



Water safety: one of the primary objectives of our time

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ABSTRACT

This article discusses the benefits of an innovative approach to the problem of water security introduced by WHO in 2004, through the establishment of the Water Safety Plan (WSP). It was recently included in Commission Directive (EU) 2015/1787 – October 6, 2015 – the implementation of which is expected in the EU countries by 27 October 2017. The WSP is the most effective means of consistently ensuring the safety of a drinking water supply. The method is based on the use of a comprehensive risk assessment and risk management approach that involves all steps in water supply from catchment to consumer. The knowledge acquired by some experiences of WSP application, both in Italy and in countries with limited resources, is proving the effectiveness of the model as the best way to manage drinking water systems and protect public health.

Keywords: drinking water, risk management, water safety plan.

Segurança da água: um dos objetivos primários do nosso tempo

RESUMO

Este artigo discute os benefícios de uma abordagem inovadora para o problema da segurança da água introduzido pela OMS em 2004, por meio do estabelecimento do Plano de Segurança da Água (acrônimo em Inglês WSP). Foi recentemente incluído na Directiva da Comissão (UE) 2015/1787 - 6 de outubro de 2015 - cuja implementação está prevista nos países da UE até 27 de outubro de 2017. O WSP é o meio mais eficaz para garantir consistentemente a segurança de um abastecimento de água potável. O método baseia-se no uso de uma abordagem de gestão de avaliação e gerenciamento abrangente de risco, que envolve todas as etapas de abastecimento de água desde a captação até o consumidor. O conhecimento adquirido por algumas experiências de aplicação do WSP, tanto na Itália quanto em países com recursos limitados, está demonstrando a eficácia do modelo como a melhor maneira de gerenciar o sistema de água potável e proteger a saúde pública.

Palavras-chave: água potável, gestão de riscos, plano de segurança da água.

DISCUSSION

The availability of water in sufficient quantity and with a quality able to ensure health is one of the most important problems facing mankind today.

The importance of this was previously recognized among the goals of the millennium, and in goal 6 of the United Nations' plan for sustainable development (Clean water and sanitation): "Ensure availability and sustainable management of water and sanitation for all". In goal 6, it is of note that the basic requirements for "drinking water" are: "quantity" (volume of water available to consumers), "quality" (conformity to potability requirements), "continuity" (water supply over time), "coverage" (population served by drinking water supply) and "cost" (costs incurred by consumers for drinking water supply).

A large portion of the world's population today has no access to water that fully meets the goal's requirements, or that meets them in a sustainable way. Just think about it, according to WHO/UNICEF data, in 2015 almost seven hundred million people had no access even to an "improved water source" (according to WHO and UNICEF (2010), a "water source that, by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with fecal matter"). Moreover, if one considers that the so-called "improved sources" can distribute no safe water (both from chemical and microbiological points of view) (Sorlini et al., 2013a), and that the distribution of "safe water at the source" does not guarantee the quality at the point of use (Sorlini et al., 2013b), as contamination may occur along the supply chain (transport and storage), then it becomes clear that the population number above is under-estimated, and that the number of people with no safe water is actually much higher.

Faced with this situation, in 2004 WHO introduced an innovative approach to the problem of water security, through the Water Safety Plan (WSP) (WHO, 2004). The characteristic approach of a WSP is based on the assessment and management of risk of water contamination at all stages of the water supply chain, from the point of capture to the point of consumption. The WSP's goal is to eliminate or reduce any chemical, microbiological, physical and radiological danger and to prevent re-contamination during storage and distribution to the point of use.

The WSP redefines the drinking water control mode, which is today based upon monitoring of limited segments of the "waterworks system" (withdrawal – processing – distribution), and turning it into a "global system of risk management from collection to the point of use".

The general objectives of a WSP are summarized below:

- describe and analyse the drinking water supply chain;
- identify all the factors that can cause a risk of contamination;
- eliminate or mitigate these factors;
- prevent possible re-contamination.

In more detail, the first experiences of the WSP implementation in Italy (Sorlini et al., 2015a; 2016) have led to a detailed procedure for its application, based on the following steps:

1. formation of a multidisciplinary team;
2. description of the water system;
3. identification of hazardous events, hazards and risks;
4. identification and validation of control measures and re-calculation of the risk;
5. development of an upgrade plan;
6. development of a monitoring plan of the control measures;

7. development of a plan to test the WSP's effectiveness;
8. development of management procedures;
9. planning and implementation of periodic WSP reviews;
10. revision of the WSP as the result of an accident;
11. development of support programs.

All indicated steps are important and must be developed with skill and care if the WSP is to fully attain its intended purpose. However, the success of the procedure is based upon the "technical phases" related to the system description (step 2) and to the knowledge of its performance and optimization (steps 5, 6, 7, 8, 9). An example of methodological plan for the control and optimization of the performance of a water treatment plant is presented in Figure 1 (from Sorlini et al., 2015a); it was the basis for the operator's implementation of the WSP. In that plan, or in similar plans which were applied in Italy (Crotti et al., 2012), the first part is routine monitoring (Phase 1), the outcomes of which are examined through intensive monitoring (Phase 2), which allows a focus on problems that are then highlighted, also in their quantitative aspects, by means of laboratory and/or field tests (Phase 3). These are the so-called "experimental functionality tests" which, with appropriate frequency, should become an established procedure for the "good management" of water treatment plants. These checks are essential support for the WSP's success and for the basic knowledge to define the operational and structural upgrading interventions that must be made to meet the needs of the particular plant (Phase 4). In this regard, recent literature (Lamrini et al., 2014; Vieira et al., 2008; Chang et al., 2007) offers interesting studies that, using the methodology described in Figure 1, have led to the optimization of different water treatment plants by means of "targeted upgrading" and, at the end of the intervention, have sometimes even resulted in a substantial savings of operating costs (Sorlini et al., 2015b). In addition, this method was successfully applied when it was necessary to adapt to a new, more stringent limit for some specific parameters. For instance, this was the case with arsenic, whose limit for human consumption was recently reduced to $10 \mu\text{g L}^{-1}$ from its previous limit of $50 \mu\text{g L}^{-1}$. After application of the functionality tests to the already-operating plants, the new limit for arsenic was achieved, sometimes through targeted structural upgrading in the treatment chain, sometimes with simple plant adaptations to new requirements (for example, by using an existing unit operation for a different process purpose), sometimes even with only the introduction of dosing and control systems without changing the process chain (Sorlini et al., 2014; Sharma et al., 2016). However, the facilities already subject to "monitoring/functionality tests" were the first to implement the new WSP procedure.

Besides ensuring reliability of the water systems (both for drinking water treatment plants and for water distribution system - Bigoni et al., 2014) through the identification of risks and a good knowledge of water treatment processes, the WSP also enables the discovery of problems related to compounds usually not controlled by routine monitoring, such as chemicals of geogenic or anthropogenic origin (uranium, chemicals from industrial and mining contamination, etc.), residues of pharmaceutical, personal hygiene and care products, perfluorinated compounds, and nanomaterials (Lucentini et al., 2016). Among the risk factors are emerging ones also to be considered, such as the monitoring of chemicals compounds not previously analyzed or the monitoring at significantly lower levels of known analytes. These compounds are generally referred to as contaminants of emerging interest, and the risk posed to human health or to the environment as well as their frequency or their origin are not fully known.

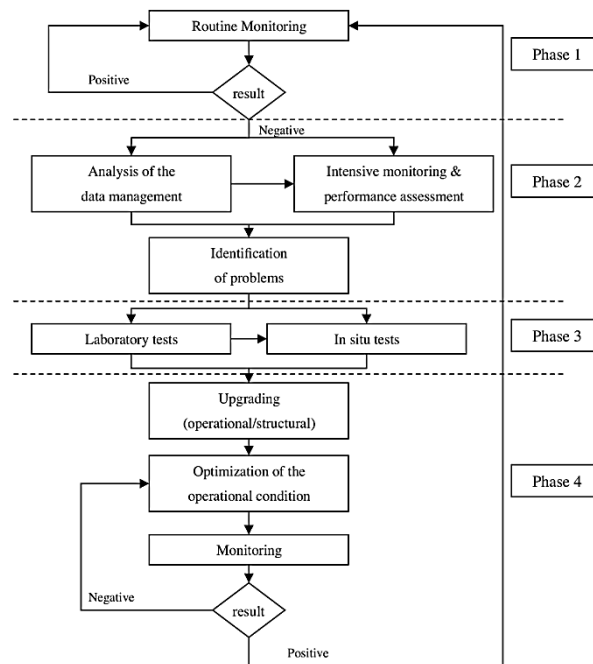


Figure 1. Scheme of the methodological approach proposed in order to assess and optimize Drinking Water Treatment Plants performance (Sorlini et al., 2015a).

An interesting aspect of the WSP is its versatility: it is applicable to all water supply systems, irrespective of their size or complexity; therefore, large- and small-scale urban and rural water supply chains may be included (Lucentini et al., 2016).

In particular, the WSP has proven to be a useful instrument even in countries with limited resources. Interesting results were achieved in Senegal and Burkina Faso (Rondi et al., 2015). In Senegal, the issue was the high contamination of the groundwater by fluorides, but there were also hygienic problems related to treatment, storage and water distribution. The WSP was implemented through the formation of a composite team, formed by the Health Authorities of Diourbel, the network operator and the representatives of the population. All of the WSP steps were then developed, although sometimes in a simplified form, leading to the final sharing of interventions to counter contamination, often by means that were very simple but very effective in the local context (e.g., cleaning of tanks, protection of wells from animal intrusions, etc.).

In the case of Burkina Faso, unprotected wells were contaminated by microbes in the absence of chlorination. A simplified WSP was implemented for each well in the 11 villages included in the intervention. Even though all of the steps of the procedure were not applied, it achieved a positive result, as the WSP has raised the awareness of local communities to minimize contamination hazards, and has also achieved an important improvement in the microbiological quality of water (with removal of 60 to 85% of *E. coli* contamination at the source, along the transport and at the point of use).

The first "experimental" applications of the WSP are confirming the expected benefits in practice. These cover many aspects, from human health to management, including economic and institutional components. These cases show the method's ability to identify and manage all possible risks of water contamination and at the same time to improve the degree of consumer confidence in water services. These two fundamental objectives are similar in the first applications in Italy and in very different contexts, such as in the rural African situations mentioned above (Rondi et al., 2015). Among the expected results that are being confirmed in

the described cases, the identification of critical points of the system that would not otherwise have been identified without the WSP, and investments on “critical points” of the system, where the level of risk is higher, are very important.

The first applications of the WSP identified some problems in the procedure: these range from the difficulty of identifying all hazards to the classification criterion of the consequences’ severity, to the lack of a "simplified" procedure to be applied to small water supply systems.

However, "concrete" proposals for improvement of the procedure have resulted from these problems. For example:

1. definition of simplified criteria for the application of the WSP for small drinking water supply systems;
2. more active involvement of consumers during the WSP drafting process;
3. establishment of incentives for managers who implement the WSP.

Among the proposals, one is perhaps the most important for emphasizing the role of Sanitary and Environmental Engineering: the spread and systematic implementation of "functionality tests". This approach, based on experiences already available, will give rigorous and effective methodology for:

- performance evaluation of the system in its actual configuration;
- assessing the effectiveness of existing control measures;
- the identification of the “critical problems” of the system in its actual configuration;
- the definition of new preventive and control measures;
- the definition of a monitoring plan to verify the effectiveness of new control measures.

The last aspect that must be emphasized is perhaps the most important and deals with the education and training of all stakeholders: health and environmental authorities, water system operators, consumers, institutions (from supranational ones to small municipalities) etc. In this education and training, the contribution of University with different water-related disciplines is of course important: it can provide not only the research results of innovative technical systems, but also more direct and immediate support of application methods appropriate to different contexts.

On this front, in many countries institutions operate with the aim of utilizing "appropriate technology" (Sorlini et al., 2015c). The new “safe water for all people” challenge, with useful procedures such as the WSP, will be a stimulus to achieve a goal that may also help to "harmonize" discordant policies in a world today so divided.

REFERENCES

- BIGONI, R.; SORLINI, S.; COLLIVIGNARELLI, M.C.; BERBENNI, P. Drinking water quality assessment and corrosion mitigation in the hospital water supply system of Chacas village (Peru). **Revista Ambiente & Água**, v. 9, n. 3, p. 379-389, 2014. <http://dx.doi.org/10.4136/ambi-agua.1407>

- CHANG, E.-E.; CHIANG, P.-C.; HUANG, S.-M.; LIN Y.-L. Development and implementation of performance evaluation system for a water treatment plant: case study of Taipei water treatment plant. **Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management**, v. 11, n. 1, p. 36-47, 2007. [http://dx.doi.org/10.1061/\(ASCE\)1090-025X\(2007\)11:1\(36\)](http://dx.doi.org/10.1061/(ASCE)1090-025X(2007)11:1(36))
- CROTTI B. M.; COLLIVIGNARELLI, M. C.; SORLINI, S.; CASTAGNOLA F. Performance assessment of real scale drinking water treatment plant. In: INTERNATIONAL SYMPOSIUM ON SANITARY AND ENVIRONMENTAL ENGINEERING, 9., 26-29 June 2012, Milan, Italy. **Proceedings...** Balmain: TheMHS, 2012.
- LAMRINI B.; LAKHAL E. K.; LE LANN M. V. A decision support tool for technical processes optimization in drinking water treatment. **Desalination and Water Treatment**, v. 52, n. 22-24, p. 4079-4088, 2014. <http://dx.doi.org/10.1080/19443994.2013.803327>
- LUCENTINI, L.; ACHENE, L.; VESCHETTI, E.; FUSCOLETTI, V.; NIGRO DI GREGORIO, F.; COLAGROSSI, R.; DI BENEDETTO A. Water Safety Plan implementation in Italy. In: INTERNATIONAL SYMPOSIUM ON SANITARY AND ENVIRONMENTAL, 10., 19-23 June 2016, Rome, Italy. **Proceedings...** Balmain: TheMHS, 2016.
- RONDI, L.; SORLINI, S.; COLLIVIGNARELLI, M. C. Sustainability of water safety plans developed in sub-saharan Africa. **Sustainability**, v. 7, n. 8, p. 11139-11159, 2015. <http://dx.doi.org/10.3390/su70811139>
- SHARMA, A. K.; SORLINI, S.; CROTTI, B. M.; COLLIVIGNARELLI, M. C.; TJELL, J. C.; ABBÀ, A. Enhancing arsenic removal from groundwater at household level with naturally occurring iron. **Revista Ambiente & Água**, v. 11, n. 3, p. 486-498, 2016. <http://dx.doi.org/10.4136/ambi-agua.1815>
- SORLINI, S.; PALAZZINI, D.; MRAWALA, A.; NGASSOUM, M. B.; COLLIVIGNARELLI, M. C. Is drinking water from "improved sources" really safe? A case study in the Logone Valley (Chad-Cameroon). **Journal of Water and Health**, v. 11, n. 4, p. 748-761, 2013a. <http://dx.doi.org/10.2166/wh.2013.017>
- SORLINI S.; PEDRAZZANI R.; PALAZZINI D.; COLLIVIGNARELLI M.C. Drinking Water Quality Change from Catchment to Consumer in the Rural Community of Patar (Senegal). **Water Quality, Exposure and Health**, v. 5, n. 2, p. 75-83, 2013b. <http://dx.doi.org/10.1007/s12403-013-0089-z>
- SORLINI, S.; GIALDINI, F.; COLLIVIGNARELLI, M. C. Survey on full-scale drinking water treatment plants for arsenic removal in Italy. **Water Practice and Technology**, v. 9, n. 1, p. 42-51, 2014. <http://dx.doi.org/10.2166/wpt.2014.005>
- SORLINI, S.; COLLIVIGNARELLI, M. C.; CASTAGNOLA, F.; CROTTI, B. M.; RABONI, M. Methodological approach for the optimization of drinking water treatment plants' operation: a case study. **Water Science & Technology**, p. 71, n. 4, p. 597-604, 2015a. <http://dx.doi.org/10.2166/wst.2014.503>

- SORLINI, S.; BIASIBETTI, M.; COLLIVIGNARELLI, M. C.; CROTTI, B. M. Reducing the chlorine dioxide demand in final disinfection of drinking water treatment plants using activated carbon. **Environmental Technology**, v. 36, n. 12, p. 1499-1509, 2015b. <http://dx.doi.org/10.1080/09593330.2014.994043>
- SORLINI, S.; RONDI, L.; POLLMANN GOMEZ, A.; COLLIVIGNARELLI, C. Appropriate technologies for drinking water treatment in Mediterranean countries. **Environmental Engineering and Management Journal**, v. 14, n. 7, p. 1721-1733, 2015c.
- SORLINI, S.; BIASIBETTI, M.; ABBÀ, A.; COLLIVIGNARELLI, M. C. Elaboration of a Water Safety Plan (WSP) for risk management in Mortara (PV) drinking water supply system. In: INTERNATIONAL SYMPOSIUM ON SANITARY AND ENVIRONMENTAL, 10., 19-23 June 2016, Rome, Italy. **Proceedings...** Balmain: TheMHS, 2016.
- VIEIRA, P.; ALEGRE, H.; ROSA, M. J.; LUCAS, H. Drinking water treatment plant assessment through performance indicators. **Water Science and Technology: Water Supply**, v. 8, n. 3, p. 245-253, 2008. <http://dx.doi.org/10.2166/ws.2008.068>
- WORLD HEALTH ORGANIZATION - WHO. **Guidelines for Drinking-water Quality**. 3rd ed. Geneva, 2004.
- WORLD HEALTH ORGANIZATION - WHO; UNITED NATIONS CHILDREN'S FUND - UNICEF. **Progress on sanitation and drinking water: 2010 Update**. Report of the Joint Monitoring Programme for Water Supply and Sanitation. Geneva; New York, 2010.