

Qualitative and quantitative aspects of drinking water supply in Sardinia, Italy. A descriptive analysis of the ordinances and public notices issued during the years 2010-2015

M. Dettori¹, A. Piana², P. Castiglia², E. Loria³, A. Azara⁴

Key words: Drinking water supply, disinfection by-products, water for human consumption, non-potable water ordinance, derogation

Parole chiave: Fornitura di acqua potabile, sottoprodotti di disinfezione, acqua destinata al consumo umano, ordinanza di non potabilità, deroga

Abstract

Background. The aim of the study is to analyze the regional district ordinances and the warnings regarding qualitative and quantitative drinking water abnormalities discovered by the Sardinian Municipalities and the Water Managing Authority between 2010 and 2015 in order to describe and identify the causes leading to an interruption or a limitation of the drinking water supply.

Methods. We carefully reviewed all ordinances and warnings of non-potable water and service interruption published between 2010 and 2015 by the websites of 377 Sardinian Municipalities and by the main regional newspapers, the Water Managing Authority and the Regional Health Trusts.

Results. From 2010 to 2015, 738 warnings/ordinances regarding drinking water supply limitation or interruption were issued. The warnings involved more than half (n. 191, 50.7%) of the 377 Sardinian Municipalities. Considering that these Municipalities included the main Sardinian cities we estimated that 80.3% of the population was affected by the issue. During the 6 years we observed a progressive increase of Municipalities involved beginning with 25 and reaching up 110 in 2014. The initial 29 warnings rose to 256 in 2014 along with an increased number of abnormal values, parameters and standards of the drinking water. Regarding the ordinances issued by the 191 Mayors we noticed that the legal limits were exceeded in 23 cases. Among those, we underline the abnormal levels of chlorites and trihalomethanes (22% of cases), the turbidity, the abnormal concentration of total chemical substances and the abnormal level of coliforms, *Escherichia coli*, manganese, aluminum, nitrites and iron.

Conclusions. According to our observations, the Sardinian drinking water supply system is affected by a major inconvenience and the data suggest that qualitative abnormalities are mainly due to water purification treatments used in addition to the poor water supply network in existence.

Considering these results, a cooperation between all Authorities involved would be desirable in order to analyze official data and provide a careful evaluation of population exposure and real risks related to the level of every parameter considered.

¹ MSc, Department of Architecture, Design and Urban Planning, University of Sassari, Alghero, Italy

² PhD, Department of Biomedical Science, Hygiene and Preventive Medicine, University of Sassari, Sassari, Italy

³ Department of Architecture, Design and Urban Planning, University of Sassari, Alghero, Italy

⁴ MD, MPH, Department of Biomedical Science, Hygiene and Preventive Medicine, University of Sassari, Sassari, Italy

Introduction

Water for human consumption is affected even nowadays by quantitative and qualitative abnormalities: despite the fact that since the '90s the world population with access to safe and purified water has increased, 768 million people, about 4% of the worldwide urban population, still have no access to drinking water (1). Furthermore, out of the world population, 1.8 billion people have access to water with a heavy fecal pollution (2, 3). In fact, water consumption related diseases have a high mortality and morbidity rate even in the European Union, frequently due to lack of disease surveillance and management systems and to ineffective intervention tools (4).

Given that safe drinking water is essential for humans, a careful and meticulous prevention activity is needed mostly in areas where water supply is not adequately inspected and water supply networks do not offer proper safety features for water protection and distribution (damaged pipes made with unsuitable materials, pollution and leaking risks) or ineffectively managed and technologically outdated purification plants.

In Italy water supply problems are evident (5): beginning 2012, 112 Municipalities in 14 different Italian regions benefit from a specific EU derogation from the current regulations issued by the Government to bypass the fact that the water for human consumption values were abnormal compared to those regulated by law (6-10).

In this scenario Sardinia plays a peculiar role considering a longstanding (and recurrent) drought and a widespread qualitative decline of water supplies in the island. To tackle the situation of the poor quantitative supply, mainly in the last century, various major large scale projects aimed at regulating the course of water streams have been implemented. The objective was to create large artificial lakes because

the Sardinian water supply (divided into 8 hydrographic zones: Sulcis, Tirso, Nord occidentale, Liscia, Posada-Cedrina, Sud orientale, Flumendosa-Campidano-Cixerri, Rio Mogoro, Temo) is mainly dependent (75%) on superficial waters collected and regulated in 35 water reservoirs for a total authorized volume of 1,799.33 million m³ (11). Such a distribution system is outdated and ineffective, as reported by the National Statistics Institute (ISTAT) in the "Drinking Water Census for Civil Use 2014", pointing out that Sardinia suffered from a water leakage rate of 54.8% from the supplying network (the highest rate nationwide), far beyond the already quite high rate of 45.9% registered in 2008 (12).

Moreover, these superficial water streams, by definition, are more exposed to anthropic contamination and provide qualitatively poor water for various reasons:

- pollution due to deficient sewer system;
- improper use of agricultural nutrients;
- high trophic levels within the reservoirs that worsen water organoleptic properties, interfering with purification systems and representing a potential health risk considering the proliferation of some algae capable of producing toxins;
- inadequate water purification plants (13-17).

The national regulations accept the European indications regarding the environmental quality objectives, difficult to achieve in Sardinia because of the forementioned risk of pollution of superficial waters that causes chemical and microbiological issues. In addition, some potential risks arise from the complex and expensive water purification and disinfection treatments required that may produce unhealthy substances (DBPs: *Disinfection By Products*) (11, 20-22).

In the past the Sardinian Government has benefited from some government derogations from current regulations due to high levels of chlorites and trihalomethanes in the drinking

water, products of disinfection coming from purification treatments (23-25).

Poor quality, declining organoleptic properties and frequent supply interruptions through the years were highlighted in a 2012 report from ISTAT which assessed aspects of the Italian population's daily life. According to this report, the Sardinian population is highly suspicious toward the quality of public drinking water and discourages its consumption (26).

The forementioned qualitative deficiencies, according to the current regulations (7), frequently lead to the interruption and/or limitation of the water supply following a published ordinance from the Regional Health Authority as regulated by the Legislative Decree 18/08/2000 n. 267 (modified by the Law Decree 92/2008, converted into Law 125/2008) (27-29).

These urgent ordinances are published in the District Bulletin of the Municipality and are advertised through different mass media such as their institutional websites.

The described situation outlines the peculiar role of the island in the national scenario and represents the rationale of the present study that aims to assess and verify the quality of the drinking water supplied in Sardinia. In particular, accessing the official institutional data and facing the system from the point of view of the consumer, we studied the ordinances and the warnings regarding the qualitative and quantitative drinking water issues published by the Municipalities and the Water Managing Authorities between 2010 and 2015.

Materials and methods

To achieve the aim of the study we carried out an extensive research through a comparison between the different data and a literature review.

In particular, the research of the ordinances and/or warnings regarding qualitative or

quantitative abnormalities detected in the Sardinian drinking water supply system was carried out by analyzing all 377 Sardinian Municipalities' websites. The survey, alongside with the consultation of the Municipalities District Bulletin, considered a further research within the institutional websites. The obtained data have been cross-checked with those available online as published by the Water Management Authority and/or the regional Health Trusts or the main Sardinian newspapers.

All data were subsequently collected in a spreadsheet in order to organize them by the main causes and identify the possible factors leading to the ordinances. Results are expressed as frequencies and percentages. The analysis of the variation in the number of observations in the different months during the year was performed through a quadratic regression. The 95% confidence interval was based on the standard error of the forecast. A first type error was set at 0.05.

Results

From the consultation of the websites of the 377 Sardinian Municipalities and the websites of the regional Health Trusts, the Water Management Authority and the main Sardinian newspapers, we noticed 738 warnings from 2010 to 2015. Dividing the overall number of warnings into different types, we noticed an increasing trend through the years either for maintenance intervention warnings and the related damage or for the non-potable water ordinances.

In particular, regarding the quantitative issues, the lack of supply was subsequent to 251 maintenance interventions (34%), whereas warnings of water network damages and limitation ordinances were issued in 70 cases (9.5%). The qualitative abnormalities, on the other hand, caused a Health Authority ordinance publication in 417 cases (56.5%) involving 535 parameters (Figure 1).

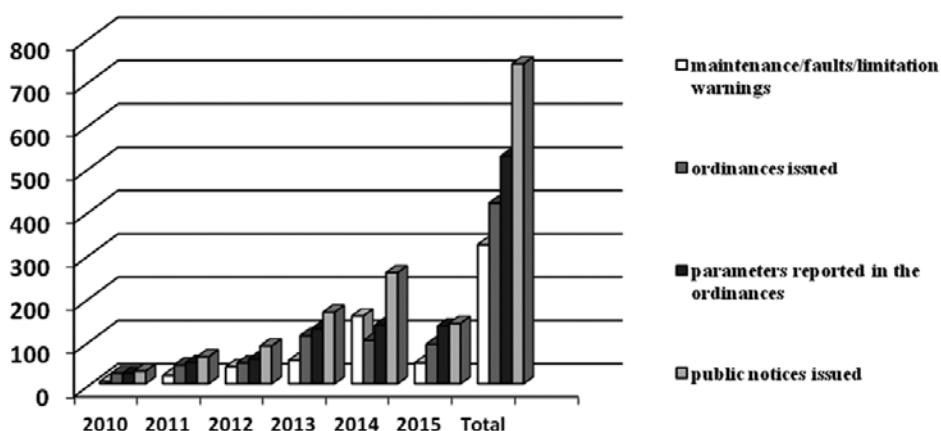


Figure 1 - Number of public notices issued during the years 2010-2015 divided by municipal ordinances, maintenance/faults/limitation warnings and number of parameters.

Considering the geographic sites, we observed that the warnings involved more than half of the Sardinian Municipalities (191, 50.6%), including the major Sardinian cities and therefore exposing 80.3% of the entire Sardinian population. In particular, examining the regional districts data we noticed that the more affected areas were: Sassari (23.6%) and Nuoro (22.5%), followed by Cagliari (14.1%), Olbia-Tempio (11.5%), Oristano (11.5%), Medio Campidano (6.8%), Carbonia-Iglesias (6.8%), and Ogliastra (3.1%). Sassari (Sassari) and Siniscola (Ogliastra) were the most affected Municipalities, respectively with 52 and 36 warnings. Although data on the duration of the ordinances are not known for all events, the longest duration detected regards the Municipality of Luras (Olbia-Tempio) where for 7 months between 2012 and 2013 the water supplied did not reach an adequate level of standard. Moreover, 132 Municipalities of the 191 involved (69.1%) disclosed more than one notice during the survey (Figure 2).

From 2010 to 2015, we observed a progressive extension of the issues: the 25 Municipalities initially involved became 86 in 2012, reaching a peak of 110 in

2014. The initial 29 warnings became 256 in 2014 in association with an increasing number of abnormal parameters detected. In order to evaluate a possible link between the publication of ordinances and the year/

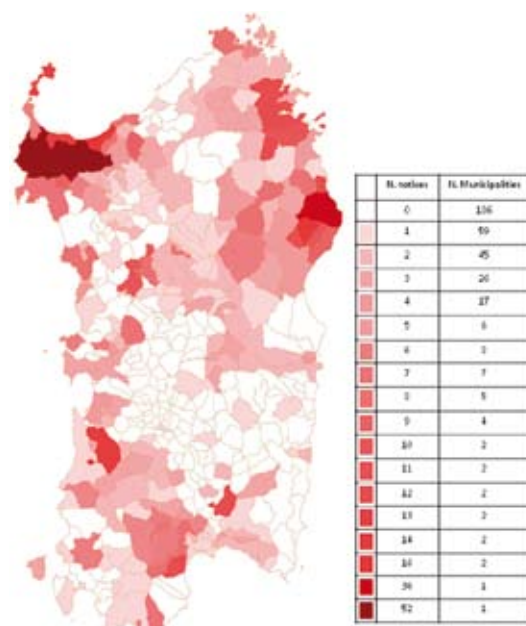


Figure 2 - Geographical distribution of the public notices issued by the Sardinian Municipalities during the period 2010-2015.

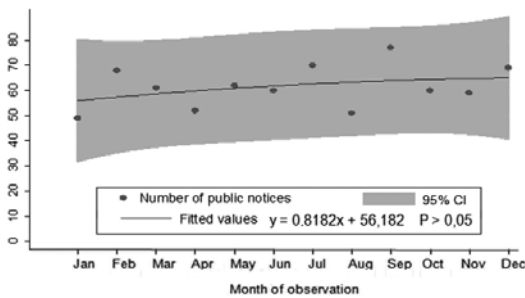


Figure 3 - Number of public notices issued sorted by month of occurrence (2010-2015).

season we analyzed the monthly trend. The number of ordinances seems not to depend on seasonality. In fact, no trend was observed ($P > 0.05$) and all the observed numbers of ordinances fell within the 95% CI in respect to the fitted values. The month with the highest number of published ordinances (77) was September and the lowest January (49 notices), without any statistical significant difference (Figure 3).

We investigated the real causes leading to the ordinances (417 cases of interruption or supply limitation) and we discovered

23 parameters which exceeded the limits regulated by the Decree 31/2001: among those we underline the presence of chlorites and trihalomethanes (22% of cases), turbidity, the presence of total chemical substances, nitrites, aluminum, manganese, iron and the presence of coliform bacteria and *Escherichia coli*. We detected a single case of supply interruption due to the high level of mercury (Figure 4).

Conclusions and discussion

The results of our study show a major inconvenience in the Sardinian water supply network, often criticized by the large majority of consumers because clearly unable to guarantee an adequate level of quality and quantity of this essential resource.

Although every regional district is involved in the issue, the mid-northern regions are particularly affected considering that Municipalities like Sassari and Siniscola are facing a critical situation with safety intervention programs adopted by the

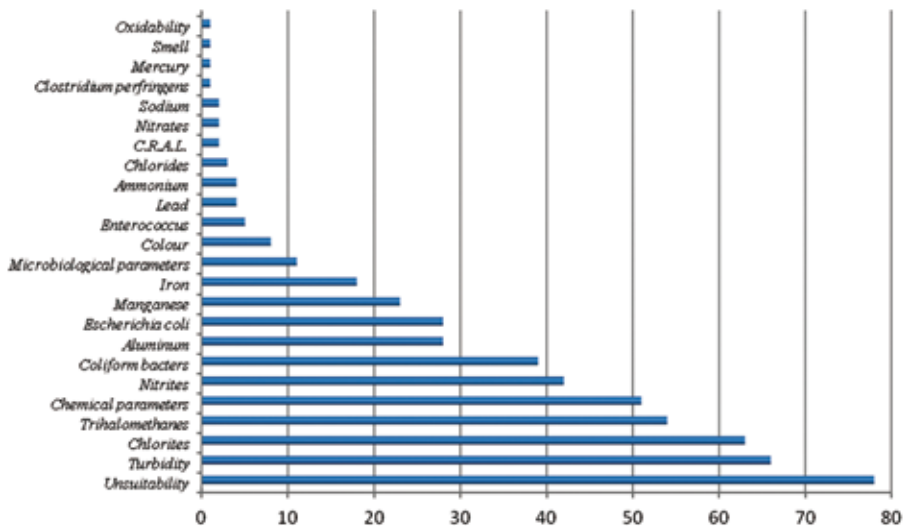


Figure 4 - Number of the parameters out of range observed in the 417 municipal ordinances issued in Sardinia from 2010 to 2015.

District Health Authority. Furthermore, a great concern has been created by the number of warnings that showed an exponentially increasing trend until 2014, although during the last year of the investigation (2015) we registered a minor reduction.

Despite the critical conditions of the water production and distribution network, a careful analysis of the data shows that the purification treatments are more responsible for the low quality of the drinking water rather than the poor state of the pipes. In fact, despite a great improvement in the purification treatment systems in recent years (transition from hypochlorite to chlorine dioxide; combined use of chlorine dioxide and chloramines) (24), the poor quality of the superficial waters represents the main reason for the presence of DBPs. In fact, chlorites and trihalomethanes are known to be produced by water disinfection and even if studied and understood, they have become endemic and difficult to eradicate from the Sardinian water supply network. Overall, chlorite and trihalomethanes, present in almost 25% of the warnings, represent together the main cause of potability limitation.

Furthermore, since the ordinances partially hide the real causes of the potability limitation, mentioning an unspecific “inadequate level of standards”, the consumer’s suspicion and concern regarding the public supplied water is increasingly heightened. It is in fact well-known that an unknown hazard usually generates outrage (30).

A further problem is represented by the fact that the real measured concentration of the specific parameter is often not reported and that, as already pointed out, the duration of the order is not generally known, making it difficult to quantify the real hazard. A strong cooperation between the Institutional and Managing Authorities would be desirable in order to analyze the official data and provide a more careful exposure evaluation and identify the real risks related to the level of every parameter considered.

Despite the limitations of the aforementioned methods, from the analysis of the survey results a large and widespread problem arises. The results allow us also to identify the most likely causes, evaluating the responsible parameters leading to an ordinance.

In fact, the purification treatments are responsible, as previously reported, not only for the presence of chlorites and trihalomethanes, but also for the presence of other substances: ammonia, nitrates and nitrites as a result of post-disinfection with chloramine; turbidity, colour and aluminum are related to the difficulty of clarifying the murky waters, particularly after very violent rainfall events; the presence of iron, manganese, microbiological agents and free residual chlorine may also be related to the poor state of maintenance of the networks and with the difficulties in purification.

Even if most of the problems of the drinking water quality are generally related to a failing management and to the poor quality of the water, the Water Managing Authority blames the age of the pipes and of the network arguing that the system needs major maintenance interventions.

In particular, the present study registered 251 maintenance interventions and 70 cases of damages or service limitation in the time span of the survey; the maintenance interventions often require purge plans that lead to water turbidity and the release of aluminum, iron and manganese.

In conclusion, considering the relevance of the problem described regarding the management of drinking water for human consumption, the Institutional Authorities responsible, in particular the Water Managing Authority and the Surveillance Authorities, should urgently and broadly cooperate in order to deliver to the consumers a drinking water with the best possible characteristics. This situation highlights the need for a project of water safety planning to lower the risks to public

health, as stated by the WHO, revealing a managing gap (31-33).

Furthermore, it is desirable that all institutions involved will operate with greater transparency, in order to guarantee, as required by law, the consumers with the right of adequate information; if more involved, the people could better manage their risk without alarmism, in agreement with the health authority communications.

This could limit the widespread habit in the population of the increasing use of alternative supply sources (whose parameters are infrequently and rarely checked) exposing the population to risks potentially higher than those coming from network supplied waters, even if they might not perfectly meet the criteria described in the current regulation.

Riassunto

Aspetti qualitativi e quantitativi della fornitura di acqua potabile in Sardegna, Italia. Analisi descrittiva delle ordinanze e avvisi pubblici emessi nel corso degli anni 2010-2015

Premesse. Al fine di effettuare un'analisi descrittiva e identificare le cause che conducono all'interruzione o limitazione del servizio di erogazione idrica, il presente lavoro intende rilevare gli avvisi pubblici (distinti in ordinanze comunali o interruzioni del servizio idrico per manutenzione e guasti delle condotte) divulgati nell'Isola nel periodo compreso tra il 2010 e il 2015.

Metodi. Il lavoro ha previsto una ricerca accurata delle ordinanze e avvisi di non potabilità e/o interruzione del servizio resi pubblici tra il 2010 e il 2015 sui *websites* istituzionali dei 377 Comuni sardi e dei siti delle principali testate giornalistiche, dell'Ente Gestore e delle Aziende Sanitarie Locali.

Risultati. Nel periodo di osservazione sono stati emanati 738 pubblici avvisi e/o ordinanze, interessando oltre la metà dei 377 Comuni della Sardegna (n. 191, corrispondenti al 50,6%) ed esponendo l'80,3% dell'intera popolazione sarda. Il fenomeno si è progressivamente esteso negli anni con un picco di 110 avvisi pubblici nel 2014. Tra i parametri che hanno superato i limiti normativi, spicca la presenza di cloriti e trihalometani (22% dei casi), oltre ai fenomeni di torbidità e alla presenza di generici parametri chimici, cui fanno

seguito nitriti, coliformi, *Escherichia coli*, alluminio, manganese e ferro.

Conclusioni. Traspare uno stato di notevole disagio in relazione all'approvvigionamento idrico in Sardegna e i dati suggeriscono che i problemi legati agli aspetti qualitativi siano da correlare non solo con le precarie condizioni della rete idrica ma soprattutto con le metodiche di potabilizzazione adottate.

References

1. Dichiarazione sul diritto allo sviluppo, ONU, 1986. Available on www.un.org/documents/ga/res/41/a41r128.htm [Last access: April 14, 2016].
2. World Health Organization (WHO), United Nations Children's Fund (UNICEF). Progress on drinking-water and sanitation. 2014 update. Geneva: WHO, 2014.
3. World Health Organization (WHO). Preventing diarrhoea through better water, sanitation and hygiene. Geneva: WHO, 2014.
4. Blasi M, Carere M, Funari E. National surveillance capacity of water-related diseases in the WHO European region. *J Water Health* 2011; **9**(4): 752-62.
5. Azara A, Moscato U, Mura I. Disponibilità di acqua potabile. In: Rapporto Osservasalute 2010. Stato di salute e qualità dell'assistenza nelle regioni italiane. Milano: Prex S.p.A., 2010: 159-63.
6. Azara A, Piana A. La qualità dell'acqua potabile: concessione di deroghe. In: Rapporto Osservasalute 2006. Stato di salute e qualità dell'assistenza nelle regioni italiane. Milano: Prex S.p.A., 2006: 94-8.
7. Decreto Legislativo n. 31 del 2001. Attuazione della direttiva 98/83/CE relativa alla qualità delle acque destinate al consumo umano. *GU Repubblica Italiana* n. 58 del 9 marzo 2002.
8. Decreto Ministeriale 08/05/1991 concernente le deroghe alle caratteristiche di qualità delle acque destinate al consumo umano. *GU Repubblica Italiana* n. 157 del 6 luglio 1991.
9. Direttiva 98/83/CE del Consiglio del 3 novembre 1998 concernente la qualità delle acque destinate al consumo umano. *GU L Repubblica Italiana* n. 330 del 5 dicembre 1998.
10. Zicari G, Marro S, Soardo V, et al. The history of derogations from chemical parametric values set by the European Drinking Water Directive (Council Directive 98/83/EC), in Italy and the Piedmont region. *Ig Sanita Pubbl* 2014; **70**(3): 323-38.

11. Romano G, Mura I, Azara A, et al. I trialometani nelle acque adibite ad uso potabile nel Nord-Sardegna. Nota 2. Primi risultati sull'impiego dell'ozono nella potabilizzazione di acque superficiali. *Ig Mod* 1996; **105**: 139-61.
12. ISTAT. Censimento delle acque ad uso civile, 2014.
13. Deliberazione del 26 agosto 2005, n. 40/12. Classificazione delle acque superficiali destinate alla produzione di acqua potabile ai sensi dell'art. 7 del decreto legislativo 11 maggio 1999, n. 152, così come modificato dal decreto legislativo 18 agosto 2000 n. 258, recante "Disposizione sulla tutela delle acque dall'inquinamento e recepimento della direttiva 91/271/CEE e della direttiva 91/676/CEE." Available on: www.regione.sardegna.it/documenti/1_45_20050908094207.pdf [Last access: April 14, 2016].
14. Istituto di Studi sulle Relazioni Industriali (ISRI). Programma Operativo della Regione Autonoma della Sardegna. Le risorse idriche in Sardegna, 2008.
15. Regione Autonoma della Sardegna. Piano di Gestione del Bacino Idrografico della Sardegna, 2010.
16. Regione Autonoma della Sardegna. Piano di Tutela delle Acque, 2006.
17. Regione Autonoma della Sardegna. Piano Regolatore Generale degli Acquedotti della Sardegna, 2006.
18. Decreto Legislativo 3 aprile 2006, n. 152. Norme in materia ambientale. *GU Repubblica Italiana* n. 88 del 14 aprile 2006 (Suppl Ord n. 96).
19. Direttiva 2000/60/CE del Parlamento Europeo e del Consiglio del 23 ottobre 2000 che istituisce un quadro per l'azione comunitaria in materia di acque. *GU L Repubblica Italiana* del 22 dicembre 2000, n. 327.
20. Azara A. Le acque in Sardegna: aspetti qualitativi. *Cooperazione Mediterranea: cultura, economia, società: Un filo d'acqua: verso la gestione sostenibile delle risorse idriche*. Cagliari: AM&D Edizioni, 2003; **3**: 222-32.
21. Maida A, Romano G, Azara A, Piana A, Brandis A. La qualità delle acque condottate nel Nord Sardegna. *Ig Mod* 1993; **100**: 1358-79.
22. Romano G, Dettori B, Maida et al. Risorse idriche e territorio nella Sardegna Nord-Occidentale. *Ig Mod* 1996; **105**: 163-200.
23. Azara A, Masia MD, Posadino S, Ciappeddu PL, Piana A. Water resources destined for human consumption: qualitative monitoring. *Ann Ig* 2004; **16**: 255-64.
24. Azara A, Muresu E, Dettori M, Ciappeddu P, Deidda A, Maida A. First results on the use of chloramines to reduce disinfection byproducts in drinking water. *Ig Sanita Pubbl* 2010; **66**: 583-600.
25. ISTAT. Indagine campionaria "Aspetti sulla vita quotidiana della popolazione italiana 2014".
26. Decreto legge 23 maggio 2008, n. 92. Misure urgenti in materia di sicurezza pubblica. *GU Repubblica Italiana* n. 173 del 25 luglio 2008.
27. Decreto Legislativo 18 agosto 2000, n. 267. Testo unico delle leggi sull'ordinamento degli enti locali. *GU Repubblica Italiana* n. 227 del 28 settembre 2000 (Suppl Ord 162).
28. Legge 24 luglio 2008, n. 125. Misure urgenti in materia di sicurezza pubblica. *GU Repubblica Italiana* n. 173 del 25 luglio 2008.
29. Decreto Legislativo 3 aprile 2006, n. 152. Norme in materia ambientale. *GU Repubblica Italiana* n. 88 del 14 aprile 2006 (Suppl Ord n. 96).
30. Sandman PM. Hazard versus outrage in the public perception of risk. In: Covello VT, McCallum DB, Pavlova MT, Eds. *Effective risk communication: the role and responsibility of government and nongovernment organizations*. New York: Plenum Press, 1989: 45-9.
31. Azara A, Moscato U, Mura I. Disponibilità di acqua potabile. In: *Rapporto Osservasalute 2010. Stato di salute e qualità dell'assistenza nelle regioni italiane*. Milano: Prex S.p.A., 2010: 159-63.
32. Ottaviani M, Lucentini L, Bonadonna L, Ferretti R. Istituto Superiore Di Sanità. Valutazione e gestione del rischio nella filiera delle acque destinate al consumo umano: i Water Safety Plan nella revisione della direttiva 98/83/CE. *Notiz Ist Super Sanita* 2009; **22**(1): 3-8.
33. Decreto Legislativo 18 agosto 2000, n. 267. Testo unico delle leggi sull'ordinamento degli enti locali. *GU Repubblica Italiana* n. 227 del 28 settembre 2000 (Suppl Ord 162).