

Environmental effect of the WWTP discharge on the quality of the receptor river

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Abstract The aim of this paper is to examine the Po River water quality in a small stretch in Piedmont (northern Italy). In this stretch a large pollution load, derived from the wastewater treatment plant of Torino area (more than 2 million inhabitants), is discharged and diluted in the water. In this study this load has been quantified and modeled in order to understand the sources, destinations and effects of the emitted pollutants. The objective was to determine the impact produced by the Torino Wastewater Treatment Plant on the quality of the water, based on various hydrological conditions and the possible intervention on the point and diffuse loads.

Keywords: water quality; flow rate; wastewater treatment plant, pollution load

1. Introduction

The condition of the water in the stretch of the Po River that runs through the city of Torino, already critical, is subjected to pollution loads from several sources. Yet the water quality must be considered in relation to all the emissions in the metropolitan area, concerning the diffused industrial activities, and also to the loads coming from agricultural activities (Genon and Marchese 2007).

The SMAT wastewater treatment plant (more than 2 million inhabitants, the biggest wastewater treatment plant present in Italy) discharge of Castiglione Torinese certainly has an influence on the quality of the river water. Therefore as part of the implementation of the Water Framework Directive 2000/60/EC (Directive 2000/60/EC), it was necessary to determine any effect this major intervention is having on the quality of the river water, with particular attention to the nutrients that could cause eutrophication (Cozzi and Giani, 2011; Chidya *et al.*, 2011), as identified in the Water Framework Directive 2000/60/EC (Directive 2000/60/EC).

Eutrophication is the enrichment of water bodies by nutrients, especially compounds of nitrogen (N) and phosphorus (P), causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms and the quality of the water concerned (Ansari *et al.*, 2011).

Because the Po River is subjected to other essentially non-point pollution loads, and vulnerable to biological effects,

it is important to establish what limits should be placed on impact from various origins in order to achieve the desired quality objectives for the river water. Consequently, it is important to understand how, and how much, the stretch of the Po River that runs through Torino is affected by point and diffusive load sources.

In this work a modeling approach was chosen in order to analyze the Po River water quality in the stretch between Castiglione Torinese and Chivasso—localities situated in Piedmont (northern Italy). This selected river stretch is affected by three principal types of loads that affect the water quality in the Torino area and in the stations downstream. Two of these loads are of diffused origin (one from agricultural sources and the other from meteoric waters) while the third is of point origin: the effluent from the SMAT treatment plant.

In this work a model has been built of the average load, by using the mass balance method (Xia *et al.* 2009; Boskidis *et al.*), and the influence of the SMAT wastewater treatment plant on the Po River water quality over a period of 4 years, 2007 to 2011 was analyzed. Subsequently, on the basis of our sampling the SMAT wastewater treatment plant discharge influence has been recalculated and it has been performed a comparison between the actual (sampling) and historical data, in order to determine whether the pollution loads are changing.

2. Materials and methods

2.1. Studied stretch of the river

The study considered the stretch of the Po River between Castiglione Torinese and Chivasso (Fig. 1), approximately 20 km.

In this stretch, the river runs past the SMAT wastewater treatment plant and also through a territory primarily used for agriculture. The SMAT wastewater treatment plant is the largest Italian wastewater treatment plants, treating the metropolitan wastewater of the entire Torino area (with more than 2 million inhabitants).

The aim of this work was to determine the influence of the SMAT wastewater treatment plant discharge on the quality of the river water.

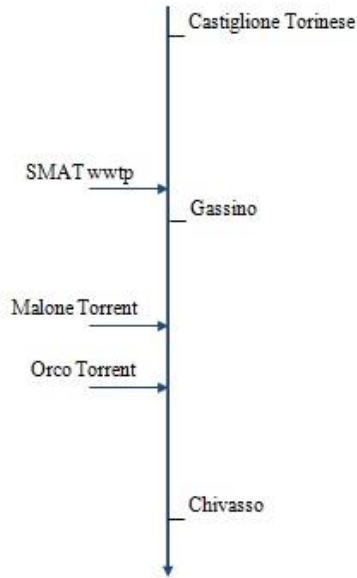


Figure 1. Studied area

2.2. Analysis

In this work three kinds of analyses were performed:

- The first analysis consisted, after reconstructing the hydrological and qualitative framework with historical data (2007 – 2011), in the following simulation:
 - Definition of the load increase in the stretch between Castiglione Torinese and Chivasso, and the separation of this load increase into two parts, one attributable to the SMAT discharge and the other to the diffusive source;
- The second analysis consisted in a simulation parallel to the previous one but based on a sampling campaign to reconstruct the hydrological and qualitative framework;
- The third analysis consisted of a comparison between the simulation performed with historical and actual data (obtained from the sampling campaign).

2.3. Data acquisition

For the evaluation of the pollution loads official concentration data measured with a monthly cadence has been used, daily flow rates were obtained from the Piedmont Regional Administration (Piedmont Region, 2015) and plant data were supplied directly by SMAT.

In order to define the pollution load, which is required for the model and for the mass balance method, it was necessary to compile a complete hydrologic description of the area. Unfortunately, it was difficult to acquire all the needed data.

The main source for the necessary flow data was therefore the Piedmont Regional Administration. Even these data,

though, were incomplete; in fact data for some stations were not available.

In order to define the flow rate data concerning the missing stations a chloride balance was performed (while considering the conservative nature of this parameter) using the tool of the mass balance.

3. Results and Discussion

In the following the results of the historical and sampling data are reported.

3.1. Analysis of the historical data

The aim of the analysis was the definition of the influence of the SMAT wastewater treatment plant compared to that of the other main source (a diffused source, due primarily to the agricultural discharge), on the increased pollution between the two stations Castiglione Torinese and Chivasso. For the analysis it has been used the following equation was used:

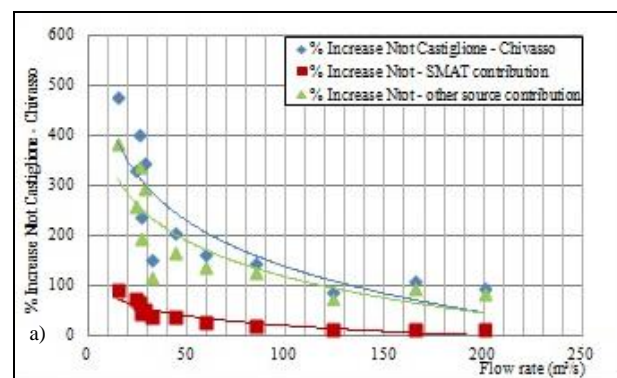
$$\text{Load increase}_{\text{CHIVASSO-CASTIGLIONE}} = \text{Load}_{\text{CHIVASSO}} - \text{Load}_{\text{CASTIGLIONE}} \quad (1)$$

$$\text{Influence of SMAT} = (\text{Load}_{\text{SMAT}} / \text{Load increase}_{\text{CHIVASSO-CASTIGLIONE}}) * 100 \quad (2)$$

$$\text{Diffuse load} = \text{Load increase}_{\text{CHIVASSO-CASTIGLIONE}} - \text{Load}_{\text{SMAT}} \quad (3)$$

The analysis was performed for the two parameters total nitrogen and total phosphorous.

The following figures show the load increase and its split in the two sources, the point load source (attributable to the SMAT wastewater treatment plant) and the diffuse source.



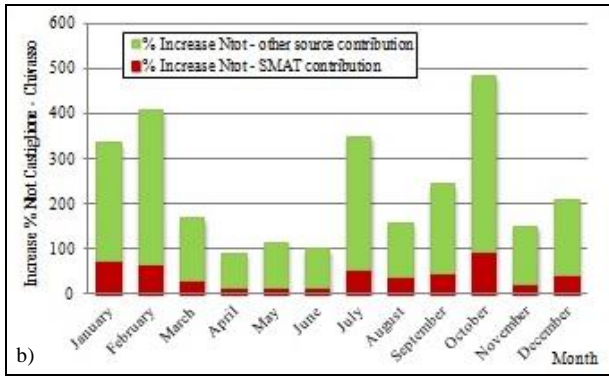


Figure 2 Total nitrogen load increase, split between point and diffuse sources (historical period 2007 – 2011)

By analyzing Figure 2 it is possible to observe that the trend of the Total nitrogen parameter decreases in connection of the Flow rate increasing (dilution effect). The contribution of the SMAT wastewater treatment plant to the increase in the total nitrogen load between the stations Castiglione and Chivasso was lower than the contribution of the diffuse source.

In particular by thinking in terms of average value the load increase measured at the Chivasso station was 231 % (compared to the load measured at the Castiglione station) and splitting this increase between the two sources (point and diffuse) reveals that only the 40 % was from the SMAT wastewater treatment plant and the other 191 % from the other (diffuse) source.

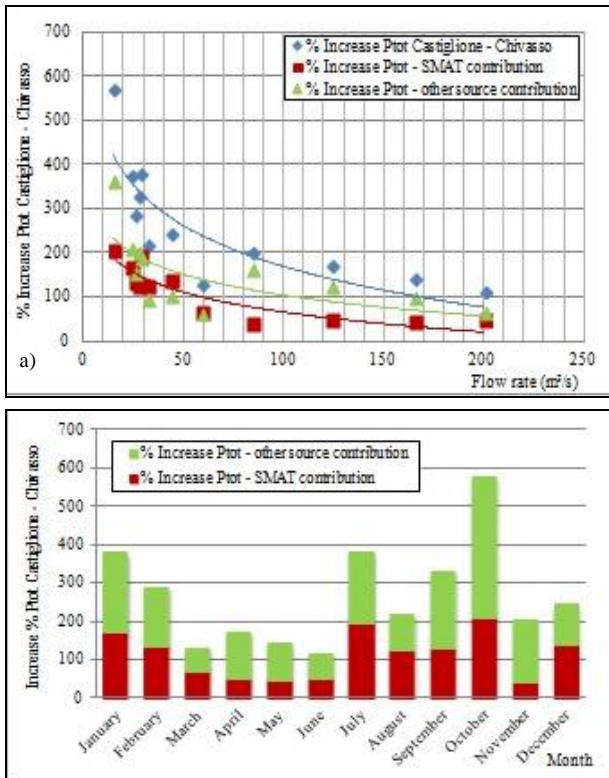


Figure 3 Total phosphorous load increase, split between point and diffuse sources (historical period 2007 – 2011)

By analyzing Figure 3 it is possible to observe that the trend of the parameter Total Phosphorous decreases in connection of the Flow rate increasing. The contribution of the SMAT wastewater treatment plant to the increase in the Total Phosphorous load between the stations Castiglione and Chivasso was lower than the contribution of the diffuse source (more or less the half).

3.2. Sampling data

In order to define as the current water quality in the Po River has changed, compared to the previous years, a sampling campaign has been performed in order to build a representative database and to analyze the changes in the Po River system.

The sampling was performed at five different stations: San Mauro, Castiglione Torinese, Gassino, Orco Torrent, and finally at the station of Chivasso.

Using the data obtained from the sampling and subsequent calculation, the same analyses has been performed as with the historical data, focusing in particular on the pollutant increase between Castiglione and Chivasso and subsequently split this pollutant increase into two parts, separately attributable to the SMAT wastewater treatment plant and to the diffusive source.

3.3. Analysis of the sampling data

On the basis of the sampling campaign it has been defined the influence of both the SMAT wastewater treatment plant and the diffuse source (due primarily to agricultural discharge) on the increased pollution between the two stations Castiglione Torinese and Chivasso. Analysis were conducted separately for the two parameters Total Nitrogen, and Total Phosphorous.

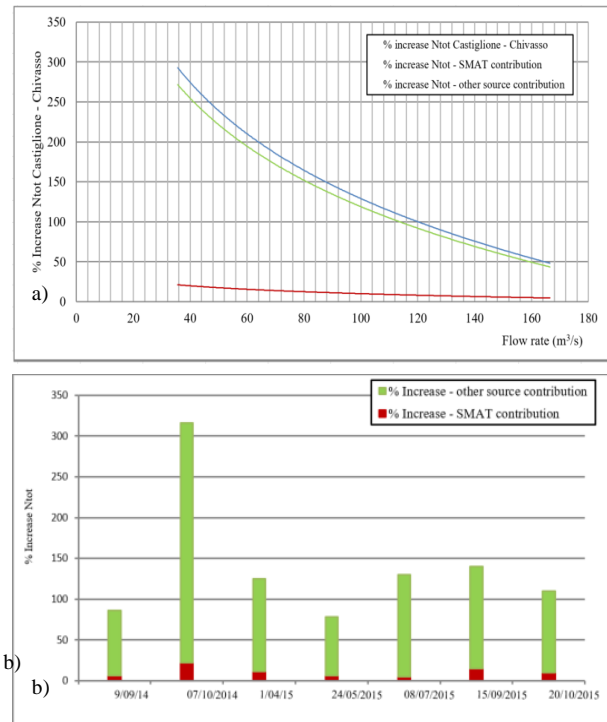


Figure 4 Total nitrogen load increase, split between point and diffusive sources (years 2014 – 2015)

Figure 4 shows for the pollutant parameters Total Nitrogen the trend of the pollution increase between Castiglione Torinese and Chivasso stations as a function of the flow rate measured in Castiglione station and how this load increase is split between the two sources.

By analyzing the Figure 5 it is possible to note that:

- the amount of load increase in the considered stretch decrease as a function of increasing flow rate;
- the contribution of the SMAT wastewater treatment plant was very low in comparison of the contribution of the diffuse source.

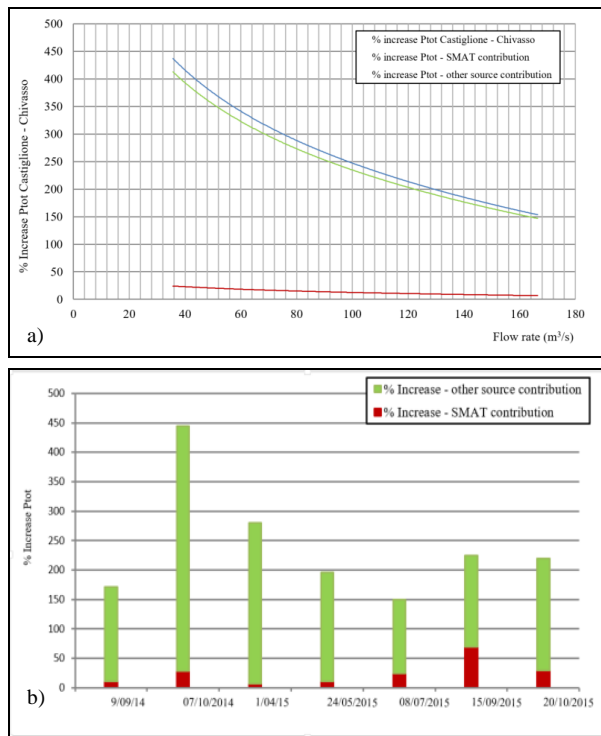


Figure 5 Phosphorous load increase, split between point and diffusive sources (years 2014 – 2015)

Figure 5 shows the Total Phosphorous trend of the pollution increase between Castiglione Torinese and Chivasso stations as a function of the flow rate measured in Castiglione station and how this load increase is split between the two sources.

By analyzing the Figure 5, also in this case as the previous reported cases (Total Nitrogen), it is possible to note that the amount of increased load decreases as a function of increasing flow rate and the contribution of the SMAT wastewater treatment plant was very low in comparison of the contribution of the diffuse sources. The increase from the SMAT discharge resulted more significant in the first stretch, just after the point of its insertion in the river, as could be evident from the data in the intermediate Brandizzo station.

3.3. Comparison of historical and sampling data

By performing a comparison between the historical and sampling data it is possible to note that the current values (corresponding to the sampling values) are very low in comparison with the historical data.

The main reason of these results have to be searched in the current major treatments performed by the wastewater treatment plant in comparison to the previous ones.

4. Conclusions

The results of the interpretation of the historical data concerning the water quality of Po river and the definition of the actual conditions indicate some general trends, as it is reported in the following:

- the influence of the discharge of the the Turin area wastewater treatment plant on the quality of the Po river after its insertion can be considered lower in comparison with diffused loads coming from agricultural activities or from surface leaching waters (considering all the stretch Castiglione T.se – Chivasso);
- from the comparison between historical and actual data, it is possible to observe an important decrease in the responsibility of the wastewater treatment plant on the river quality, and this fact is connected to an increased removal efficiency of the plant;
- it is possible to observe a strong influence of the river flow rate on the contribution of the wastewater load, with the indication of the importance of dilution effect;
- both the parameter total nitrogen and phosphorus must be considered, taking in any case into account their load, on the evaluation of the potential eutrophication effect on the Po river;
- the considered stretch, with a length of 20 km, can be taken as meaningful for some considerations about the auto purification capacity of the river, in account of hydraulic and biological effects.

On the basis of another analysis performed some interesting consideration are possible. In particular we evaluated the state of pollution in the studied stretch by using the classification methods specified in the D. Lgs. 152/99 (decree on pollution protection, based on Directive 91/271/EC concerning urban water treatment and Directive 91/676/ EC concerning protection of water from nitrate pollution) and in the D. Lgs. 258/2000 (decree on correction and integration of reporting for D. Lgs. 152/99), now both replaced with the D. Lgs. 152/2006 (decree on environmental protection) (D. Lgs. 152/99, Gazzetta Ufficiale n. 218, S.O. n. 153; Directive 91/271/EC, Gazzetta Ufficiale n. L 135; Directive 91/676/EC, Gazzetta Ufficiale n. L 375; D. Lgs. 258/2000, Gazzetta Ufficiale n. 218, S.O. n. 153; D. Lgs. 152/2006, Gazzetta Ufficiale n. 88, S.O. n. 96). This analysis was conducted in order to evaluate the state of the Po River water, considering that the quoted regulations require the water quality to reach the state of “good” by 31 December 2016.

The obtained results shows:

- an improvement of the environmental state from Castiglione T.se station to Chivasso station. In fact the environmental state in Castiglione T.se station is “poor”, in Brandizzo station is “sufficient” and in Chivasso station is “good”

(validating the hypothesis of self – depuration capacity of the Po River);

- in order to achieve the “good” environmental state also in S. Mauro and Castiglione T.se stations it will be necessary:
 - to perform some interventions upstream the station of Castiglione (in fact the situation is yet compromised upstream to Torino station);
 - reducing the withdrawal from Canale Cimena. This withdrawal is necessary for the ENEL Cimena power plant, which takes up a large hydraulic volume in correspondence of S. Mauro and it returns the same volume just before the Chivasso station. For this reason the environmental impact of the plant discharge is very important in a river stretch where the situation is heavily endangered from the hydraulic point of view. Since as a consequence of the Cimena channel withdrawal the river flow rates in some periods of the year are very low.

The so indicated observations can be considered useful both for the methodological study of the environmental state of an important river stretch, and also for the definition of the necessity of interventions on the different introduced loads that must be defined by the river authorities.

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