IDENTIFICATION AND RISK ASSESSMENT OF CENTRAL WATER SUPPLY SYSTEMS – CASE STUDY

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ABSTRACT. - Risk assessment of central water supply systems - a case study. This paper presents methods for identification and risk assessment of central water supply systems, exemplified by a case study of the central water supply system in Luna locality, Cluj county during 2009-2010. System assessment was performed by means of previous data on water quality monitoring and water samples analysis for the parameters imposed by Law 458/2002 (audit monitoring) in the laboratories of the Environmental Health Center. The main risk identified at source was the significant water contamination with nitrates, in this regard results did not show significant change of the raw water quality (drain) over time. Occurence of nitrates in excess is of mixed origin in Luna water source, predominantly telluric net and accentuated anthropogenic due to agricultural practices in the area. In this respect, evolution of bacterial load was significantly related to the drain positioning in an intensively exploited agricultural area, the important increase of contamination being due to manure application on upstream lands. Two kinds of hazards were identified at the water treatment plant output and in the distribution network, as well as at the water source: contamination with nitrates and bacteriological contamination of faecal origin, the latter as a consequence of a completely inadequate chlorination. Water in the distribution network of Luna locality represents low health risks for small population groups (risk score 8), as characterized qualitatively on the basis of monitoring. The compliance plan for preventing effects targets the water source, treatment process, distribution network and health status indicators.

Keywords: drinking water, risk identification, risk assessment

1. INTRODUCTION

Central water supply of localities represents an activity accompanied by risks, and maintaining them within the limits of acceptability requires sustained efforts and additional costs justified by the prevention of diseases and avoiding environmental damage. Any definition of risk includes the idea of exposure to a potential loss, of "probability of an undesirable result" of minor importance up to a catastrophic one. The safe water expresses the accordance to the maximum admissible limits of the relevant water parameters for human health.

In accordance with the Bonn Objective for obtaining "sanogenic drinking water, in which consumers trust" the water safety plans (PSA) have major

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requirements represented by the risk identification in each stage of the water production process from the water catchment to consumer tap and by the risk assessment, that is the probability that a hazard causes health effects or determines an unacceptable water quality. (WHO 2005, Ritter et al.2002, Summerhill ey al.2010, Schmoll et al. 2006).

A water safety plan combines elements of a "hazard analysis and critical control point" (HACCP) approach, quality management and the "multiple barriers" principle, to provide a preventive management approach specifically developed for drinking-water supply. It can provide a framework for evaluating microbial control measures by helping to focus attention on process steps such as coagulation, filtration and disinfection, which are important for ensuring the microbial safety of water. (LeChevallier MW and Au K-K 2004).

Rules of good practice state that sanitary surveillance is organized when a water source does not meet a requirement of the law that regulates it. This refers mainly to microbiological contaminants and prevention of possible water-related diseases, but also to certain chemicals (arsenic, fluorine or nitrates) when present in high concentrations.

This paper presents methods for identification and risk assessment of central water supply systems, exemplified by a case study of the central water supply system in Luna locality, Cluj county.

2. MATERIAL AND METHOD

The study was conducted in 2010. The raw water source for Luna water treatment plant is groundwater collected by a drain from 6 drillings. Luna water treatment plant processes water by chlorination. The assessment of the central water supply system in Luna locality, Cluj county was based on type HACCP inspection (Hazard Analysis and Control in Critical Points). Previous data of water quality monitoring were also considered in the study (laboratory of the water supplier) as well as water samples analysis for the parameters imposed by Law 458/2002 regarding drinking water quality (audit monitoring) in the laboratories of the Environmental Health Center. Risk assessment was performed by risk scores determination based on a specific matrix.

3. RESULTS AND DISCUSSIONS

3.1. Water source location

The drillings are located in the western part of Luna locality, upstream the stables of the former cooperative farm, between the road linking the military base with the airport and the group of houses "Bazil".

The catchment front area is slightly sloping from V to E and from S to N, drillings being surrounded by agricultural lands exploited only for cereal crops. These lands belong to an agricultural association and they are treated with herbicides. Due to the small depth of the drillings and soil structure, but especially due to its location in the area of agricultural holdings, the collected water layer is highly vulnerable to pollution.

Sanitary protection areas are limited to the area with strict sanitary protection regime, established on an area of 610 m in length (slightly larger than the drain length) and 63 m in width. Under these conditions, water quality in the aquifer is influenced by the external factors from the soil surface, the collected water quality varies and depends mainly on the chemical and physical structure of the soil.

3.2. Water quality exiting Luna water treatment plant and in the distribution network – control monitoring

In order to assess the water treatment plant efficiency and the supplied water quality, the analysis results were interpreted (color, odor, pH, conductivity, turbidity, free residual chlorine and bound chlorine, ammonia, nitrites, nitrates, oxidability, total hardness, iron, E.Coli, enterococci, coliform bacteria, faecal coliforms) as part of the control monitoring during June 2009 - September 2010. Among the analysis provided by the laboratory from Luna water treatment plant, find below the parameters considered relevant for the water quality characterization.

During 2009, the oxidability average values framed within the normal limits, being very low. Instead, the nitrates average value in the three types of monitored water (source-drainage basin, reservoir and Luna village network) recorded average values above the maximum admitted by legislation (50 mg/l), ranging between 52-59 mg/l. Chlorination was performed at extremely low levels, well below the standard ones for microbiological safety, and the free residual chlorine averaged between 0.04-0.07 mg/l.

During 2010, nitrates, the major contaminant of Luna water supply system, kept at elevated levels above the admitted standard, the highest value of 71.4 mg/l being measured in the reservoir.

The average values for nitrates were higher in 2010 than in 2009 both at the level of the collector tank and the reservoir (Table 1).

Table 1. ***Comparative levels of nitrates in Luna water supply system***

Nitrates	**2009**	**2010**
Collector basin	52.71	58.22
Reservoir	55.87	65.29

During 2009 a constantly increasing bacteriological contamination has been observed at the level of the collector tank starting in August (16 Enterococci/L and 16 Coliforms/L) with a maximum in November (149 Enterococci/L, 415 Coliforms/L and 346 E.coli/L). Evolution of the bacterial load is significant in relation to the drain positioning in an intensively exploited agricultural area, the important increase of contamination being probably due to the application of natural fertilizers (manure) on upstream lands. Bacteriological contamination is severe even more because chlorination is practiced in the drainage basin. It is to be noted that during November 2009 the highest concentration of nitrates in water was recorded in the collector tank. Insufficient chlorination is reflected by the bacteriological contamination in the reservoir, enterococci being known as germs with a higher resistance to chlorine.

During 2010, the bacteriological contamination of water in the drainage basin was more reduced although chlorination followed the same procedure, the free residual chlorine level being very low. During this period the nitrates level was increased and higher than in 2009. Regarding the bacteriological examination of water in the distribution network, it was performed only once in 2009 and it was negative. Other two bacteriological examinations of water at school show contamination with total coliforms in a sample, the other one being negative. During 2010, also a single water sample was analyzed in the distribution network, and it was contaminated with total coliforms.

According to the control monitoring, during the period January 2009 - August 2010, on the whole, water in Luna supply system was 100% undrinkable in terms of the free residual chlorine, 81% in terms of nitrates and 51% bacteriological.

3.3. Water quality at the output of Luna water treatment plant and in the distribution network – audit monitoring

In order to assess the water quality at the source and in the distribution network we collected water samples on 13.09.2010. We mention that starting on 07.09.2010 at Luna water treatment plant an automatic chlorination station with sodium hypochlorite solution and a denitrification station (filters) were put into operation next to the reservoir near the school, thus the manual chlorination at source being interrupted (collector drainage tank). The following samples were collected: raw water at collector drainage tank (treatment station input), drinking water at Luna water treatment station output - Luna network.

Raw water is characterized by a higher concentration of nitrates and bacteriological contamination of faecal origin. Water contamination with Salmonella, a dangerous pathogenic intestinal germ common to man and warm-blooded animals, in the collector tank represents a special situation. In this case, given the drain location, the faecal contamination of human origin is unlikely, but possible due to application of manure, especially of poultry origin.

Like in the previously analyzed period, i.e. January 2009 - August 2010, concentration of nitrates, very low levels of free residual chlorine and bacteriological contamination of faecal origin remain as major problems of water quality at the output of the water treatment plant. Subsequently, water quality in the distribution network has the same deviations from the quality standards, with the mention that the level of nitrates in the network records a significantly higher value (78.25 mg/l). Hazardous substances (toxic) were not identified in the collected water, other than nitrates, such as polycyclic aromatic hydrocarbons, benzene, pesticides, heavy metals, etc. The results allow us to appreciate that at the time of sampling, water was chemically and bacteriologically undrinkable and the efficiency of the denitrification station was null (unchanged value of nitrates exiting the water treatment plant compared to the raw water), as well as that of chlorination. Reproducing the water analysis for nitrates after regeneration of the denitrification filters shows that the level of nitrates decreases by 15.1% after the denitrification process, the value at the output of the water treatment plant framing within normal limits.

3.4. Risk assessment

A. Water source – drain

Risk identification

The following parametric risks were identified at Luna catchment front: **nitrates and bacteriological contamination**.

Health risk assessment

Characterization of the source and catchment – The drain location in an exploited agricultural area long before drilling is a major hazard. In the given situation, the hydrogeological survey shows that soil is not a protective barrier for the drain that captures the raw water. The sanitary protection areas are not formed properly, on the basis of professional studies, as the perimeter with restriction regime is lacking.

Data resulting from water monitoring

The risk generated by the chemical and bacteriological contaminants at Luna catchment front is determined by different risks for each contaminant: risk of nitrate poisoning and epidemiological risk regarding occurrence of waterborne infectious diseases.

On the basis of the risk assessment matrix, a risk score 20 (major consequences) was set for the water source, which implies an urgent operational action and a probable capital investment necessary at the water treatment plant.

B. Treatment process

Risk identification depending on the treatment steps

Denitrification and chlorination are the water treatment methods at Luna water treatment plant. Denitrification has a variable efficiency. Chlorination is too low related to the water bacteriological quality and standards in force that provide 0.5 mg/l free residual chlorine at the output of the water treatment plant. There have not been identified high levels of THM. Bacteriological contamination is present inconstantly.

Health risk assessment

High levels of nitrates were found inconstantly, having the possibility of generating acute and chronic poisoning. Periodical bacteriological contamination can cause the occurrence of waterborne infectious diseases.

On the basis of the risk assessment matrix, a risk score 8 (minor consequences) was set for the water treatment plant, which implies an operational action and a probable capital investment necessary at the water treatment plant.

C. Distribution network

Risk identification

The following parametric risks were identified: nitrates si bacteriological contamination, both inconstant.

Health risk assessment

The risk score is 8 (minor consequences), which implies an operational action and a probable capital investment necessary at the water treatment plant.

In individual or social context, homeostasis requirements impose risk management, that implies adoption of measures either for reducing or accepting an undesirable outcome (Jardine et all 2003).

Thus, by means of modern risk management, they are transferred from the "minimum area" in the "optimal acceptability area”, where risks are slightly higher and the overall social costs are kept to more acceptable levels. In a growing extent, however, public training and participation are necessary for the compliance with the legislation process, prevention of diseases and avoiding environmental damage.

3.5. Aspects of noninfectious and infectious water-related pathology

Among the chemicals possible present in the drinking water, some represent special interest, such as those having toxic or carcinogenic effects.

Nitrates are inorganic compounds characterized by high solubility in water. Major sources of nitrates in drinking water are fertilizers, sewage and animal manure. Nitrates also occur naturally in the environment, mineral deposits, soil, sea water, fresh water systems and in the atmosphere (Shuval et al. 1992). Sufficient high concentrations of nitrates in drinking water can cause methemoglobinemia in infants, also called "blue baby syndrome". Healthy adults do not develop methemoglobinemia at levels of nitrates in drinking water that place infants at risk. The only non-carcinogenic effect known determined by nitrates is methemoglobinemia. No other non-carcinogenic effect following chronic exposure has not been demonstrated and there is no valid evidence that nitrates and nitrites can cause cancer in the absence of amine-containing substances (ATSDR 2010, Ritter et al. 2002, Mesinga et al. 2003).

In 2004-2007, considering the requirements of the EC Directive, delimitation of vulnerable areas imposed the extension of areas declared as vulnerable, including potentially vulnerable areas, to 58% of the country’s surface (European Commission 2010). Studies performed in Transylvania showed that nitrates pollution of the groundwater in Niraj River Basin is a major concern and an important issue, in 43% of the sampled wells nitrate concentrations exceeded EU standards (50 mg/l), the main cause of groundwater pollution with nitrates being due to agricultural practices and untreated household water (Hajdu 2007).

The vast majority of water-related diseases are transmissible (LeChevallier and Au K-K 2004, Craun et al. 2006). Diarrheal disease alone amounts to an estimated 4.1% of the total disability-adjusted life years of the global burden of disease and is responsible for the deaths of 1.8 million people every year (WHO 2004, Havelaar et al. 2003). It was estimated that 88% of that burden is attributable to unsafe water supply, sanitation and hygiene and is mostly concentrated in children in developing countries (WHO, 2004). In Romania also, the major risk deriving from the drinking water quality is the microbiological one, and consists essentially in causing water-related diseases - epidemics, endemics or isolated diseases of causes associated with ingestion of water contaminated with human and animal excrements.

3.6. Compliance plan for preventing effects

Subsequent to hazard identification and risk assessment the compliance plan for preventing effects targets the source, treatment process, distribution network and health status indicators:

- Organizing the sanitary protection perimeter with restriction regime.
- Technical maintenance of drain manholes in perfect condition in order to avoid the aquifer contamination
- Reconsidering the water treatment process. With reference to the chlorination station that does not operate/is not properly exploited. Maintainance of denitrification filters in proper operation (washing for regeneration) so that the filter efficiency is at least 40%
- Monitoring of health indicators related to water quality as the incidence and spatial distribution of acute diarrheal disease

CONCLUSIONS

The main risk identified at source was the significant water contamination with nitrates, the results did not show temporally changes of the raw water quality (drain) in terms of nitrates. Presence of nitrates in excess in Luna water source is of mixed origin, predominantly telluric net and accentuated anthropogenic due to agricultural practices in the area. In this sense, evolution of bacterial load was significantly related to the drain positioning in an intensively exploited agricultural area, the important increase of contamination being due to manure application on upstream lands.

Similar to the source, two hazards were identified at the output of the water treatment plant and in the distribution network: contamination with nitrates and bacteriological contamination of fecal origin, the latter as a consequence of a completely inadequate chlorination.

As qualitatively characterized on the basis of monitoring, water in the distribution network of Luna locality represents low health risks for small population groups (risk score 8).

The risk assessment and management cannot be based on epidemiological data, which are not sufficiently conclusive, following intervention through special actions, provided by law, in case of source quality deterioration or contamination incidents in the network sectors.

The compliance plan for preventing effects targets the source, treatment process, distribution network and health status indicators. Changing the water source is not required but adjustment of the water treatment process is.

Also, actions are required in terms of public relations (social marketing activities) and risk communication.

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