impacts

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1. Abstract

This project focuses on the determination of the quality of the river Ausa in Cervignano del Friuli (Italy), in order to study the trend of some parameters along the river and to verify the compliance with the environmental recommendations coming from European Directives and Italian Laws. We decided to analyze both the river Ausa and its main tributary Taglio, in order to look for similarities between them and to study how their characteristics vary seasonally at each site and along the axis, especially after the impact of the town.

We first gave a general characterization of the water using parameters such as temperature, pH and conductivity, then we focused on the amount of **nitrates**, since their excess can cause **eutrophication** on the Marano and Grado Lagoons, where our river flows into. Moreover, we performed a microbiological survey with *Escherichia Coli* test, that is one of the recommended measures to do on water used for recreational activities, since its presence is related to **fecal contamination**.

We used the GLOBE protocols to select the sites for sampling and to perform our analyses of pH, temperature, conductivity and nitrates. For nitrates we also used a lab spectrophotometric method-kit. *E.coli* was determined by growth on a selective commercially available test-kit.

The results of the campaign are significant: they provide useful information on natural trends and seasonally related phenomena. Besides, they depict a very low quality of the water. Our data have been shared with local authorities. The European Community has given an infraction procedure to the city of Cervignano for the violation of the Directive 91/271 CEE, which deals with the water treatment plants. In some areas, in fact, these plants haven't been realized yet. We are going to start a new set of analyses when the improvements on the sewage systems are finished.

2. Research questions

The aim of this project is to investigate the quality of the water of the river Ausa, which flows in Cervignano del Friuli (Italy), the town where we live and where our school is situated (Lat 45.821617, Long 13.333381).

We performed our analyses during all the year, in order to collect a large amount of data and to properly characterize the water. In this way, we had a clear idea about the situation of the river, which is used both for recreational activities and agriculture.

a. Background information – Review of the literature

Our Region Friuli – Venezia Giulia is geographically characterized by mountains – the Alps - in the North, a hill area, and a plain that after few km goes into the Adriatic Sea (Fig. 1).

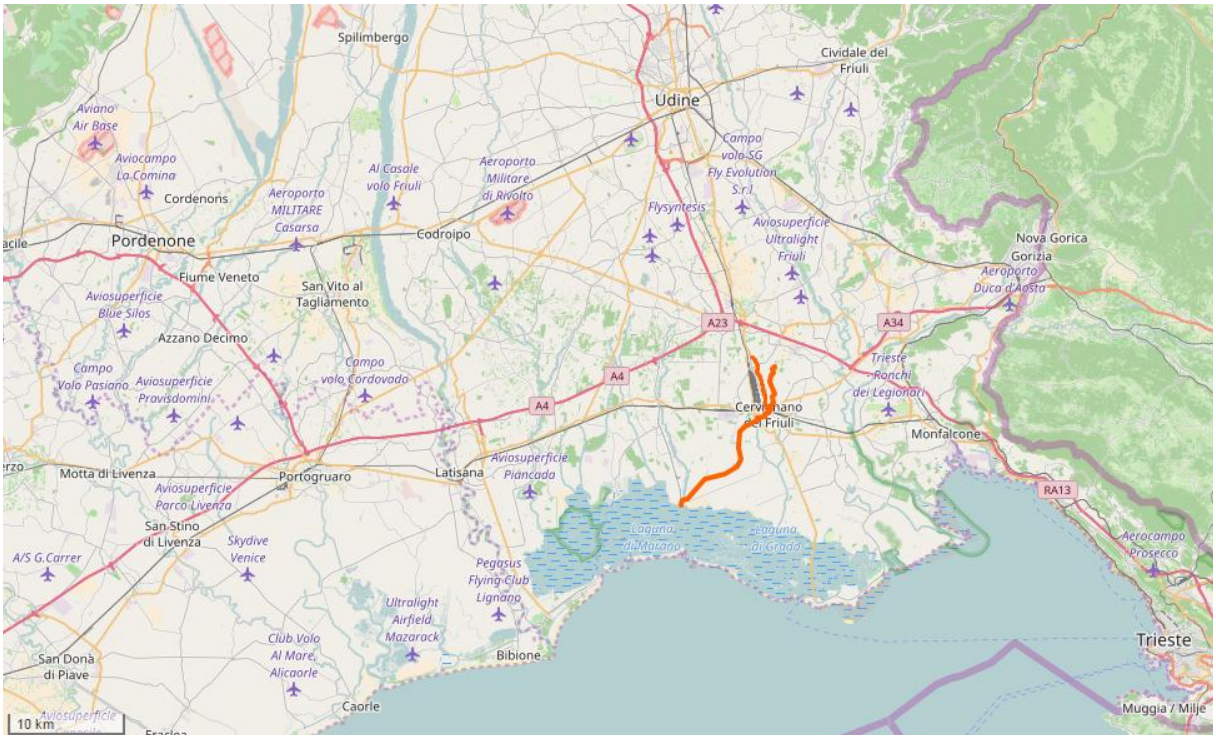


Fig. 1 – Region Friuli Venezia Giulia – Italy. In red: Ausa and Corno rivers, topic of the study-case.

As far as the climate is concerned, Friuli is characterized by abundant precipitations at the mountains, that form several rivers. While these rivers are flowing towards the sea, they find a permeable soil and percolate underground, forming many reservoirs of water. For this reason, in the central part of the region there are only a few rivers. When these rills arrive in our area, they find impermeable rocks, so they have to come out to the surface again (Fig. 2) This phenomenon, whose Italian name is "Risorgiva", is responsible for the formation of several rivers in our area, and, in particular, of the river Ausa. For this reason, we don't know exactly the origins of the river Ausa, which is the result of the union of several little rills.

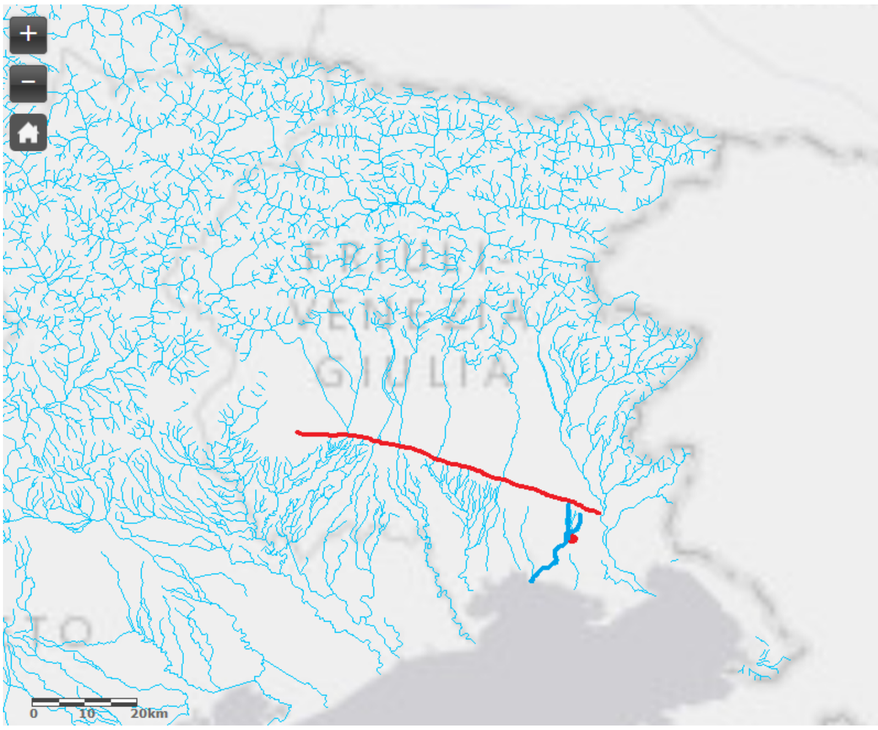


Fig. 2 – Region Friuli Venezia Giulia – Italy.

The red line: "Risorgive"line

The blue lines: the rivers (Ausa and Corno are highlighted)

The red dot: the town of Cervignano del Friuli

Even though it is not the only one, the official source of the Ausa is in Novacco village, where the rills Sobresco and Barisada join together. Then, the river flows collecting water from other little streams, until the confluence to its main tributary: the river Taglio. In this place, it enters the town of Cervignano del Friuli to cross it entirely. Leaving the town center, the Ausa courses towards the sea, joining other rivers and finally flowing into the biggest river Corno in the industrial area named "Ausa-Corno".
On its whole, the river covers 22 km, and its flow rate is about 45 m^3/s. At the end, the Ausa flows into the Marano Lagoon, into the Adriatic Sea.
The "Marano and Grado Lagoon" has been identified in 2005 as Site of Community Importance (SIC IT3320037), because of its relevance as natural habitat for plants and fauna, as the European Community Directives require. Moreover, the Italian law recognized in 2006 the Adriatic Sea as "Sensible area", in order to control the nutrients and the amount of pollutants, because of the shallowness of the sea and the limited circulation of water.
ARPA-FVG, our local environmental agency, conducted a study in which is given to the river Ausa a "sufficient" ecological status. In its official document, published in 2013, ARPA examined some chemical parameters, only studied in a single site situated before the entry of the river in the town. In this paper, the amount of nitrates is higher than 20 mg NO_3^-/L. Since the river Ausa flows into a lagoon, an high amount of nitrates may cause eutrophication phenomena and lead to algae blooms, and affect considerably the sea. The primary source of nitrates in surface waters is the runoff from agricultural areas that have received too much nitrates fertilizers. So, we decided to investigate this parameter to better understand the presence of this pollutant into our river. Then, we analyzed the effectiveness of the EU Nitrates Directive (91/676/CEE), whose aim is to protect water quality across Europe by preventing nitrates from agricultural sources polluting ground and surface waters, and by promoting the use of good farming practices.
Moreover, we know that in our Region Friuli-Venezia Giulia only the 47,9% of the total sewage amount is properly treated in water treatment plants, as an ISTAT (National Institute of Statistics) study reports (3b). As a matter of fact, several towns in our area don't follow the European laws on the quality of water and its treatment, and, among these towns, also Cervignano del Friuli has broken the law, in particular the 3rd article of the directive 91/271 CEE, which deals with the water treatment plants (3c). Since in the last years our school has performed chemical and microbiological analyses on the river Ausa (4), we already knew about a certain level of microbiological pollution, due to the sewage coming directly into the river. To study this kind of issue, we can usually consider several parameters that characterize a sewage, such as COD and BOD: they both show the amount of organic oxidizable matter in water. Otherwise, we can consider the amount of NH_3 present, which comes from the biodegradation of organic nitrogen, as well as the microbiological content of the water, in particular the amount of Escherichia coli. Since these microorganisms are present in human feces, their presence in the river would point out a pollution due to a bad sewage treatment. For this project, we decided to perform a monitor campaign on this phenomenon, in order to collect more data and to definitely understand the real risk related to the recreational uses of the Ausa river and to understand whether an agriculture employment of its water could be safe. By the way, in the document of ARPA-FVG no microbiological data are described.

b. Research plan

Considering the Background information, we decided during our campaign to investigate the following parameters:

- **General parameters**:

pH, temperature and electrical conductivity, measured according to Globe Protocols.

- **Indicators of pollution:**
  Nitrates, analyzed according to Globe Protocols, and verified in lab with an UV-VIS spectrophotometric method
- Escherichia coli, analyzed by growth on a selective commercially available test-kit

We also decided for a certain number of sampling sites, located along the axis of Ausa and Taglio rivers, from the sources to the exit from the town of Cervignano. In this way we could improve the investigation provided by our local protection agency, which was referred to the above mentioned single site.

The campaign started in November 2015. We decided to repeat the samples at the same sites periodically, in order to notice seasonally related phenomena, that could tell us more about the situation and the nature of the pollution.

We collected the data, taking care in not forcing towards premature conclusions, just tabulating the data or putting into the Globe site. We expected, after this long-term data collection, to have an answer to these questions:

- How can we describe the complexity along the axis of the river? Can we characterize the water through general parameters such as pH, conductivity and temperature? Are there similarities between the waters of Ausa river and its tributary Taglio? How these characteristics vary when they join together? Are these parameters sufficient to prove the human impact (changes before and after the town?)
- How does the content of nitrates change during the flow of the two streams? Can we notice an increase along the river, due to agricultural runoff? Or can we notice a loss of quantity, due to natural depuration phenomena related to the Nitrogen Cycle? What about the actual concentration of nitrates that flows towards the Lagoon?
- How is the status of the river, as far as the microbiological aspects are concerned? Are there problems related to the lack, or the inadequacy, of the sewage systems? Are the waters safe for recreational or agricultural uses?
- Can we compare the values to the law limits?

3. Research methods

a. Study site

First of all, we decided to focus on the part of the river Ausa and Taglio that goes from the source to the exit from Cervignano area. So, we located 11 sites both along the river Ausa and Taglio, in order to obtain a trend of the variability of the parameters along their flows first, and to analyze the change of the water characteristics at the confluence.

• Site 1: Novacco – Ausa sources	45° 51' 37,6'' N 13° 20' 37,2'' E 45,8604 N 13,3404 E
• Site 2: Pradulin – Ausa enters Cervignano	45° 49' 50,5" N 13° 20' 25,6" E 45,8307 N 13,3404 E
• Site 1’: Strassoldo – river Taglio	45° 51' 42,2" N 13° 19' 25,5" E 45,8617 N 13,3237 E
• Site 2’: Muscoli – river Taglio	45° 50' 20,5" N 13° 19' 59,4" E

45,8390 N 13,3331E

- Site 3’: River Taglio enters Cervignano — 45° 49' 47,9" N 13° 20' 01,0" E
  45,8299 N 13,3332 E
- Site 4: Confluence Ausa – Taglio — 45° 49' 36,5" N 13° 20' 20,6" E
  45,8268 N 13,3391 E
- Site 5: Cervignano city center — 45° 49' 26,6" N 13° 20' 06,5" E
  45,8241 N 13,3389 E
- Site 6: Cervignano bridge — 45° 49' 27,9" N 13° 20' 02,1" E
  45.8244 N 13.3389 E
- Site 7: Right bank of the Ausa — 45° 49' 22,1" N 13° 19' 53,6" E
  45.8228 N 13.3316 E
- Site 8: Left bank of the Ausa — 45° 49' 16,0" N 13° 19' 43,9" E
  45.8228 N 13.3289 E
- Site 9: Ausa leaves the city center — 45° 49' 15,9" N 13° 19' 38,3" E
  45.8211 N 13.3273 E

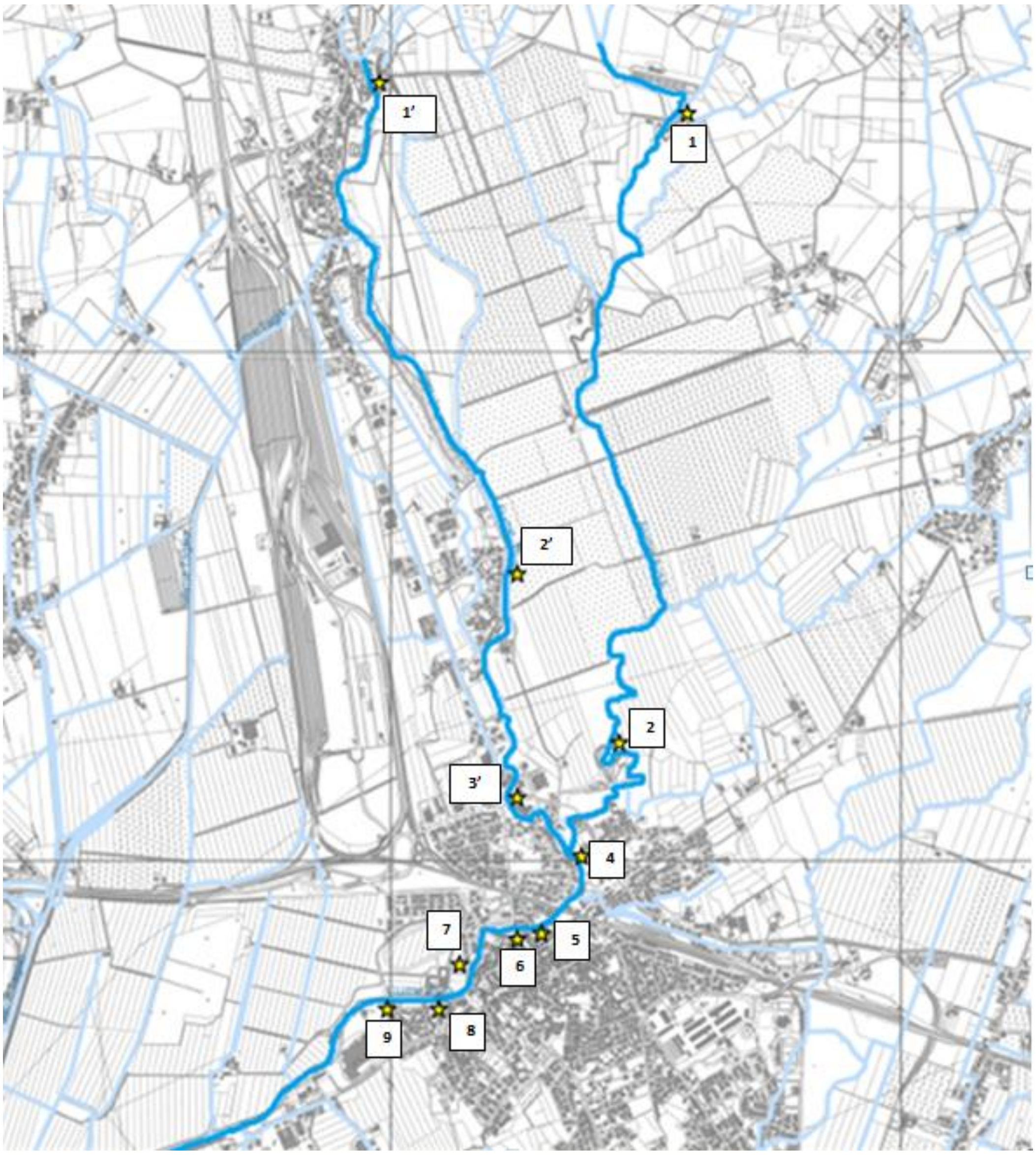


Fig. 3 – Sampling sites along Ausa and Taglio rivers

A localization of the sites is described in Fig. 3. According to the suggestions coming from the GLOBE Protocols, while identifying our stations, we tried to consider significant areas, in order to draw attention to specific characteristics of the river. In particular, we wanted to analyze the sources to better understand the quality of water before it could be contaminated by the impact of the city. Then, we looked for a balance between the data of the different rivers examining the confluence Ausa – Taglio. Moreover, in this area the water from the river is used to irrigate some vegetable gardens, so we wanted to check the quality of this water. Otherwise, as the city center is concerned, the two stations on the two banks are situated next to two drains, to look for a possible microbiological contamination due to a bad sewage treatment.

b. Sample Collection, Preservation, and Storage

Sampling techniques as described in GLOBE Protocols were used for physical-chemical parameters, while suggestions coming from Method EPA 1103.1 for Escherichia coli were used for the Microbiological samples. The analyses began immediately, preferably within 2 hours of collection. Samples were processed in the same date of collection.

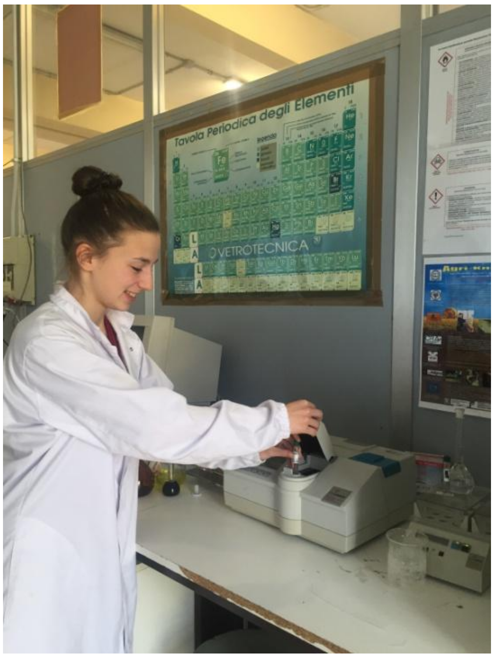
The samples were collected in double or in triple, in order to always obtain more than one data per each parameter, and to provide an average data as representative of the water at the site of sampling.

c. Data collection

pH, Temperature, Electrical conductivity
The Globe Protocols have been used on field to measure temperature, pH, electrical conductivity. We used a portable pH-meter and a conductimeter equipped with a temperature probe (both ORION Scientific).

Nitrates
As far as the Nitrates parameter is concerned, we also conducted the measurements following the Globe Protocol as we shared in Italy (Italian schools normally use Hach kit for Nitrates). For this parameter, we would like to point out that:
- in the GLOBE program, concentrations of Nitrates are expressed as the amount of elemental nitrogen in the form of nitrate, i.e. are expressed as nitrate-nitrogen (NO_3--N) in milligrams per liter.
That's a problem for us, because the Italian Law and the European Directives both express the limits in mg NO_3^-/L. For this reason, in this report, we will refer to the amount (mg) of Nitrates per liter.
- the field-kit for Nitrates, especially if the waters are not clear, often gives under-estimated values. That's the reason why we decided to verify the values by comparison with a well-tested laboratory kit based on a spectrophotometric UV – VIS measurement (LCK 339 HACH LANGE). The principle of the method is that nitrate ions in solutions containing sulphuric and phosphoric acids react with 2.6-dimethylphenol to form 4-nitro-2.6-dimethylphenol (which has a pink colour). The cuvette (containing the pink solution) is placed in the spectrophotometer, which gives us the result in mg/L of NO_3^-.
In this report we used only the data obtained with this test, which is considered more reliable.
Protocol:
1. Slowly pipette 1.0 mL sample.
2. Slowly pipette 0.2 mL solution LCK 339 A.
3. Close cuvette and invert a few times until no more streaks can be seen.
4. After 15 min thoroughly clean the outside of the cuvette and evaluate through spectrophotometric measurements, record data on the Data Sheet.

Fig. 4 – Analysis of Nitrates – Method LCK 339 HACH LANGE



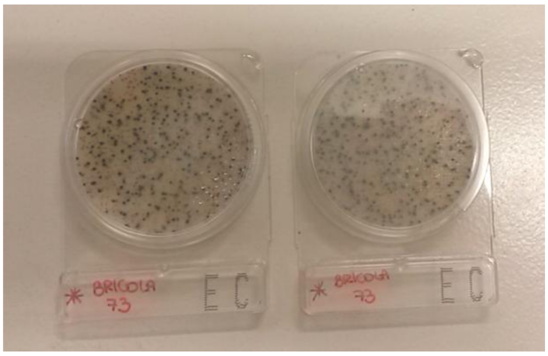


Fig. 5 – E. Coli analysis

Escherichia Coli

Escherichia coli has been analyzed using Compact Dry EC provided by International PBI.
Compact Dry EC is a medium for E.coli and Coliforms. The medium contains two kinds of chromogenic enzyme substrates: Magenta-Gal and X-Gluc. E.coli forms blue colonies, whereas the total Coliform group count is given by the sum of the red and blue colonies.

P*rotocol:*

1.Sow 1 mL of the water sample in Compact dry EC using a sterile pipette.
2.Put the Compact dry EC in the stove at 37°C for 24 hours.
3.Count only the blue colonies, express the result in UFC/100mL and record the data on the Data Sheet.

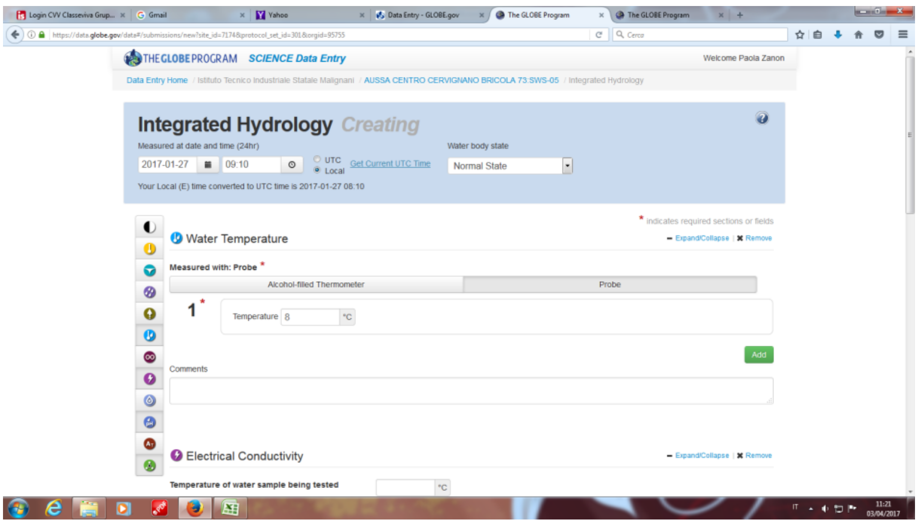
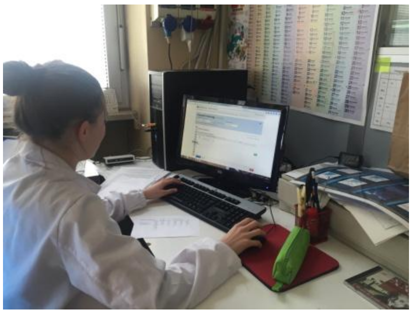


Fig. 6 – Print screen of data entry in the Web page of GLOBE.



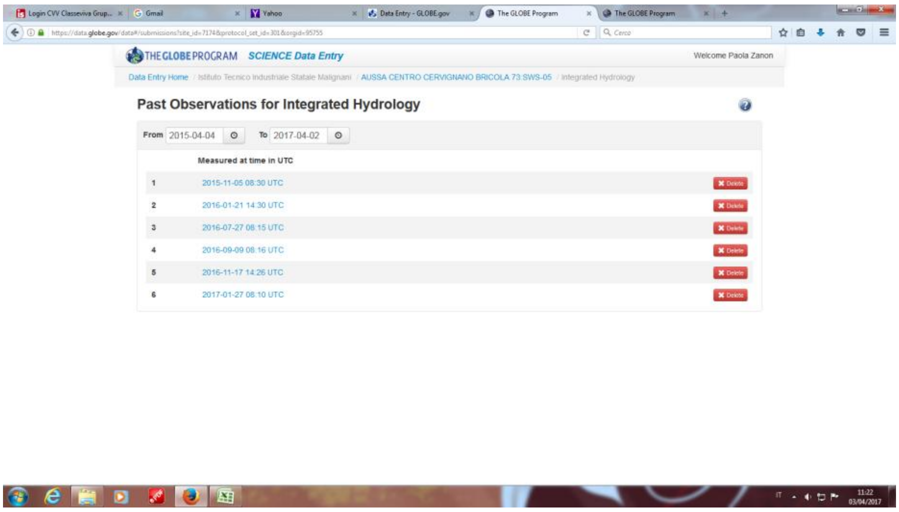


Fig. 6' – Print screen of data entry in the Web page of GLOBE.

4. Results

Site 1: Novacco - Ausa sources	45° 51' 37,6'' N 13° 20' 37,2'' E				
	15.04.2016	27.07.2016	09.09.2016	17.11.2016	27.01.2017
pH	7,71	7,79	7,44	7,66	7,53
Conductivity (µS/cm)	492	552	539	498	422
Nitrates (mg/L)	24,5	25,2	24	25,8	29
E. Coli (UFC/100 mL)	<100	800	400	200	200

Site 2: Pradulin - Ausa enters Cervignano	45° 49' 50,5'' N 13° 20' 25,6'' E					
	05.11.2015	21.01.2016	27.07.2016	09.09.2016	17.11.2016	27.01.2017
pH	7,71	7,93	7,76	7,59	7,60	
Conductivity (µS/cm)	502	486	485	475	434	363
Nitrates (mg/L)	19,4	19,0	19,0	17,9	19,2	
E. Coli (UFC/100 mL)	1400	1600	400	200	400	100

Site 1': Strassoldo - river Taglio	45° 51' 42,2'' N 13° 19' 25,5'' E					
	05.11.2015	21.01.2016	27.07.2016	09.09.2016	17.11.2016	27.01.2017
pH	7,52	7,88	7,70	7,52	7,64	7,73
Conductivity (µS/cm)	552	534	532	514	454	417
Nitrates (mg/L)	26,1	28,9	23,7	23,3	19,5	30,2
E. Coli (UFC/100 mL)	600	1400	1000	1100	1400	900

Site 2': Muscoli - river Taglio	45° 50' 20,5" N 13° 19' 59,4" E					
	05.11.2015	21.01.2016	27.07.2016	09.09.2016	17.11.2016	27.01.2017
pH	7,55	7,68	7,60	7,42	7,62	7,76
Conductivity (µS/cm)	530	489	502	493	444	384
Nitrates (mg/L)	25,0	24,7	23,0	21,8	22,9	25,0
E. Coli (UFC/100 mL)	1500	370	1800	1000	2800	800

Site 3': River Taglio enters Cervignano	45° 49' 47,9" N 13° 20' 01,0" E					
	05.11.2015	21.01.2016	27.07.2016	09.09.2016	17.11.2016	27.01.2017
pH	7,67	7,73	7,64	7,46	7,62	7,80
Conductivity (µS/cm)	526	463	500	488	441	381
Nitrates (mg/L)	24,3	24,0	22,8	22,3	22,5	24,6
E. Coli (UFC/100 mL)	2500	6000	1400	3000	4300	1600

Site 4: confluence Ausa - Taglio	45° 49' 36,5" N 13° 20' 20,6" E					
	05.11.2015	21.01.2016	27.07.2016	09.09.2016	17.11.2016	27.01.2017
pH	7,70	7,85	7,79	7,54	7,72	7,87
Conductivity (µS/cm)	511	473	492	480	435	373
Nitrates (mg/L)	20,6	21,4	20,9	21,4	20,8	22,0
E. Coli (UFC/100 mL)	1100	2100	1600	3100	2000	2100

Site 5: Cervignano city center	45° 49' 26,6" N 13° 20' 06,5" E					
	05.11.2015	21.01.2016	27.07.2016	09.09.2016	17.11.2016	27.01.2017
pH	7,73	7,89	7,74	7,60	7,76	7,90
Conductivity (µS/cm)	501	462	482	440	426	362
Nitrates (mg/L)	20,8	19,8	20,0	19,7	20,5	20,9
E. Coli (UFC/100 mL)	3200	2800	2200	2800	3800	3700

Site 6: Cervignano bridge	45° 49' 27,9" N 13° 20' 02,1" E					
	05.11.2015	21.01.2016	27.07.2016	09.09.2016	17.11.2016	27.01.2017
pH	7,66	7,96	7,76	7,64	7,82	7,85

Conductivity (µS/cm)	502	462	481	457	426	379
Nitrates (mg/L)	20,4	18,8	20,0	19,7	19,8	21,0
E. Coli (UFC/100 mL)	3200	3200	2200	5100	3000	4000

Site 7: right bank of the Ausa	45° 49' 22,1" N 13° 19' 53,6" E					
	05.11.2015	21.01.2016	27.07.2016	09.09.2016	17.11.2016	27.01.2017
pH	7,76	7,87	7,80	7,63	7,76	7,92
Conductivity (µS/cm)	504	473	482	466	428	463
Nitrates (mg/L)	20,2	19,3	19,8	19,7	19,4	20,5
E. Coli (UFC/100 mL)	8800	13700	41600	52600	33000	12100

Site 8: Left bank of the Ausa	45° 49' 16,0" N 13° 19' 43,9" E					
	05.11.2015	21.01.2016	27.07.2016	09.09.2016	17.11.2016	27.01.2017
pH	7,73	7,83	7,75	7,63	7,76	7,84
Conductivity (µS/cm)	496	1152	479	576	422	586
Nitrates (mg/L)	19,8	19,0	19,8	18,5	19,3	20,1
E. Coli (UFC/100 mL)	18000	11300	13000	57200	9000	7000

Site 9: Ausa leaves the city center	45° 49' 15,9" N 13° 19' 38,3" E					
	05.11.2015	21.01.2016	27.07.2016	09.09.2016	17.11.2016	27.01.2017
pH	7,73	7,91	7,73	7,65	7,86	7,84
Conductivity (µS/cm)	501	1356	480	976	428	676
Nitrates (mg/L)	20,2	18,2	19,4	19,2	19,6	19,9
E. Coli (UFC/100 mL)	6700	8900	4400	6600	5700	5600

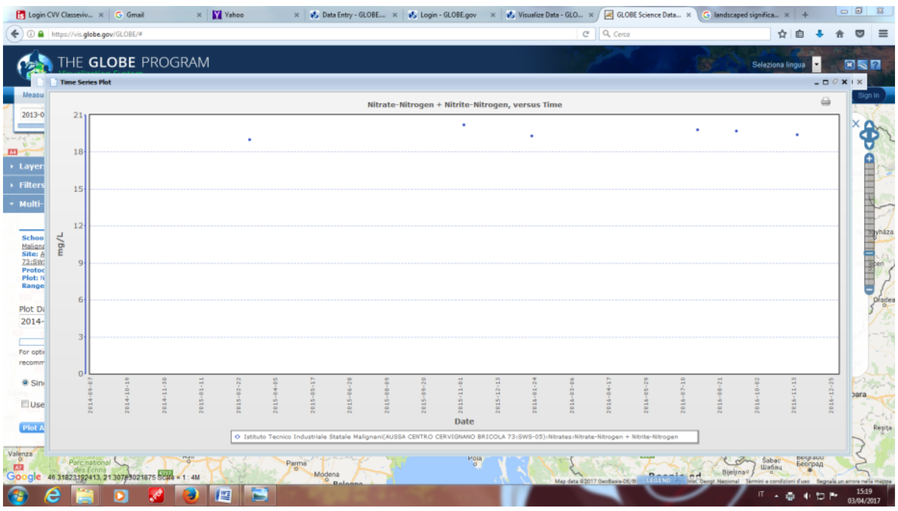
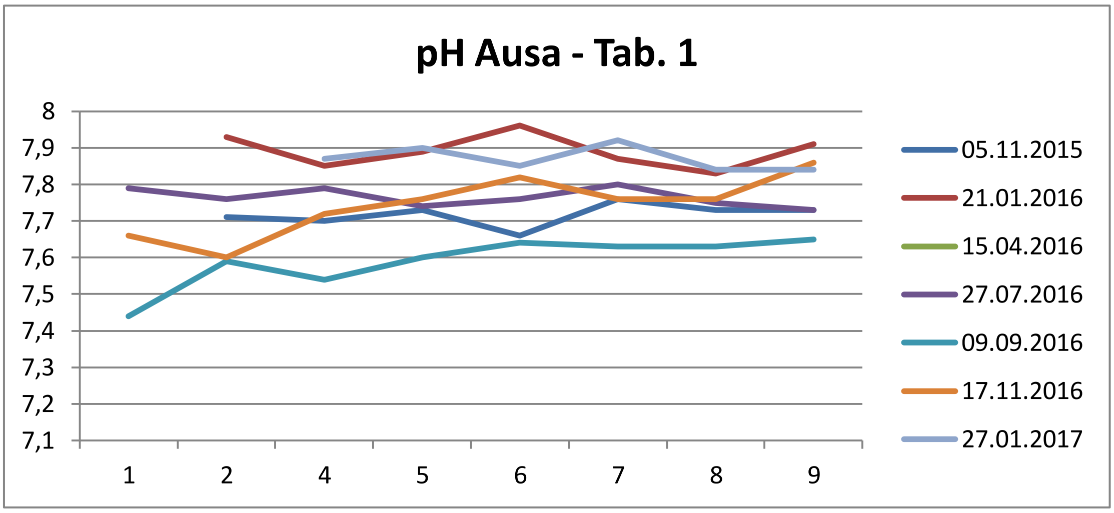
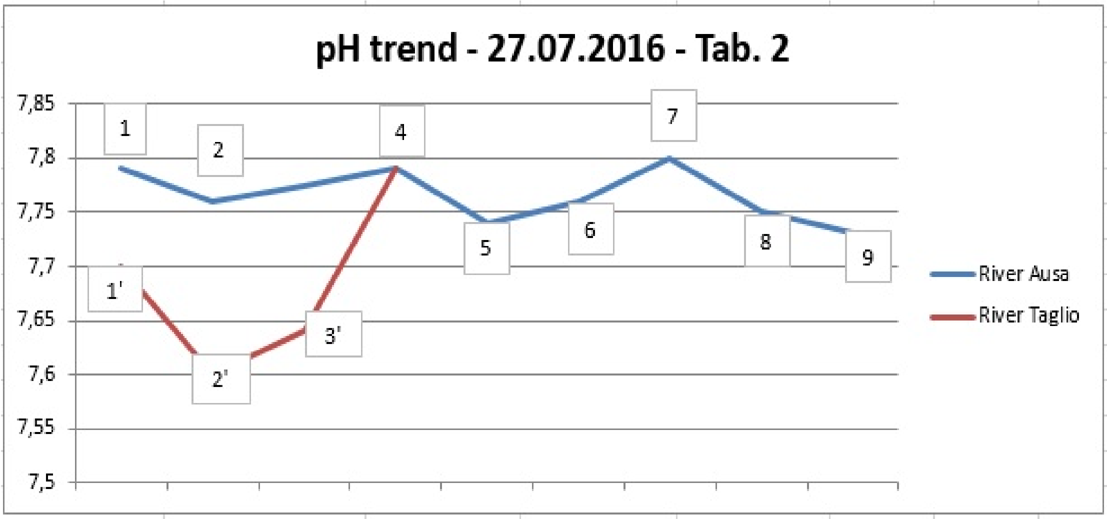


Fig. 7 – Print screen of data visualization in the web page of Globe

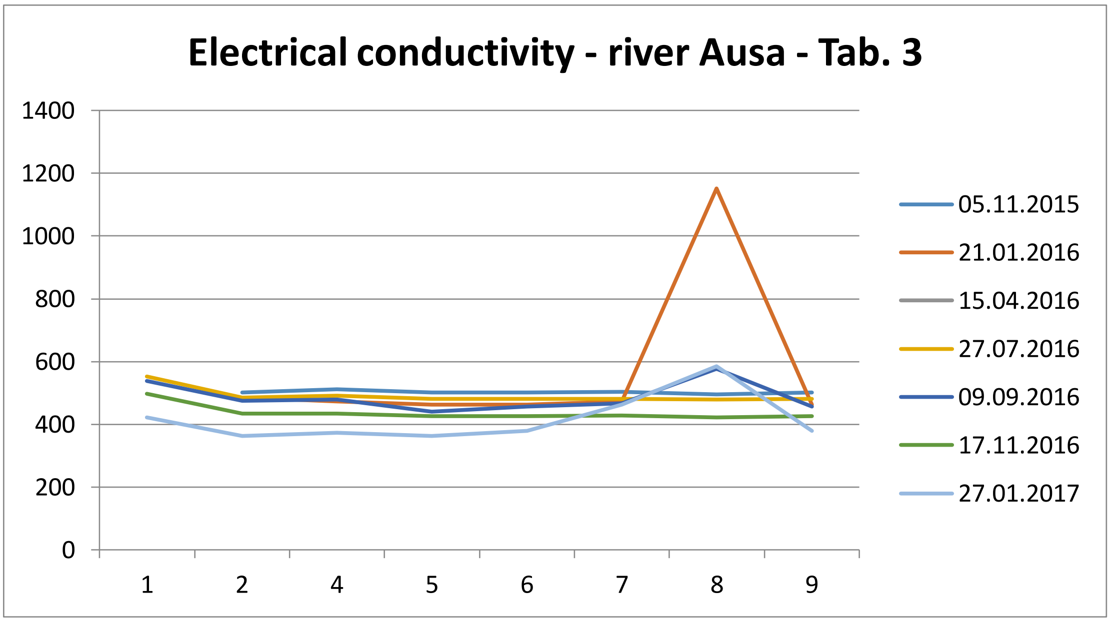
5. Discussion



Tab. 1 describes the trend of pH in the study sites on the river Ausa during the different samplings on the different days. Examining this graphic, it is possible to notice a quite regular tendency. In fact, pH is always variable between 7,5 and 7,9 units. Besides, the variability is higher among the different dates than among the sites, maybe because of different dilution situations.
Every sample has a slightly basic pH, possibly due to the fact that the soil of our area is rich in carbonates, so we can aspect to have high levels of bicarbonates in the water.



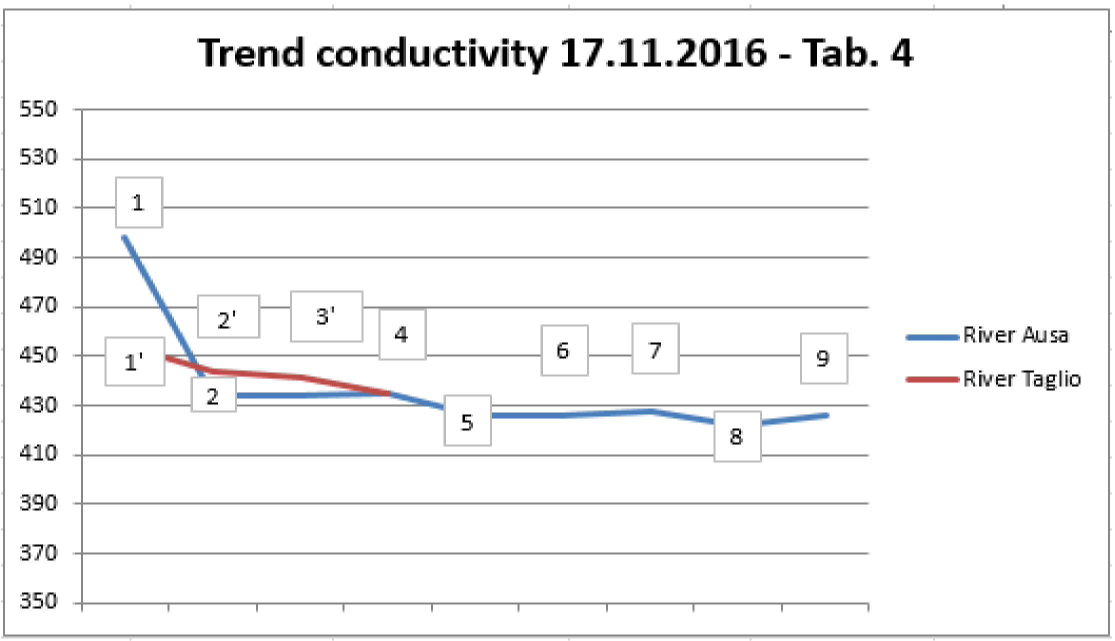
Otherwise, Tab. 2 describes the trend of pH in the rivers Ausa and Taglio during the same date.
Here, you can see the differences between the two rivers, that evidently come from different sources (different water reservoir in the subsoil), even if the springs are really nearby. After the confluence of the two streams, the pH is mainly determined by the river with the largest flow.



As far as electrical conductivity is concerned, then, in Tab. 3 we can observe that the water contains a moderate amount of minerals, that results in a conductivity of about 400-500 μS/cm.

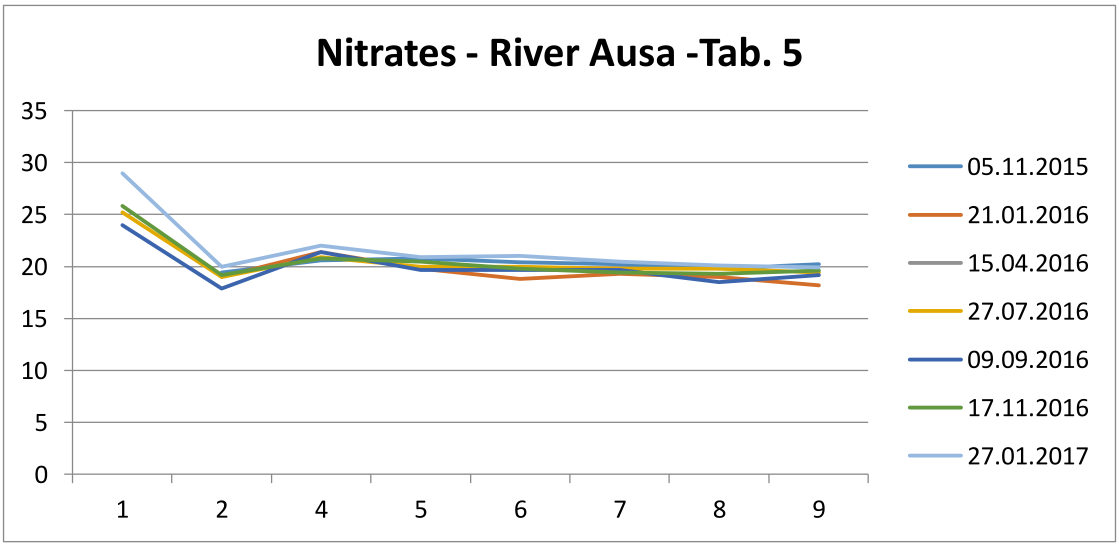
Nevertheless, in some analyses the conductivity is really high (more than 1000 μS/cm), but only in the stations downstream the city center. These results, paired with a rapid qualitative chloride research, that confirmed a high level of Cl^-, are probably caused by the come-back of water from the sea (and so rich in salts) during the high tide periods. The town of Cervignano, in fact, is only 2 meters above the sea level, and is located in an area that often goes under the zero level.

As our sample is instantaneous and not representative, we had this result only sometimes, according to the period of the tides.

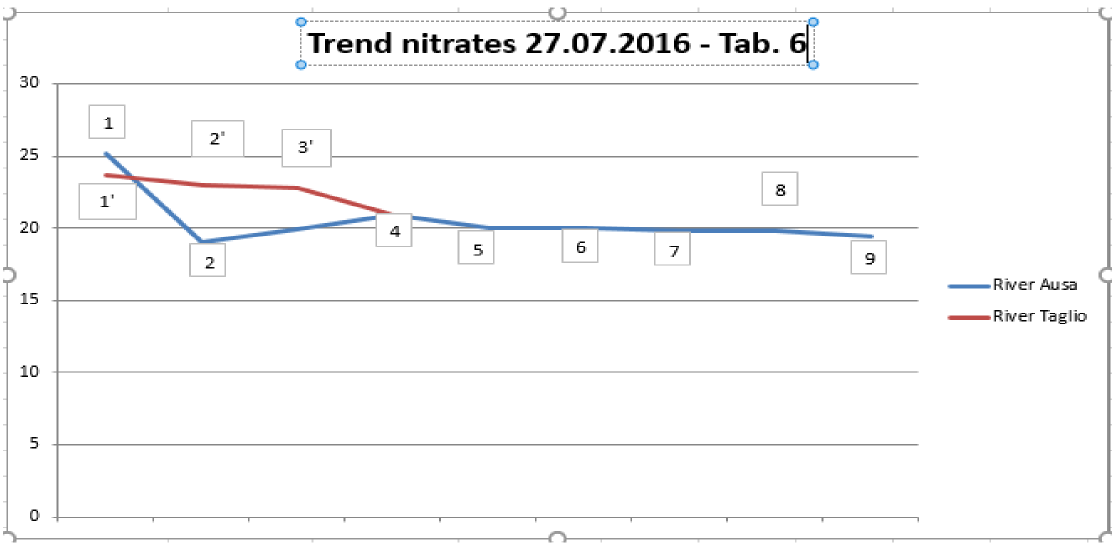


In Tab. 4, then, we can see that the content in salts in the sources is higher than in the last study sites. This trend may be caused by a dilution of the water due to the atmospheric precipitations, or, more likely, to an absorption of part of the ions by the aquatic plants.

The trends of conductivity are strictly connected to the nitrates ones. In fact, also in this case it is possible to see a constant decrease in the amount of NO_3^- . Since the runoff from our agricultural area doesn't affect the total amount of nitrates, their presence must be due to other sources.

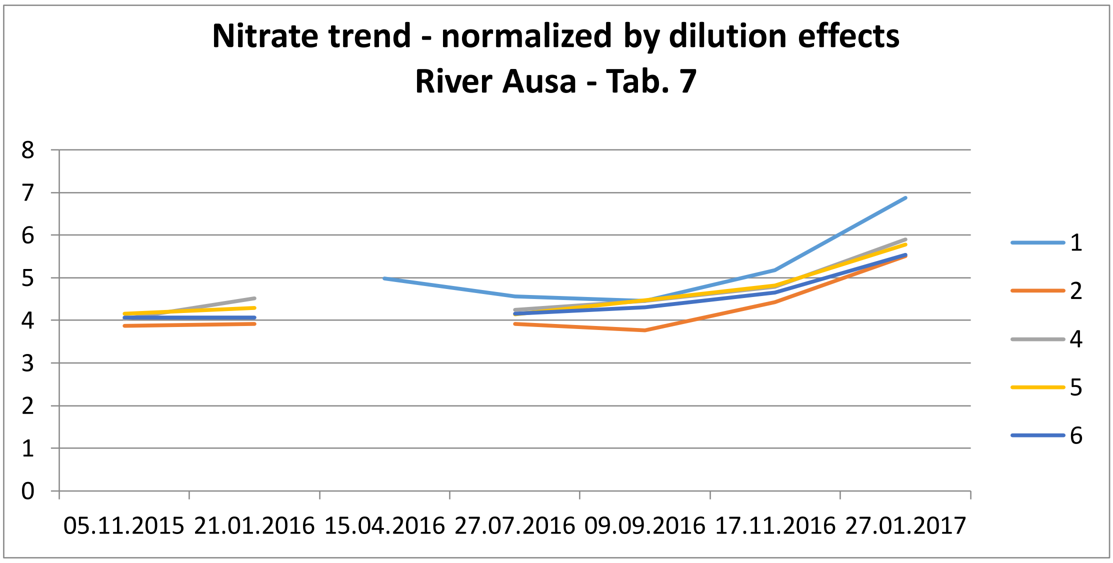


It's very interesting to notice that the waters at their springs have higher content of nitrates than the in the other parts of the axis: it means that our waters are seriously polluted in underground reservoirs. In this case, we must consider the morphology of our territory. In fact, the waters, due to the differences in the permeability of the soil, in the medium of the Plain of the Region Friuli Venezia Giulia percolate underground for a long trait, and naturally flow again on the surface in our area. In this underground trait, water is affected by the several substances contained in the soil. In particular, the land of our area is used to plant crops, so the soil is rich of pesticides as well as fertilizers.



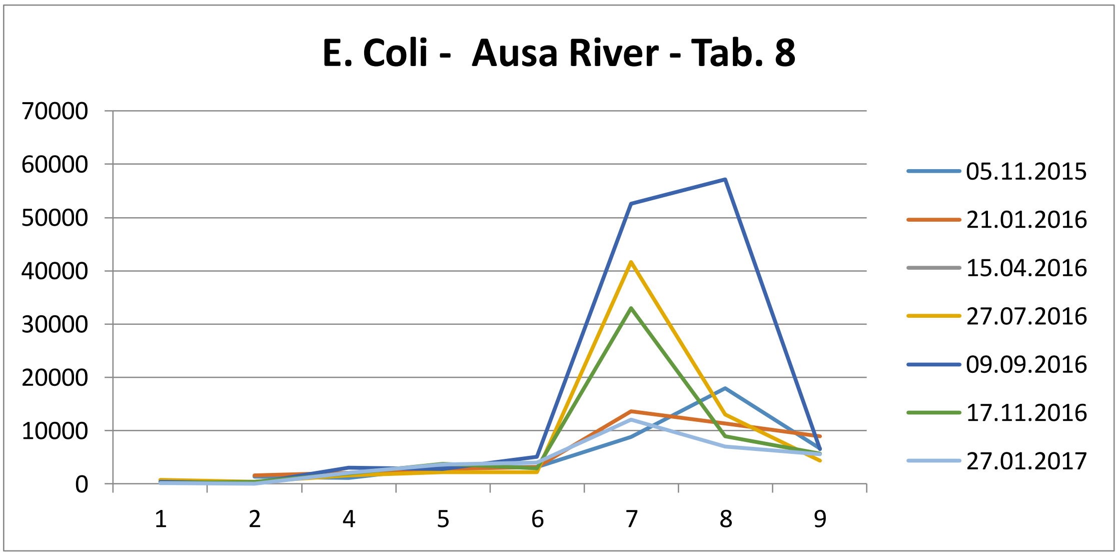
When the river flows towards the city, these ions are probably absorbed by the aquatic plants (natural phytodepuration) and enter the nitrogen cycle. In particular, in station 2, where the sampling is done directly on the natural banks of the river, this parameter is always quite lower than the others, thanks to the high presence of shrubs and plants.

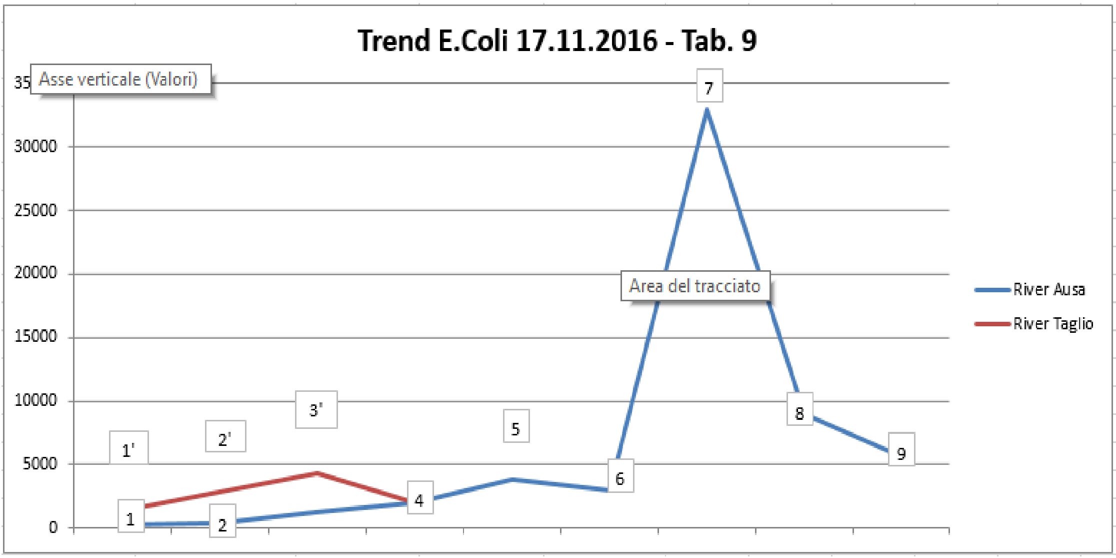
In order to confirm the hypothesis of the phytodepuration of the water, we wanted not to consider the scattered data due to possible different dilution conditions in the different dates, coming from natural precipitation phenomena (rain). To reduce the dependence of the Nitrate values from this dilution factor, we considered the parameter of conductivity, which surely varies with the dilution. So, we tried to evaluate a ratio: we divided the amount of NO_3^- by the date of conductivity.



The trend obtained with this method, which is reported in Tab. 7 (just for site of sampling where the conductivity is surely not affected by sea salts – sites 1 to 6) shows that the amount of nitrates is very clearly dependent on the season, and is higher during the winter, when the biological cycles stop and nitrogen is less absorbed.

Finally, Tabs. 8 and 9 report the amount of Escherichia Coli in the water.





In these graphics we can see that upstream the city center this parameter is low and controlled, but not enough to consider the water suitable for swimming (the limit for balneation is only 200 UFC/100 mL) probably because of a small contamination by some drain pipes.

Nevertheless, the biggest problem is the impact of the town: downstream the city center this parameter is incredibly high, pointing out an evident fecal contamination due to a very bad sewage treatment.

6. Conclusions

Our knowledge of the rivers Ausa and Taglio has highly increased after this long-term study. Most of our doubts and questions have been cleared with this research. The new question we wanted to consider is: what can we do locally? The collected data concerning the E.coli have been shared with the Municipality authorities, that could imagine the situation but didn't have such a big amount of data that well explained the situation. The City council really appreciated our research and asked for a further collaboration with the school in the control of the quality of the water of the river. Now they have planned some engineering solutions, in order to make significant improvements on the sewage systems that drain into the river. Of course they must submit this Project to the European Commission and actuate in few time, in order to reduce the infraction procedure that actually costs a lot to the Community.

The future aim of this project, then, will be to continue the analyses on the situation of the river, in order to compare it, when the works on the sewage systems are finished, to demonstrate the effectiveness of the solutions and the hopefully improved situation.

7. Bibliography/Citations

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