WATER QUALITY MANAGEMENT TOOLS FOR THE APPLICATION OF THE EU WATER FRAMEWORK DIRECTIVE.

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Abstract

Fulfilling the ultimate objective of a ''good'' overall quality of all waters is questionable in terms of the high costs entailed and the lack of adequate legal enforceability. The new EU water framework directive institutionalizes ecosystem-based objectives and planning processes at the level of the hydrographic basin as the basis for water resource management. The directive, affecting 27 countries, marks an important trend towards an ecosystem-based approach for water policy and water resource management.

In this paper, after a overview of the WFD implementation in Italy, problems related to a case study and adopted decision making tools are shown. Area of the case study is Parco del Cilento*, a protected area in Southern Italy, in which water quality monitoring, proposed in the normative, has been performed on a river. During the period from February 2001 to July 2002, 2570 samples were collected and the water quality of the Mingardo river was analyzed. The results obtained have allowed a preliminary definition of the chemical, physical and biological water quality of the river as well as its classification according to the WFD outlines. Non parametrical statistical procedures have also been proposed as possible water quality management tools for the application of the EU water framework directive.*

Keywords: *Environmental status; river water quality monitoring; hydrographic basin management; non-parametric tests.*

1 INTRODUCTION

The new EU directive 2000/60/EC, also known as the Water Framework Directive (WFD), identifies new processes for developing and safeguarding the territory through surface water quality characterisation. This implies controlling pollution loads as well as defining the constraints that are connected to territorial planning. It will be therefore necessary to know in detail the surface water quality in order to forecast the possible consequences of a either new civil or industrial site. Investigating methodologies, data analysis procedures and water quality management tools will be needed to be defined.

The aim of this study is to describe the implementation of WFD in Italy (Legislative Decree 11.05.1999 n. 152), with a discussion of a case study.

The results obtained have allowed a preliminary definition of the chemical, physical and biological water quality of a river located in a protected area of Southern Italy (Parco del Cilento) as well as its classification according to the main WFD outlines.

Non parametrical statistical procedures have also been proposed as possible water quality management tools for the application of the EU directive.

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2 EUROPEAN AND ITALIAN REGULATION

Water is the sector with the most comprehensive coverage in EU environmental regulation. EU water directives have effected considerable changes in national legislative statutes even in the countries with the most developed environmental regulation. The WFD sets common approaches and goals for the management of water in 27 countries (15 Member State countries and the 12 pre-accession countries which should conform in the long term with Community law).

The WFD sets new goals for the condition of Europe's water and introduces new ways and processes for achieving them. The overall goal is a ''good'' and non-deteriorating ''status'' for all waters (surface, underground and coastal). The main tool is organisation and planning at a river basin level and identification of pollution-control measures. The WFD sets out clear deadlines for each of the requirements which adds up to an ambitious overall timetable (Table 1).

Table 1: WFD deadlines.

WFD Reference	Issue	Year
Art. 25	Directive entered into force	2000
Art. 23 Art. 3	Transposition in national legislation Identification of River Basin Districts and Authorities	2003
Art. 5	Characterisation of river basin: pressures, impacts and economic analysis	2004
Art. 8 Art. 14	Establishment of monitoring network Start public consultation (at the latest)	2006
Art. 13	Present draft river basin management plan	2008
Art. 13 & 11	Finalise river basin management plan including programme of measures	2009
Art. 9	Introduce pricing policies	2010
Art. 11	Make operational programmes of measures	2012
Art. 4	Meet environmental objectives	2015
Art. 4 & 13	First management cycle ends	2021
Art. 4 & 13	Second management cycle ends, final deadline for meeting objectives	2027

For surface waters the objective is that of a ''good'' ecological and chemical quality status. A surface water is defined as being of good ecological quality if there is only slight departure from the biological community that would be expected in conditions of minimal anthropogenic impact; a standard process is provided in the WFD for defining local standards accordingly. Quality elements for assessment are divided into biological elements (e.g. composition and abundance of flora and fauna), hydromorphological elements (e.g. quantity and dynamics of flow, river depth and width variation) and supporting physico-chemical elements (e.g. thermal/oxygenation conditions, salinity, nutrients, etc.) for rivers, lakes, transitional and artificial/modified'' waters (those created or resulting from a human physical modification and serving economic activities).

For each element a descriptive definition of a high, good, moderate, poor and bad status is given. Each National authority should set standards for the elements most relevant to the pressures faced by the water body under its responsibility and classify waters accordingly. Chemical status is classified only in two categories: ''good'' and ''failing to achieve good''. A ''good'' water body fulfils all the standards set by EU legislation for the concentration of chemicals in water (i.e. as defined in the urban w/w, IPPC and nitrates directives and most importantly, the dangerous substances ''daughter'' directives which have set standards for a number of hazardous chemicals) (Figure 1).

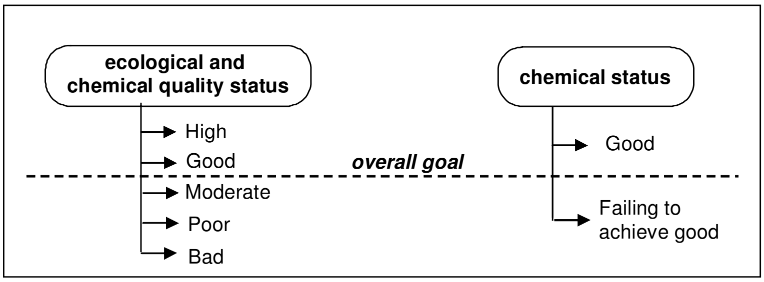


Figure 1: Water quality classification by WFD.

The current Italian normative regarding the safeguard and management of water quality is the Legislative Decree 11.05.1999 n. 152 (D.L. 152/99), based on both EU directives 91/271/CEE and 91/979/CEE and elaborated on the preliminary draft of the WFD.

The D.L. 152/99 defines the safeguarding of all waters, surface, marine and underground following the objectives and tools in Table 2.

Table 2: Framework Matrix of D.L. 152/99.

Objective	Tools	Outcomes (by the 31.12.2016)
• Prevent and reduce pollution and active the recovery of water bodies; • Improve water quality status and active adequate protection plans of water with specific uses; • Sustainable and long lasting use of water resources, with priority given to drinking water; • Maintain the self depuration of water bodies as well as protect the wildlife and nature present.	• Identification of the environmental quality objectives, with regard to a specific use of the water body; • Integrated safeguard of the qualitative and quantitative aspects of each basin with an adequate monitoring network; • Improving the drainage system, the treatment plants in accordance to the law 05.01.1994 n. 36; • Identification of the measures needed to be taken in order to reduce pollution in vulnerable areas; • Identification of the measures needed to be taken in order to conserve, save, reuse and recycle water resources.	• Maintain or reach a "good" environmental status with reference to the specifications of Appendix 1; • Maintain, where already existing, a "high" environmental status with reference to the specifications of Appendix 1; • Maintain or reach the quality objectives with regard to specific use of the resources with reference to Appendix 2.

D.L. 152/99 identifies the minimum environmental status as well as the quality status for waters with specific uses. The environmental quality objectives are defined taking the ability of the water body to maintain its natural self depuration processes into consideration as well as its capacity to support wildlife and vegetation, that can greatly influence both quantitatively and qualitatively the water body and ecosystem.

3 IMPLEMENTATION OF THE WFD IN ITALY

The study was carried out as described in Figure 2 and shows how the phases of the Italian norm (steps 1-4) can be integrated with the decision making tools proposed for the management of water quality (step 5).

The initial phase (Step 1) has the aim of supplying the base and support tools required for designing a suitable system for monitoring and controlling surface water quality. This is followed by the identification and physical characterisation of the hydrological basin using cartographic maps as well as any other historical data available on the basin under study. Any alterations, natural or anthropic (depuration plants, sewerage etc) and the state of the ecosystem are subsequently identified. Thematic maps are then drawn up based on the information obtained, in order to have a complete picture of the territory.

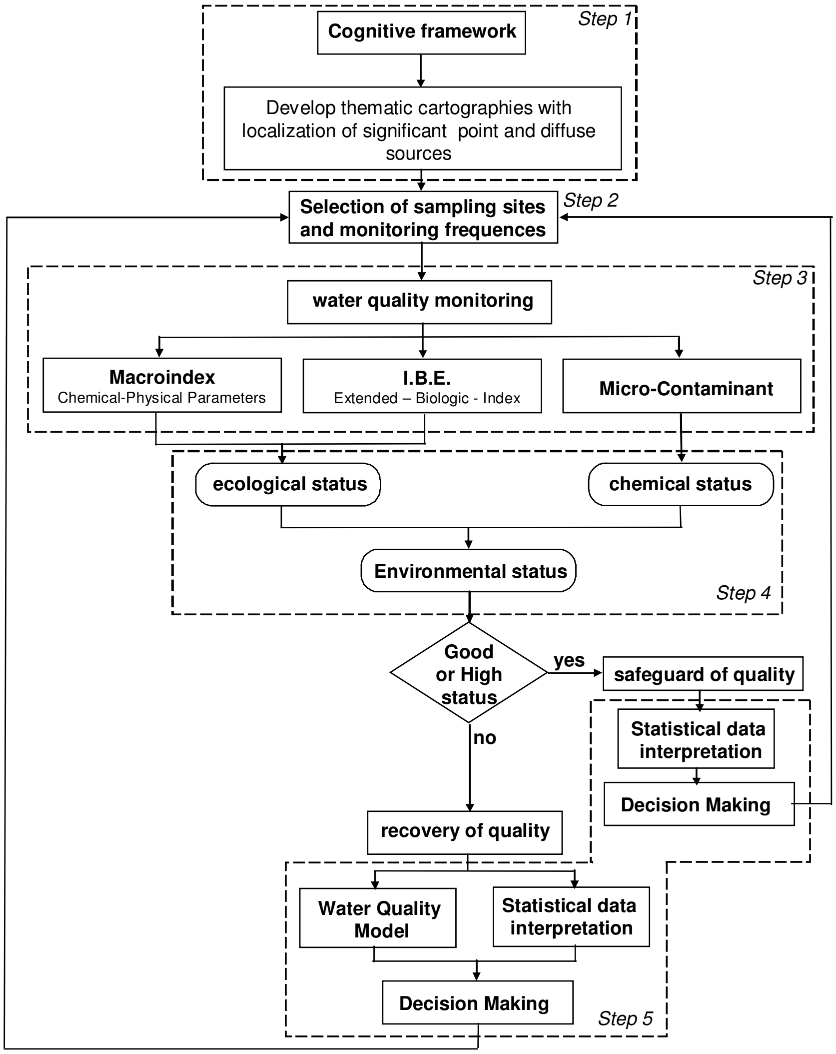


Figure 2: Methodology steps.

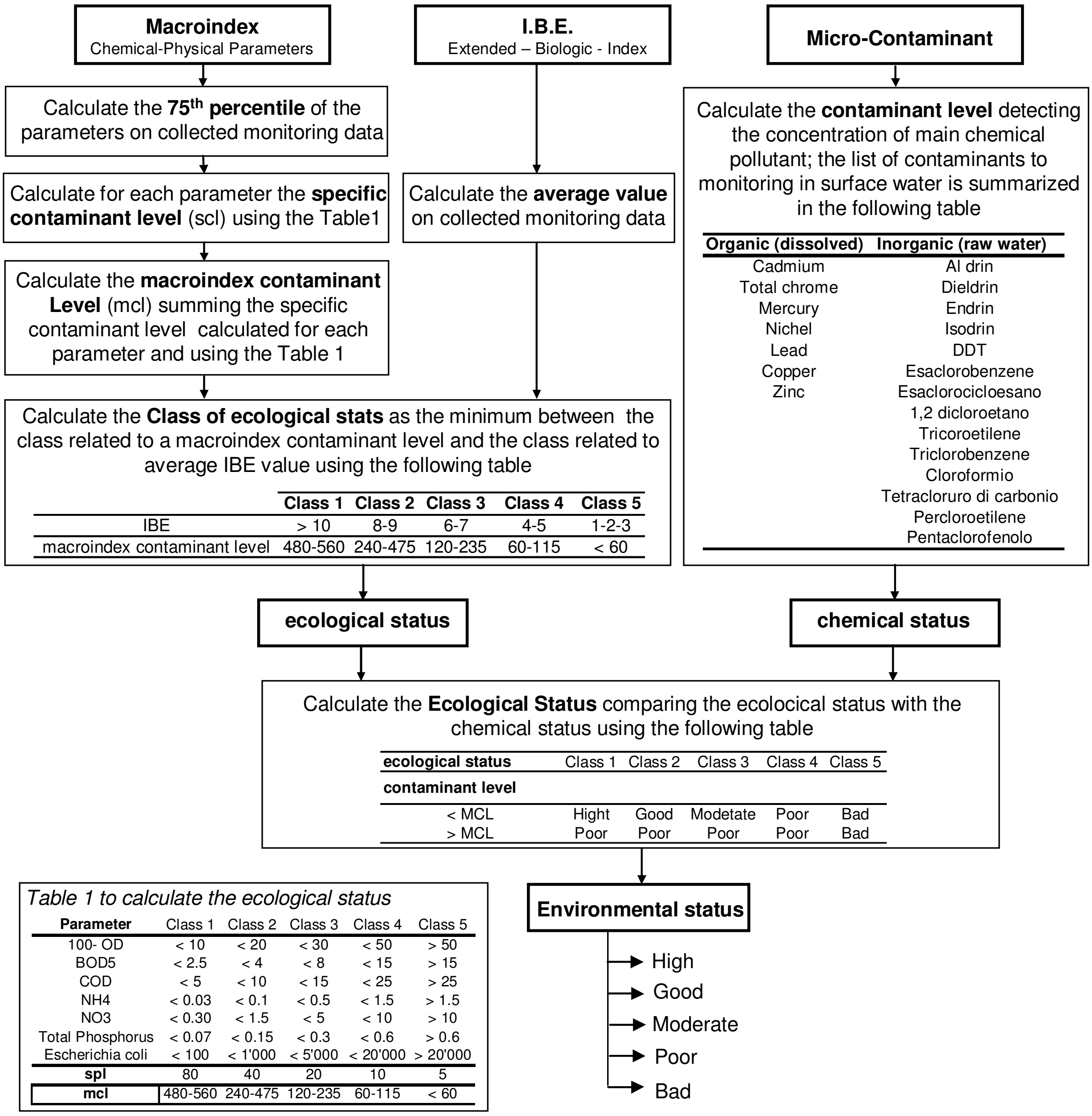
The thematic maps drawn up and the data obtained are useful for subdividing the rivers into homogenous reaches, therefore identifying monitoring sections. The number and position of the monitoring stations is based upon the minimum requisites in accordance to the law (see Table 3) as well as by the presence of any constraining conditions that influence sample taking and subsequent analysis (Step 2).

Table 3: Minimum number of sampling site (Table 6, Appendix 1, D.L. 152/99).

Basin Area (km^2)	**Number of Stations**	
	Rivers of the 1st order	*Rivers of the 2nd order or greater*
200-400	1	-
401-1000	2	1
1001-5000	3	2
5001-10.000	5	4
10.001-25.000	6	-
25.001-50.000	8	-
> 50.000	10	-

The monitoring frequency must include at least one sample per month for the macro-index parameters and one per season for the biological parameters, as set out in Italian norm with reference to the initial monitoring phase. Once the monitoring stations have been identified along with the relative sample frequencies for each parameter (macro-index, IBE, micro-contaminant), the water quality monitoring can begin (Step 3).

The environmental status of every single homogenous reach is then defined on the basis of the data obtained (Step 4). The environmental status is defined using both the biological and chemical definitions, with the first being the synthetic expression of the aquatic ecosystem complexity, while the latter is based upon the presence of dangerous chemicals (micro-contaminants) that must be kept under control. The procedure followed in described in detail in Figure 3.



Organic (dissolved)	Inorganic (raw water)
Cadmium	Al drin
Total chrome	Dieldrin
Mercury	Endrin
Nichel	Isodrin
Lead	DDT
Copper	Esaclorobenzene
Zinc	Esaclorocicloesano
	1,2 dicloroetano
	Tricoroetilene
	Triclorobenzene
	Cloroformio
	Tetracloruro di carbonio
	Percloroetilene
	Pentaclorofenolo

	Class 1	Class 2	Class 3	Class 4	Class 5
IBE	> 10	8-9	6-7	4-5	1-2-3
macroindex contaminant level	480-560	240-475	120-235	60-115	< 60

ecological status	Class 1	Class 2	Class 3	Class 4	Class 5
contaminant level					
< MCL	Hight	Good	Modetate	Poor	Bad
> MCL	Poor	Poor	Poor	Poor	Bad

Table 1 to calculate the ecological status

Parameter	Class 1	Class 2	Class 3	Class 4	Class 5
100- OD	< 10	< 20	< 30	< 50	> 50
BOD5	< 2.5	< 4	< 8	< 15	> 15
COD	< 5	< 10	< 15	< 25	> 25
NH4	< 0.03	< 0.1	< 0.5	< 1.5	> 1.5
NO3	< 0.30	< 1.5	< 5	< 10	> 10
Total Phosphorus	< 0.07	< 0.15	< 0.3	< 0.6	> 0.6
Escherichia coli	< 100	< 1'000	< 5'000	< 20'000	> 20'000
spl	80	40	20	10	5
mcl	480-560	240-475	120-235	60-115	< 60

Figure 3: Characterization procedure of environmental status.

The Italian normative, conforming to the WFD, foresees at least a "good" status for the water bodies as well as a safeguarding and recovery plan, that is subsequently adapted to the classification obtained. A recovery of quality is necessary if the environmental status is lower than "good" with the aim of improving water quality. If the environmental status is "good" or "high" it is important to maintain this level with an appropriate safeguard plan and any necessary interventions. The normative however does not give any indications on how to safeguard or recover the water body quality, so therefore in this paper the use of water quality management tools is proposed (Step 5).

When safeguarding water quality, statistical tools can be used for both interpreting and validating of monitoring data as well as reorganising and optimising the monitoring network (redefining the sampling site based on the new sampling frequencies with the aim of lowering costs) (Harmancioglu et al., 1999). While for recovering water quality, the combined use of water quality models and statistical tools for interpreting data should be used, with the aim of simulating and forecasting possible scenarios.

4 METHODS

The number and location of the sampling sites was established taking the presence of urban settlements, production plants and all polluting loads into consideration. The sampling sites were also set up at a suitable distance from the source of emission that guaranteed a complete mix of the water, with the aim of evaluating the river water quality and not that of the influent. The location of the sites was influenced by technical as well as operative constraints (e.g. difficulty in sample taking). 18 sampling sites were set up on the basin of the river Mingardo, with 11 being on the main river, while the remaining 7 were on the tributarys.

2570 samples were collected and the water quality of the Mingardo river was analyzed, monitoring river flow, pH, suspended solids (SS), water temperature, air temperature, NH4-N, NO2-N, NO3-N, dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD5), phosphate concentrations, Escherichia coli, and the Extended Biotic Index (IBE), micro-contaminants during the period from February 2001 to July 2002 (not including the months of August and December).

The methodologies used to analytically define the macro-index, were those set out by Italian Research Council (IRSA-CNR,1994).

The water samples were collected in 2 litre glass bottles, transported to the laboratory in thermal bags and analysed in the same day. The pH level, the air temperature, the water temperature and dissolved oxygen were all measured on site.

4.1 Statistical tools for interpreting environmental monitoring data

The environmental monitoring data can be elaborated and interpreted using non parametric tests (Harmancioglu et al., 1999). These tests can be used when the data are either incomplete or when a significant amount of the data is missed, because most of the traditional parametric tests can not be applied due to the data available not being conform to any particular distribution. Most of these tests highlight temporal and spatial trends in the monitoring data available.

The statistical tools that can be used for interpreting environmental monitoring data are the non-parametric tests of the Mann-Kendall, Mann-Kendall modified, and van Belle-Hughes.

The Mann-Kendall Test (Mann, 1945; Kendall, 1975) is a non parametric test for trends in data. It is particularly useful when data are incomplete or when the amount of data available is limited. (Gilbert, 1987; Gibbons, 1987; Hippel and McLeod, 1994).

The Mann-Kendall Test, modified by Gilbert (1987) can be used even when there are multiple observations per time period. The test consists of applying the Mann-Kendall procedure to each median calculated in each time period and allows the evaluation of the data, if the data present either a systematic increase or decrease.

When the data are collected from more than one sampling site within the same area or the same hydrological basin (as is the case in this study), it is worth while evaluating the trends on the entire basin. A general statement about the presence or absence of monotonic trends will be meaningful if the trends at all sites are in the same direction. A procedure for testing trend homogeneity between different sites was originally proposed by van Belle-Hughes (Gilbert, 1987) and use the Mann-Kendall statistic for each sampling site.

5 RESULTS AND DISCUSSION

5.1 Territorial framework

The area of the case study is the Parco del Cilento, a protected area in Southern Italy (Figure 4), in which water quality monitoring has been carried out on the Mingardo river.

The water basin of the Mingardo river covers a surface of 226,75 km^2; the overall length of the main tributary is approximately 38 km (Figure 5). The river, predominantly creek state, is made up of a gravely-pebbly bottom in the downstream part, with broad riverbed and small riverside in the intermediate reach, while it is built-in and calcareous formations exist in the upstream reach where the riverbed has a width that is seldom grater than 5 m.

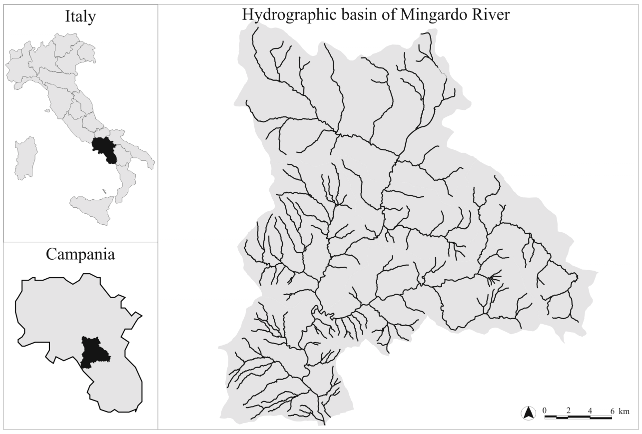


Figure 4: Territorial lay out of the Mingardo basin.

The study of the acquired cartographic documents and the characterization of the main point pollution sources allowed to set up 18 sampling stations (M1, M2, …, M18).

The more significant pollution point loads are due to discharges coming from civil wastewater treatment plants of the following towns (figure 5): Celle di Bulgheria (two plants, M13-M14), Alfano (M17) and Rofrano (M18).

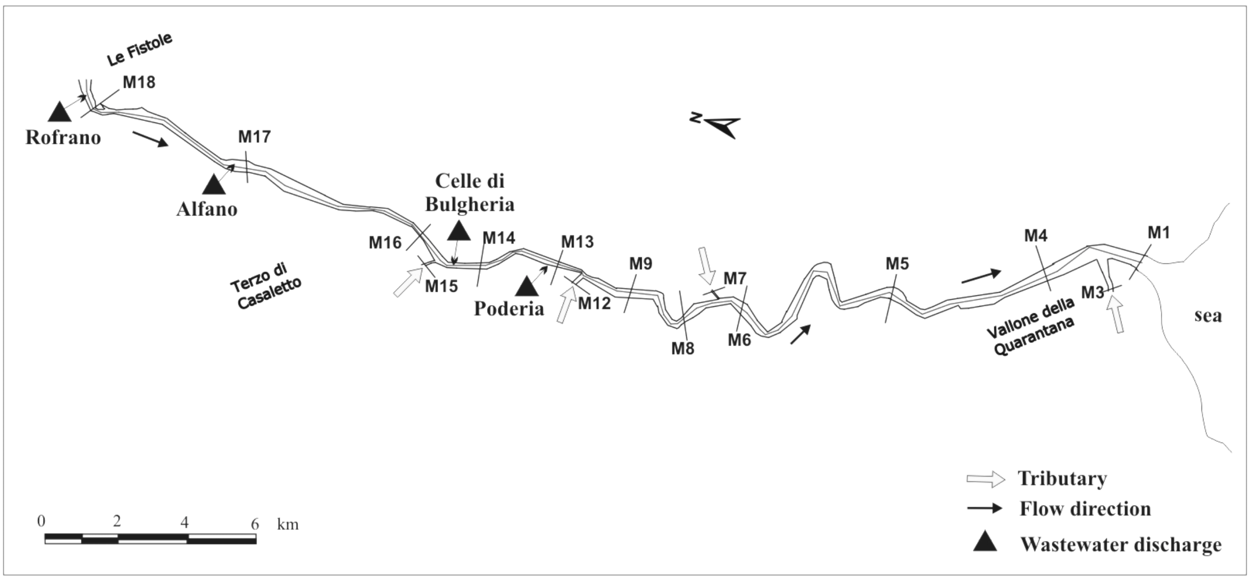


Figure 5: The location of the sampling sites and main pollution point loads on the river Mingardo.

5.2 Environmental status characterization

The analytical results of the monitoring activity were used to define the ecological and chemical state. With regard to the latter, the analysis of the main micro-contaminants showed a contamination level always below the permitted maximum level. The operation, repeated for each homogeneous part of the main tributary, that is for each part included between two sequential monitoring sections, allowing the definition of the environmental state; the results of the procedure are summarized in Table 4. The ecological state resulted binding for environmental state classification because the chemical state was high for all the sections. Instead, figure 6 shows the contribution of each macro-index for the achievement of the quality state for each section.

Table 4: Calculation of the Ecological and Environmental Status.

	M18	**M17**	**M16**	**M15**	**M14**	**M13**	**M12**	**M11**	**M10**	**M9**	**M8**	**M7**	**M6**	**M5**	**M4**	**M3**	**M2**	**M1**
Macro-index level	480	480	520	480	460	460	440	440	480	480	520	440	460	460	420	560	520	480
IBE	10	10	9	8	10	10	9	8	10	10	10	8	8	10	9	10	9	10
Ecological Status	**C1**	**C1**	**C2**	**C2**	**C2**	**C2**	**C2**	**C2**	**C1**	**C1**	**C1**	**C2**	**C2**	**C2**	**C2**	**C1**	**C2**	**C1**
Environmental Status	**H**	**H**	**G**	**G**	**G**	**G**	**G**	**G**	**H**	**H**	**H**	**G**	**G**	**G**	**G**	**H**	**G**	**H**

C1= Class 1; C2= Class 2; H= High; G= Good

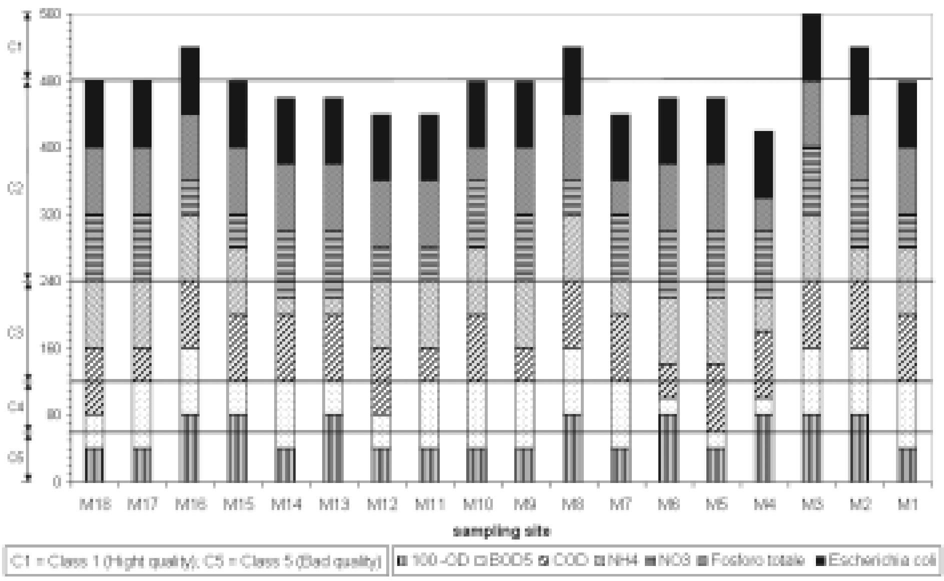


Figure 6 Representation of the quality class of the macro index -Mingardo basin (M1-M18).

The water basin of the Mingardo river is characterized by both high environmental quality state in 7 of the 18 sections and good quality state in the remaining 11 stations. As shown in figure 6, which describes the ecological status unless biological contribution (IBE), the sections marked as C2 show chemical-physical characteristics near to a high quality status. The Mingardo river shows a good selfdepuration capacity as highlighted by the improvement of the quality state in section M16 located downstream of Rofrano (M18) and Alfano (M17) wastewater discharges.

The quality of the river is negatively influenced by contributions of the tributaries corresponding to the M15, M12, M7 and M3 sections, characterized by lower quality state, and positively by the tributary located in section M3.

5.3 Water quality management tools

The Italian normative also contemplates the classification of water bodies for specific uses, among them surface water for drinking use and suitable for salmon and freshwater fish. The data obtained from the monitoring activity was compared with corresponding values imposed by Italian normative for classification of the specified waters. In particular, reference and maximum contaminant levels were considered for drinking waters and freshwaters fish respectively (Table 5).

Table 5: Reference and maximum contaminant levels for waters with specific use.

Parameter	Freshwater fish[a] (L1)	Drinking waters[b] (L2)
BOD5 (mg/l)	5	<3
Dissolved oxygen (%)	50	>70
Suspended solids (mg/l)	60	25
Nitrite (mg/l)	0,88	-
Nitrate (mg/l)	-	25

[a] maximum contaminant level (Table 1/B, enclosure 2, section B, D.Lgs 152/99)

[b] reference level (Table 1/A, enclosure 2, section A, D.Lgs 152/99)

The samplings and analysis were carried out from February 2001 to March 2002 (except August and December). The charts in Figure 8 show only the main examined parameters, the water of Mingardo river is characterized by average values in accordance to the restrictions set out the rule for specific use resources. The average BOD_5 and suspended solids values respect the reference levels for all sections of the river (except BOD_5 in the section M12). In two cases (M16 and M12), the BOD_5 maximum values were significantly greater than the limit reference values; these sections are located downstream to wastewater discharges of the treatment plants in the towns of Alfano and Celle di Bulgheria respectively. Whereas the maximum concentration value for nitrite and nitrate were less than the corresponding limit reference values during all monitoring period.

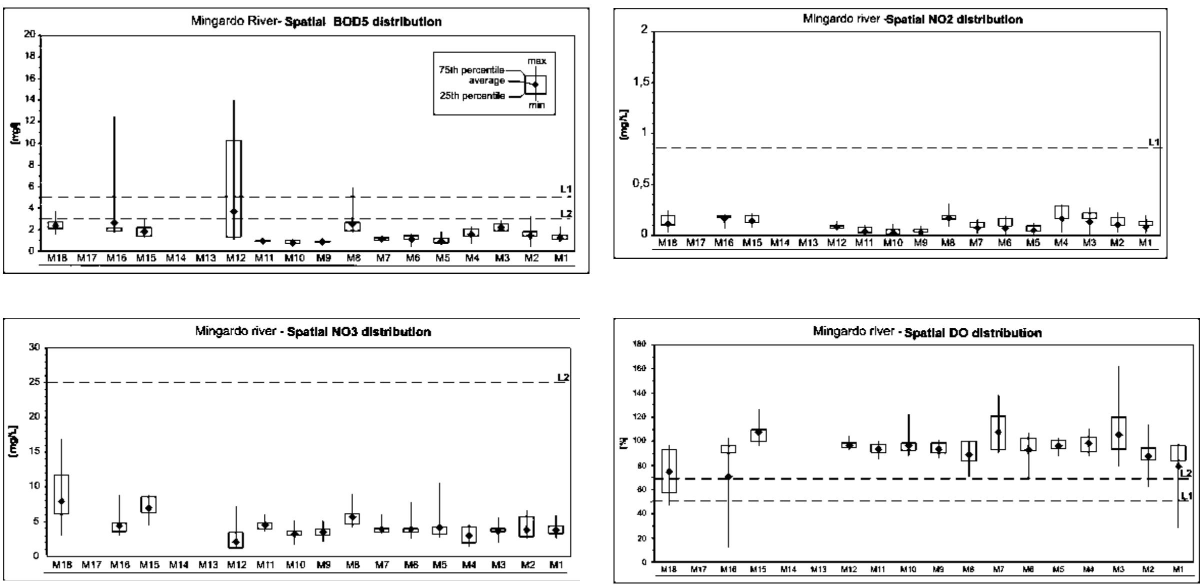


Figure 8: Spatial distribution of BOD_5, DO, NO_2 and NO_3 (Box-Whisker representation).

The charts in Figure 9 discuss the overall seasonal variations of the river. Although the average BOD_5 and SS values are conformed to limits, it is difficult to point out seasonal effect in data variation because the difference among the months concerns mg per litre fractions. A more significant seasonal variation is shown in DO chart, where the average saturation percent value for the month of July is significantly less than the data for the rest of the year.

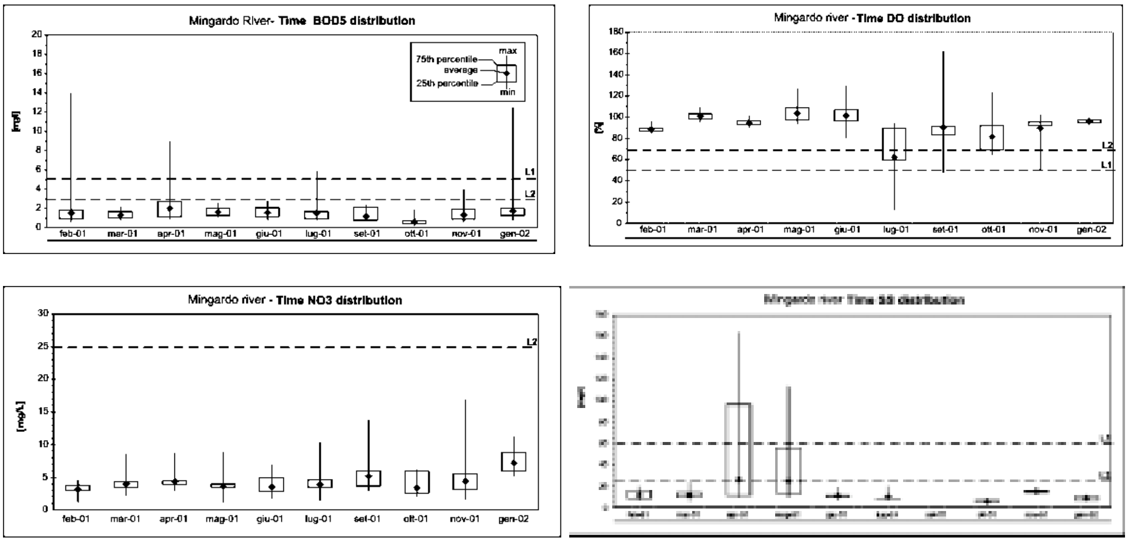


Figure 9: Time distribution of BOD_5, DO, NO_2 and NO_3 (Box-Whisker representation).

The application of the Mann-Kendall test shows how for nitrite there is a strong downward trend for more than half of the sampling sites (M16-M15-M12-M11-M9-M7-M6-M3-M2-M1); with regard to the BOD, the SS and the DO, a trend was encountered in only a few sites, and in each case downward. An upward trend for nitrates was encountered in three sites (M18, M11, M8). Regarding this last parameter, the characterisation and the study in deep of upward trend do not create any cause for concern due to the variations being limited and insignificant.

The modified Mann-Kendall test shows that all the monitoring parameters are on a downward trend. The van Belle-Hughes test has been useful in establishing homogeneity among the data from all the sites and demonstrates how all the site are homogenous at least regarding nitrates.

In conclusion, in the case study the trend characterisation compared to the concentration of the macro index parameters has not shown any pollution phenomena that can be cause for concern for the river studied.

6 CONCLUSIONS

The implementation of the WFD in Italy using a case study as an example was described and discussed in this paper. The results obtained gave a preliminary chemical, physical and biological definition of the water quality of the hydrographic basin of the river Mingardo, as well as the relative classification with reference to the outlines set out by the WFD and upheld by the D.L.152/99. The basin of the river Mingardo resulted in having a “good-high” environmental status, as well as having good self-depurating capacity, dealing with the polluting loads coming from waste water treatment plants located along the main tributary.

Non parametric statistical procedures were proposed and discussed as possible tools for water quality management for the application of the EU water framework directive. The interpretation and discussion of the non parametric test results were a valid support in characterising and defining the pollution status of specific reaches of the river. This aspect highlighted how these instruments can be useful when planning water quality control and monitoring systems.

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