



First survey on the occurrence of chlorinated solvents in groundwater of eastern sector of Rome

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Abstract

Groundwater pollution by chlorinated compounds is one of the most common environmental issues affecting urban areas, especially for those with a huge industrial vocation. Even if Rome is not an industrial city, this kind of contamination has been recently started to be detected in the groundwater. In order to better evaluate the presence and distribution of chlorinated solvents in groundwater in the eastern sector of Rome, a sampling survey in the monitoring network of the city has been conducted. First preliminary results, deriving from samples collected in wells mainly located in public green areas in a previous investigation survey, seem to show how the species tetrachloroethylene, trichloroethylene and all their degradation pathway can be associated more with point source of contamination with locally very high concentration values. On the contrary, the detection of trichloromethane and 1,1,2-trichloroethane, which have been found in the new data collection at low concentration in several of the investigated wells, could suggest a diffuse occurrence of these compounds. Unfortunately, even if the presented results represent a good starting point for further evaluations, the preliminary status of this research cannot allow to clearly understand the source of contamination and declare the possible diffusion of these two compounds.

Keywords TCE · PCE · Trichloromethane · 1,1,2-Trichloroethane · Urban groundwater

1 Introduction

The relationship between the urban fabric and groundwater inevitably impacts both the groundwater flow and quality (Ellis 1999). Most of the large urban area aquifers, especially those with a strong industrial vocation, are affected by important contamination of organohalogenated compounds. The widespread presence of various industrial and commercial activities, including numerous mechanical workshops, laundries and also petrol stations, can cause local accidental or sometimes malicious spills of polluting substances. These contaminants can infiltrate directly into the ground or can

be disperse due to sewers or water main leaking (Ellis and Revitt 2002; Howard 2002). These local accidents are the most frequent causes for ground and aquifer contamination due to anthropic activity that, during time, and depending on the velocity of groundwater flow and the hydrodynamic characteristics of the concerned aquifers, can turn on diffuse contamination (Balderacchi et al. 2014).

Chlorinated solvents such as tetrachloroethylene—PCE—and trichloroethylene—TCE—have been extensively used for years in industrial processes mainly as degreasers. Although these substances have been produced and used since the beginning of the last century, their importance as contaminants in groundwater has only been recognized since the beginning of 1980. This can be attributed to a regulatory gap that could prevent the uncontrolled leakage of contaminants into the subsoil and to the absence of analytical methods capable of detecting these compounds even at low concentrations (Pankow and Cherry 1996; Bradbury et al. 2007). It should also be highlighted that many safety manuals of chemical industries, distributed between 1940 and 1980, suggested spreading those in dry soils to allow their evaporation, not considering the ability of DNAPL to rapidly infiltrate into the soil, causing severe ground and deep

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aquifer contamination (Verdini and Majone 2015). Other typology of chlorinated compounds which can be detected in groundwater is related to other industrial processes or can be derived from water sanitation processes as trichloromethane, 1,1,1-trichloroethane, 1,1,2-trichloroethane, etc.

Chlorinated solvent contaminations are very frequent in groundwater of urbanized contexts. In Italy, there are many well-known cases located in Lombardy, Piedmont, Veneto, Emilia-Romagna, Tuscany, Marche and Umbria (Alberti et al. 2017; Colombo 2017; Conti et al. 2014; Beretta et al. 2018; Busoni and Gnocchi 2013; Filippini 2017; Guzzella et al. 2009; Menichetti and Doni 2017; Petitta et al. 2013; Pedretti et al. 2013; Vanzetti et al. 2016), and although the contamination is originated from specific sources, sometimes today it presents a widespread diffusion, also due to the multiplicity of the sources. Even in the City of Rome, although it has a very limited industrial development, some sites affected by this kind of contamination have been notified in recent years. The distribution of these sites is prevalent in the eastern sector of the city, where the few existing industrial activities are also located. Concentrations vary in a wide range showing high values typical of point source contamination and concentration attributable to a possible contamination from multiple point sources. After the recent work of Bonfà et al. (2017), which represents the state of the art about contamination due to chlorinated compounds in Rome, the aim of this study is to preliminarily investigate the potential occurrence of these contaminants and their diffusion by means of the groundwater monitoring network of Rome (La Vigna et al. 2015).

2 Background knowledge about Rome soils and groundwater contamination

The potentially contaminated sites notified in the city of Rome can be split into two main categories: the first includes sites polluted by localized anthropogenic sources and the second type includes sites showing background natural alterations (La Vigna et al. 2014; Preziosi et al. 2009). There are also some exceptions represented by a certain number of sites whose source of contamination still remains to be clarified by the Metropolitan City of Rome (institution responsible for investigations). Concerning the first category, most of the contamination events in Rome are linked to localized sources such as accidental or malicious spills from underground and aboveground distribution lines and tanks, abandoned waste, commercial or industrial activities. To date, the sites notified since 1999 on the territory of Rome (whose extension is 1285 km²) are more than 400, many of which involve only soil and not groundwater, and are partially remediated.

Numerically, contamination events caused by hydrocarbon substances derive mainly from losses by petrol stations. In the second order, but not due to significance, there have been several cases of groundwater contamination by chlorinated compounds (DNAPL) recently notified (Bonfà et al. 2017).

3 Site description

As previously mentioned, the eastern sector of Rome has been chosen by the urban planners, starting from the 1960s, as one of the areas to be dedicated to the industrial development of the city. This development, as in many cases of other urban realities, did not run together with the environmental preservation. Although the industrial sector is not the sector that drove the Roman economy, several pollution phenomena of different environmental matrices have been identified in these sectors (Bonfà et al. 2017).

In the Roman area, different groundwater circulations have been recently identified (La Vigna and Mazza 2015). In addition to a “regional” flow that affects the whole territory in a rather continuous way, there are both a confined aquifer present in the gravel bed of recent alluvia and a multilayer aquifer system located in the Colli Albani Volcano sector, where there are at least two other flow levels besides the regional one. The regional circulation starts from the more peripheral and elevated sectors of the city area connecting in the central city area to the main rivers (Tevere and Aniene) and to the sea along the coast (Fig. 1).

The studied sector is the eastern area of Rome, located in the lower Aniene River basin. In this sector, the hydrogeological setting includes important elements conditioning the groundwater flow, including the “Paleotiber Graben” (Luberti et al. 2017), the Acqua Vergine (or Salone) Springs and the Aniene River. In particular, the aforementioned “Paleotiber Graben” is a tectonic depression within coarse continental fluvial sediments that have been deposited with a thickness that in some places exceeds 80 m. It represents an important aquifer body, located under one of the most intensely urbanized areas of Rome (Bonfà et al. 2017). The investigated aquifer potentially interested by chlorinated solvent contamination is the regional one.

4 Materials and methods

In order to define in detail the water quality and chlorinated solvent pollution distribution in the eastern sector of the city, a sampling survey has been carried out (since May to September 2017). Specifically, 30 pumping wells of the groundwater monitoring network of Rome (mostly used for irrigation purposes) have been sampled one time each. The

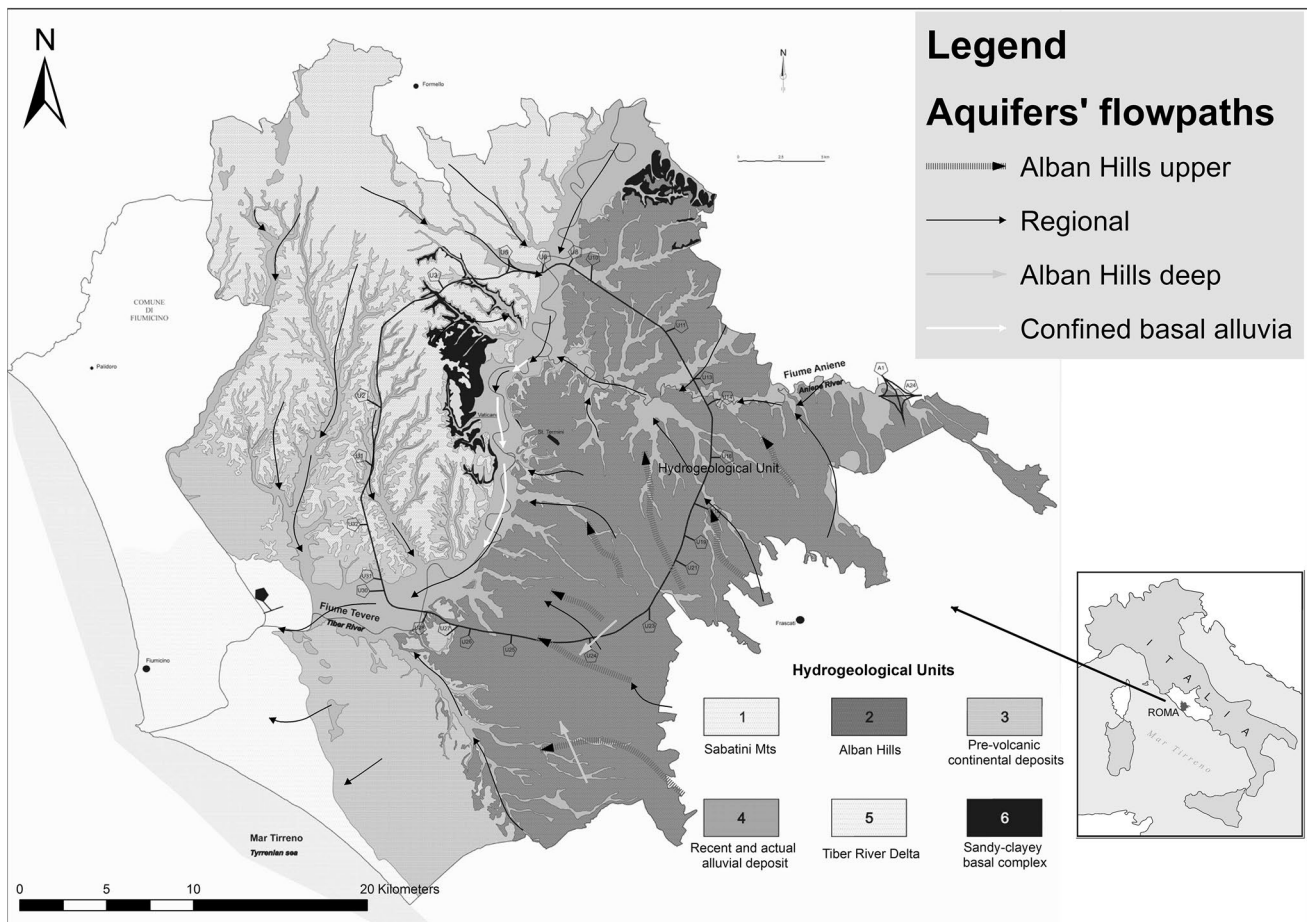


Fig. 1 Hydrogeological Units of Rome Municipality (modified from La Vigna and Mazza 2015). The regional groundwater circulation mainly flows inside the Alban Hills hydrogeological unit and inside the pre-volcanic continental deposit unit and is limited by the sandy-clayey basal complex (the aquiclude of the area). Other separated

groundwater circulations flow into some basal gravels of Tiber River alluvia and at the base of Alban Hills sector (confined), and into the surficial Alban Hills volcanic units. See La Vigna and Mazza (2015) for more details on the hydrogeology of this sector

monitoring wells selected for this study are located close to officially contaminated sites, previously studied and investigated by local environmental authorities and where periodic analyses (temporally comparable with the conducted survey) are available. The aim of this selection is the evaluation of chlorinated solvent diffusion in the aquifer, nearby the already detected polluted sites. The sampling methodology could not follow the standard methods mainly due to the difficulty in purging the pumping wells. In fact, some of the selected wells were equipped with worn-out malfunctioning pumping system not allowing purge operations. Therefore, when pumping system was in order, groundwater samples have been collected using the pumping equipment; otherwise, a double-valve bailer has been used. Water temperature, pH and electrical conductivity (EC) have been measured during field activities using a WTW Multi 3420 probe.

Overall, five groundwater samples have been analyzed for cations and anions in order to define the hydrochemical

footprint of the eastern sector of the city; 28 samples have been selected to measure minor and trace element concentrations, and 23 samples have been analyzed to detect chlorinated solvent concentrations (Fig. 2).

The groundwater samples collected for major, minor and trace element concentration measurements were filtered through 0.45- μm filters, stored in a cool box at 4 °C and immediately transported in laboratory. In addition, samples for minor and trace elements have been acidified with 0.1 N HCl. Groundwater for chlorinated solvent analyses have been collected in 40-ml brown glass vials and preserved as described above. The analyses for groundwater chemical composition have been performed at the Geochemical Laboratory, Department of Earth Sciences, Sapienza University of Rome (Italy). Specifically, major ions have been analyzed with a Chromeleon, Dionex (precision $\pm 2\%$); an ICS 1100 has been used for analyzing cations, whereas a Dionex ICS 5000 was used for analyzing anions.

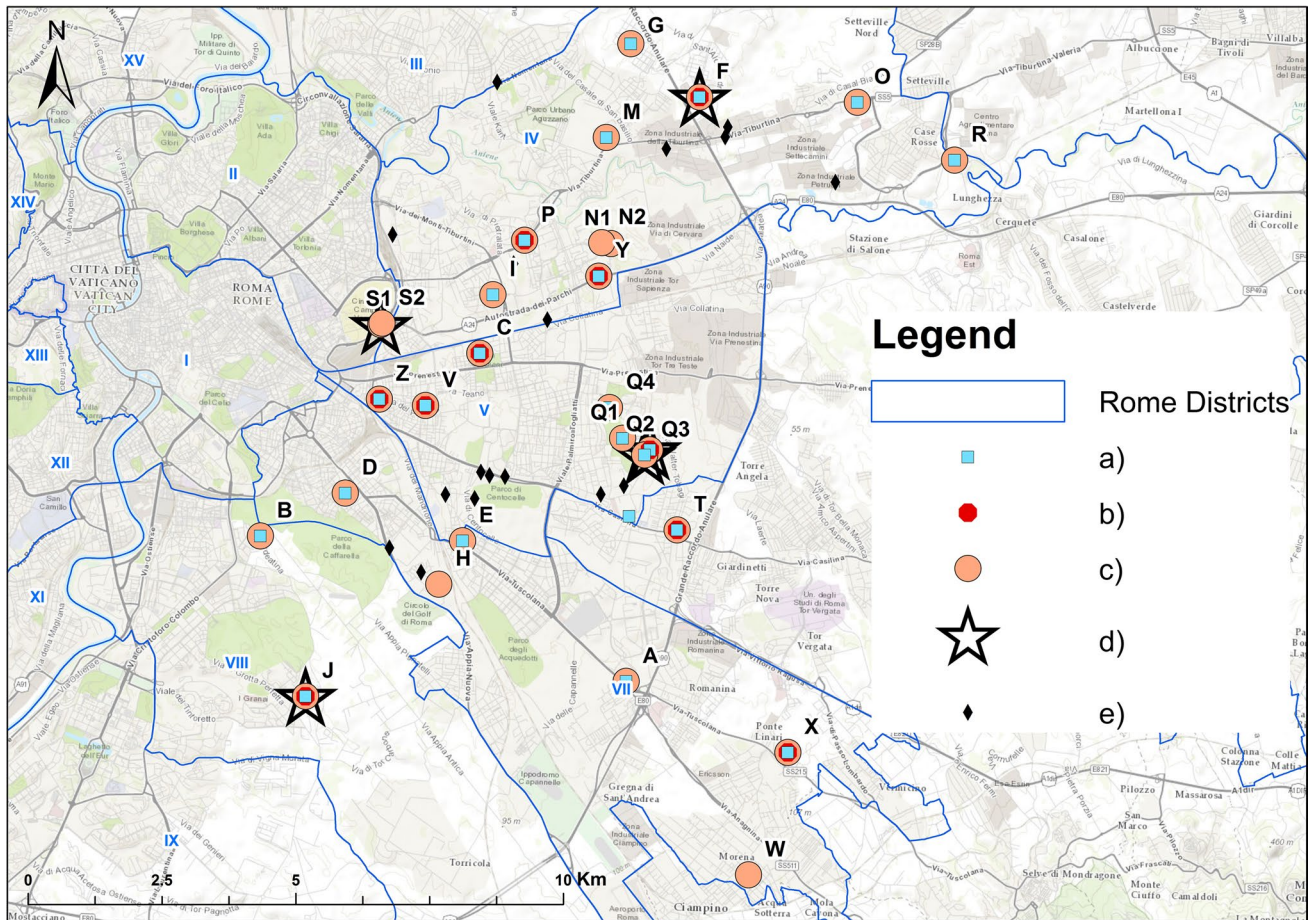


Fig. 2 Location map of investigated monitoring wells. (a) Monitoring wells selected for chlorinated solvent analyses; (b) monitoring wells with chlorinated solvent detection; (c) monitoring wells selected for

minor and trace element analyses; (d) monitoring wells selected for major ions analyses; (e) previously existing data about chlorinated solvent analysis

Concentration values of minor and trace elements have been measured by ICP-MS (X Series 2 Thermo Fisher Scientific). An internal standard, Rh, has been adopted to correct the ICP-MS instrumental drift. Ultrapure water (Millipore, Milli-Q, 16 M Ω cm) has been used in preparing blanks, standard solutions and sample dilutions. The analytical accuracy of these methods ranged from 2 to 5% (Nigro et al. 2016).

Chlorinated solvent analyses have been performed on 23 samples in a private authorized laboratory following the APHA/AWWA/WEP Standard Methods for Examination of Water and Wastewater (2012).

5 Results and discussion

5.1 Groundwater chemistry

Major ions concentrations have been analyzed in just five samples fairly distributed in the study area; in order

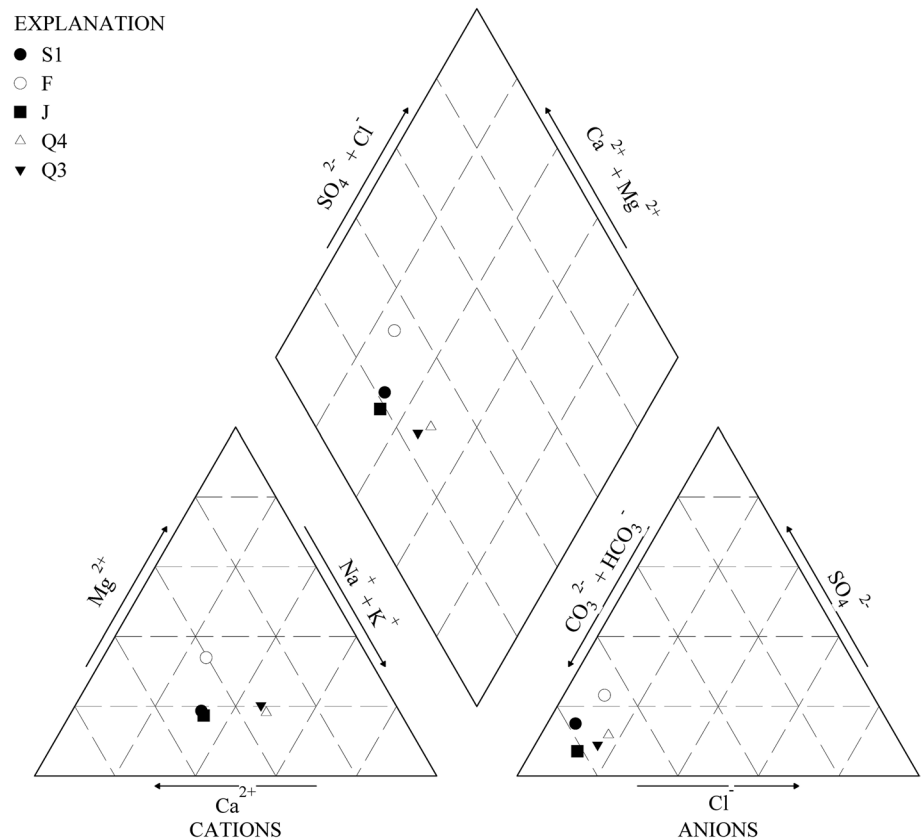
to understand the geochemical footprint of groundwater, Table 1 shows the results. Looking at the piper diagram (Fig. 3), where major ions concentration values have been plotted, it is possible to classify the analyzed samples as calcium bicarbonate water, with a sharp shift of on samples toward alkaline bicarbonate composition probably due to volcanic aquifer interaction.

Minor and trace element analysis have been carried out in almost all the samples (28) with the aim of understanding the magnitude of anthropogenic pressure on groundwater quality. Concentrations vary in a wide range of values as given in Table 2.

Generally the higher concentrations of ions probably linked with human activities have been detected for: Fe²⁺, Pb, Ni, As, Sr and V. Specifically, Fe²⁺ varies between 0.61 and 2860 $\mu\text{g/l}$ exceeding the legislation limit (D. Lgs 152/06) of 200 $\mu\text{g/l}$ only in two monitoring wells; Ni and Pb show a mean concentration values of 1 $\mu\text{g/l}$ with maximum values of 8.2 $\mu\text{g/l}$ and 15.5 $\mu\text{g/l}$, respectively, not exceeding the legislation limit (D. Lgs 152/06). Concerning As, Sr and V,

Table 1 Major ion concentration data (mg/l)

MW	Cl ⁻ (mg/l)	NO ₃ ⁻ (mg/l)	SO ₄ ²⁻ (mg/l)	Na ⁺ (mg/l)	K ⁺ (mg/l)	Mg ²⁺ (mg/l)	Ca ²⁺ (mg/l)	HCO ₃ ⁻ (mg/l)
S1	22.2	40	64.2	43.3	46.3	21.7	94.1	423
F	74.2	30.7	229	108.3	27.6	87.1	170.5	837
J	53.8	45.8	45.2	65.1	71.9	29.5	138.2	658
Q4	29.9	54.2	28.3	54.4	64.6	18.3	55.3	218
Q3	43.6	125.7	34	47.8	54.9	18.6	50.8	364

Fig. 3 Piper diagram classification for five selected monitoring wells; see Table 1 for values

measured concentrations are consistent with natural background values typical of Latium aquifer (La Vigna et al. 2014). In fact, the groundwater chemistry of Rome aquifers is strongly affected by the presence of volcanic sediments reflecting natural background concentration values of 47 µg/l for As, 1088 µg/l for Pb and 49 µg/l for V (La Vigna et al. 2014). Consequently, the recorded exceedances of As in 18 samples with respect to legislation limits (D. Lgs 152/06) could be attributable to natural sources, even if to confirm this assumption a regional and more detailed study would be necessary.

5.2 Chlorinated solvent pollution

Historically, the most abundant chlorinated compounds detected in groundwater around Rome Municipality area

were PCE and TCE (Bonfà et al. 2017). The analyzed samples regarding chlorinated compounds obtained from 2017 sampling survey gave very interesting and unexpected results, showing exceedances respect to legislation limits (D. Lgs 152/06) for trichloromethane and 1,1,2-trichloroethane (1,1,2-TCA) (Table 3).

Without considering the few previously known sites where these species have been detected (with higher concentration), the occurrence of these compounds exceeding the legislation limits (D. Lgs 152/06) is in 10 samples (Fig. 2). Their spatial distribution is pretty wide in the study area, but generally with low concentration values (maximum value detected for trichloromethane and 1,1,2-trichloroethane are respectively, 2.36 µg/l and 3.37 µg/l).

In order to figure out a possible diffusion magnitude of these compounds, these newly collected data have been

Table 2 Minor and trace element concentration data

MW	Compound concentration and legislation limit D. Lgs 152/06 ($\mu\text{g/l}$)									
	Li	Be	B	Al	V	Cr	Mn	Fe	Co	Ni
	–	4	1000	200	–	5	50	200	50	20
S1	15.1	0.4	106.5	<0.001	30.5	1.3	<0.001	0.6	0.4	<0.001
M	16.4	0	160.1	<0.001	36.9	0.7	<0.001	1	0.1	<0.001
S2	10.3	0.1	85	<0.001	37.2	0.8	<0.001	9	0.3	1.4
F	114.7	<0.001	631.6	7.6	37	1.5	1.1	13.7	0.4	0.7
I	15	0.5	103.2	2.4	40	0.7	<0.001	3	0.1	<0.001
P	13.2	0.1	82	1	40	0.3	10.2	198.6	0.1	15.5
O	8.9	0	63	10.5	20	0.6	34.4	123.7	0.2	0.7
N2	12.2	0.1	139.4	<0.001	37.3	0.3	68.4	10.4	0.1	<0.001
N1	19.3	0.1	147.8	<0.001	45.5	0.9	10.9	6.2	0.1	<0.001
Y	27.6	0.1	175.2	5.1	56.4	1.4	0.6	8	0.1	<0.001
G	6	<0.001	26	<0.001	0	<0.001	113.3	2860	0.1	0.3
R	13.2	0	85.5	9.5	35.6	0.9	<0.001	3.1	0.1	0.2
X	3.0	0.2	57.9	9.5	13.7	0.9	8.1	6.1	0.1	0.9
A	9.1	0.4	160	11.9	17	0.2	268.7	717	0.6	1
B	2.9	<0.001	26.7	21.2	0.3	0.1	57.8	127.2	0.1	9
E	3.5	0.1	111.9	9.4	27.4	0.9	2.7	6.5	0	0.9
W	1.8	0	100.8	7.7	0.3	0	449.5	2.2	1.5	6.2
D	4.9	0	57.5	36.2	40.7	0.4	0.9	12.9	0	0.3
Q4	12.3	0.3	115.4	<0.0002	35.7	0.9	1.7	5.7	0.1	0.7
Q2	17.6	0.75	184.5	11	56.3	1.8	8.2	14.2	0.1	1.8
Z	6.5	0	82.3	1.6	74	4.9	1.3	7.89	0.1	3.8
V	7.8	0.1	200	6.1	73.6	1.5	2.5	11.7	0.7	4
T	11.5	0.6	153.6	8.8	65.8	0.8	3.7	14	0.2	1.3
C	7.3	0.1	246.3	10.4	15.9	0.1	1589	319.3	1.7	2.7
Q1	14	0.3	153.4	13.2	59.4	1.4	4.9	26.7	0	1.8
Q3	12.5	0.4	129.2	11.2	59.6	1.1	4.9	8.3	0.1	0.4
J	44	0.8	288	23.7	65.3	3.8	1.9	29.6	0.1	3.4

MW	Compound concentration and legislation limit D. Lgs 152/06 ($\mu\text{g/l}$)										
	Cu	Zn	As	Rb	Sr	Mo	Cd	Cs	Ba	Pb	U
	1000	3000	10	–	–	–	5	–	–	10	–
S1	0.8	3.5	20.8	89.4	1270	0.7	<0.001	n.d.	62	<0.001	13.6
M	0.9	25.9	17.2	57.5	622.8	0.5	<0.001	n.d.	55.2	0.055	30.1
S2	0.6	6.7	18.3	74.5	1008	1.2	<0.001	n.d.	69.9	0.1	43.2
F	3.6	41.1	31	77.6	2965	0.2	0.052	n.d.	98.5	8.2	28.1
I	1.5	13.3	18.6	54.4	1253	4.7	0.01	n.d.	53.8	0.4	23.2
P	0.7	69.7	15.8	68.3	1067	0.7	0.032	n.d.	32.7	1	26.5
O	1.5	948.2	5.3	26.9	595.5	0.2	0.134	n.d.	61.6	1	9.9
N2	0.9	9.7	19.6	54.4	1153	1.8	0.021	n.d.	65.7	0.8	36.5
N1	0.7	32.2	25.4	42.6	886.4	1.4	<0.001	n.d.	47.91	1.911	30.6
Y	1.9	9.4	32.4	65.9	926	1.3	0.013	n.d.	45.3	2.3	45.3
G	1.4	17	0.6	35.2	580.8	<0.001	0.011	n.d.	120.6	1.3	0.9
R	5.6	18.7	13.6	45.4	1342	0.3	0.003	n.d.	103.8	3.755	29.12
X	0.6	65.9	3.7	53.7	318.5	0.1	0.024	1.569	16.6	0.8	0.7
A	0.7	43.9	6	61.8	766.9	0.3	0.019	0.7	17.6	<0.001	9.4
B	13.3	94.4	1.8	25.3	171.4	0.1	0.014	0.2	22.7	0.7	0.7
E	0.7	557.4	7.5	32.9	351.8	1.2	0	0.1	26	0.2	6.1

Table 2 (continued)

MW	Compound concentration and legislation limit D. Lgs 152/06 ($\mu\text{g/l}$)										
	Cu	Zn	As	Rb	Sr	Mo	Cd	Cs	Ba	Pb	U
	1000	3000	10	–	–	–	5	–	–	10	–
W	0.3	11.9	1.2	49.8	484.4	<0.001	0	1.3	28.8	<0.001	0.5
D	0.4	42.6	13.6	40.7	426.1	0.2	0.008	0.337	40	<0.001	18.7
Q4	0.6	95.6	7.8	64	683.4	0.9	0	0.2	50	0.1	10.8
Q2	2.2	23.8	17.6	61.6	607.8	0.7	0	0.5	16.2	0.5	12.2
Z	4.1	119.4	21.4	46.6	472.3	2.1	0	0.2	74.9	0.7	14.8
V	3.4	58.2	19.5	69.4	666.7	2	0	0.4	86.1	1.2	20.6
T	1.8	1578	17.2	52.3	702.5	1.2	0.2	0.1	98.9	2.1	16.5
C	1.3	175.9	6.9	62.1	615.3	11.6	0.1	0.2	91.1	0.1	15.9
Q1	0.6	317.9	17.4	56.1	651.3	0.7	0.09	0.2	55.7	0.188	13.3
Q3	1	40	19.2	32.2	991.5	0.5	0	0.1	78.1	0.2	5.3
J	0.4	330.2	70.7	98.6	860.6	1.8	0.02	0.2	24.4	0.2	3.2

Bold values indicate exceedance of legislation limits

Table 3 Chlorinated solvent concentration data

MW	Trichloromethane ($\mu\text{g/l}$)	1,2-DCA ($\mu\text{g/l}$)	PCE ($\mu\text{g/l}$)	1,1,2-TCA ($\mu\text{g/l}$)
Legislation limit D. Lgs 152/06 ($\mu\text{g/l}$)	0.15	3	1.1	0.2
G	0.06	<0.3	<0.3	<0.015
F	0.29	<0.3	<0.3	0.2
O	<0.03	<0.3	<0.3	<0.015
R	0.03	<0.3	<0.3	<0.015
M	<0.03	<0.3	0.7	<0.015
P	0.29	<0.3	<0.3	0.34
N2	<0.03	<0.3	<0.3	<0.015
Y	0.46	<0.3	<0.3	0.31
I	0.07	<0.3	<0.3	<0.015
C	0.14	<0.3	<0.3	0.31
Z	0.32	<0.3	<0.3	0.26
V	0.23	<0.3	<0.3	0.139
Q1	<0.03	<0.3	<0.3	<0.015
Q2	2.36	0.4	0.3	3.37
Q3	<0.03	<0.3	<0.3	<0.015
N1	<0.03	<0.3	<0.3	<0.015
D	<0.03	<0.3	<0.3	<0.015
B	<0.03	<0.3	<0.3	<0.015
E	<0.03	<0.3	<0.3	<0.015
T	0.48	<0.3	<0.3	0.29
A	<0.03	<0.3	<0.3	<0.015
X	0.25	<0.3	<0.3	0.33
J	0.4	<0.3	<0.3	0.27

Bold values indicate exceedance of legislation limits

combined with previously known concentrations of the same species (trichloromethane and 1,1,2-trichloroethane) related to official (registered according with law) contaminated sites and all data have been analyzed by a deterministic interpolator (IDW inverse distance weighted). Even if with several uncertainties, this analysis has been

performed only with the aim of understanding possible correlation between neighbor points. The combination of newly collected data with previously known concentrations has been possible using the most recent concentrations reported in the periodical mandatory monitoring reports related to official polluted sites.

Even if the presence of both trichloromethane and 1,1,2-trichloroethane has been detected in almost new samples analyzed in this study, the result of interpolation is not similar. This is probably due to the fact that in the previous investigations these two compounds were not always present in the same monitoring well, and in some places, they were detected at very high concentrations. Moreover, if 1,1,2-trichloroethane is exceeding the legislation limit ($0.2 \mu\text{g/l}$) mainly in the eastern sector of the area, trichloromethane exceeds the legislation limit ($0.15 \mu\text{g/l}$) in several analyzed points evenly distributed in the study area.

The distribution map of trichloromethane concentrations (Fig. 4) shows indeed an important hot spot area in the right bank of Aniene River, where different known contaminated sites are located. Other few seemed “hot spots” are located in the northern sector of the studied area as well, but as shown in Fig. 4 they seem to be driven by one single-point effect. The most interesting result is shown where the lower values are similar and homogeneously distributed. The concentration ranges vary from the analytical detection limit ($<0.03 \mu\text{g/l}$) to a maximum of $19.42 \mu\text{g/l}$, but the monitoring wells having

concentrations higher than $10 \mu\text{g/l}$ are just 3; thus, they can be considered as outliers values.

The interpolation map of 1,1,2-trichloroethane (Fig. 5) shows the presence of higher values in the southeastern sector of the area and some one-point-driven interpolation locally. The distribution of contaminated monitoring points seems limited in more specific zones. The values range in this case from the analytical detection limit ($<0.015 \mu\text{g/l}$) to only $3.37 \mu\text{g/l}$; thus, the variation in concentration values is limited. The outlier value of $578.6 \mu\text{g/l}$ detected in previous investigation surveys has been omitted in the interpolation represented in Fig. 5.

The concentration maps suggest a possible relationship between some neighbor monitoring wells characterized by low concentration values, and even if it is difficult to extend this relation to the whole studied area, local diffusion phenomena can be hypothesized.

Except for previously known and registered (according with law) contaminated sites showing high concentration values, it is not possible to identify the possible source of the low-concentration contamination, due to the limited

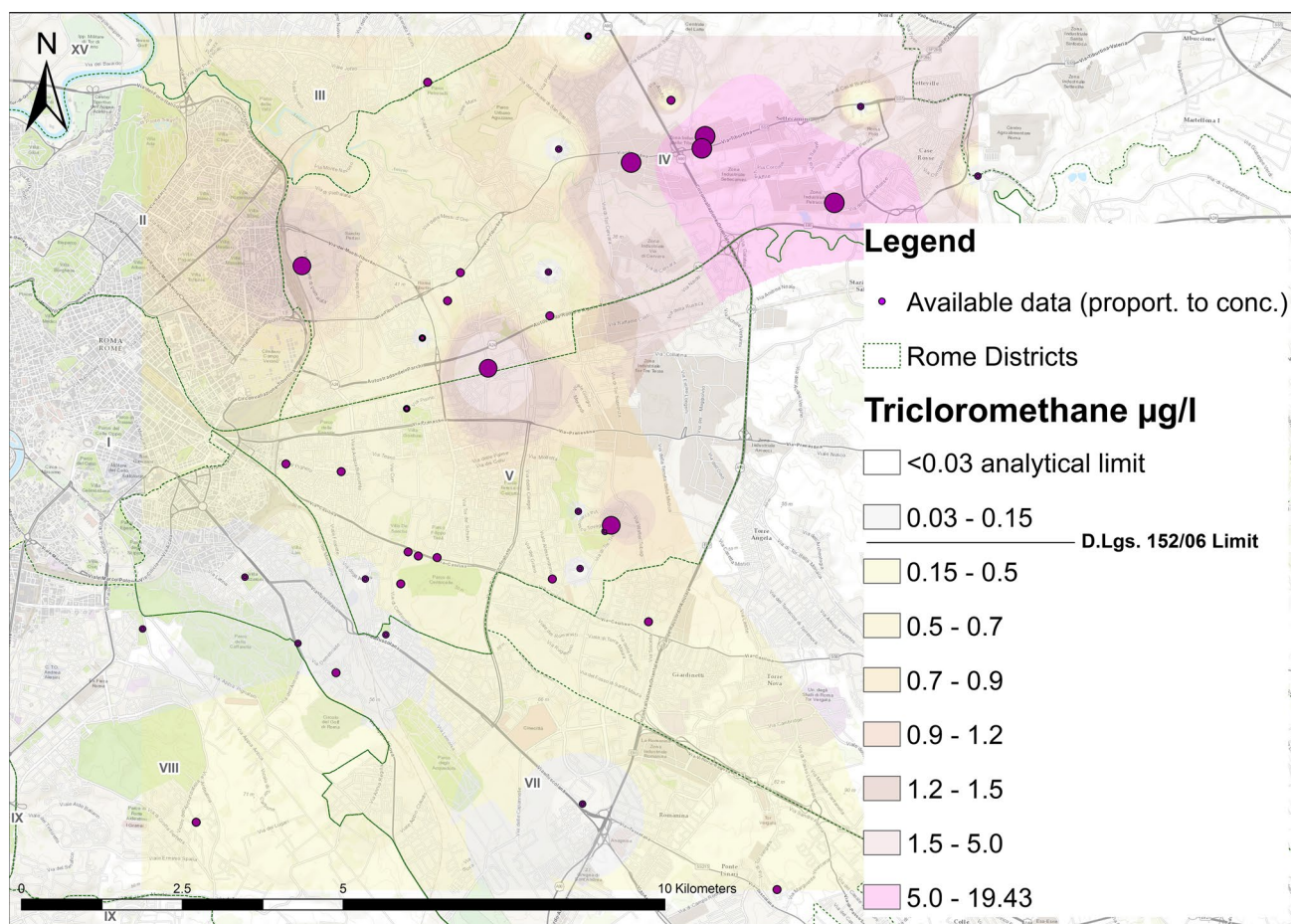


Fig. 4 Trichloromethane distribution map in the investigated area. The survey point symbols' dimension is proportional to the detected compound concentration

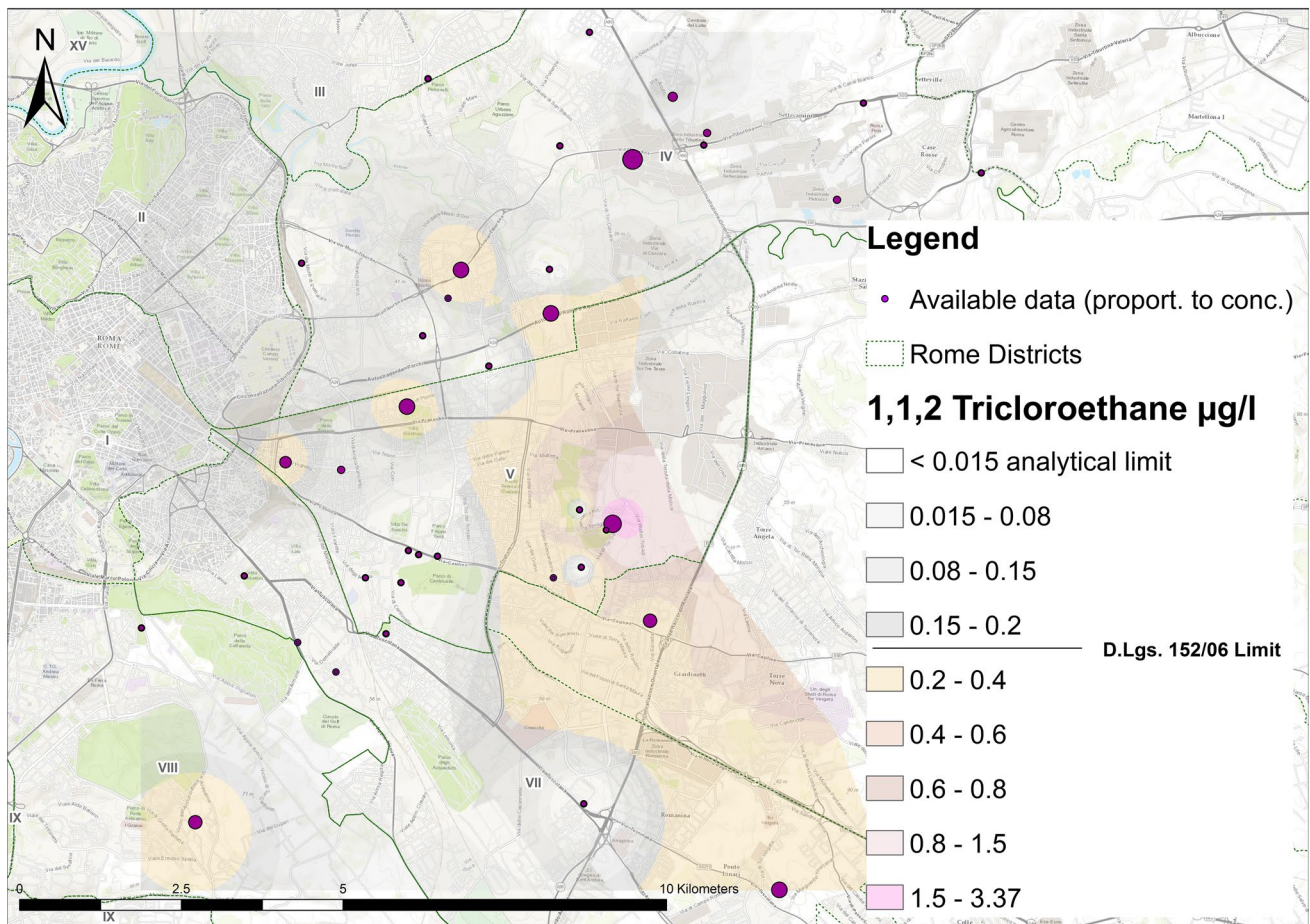


Fig. 5 1,1,2-Trichloroethane distribution map in the investigated area. The survey point symbols' dimension is proportional to the detected compound concentration

available data. In the meanwhile taking into account the distribution of occurrence sites, a diffuse source seems reasonable. As trichloromethane could be derived also from water sanitation or from the mixing of treated water with organic matter (Munson et al. 1982; Fan and Sokorai 2015; Shen et al. 2016), a possible connection between trichloromethane distribution and leakage from sewers and aqueducts networks is reasonable. Indeed, the widespread leakage (from water mains), in nonurban environment, has generally values of about 20% of losses, instead for the city of Rome is more than 45%, while currently is estimated around 38% (ACEA ATO2 2018). In addition, the location of breakages and losses of water from sewers and aqueduct network is not always up to date, especially in a wide urban context as the city of Rome. This is one of the reasons why the link between losses from sewers and/or water mains and trichloromethane distribution could be just hypothesized and not proved within the framework of this study.

6 Conclusions

In order to evaluate the diffusion of chlorinated solvents in the groundwater of eastern Rome, a sampling survey has been carried out.

First preliminary results, deriving from wells mainly located in green areas (out of official contaminated sites), show that the previously detected species (tetrachloroethylene, trichlorethylene and their daughter compounds) have not been found elsewhere, while there are two compounds (trichloromethane and 1,1,2-trichloroethane) which have been found with limited concentration (below legislation limit for drinking waters) in several of the investigated wells. Consequently a first hypothesis of diffuse occurrence of these compounds, related to leakage from sewers and water mains, has been suggested.

The preliminary status of this research cannot allow to uniquely identify the possible source of contamination, also because the sampling methodology could not follow the

standard methods, mainly due to the difficulty in purging the water wells, which sometimes were not in use since long time. For these reasons, the results have to be considered simply as a good starting point for further evaluations, insufficient for declaring officially the existence of an effective diffuse or punctual contamination due to these compounds.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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