

# **Diffuse contamination assessment for the groundwater quality protection in Functional Urban Areas (FUA)**

The Lombard territory (Italy), characterized by a historical process of industrialization, is affected by significant contamination both of the ground and of the groundwater. The continuous development of urban areas needs to face the problem linked to the growing presence of portions of the territory where there is the presence of contaminated groundwater (mainly chlorinated solvents and hydrocarbons), for which it is no longer possible to identify the position of the sources of the contamination. This type of contamination is defined as diffuse contamination due to multiple point sources and represents a common environmental problem in many developed countries. This contamination often is among the elements that causes the non-achievement of the qualitative objectives defined by the European Groundwater Directive.

Furthermore, diffuse pollution causes a significant economic impact on society, due to the costs necessary for its management and remediation. Lombardy Region, which is one of the most urbanized and industrialized areas in Europe, has recently developed specific legislation action to address the problem, which includes a regional remediation program and a regional management plan for diffuse groundwater pollution.

Thanks to the presence of efficient monitoring networks and a huge qualitative and quantitative data concerning the groundwater of Lombardy, it was possible to start a process of assessment of the diffuse pollution in the Wide Area, consisting of the city of Milan and a sector of its hinterland located in the North-East. This made it possible to define a new Reference Threshold for Diffuse Contamination (RTDC) and a Management Plan containing the management methods and measures for the prevention of diffuse pollution. Lombardy Region (2017) has delimited the first area affected by diffuse pollution and approved the intervention measures and the regulation for the reclamation procedures falling within this area.

Following this first action on the management of diffuse contamination, the Lombardy Region and the Politecnico di Milano have started the AMIIGA project (Integrated Approach to Management of Groundwater quality in functional Urban Areas) project (CE32-Interreg 2016-2019) in which, it will be developed a new Management Plan for the North-West area of Milan. The Pilot Area will include 9 municipalities in the Milan surrounding and 2 in the Varese province. This article intends to present both the European and Italian regulatory framework and the regional Management Plan of the Functional Urban Area (FUA) of Milan, presenting the methodology adopted and the results obtained.

**Keywords:** diffuse contamination, groundwater governance, Regional Operative Protocol, AMIIGA, Management Plan.

**Valutazione della contaminazione diffusa per la protezione della qualità delle risorse idriche sotterranee in aree urbane (FUA).** Il territorio lombardo, caratterizzato da un processo storico di industrializzazione, è interessato da contaminazioni del suolo e delle acque sotterranee significative. Il continuo sviluppo delle aree urbane deve sempre più confrontarsi con la problematica legata alla crescente presenza di porzioni di territorio dove si riscontra la presenza di acque sotterranee contaminate (principalmente solventi clorurati e idrocarburi), per le quali non è più possibile identificare la posizione delle fonti origine della contaminazione. Questo tipo di contaminazione viene definita contaminazione diffusa dovuta a molteplici fonti puntuali e rappresenta un problema ambientale comune in molti paesi sviluppati. Spesso, tale inquinamento, è tra gli elementi che causa il mancato raggiungimento degli obiettivi qualitativi definiti dalla direttiva europea sulle acque sotterranee. Inoltre, l'inquinamento diffuso determina un impatto economico notevole sulla società, a causa dei costi necessari per la sua gestione e il suo risanamento. Regione Lombardia, che è una del-

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## **1. Introduction to Groundwater Governance: from European to Regional environmental legislation**

In Italy, the management of the diffuse contamination undergo laws of three different levels: the European, the National and the Regional ones.

From the EU side, the framework is given by the Directive 2000/60/EC – Water Framework Directive (WFD, European Environment Agency, 2013) and the Directive 2001/42/EC – Strategic Environmental Assessment Directive (SEA). Measures to recover diffuse pollution of groundwater contribute to the achievement of quality goals for groundwater bodies defined under the WFD. Moreover, each plan or program that leads in significant environmental effects must be submitted to the SEA procedure.

The Directive was adopted by National law but the latter provides to give more detailed indications about contamination and

le zone maggiormente urbanizzate e industrializzate in Europa, ha recentemente sviluppato una legislazione regionale specifica per far fronte al problema, che comprendente un programma di risanamento regionale ed un Piano regionale di gestione per inquinamento diffuso delle acque sotterranee.

Grazie alla presenza di efficienti reti di monitoraggio e di numerosi dati quali-quantitativi riguardanti le acque sotterranee lombarde, è stato possibile avviare un processo di valutazione dello stato di inquinamento diffuso nell'Area Vasta, costituita dalla città di Milano e da un settore del suo hinterland posto a Nord-Est. Questo ha consentito di definire una nuova soglia di riferimento per la contaminazione diffusa (RTDC) e un Piano di Gestione contenente le modalità di gestione e le misure per la prevenzione dell'inquinamento diffuso. Regione Lombardia (2017) ha delimitato la prima area interessata da inquinamento diffuso e ha approvato le misure di intervento ed il regolamento per le procedure di bonifica ricadenti in tale area. In seguito a questa prima azione sulla gestione della contaminazione diffusa, Regione Lombardia e il Politecnico di Milano hanno avviato il progetto AMIIGA (Approccio Integrato alla Gestione della Qualità delle Acque Sotterranee nelle aree Urbane Funzionali CE32-INTERREG 2016-2019) nel quale, sarà sviluppato un nuovo piano di gestione per l'area nord-ovest di Milano. L'area pilota comprenderà 9 comuni della provincia Milanese e due della provincia di Varese. Questo articolo intende presentare sia il quadro normativo europeo ed italiano che il piano regionale di gestione dell'area allargata (FUA) di Milano, presentando la metodologia adottata e i risultati ottenuti.

**Parole chiave:** contaminazione diffusa, gestione della falda, Protocollo Operativo Regionale, Piao di Gestione, AMIIGA.

its management in each specific European State.

In Italy, the Legislative Decree (Dlgs. 152/06 which enforce the WFD) defines the anthropogenic diffuse contamination as the "chemical, physical and biological alteration of environmental matrixes and contaminations determined by diffuse sources and not linked to a point source". Furthermore, it designates Regions to enact actions when diffuse contamination is recognized and to define a scientific based Diffuse Pollution Background Levels (Azzellino *et al.*, 2019) for diffuse pollutants in groundwater.

Putting into actions the pre-

scription of the Dlgs. 152/06, Lombardy Region published the Regional Remediation Program (RRP, 2014) including the Regional Management Plan (MP) for diffuse pollution of groundwater. The Plan is constituted by several chapters containing the criteria for economic and financial planning, the criteria for the priorities definition, a catalogue of the areas of diffuse pollution and the Operative Protocol for the management of the diffuse pollution of groundwater (Annex 17 of RRP). Recently, the RRP has been submitted to SEA Directive procedure.

The implementation phase of

the RRP involves the definition of a MP for each area affected by diffuse pollution (fig. 2). The MPs are measures of the RRP and do not need to undergo again to the SEA.

On the other hand, the Operative Protocol is a technical tool that standardize the acting procedure to follow to manage potential situations of anthropogenic diffuse contamination.

The protocol envisages the definition of the MP for each area potentially affected by diffuse pollution and specifies the steps to be followed in order to assess its presence, to delimit its spatial extension and to identify the remediation measures. Moreover, it establishes to institute a technical panel, the Regional Implementation Group (RIG), for each single area where all the subject involved in the water management are invited.

During the meetings of the Regional Implementation Group (RIG), members jointly discuss, share decisions and evaluate results on the activities carried out to be enacted in order to manage the diffuse pollution in the area involved by the MP.

Lombardy Region coordinates the RIG, proposes drafts of remediation measures and takes care of submitting the MP to the approval of the Government of the Region. This paper aims to present the RRP development by Lombardy Region both by legal point of view and by the scientific-based methodology applied in the North-eastern sector of Milano Functional Urban Area.

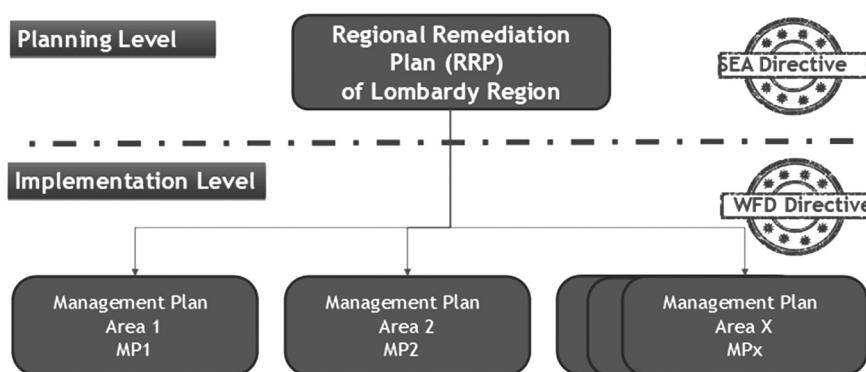


Fig. 1. A schematic summary showing the current approach among the RRP and the MPs that are developed for the different areas.

Schema riassuntivo che mostra l'approccio corrente tra il Piano Regionale delle Bonifiche ed i Piani di gestione che vengono sviluppati per le differenti aree.

## 2. The case study application: Functional Urban Area of Milan (FUA) and Wide Area

Since 2013, Lombardy Region has developed many studies to



Fig. 2. Milan FUA (bold contour) and the AMIIGA Pilot Area filled in grey. Milano city is filled by line symbol. The points represent the monitoring network.

FUA di Milano (in grassetto) e colorati in grigio i comuni dell'Area Pilota del Progetto AMIIGA. Il Comune di Milano è rappresentato con linee. I punti rappresentano la rete di monitoraggio.

deepen and remediate the contamination of groundwater in the metropolitan area of Milan. The studies have been extended to the Functional Urban Area (FUA, fig. 2) (OECD, 2012) to consider all the possible sources (green contaminated sites in the Figure 2) of pollution that affect the groundwater in Milan.

The FUA of Milan is one of the most densely populated and industrialized areas in Po Plain within Lombardy Region. It covers Milan and a crown of municipalities at its borders. The northern area of FUA has been heavily industrialized (since early 1950s) and is characterized by a dense agglomeration of industries (mainly automotive, refineries, chemical plants, still and tires production). Because of the high hydraulic conductivity and the high groundwater withdrawal rate (Alberti *et al.*, 2014; Colombo *et al.*, 2018), Milan represents the drainage area of groundwater in the FUA and many pollutants flows from the suburban area into city groundwater. The FUA considered in this study<sup>1</sup> includes 34 municipalities, is about 521 km<sup>2</sup> wide and has about 2 Million inhabitants. The monitoring network (fig. 2) used for the studies includes idrochemical data from 3,477 wells/piezometers, over 49,000 stratigraphic records. The database consists of 618,258 records, corresponding to 19 hydro-chemical parameters for the period 2003-2014.

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<sup>1</sup> The FUA originally circumscribed covered 31 Municipalities and an area of about 486 km<sup>2</sup>, 3 more municipalities were added to include several plumes that originate North-Western of Milan have a significant effect on the deterioration of the groundwater quality in Milan. The focus and the development of the MP on the North-Western area of Milan will be done within AMIIGA project.

The first studies performed highlighted that in Milan FUA there is a presence of a multitude of contamination points and that the contamination given cannot more be traced back to the single source (Alberti *et al.*, 2018). This kind of contamination, named diffuse pollution, requires effective intervention at a medium scale, neglected in existing legislation. The issue regarding these areas is that they cannot be managed with the usual remediation techniques used for small contaminated sites, mainly for two reasons: a) the difficulty to identify specific point sources and b) the wide extension of the contaminated plumes areas. Both aspects require alternative approaches.

Recently, Lombardy Region, in order to face the problem, tested for the first time the Operative Protocol for the management of the diffuse pollution of groundwater. The investigated area is named Wide Area (fig. 4), is portion of the FUA and includes the City of Milan and six surrounding municipalities. Its extension is about 286 km<sup>2</sup>.

According with the Protocol, the RIG was established with all local institutions involved in the water quality management (Municipalities, Districts, Regional Environmental Protection agencies, Water Service Managers, Regional Agency for health protection) in reason to define the first MP.

The RIG, coordinated by the Region Authorities, performed several monitoring campaigns on a big monitoring network within the FUA. The monitoring data and the recent campaigns (monitoring data between 2003-2014) revealed a presence of diffuse contamination due to chlorinated hydrocarbons especially in the North-Eastern sector of the area.

Based on the results obtained through the investigations, in 2017, Lombardy Region delimited

for the first time an area affected by diffuse pollution and, for this area, approved intervention measures and the discipline for remediation procedures.

During the follow-up emerged that several plumes that originate North-Western of Milan have a significant effect on the deterioration of the groundwater quality in Milan and affect some pumping stations used for the water supply services. Within AMIIGA, a new MP will be developed for the Pilot Action area (filled in violet in Figure 2) that covers the surface of 12 Municipalities at North-Western of Milan (including a part of Milan). The groundwater in the Pilot Action area is also affected by diffuse contamination of Chlorinated Hydrocarbons.

### 3. Diffuse contamination approach: a methodology

A new methodology was developed to manage and assess threshold values representing the diffuse contamination (VDC). More in detail, an integrated approach (statistical and deterministic numerical model) has been adopted to distinguish point sources (hotspots) and multiple-point sources (diffuse contamination). It is a multivariate and K-means statistical approach and a transport numerical modelling (Modflow+MT3DMS) (Alberti *et al.*, 2018, 2016; Azzellino *et al.*, 2019).

The methodology can be divided in three main activities and several sub activities (fig. 3):

- 1) User data and pre-processing: more than 3477 monitoring points were considered (from private, public network provided by Water Managers, from contaminated sites) thanks to local and regional agencies, covering the period 2003-2014.

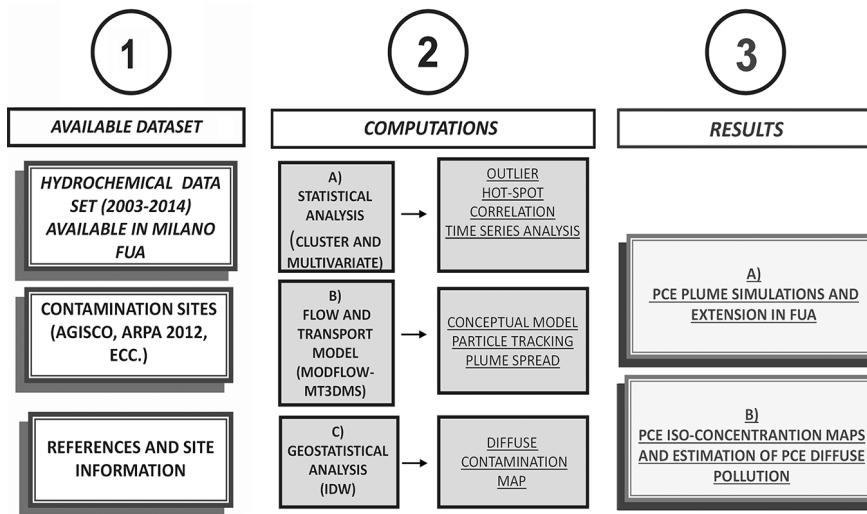


Fig. 3. Roadmap of the methodology for assessing the reference threshold of diffuse contamination (RTDC) in FUA of Milan 1) user data and pre-processing 2) tools used for computations: statistical tools for cluster and multivariate analysis, transport and flow mathematical model and geostatistical interpolator and 3) results in terms of plume extension and diffuse map contamination with estimated threshold values.

*Mappa concettuale della metodologia utilizzata per la valutazione dei livelli limite di inquinamento diffuso nella FUA di Milano 1) Fase di pre-processamento e utilizzo dei dati 2) strumenti utilizzati per i calcoli: strumenti statistici per analisi cluster e multivariante, modelli numerici di trasporto e di flusso e interpolatori geostatistici 3) risultati ottenuti in termini di estensione dei pennacchi e di mappe di contaminazione diffusa con rispettivi valori di riferimento.*

The overall data were merged into a single database with more than 600,000 records corresponding to 19 parameters (ions mono and bivalent, solvents). Figure 2 shows the spatial distribution of the sampling wells, which covers the entire territory. Data quality were checked by considering: abnormal values, outliers and absence of information into dataset.

2) A) Classification of the sampling point with coordinates, depth and a code indicating the aquifer throughout are screened. Statistical analysis allowed to select few factors able to describe the whole data set with minimum loss of original information (Principal Component and Factor Analysis) whereas k-means Cluster Analysis performed the similarities among the water quality profiles at different monitoring points.

B) Flow and transport model: for the definition of the areas affected by the passage of contamination plumes, the clusters analysis allowed to identify the "hot spots" in the area. These points, considered as point sources, were modeled to define the plumes contamination extension (Dlgs. 152/06). The groundwater model (MODFLOW+MT3D-MS developed by (Harbaugh *et al.*, 2000; Zheng and Wang, 1999) was calibrated with PEST (Doherty, 2014, 2003, 1994) with monitored head values in May 2014 and with sampled concentration in 2014.

C) Geostatistical analysis (Inverse Distance Weighted) in order to map the diffuse contamination for perchloroethylene (PCE) and trichloromethane (TCM), not directly influenced by hot spots.

3) Spatial reconstruction of diffused pollution:

A) the monitoring wells located inside the plume areas were removed from the polluted dataset with the aim to keep just the concentrations representing the diffuse contamination. The new dataset was then used for the geostatistical analysis (Inverse Distance Weighted)

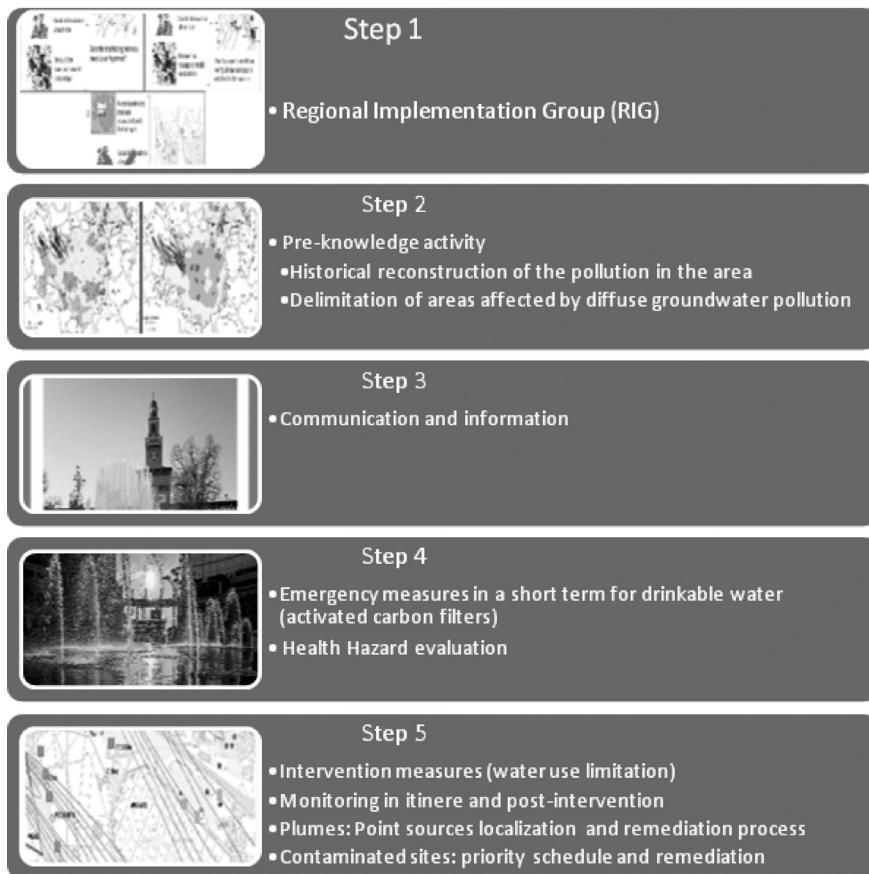
4) definition of reference values of diffuse contamination levels for the areas identified in the maps.

#### 4. Regional management of diffuse contamination

The MP for diffuse pollution, approved with the Decree of the Regional Government (n. 6737/2017) according to the Operative Protocol, contains a series of measures to cope with the presence of diffuse pollution (tab. 1). The measures aim to safeguard the health of the inhabitants, control and contrast the pollution of the groundwater and its effects on the environment. However, the measures do not overtake the central issue of the research of unknown sources.

The Public Institutions involved in remediation measures are in charge for:

- apportion contaminant sources for the application of the polluter pays principle. Recently, the Region has financed the drilling of additional piezometers to find some of these sources
- find resources for the protection of human health and the environment
- control of the correct implementation and the effectiveness of the remediation measures
- substitute the polluters responsible for the remediation in case they refuse to do the remediation (enacting legal actions to recover the costs)



Tab. I. Scheme of the Operative Protocol of Regional Remediation Program (RRP).  
Protocollo operativo per la gestione di bonifica regionale.

- assess risk in contaminated sites.

In addition to these measures, the Region has developed a procedure to assess the potential health risk for population coming from diffuse contamination by Chlorinated Hydrocarbons. It considers many key parameters like concentration of pollutants, lithology, water table, indoor/outdoor exposure, land use, environmental measurement and will be helpful both to exclude health risk and to suggest the opportunity of local investigations to refine risk assessment, to choose the most suitable actions to undertake to decrease the risk to acceptable values.

The tool has been applied for the first time to the Wide Area for the diffuse pollution of PCE and TCM and will be distributed for the use by the local Institutions.

#### **4.1. Step 1: Regional Implementation Group (RIG)**

The RIG for the Chlorinated Hydrocarbons diffuse contamination of groundwater was instituted in 2015. The members of the RIG were the Public Authorities that are in charge for the environmental problems (i.e. water management, soil conservation and environment) at local and regional level. Moreover, Regional Environmental Protection Agencies (ARPA), Water Service Managers, university (Politecnico di Milano) were invited to participate to the meeting due to their involvement in the data collection, water management and for the scientific support for modeling the phenomena.

The RIG is in charge for the implementation both of the databases and of the monitoring network, for the circumscription of the areas

affected by diffuse pollution based on the Values representative of the Diffuse Contamination (VDC) and of the Reference Threshold for Diffuse Contamination (RTDC). Moreover, it is in charge for the definition and proposal of the measures of intervention. In particular, the RIG tackled the following aspects:

- delimitation of the diffuse contamination within FUA for PCE and TCM
- evaluation of the Health Hazard for the population due to a presence of diffuse contamination and especially linked to the vaporization of PCE and TCM
- definition of the new RTDC for the remediation within the FUA
- definition of the management and interventions measures aimed at control the diffuse contamination evaluation, safeguard the citizens health and mitigate the health risk.

The experiences gained with the RIGs management, previously in the MP of the Wide Area and now applied for the Pilot Action in the North-Western area of Milan for the AMIIGA Project, are showing that this instrument is powerful because of the interdisciplinary of its members, but also that it is not easy to come in to an agreement when many actors are involved in the decisions. Moreover, it is not easy to involve actively members in the activities (only 6 municipalities out of 12 attended to the meeting).

#### **4.2. Step 2: Pre-knowledge activity, historical reconstruction of the area, delimitation of areas affected by diffuse groundwater pollution**

The reconstruction of the diffuse pollution distribution of the groundwater in the Wide Area requires an important phase of organization and integration of

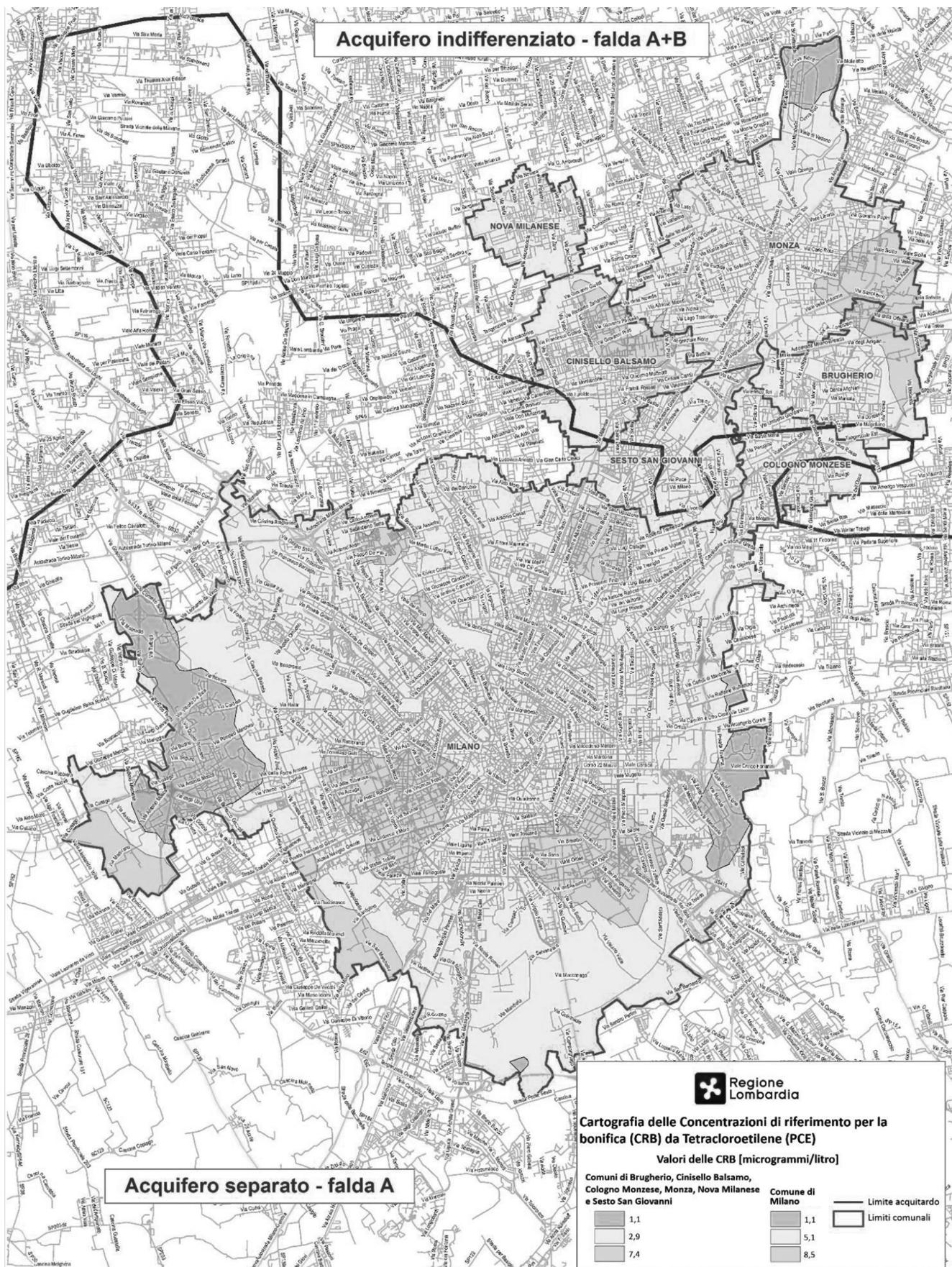


Fig. 4. Map of PCE diffuse contamination and Reference Threshold for Diffuse Contamination (RTDC) for remediation actions.  
Mappa di contaminazione diffusa da PCE e valori di concentrazione di riferimento di inquinamento diffuso (RTDC) per la bonifica.

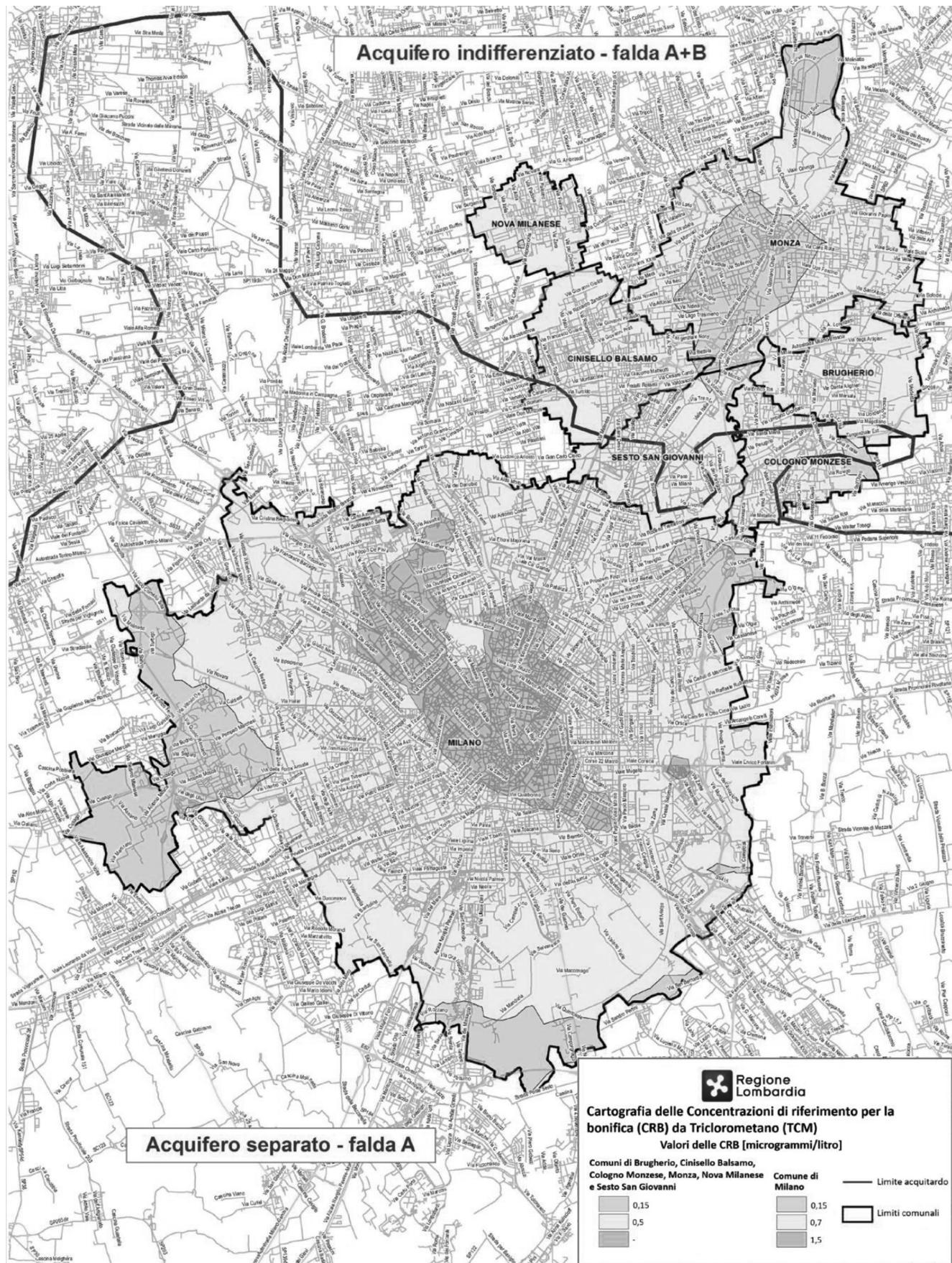


Fig. 5. Map of TCM diffuse contamination and Reference Threshold for Diffuse Contamination (RTDC) for remediation actions.  
Mappa di contaminazione diffusa da TCM e valori di concentrazione di inquinamento diffuso (RTDC) per la bonifica.

existing dataset. Moreover, a detailed analysis over the time on the typology of activities of companies in the involved area (i.e. sectoral business, types of processing) has to be done. Pre-knowledge activity and historical reconstruction of the pollution in the area have been done by Politecnico di Milano and ARPA (ARPA Lombardia, 2016, 2015) following the new methodology detailed in paragraph 3.

Based on the results of the detailed investigation carried out Lombardy Region, in May 2017 with the Decree of the Regional Government 5590/2017, delimited the areas affected by groundwater diffuse pollution of PCE and TCM. Figure 4 and Figure 5 show the maps, defining the diffuse pollution distribution in the Wide Area for PCE and TCM in the shallow aquifers, that are annexed to the Decree.

Green areas are not affected by diffuse contamination and concentrations are below the National Law Limit ( $1.1 \mu\text{g/l}$  and  $0.15 \mu\text{g/l}$  respectively for PCE and TCM: Dgls. 152/06) whereas the yellow areas represent the diffuse contamination with concentrations in the range between the National Law Limit and  $10 \mu\text{g/l}$  (drinking water Threshold limit (Dgls. 31/01) for the sum of Chlorinated Hydrocarbons). The red areas represent the areas affected by a high level of diffuse contamination (over  $10 \mu\text{g/l}$ ).

The methodology applied in this study is able to evaluate the contamination representative of the diffuse pollution for the Wide Area. Lombardy Region, in accordance with national Legislation (Annex 1 –Part IV Dgls. 152/06), adopted these values as Reference Threshold for Diffuse Contamination (RTDC) for the remediation measures. RTDC have been defined for PCE and TCM for the shallow aquifer. Since the aquifer is sepa-

Tab. 2. RTDC values for PCE ( $\mu\text{g/l}$ ).

*Concentrazioni di Riferimento per la Bonifica del Tetracloroetilene ( $\mu\text{g/l}$ )*.

RTDC ( $\mu\text{g/l}$ )	Yellow Area	Red Area
Northern Municipalities (Wide Area in the Figure 4)	2,9	7,4
Milan	5,1	8,5

Tab. 3. RTDC values for TCM ( $\mu\text{g/l}$ ).

*Concentrazioni di Riferimento per la Bonifica del Triclorometano ( $\mu\text{g/l}$ )*.

RTDC ( $\mu\text{g/l}$ )	Yellow Area	Red Area
Northern Municipalities (Wide Area in the Figure 5)	0,5	Not provided
Milan	0,7	1,5

rated in Milan while undifferentiated in the municipalities Northern Milan, two different RTDC have been defined. Moreover, separated RTDC have been defined also for areas with different concentrations of diffuse contamination (yellow ad red areas). Table 2 and Table 3 contains the RTDC for PCE and TCM with reference to Figure 4-Figure 5. The RTDC was defined with a methodology (presented in the paragraph 3) composed by a numerical transport model (definition of plumes contour due to a presence of known point sources) and multivariate statistical approach (cluster analysis and factor analysis able to evaluate the concentration of diffuse contamination in different areas). For more details about the methodology and the application done to obtain the RTDC, see (Alberti *et al.*, 2016b; Azzellino *et al.*, 2019; Colombo, 2017).

The RTDC, are less restrictive than National Law Limit and are the new concentration targets for individual remediation procedures in this aquifer.

For the red areas, the RTDC is set as  $8.5 \mu\text{g/l}$  in order to respect the law concentration limit for drinking water (Dgls. 31/01) for the total sum of PCE-TCE.

Within the delimited area, the remediation procedures for point sources remain in charge to the polluters, and have to be managed within traditional administrative

procedures, but the concentration limits to be reached for the PCE and TCM in shallow aquifer become the RTDC instead of the National Law limit.

#### **4.3. Step 3: Communication and information**

The communication about the groundwater diffuse contamination, because of the high rate of population living in the area and interest of the institutions and municipalities involved in the groundwater quality, needs a coordinate management. In this context, a communication plan to disseminate environmental information and results of the methodology applied will be prepared. The proposal aims to promote knowledge and awareness not only on the presence of diffuse pollution but also on the measures taken to limit the use of impacted resources and on environmental-health issues.

The Plan will also take into account the need to disseminate information to the public, citizens, on the evolution with reference both to implementation of the measures and actions envisaged and to the evolution of the pollution situation. Moreover, stakeholders like Land Owners, Polluters, Remediation Performers and Residents will be involved in the knowledge and progress of the MP in the FUA.

## 4.4. Step 4: Drinkable water use and hazard evaluation

The use of groundwater for drinking purposes in the studied area is monitored in continuous way from Water Supply Managers and institutions. Moreover, water supplied by distribution networks are treated in order to ensure the complete safety for the population. Concerning the water for human consumption, the Legislation considers control in-house done by Water Supplied Managers or by Regional Agency for Health Protection in order to guarantee the potable water threshold Limit (Dgls. 31/01 –for Chlorinated Hydrocarbons 10 µg/l).

The Water Supply Managers on the investigated area, which are involved in the RIG, have developed and implemented strategy providing drinkable water of high quality, adopting suitable Water Safety Plan based on a risk condition management. In addition, the protection of the population affected by diffuse pollution will be addressed in the most exhaustive way. The provided actions will be developed to get, more complete as possible, a full framework of critical issues associated to water uses. It will be assessed the hazards derived from water affected by diffuse contamination used for irrigation, livestock or recreational use and from sites with excavations in the saturated areas.

## 4.5. Step 5: Intervention measures

Based on the groundwater modeling (see paragraph 2) and on a sanitary risk assessment (developed by Regione Lombardia), a series of remediation measures have been defined:

a) Limits on the water use

Within the intervention measures, there is the possibility

to limit the use of water for the activities concerned in order to avoid risk for the population.

b) Monitoring of groundwater quality

The Regional Environmental Protection Agency will develop a groundwater monitoring plan, it will be funded by the Region. The monitoring activities will be based on the use of the existing network, with a possibility to integrate dataset with the data of Water Services, with a 6-month measurement field campaigns. The monitoring activity will allow to verify and update the mapped RTDC during the years (in a time interval 4-5 years) and evaluate the effects of the measures adopted in a medium-long term.

c) Study and definition of plumes, localization and remediation of point sources

By using groundwater modelling tool, it will be possible to trace the plumes and study their evolution in space and time. An effort will be done for the identification of contaminant sources for the application of the polluter pays principle in order to find resources for the protection of human health and the environment.

d) Contaminated sites

Documentary research and survey plan will be useful to assess the interventions for site-specific contamination problems.

## 5. Conclusion

Significant contamination affect most of the groundwater bodies of Lombardy Region due to an intense process of historic industrialization. While in some areas the contamination depends on point sources (known or under investigation), in others groundwater presents pollution of diffuse nature.

The management of diffuse pollution represents a difficult challenge for the Public Authorities, as it involves large portions of territory, with low concentrations of pollutants and consequences both on the use of water and on the health of citizens. This problem cannot be managed with the ordinary technical-administrative tools available for the remediation of point sources.

This kind of contamination requires an important systematization and integration of existing data. Therefore, Lombardy Region has defined the diffuse pollution management strategy in land remediation planning.

Since diffuse pollution affects large areas and multiple subjects, the Region has standardized the procedure for its management, including the creation of a RIG (or Technical Panel) to coordinate the procedures and activities among all the involved public bodies.

The regional experience about the management of groundwater diffuse pollution in the Wide Area of Milan (about 2 million inhabitants) represents an innovative procedure in the groundwater protection.

The intervention measures, included in the MP approved by the Lombardy Region in 2017 for this area, aim to protect the health of the population concerned, to control and contrast pollution and its effects on the environment and to raise awareness about it. The monitoring process to assess the evolution of pollution over time have been also established.

Given the importance of protecting human health, new studies have been ongoing to assess, through the application of groundwater models, the potential risks, even cumulated, of the uses of groundwater affected by diffuse pollution.

Because in presence of groundwater diffuse pollution, the re-

mediation procedures admit less restrictive reference values, the issue is sensitive with far-reaching implications and several interested parties. Lombardy is the first region in Italy that is investigating this issue and implementing a new methodology that can be assumed as a test of the national guidelines of diffuse pollution recently issued by the Ministry for the Environment.

This activity will be enhanced thanks to the AMIIGA Project: considering that in Europe there are many areas with similar forms of groundwater pollution, the development of common management modes, focusing on densely populated areas, is strategic to successfully address the complex profile of the problem. At the end of the project, the Plan for the Wide Area and those of the Pilot Action area will be merged in a comprehensive Plan for the whole Milan FUA.

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