Management of Water Treatment Plants During Emergencies

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DOI: 10.29227/IM-2016-01-05

Abstract

Public water supply systems make a component of the environment with a high significance for preservation of numerous emergency services to the population in case of an emergency. Damage or elimination of potable and fire water production and distribution can significantly reduce living standard of the population, but, more importantly, endanger activity of health facilities, food processing facilities and fire safety in built-up areas. The water supply system incorporates water treatment facilities, which essentially affect quality of the produced water. As the risk of interrupted supply of potable water for natural or anthropogenic reasons cannot be eliminated, it is necessary to at least minimize negative impacts on the consumers [1]. This article offers a solution of this complicated task in real conditions of water treatment and provision of the necessary amount of potable water during an emergency at least to important consumers and strategic subjects.

Keywords: water supply system, water treatment, emergency, breakdown, risk analysis, monitoring, controlling

Brief characteristics of a water treatment plant

The plant is a technological supply structure for mechanical, biological and chemical treatment of raw water pumped from a collecting territory for potable water supply. It incorporates a system of technological devices for the individual operations that result in reaching the specified parameters of potable water defined by the law (in the Czech Republic, law No. 258/2000 on Protection of public health and decree of the Ministry of Health No. 252/2004 Coll., on Sanitary demands for potable water and the scope of potable water inspections).

In the European Union member states, the law defines obligations of the owner (operator) of the water supply system (in the Czech Republic, law No. 274/ 2001, on public potable water and sewerage services), in which water treatment makes an inseparable component:

– the owner of the water supply system is obliged to secure uninterrupted and safe operation of the system (Article 8),

– the operator is allowed to interrupt or limit water supply without prior announcement only in case of a natural disaster, a water pipe or connection burst or potential threat to the people's health or property. The operator is obliged to report interruption or limitation of the supply immediately to the corresponding public health organ, the water management authority, hospitals, the regional fire brigade and the affected municipalities (Article 9, Section 5),

– the operator is allowed to interrupt or limit water supply until the reason for interruption or limitation has been removed (Article 9, Section 6),

– the operator is obliged to announce a scheduled interruption of water supply to the customer within a specified period (Article 9, Section 7),

– the operator is obliged to remove the cause of water supply interruption or limitation immediately and restore the water supply without delay (Article 9, Section 9),

– during a crisis, the operators are obliged to inform the ministry and the crisis management organ about the condition of potable water supply on their demand (Article 21, Section 2),

Definition of an emergency

Emergency is a harmful action of forces and effects caused by the human activity, natural circumstances or a breakdown, which threatens the lives, health, property or the environment; it demands rescue and liquidation activities. In the Czech Republic, the organization and structure of crisis management on the national level is subject to the law on crisis management [2].

The causes of interruption or limitation of water supply can occur during an emergency that can be managed by system and technical measures taken by the water supply operator:

– burst on the main and feeding pipelines,

– breakdown of important waterworks objects (water tank, treatment plant, pumping station),

– higher consumption during fires,

– excessive deterioration of water quality in the water source or during distribution.

– electric power failure,

– failure of the telemetric system

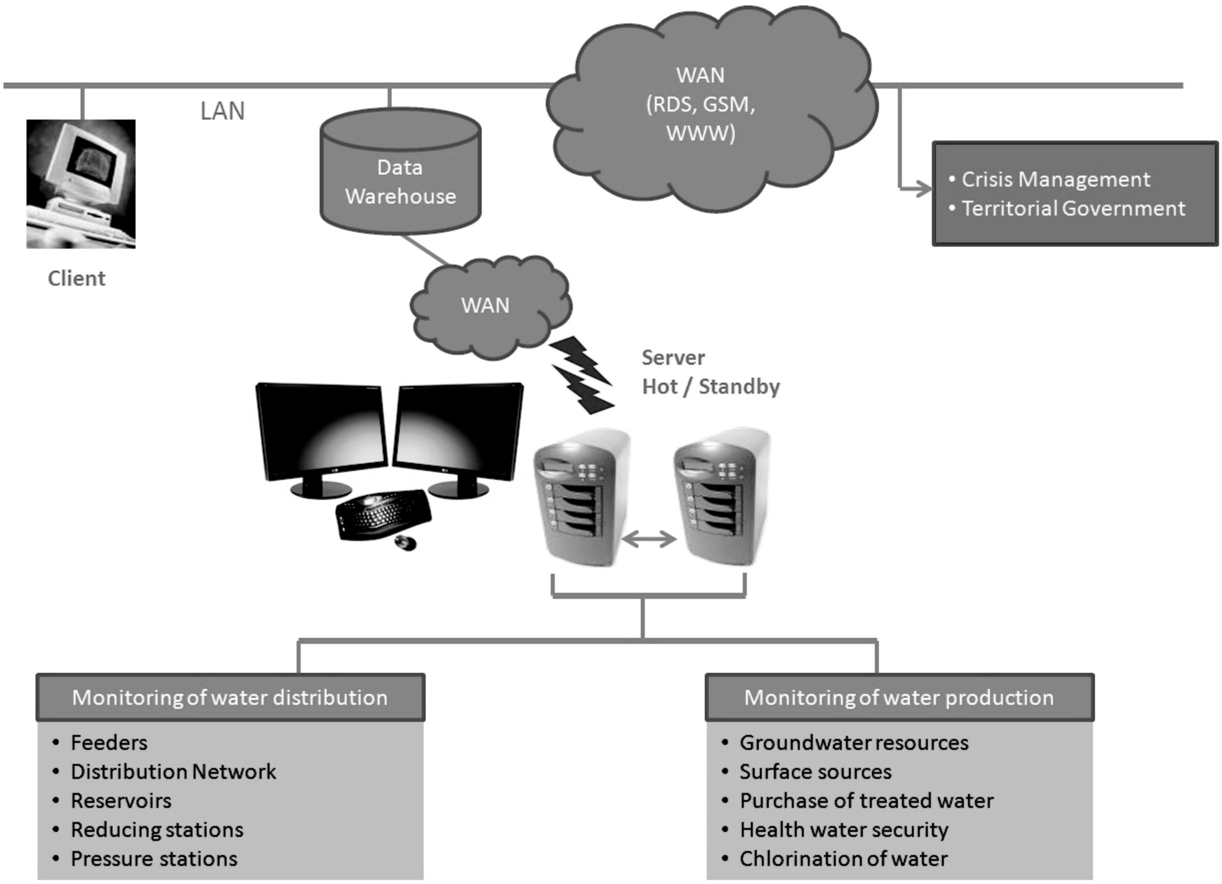

Fig. 1 Chart of water supply control centre [7]

Rys. 1. Schemat centrum kontroli zaopatrzenia w wodę [7]

Risks connected with an emergency in the water treatment plant

Risk analysis

In general, potable water treatment plants have lower vulnerability. High vulnerability is imminent during a terrorist act, when the danger of water poisoning is real because the surface of the water is open throughout the treatment cycle.

Analysis of consequences [3]

Regarding the impact on public infrastructure, the danger is high especially with view to securing non-interruption of water supply to special objects such as hospitals or food processing plants. When the limits are exceeded, distribution of potable water to the consumers must always be interrupted. The negative impact is higher in water treatment facilities of regional pipelines and treatment plants that represent the only source of raw water treatment into potable water.

Identification of the danger:

– easy to access the open water surface,

– easy to contaminate the water,

– easy to eliminate the water treatment plant for a long time,

– if a large water treatment plant is eliminated, it always means an emergency,

– frequent full automatic control of the treatment plants and their distance from residential areas of the municipalities.

An emergency can occur

– an emergency can really occur during a terrorist attack or a military action. Exceptionally, during an industrial or traffic accident.

The frequency analysis

– minimal, exceptional cases.

Risk-mitigating measures

– remote sensing of all inputs into the treatment plant by contact or space sensors,

– continuous sensing of raw water quality before entering the treatment plant,

– continuous sensing of potable water output,

– secondary monitoring of the treated water quality before its health safeguarding, e.g. by usage of a specific fish species with maximally increased sensitivity to water toxicity [4],

– immediate shutdown of the treatment plant and stopping discharge of the water by remote control (radio, telephone)

Water treatment as a component of the water supply system

The water supply system is a system of interconnected water mains fed by various types of water sources (reservoirs, rivers, deep boreholes, wells). These water supply systems incorporate technological structures such as water treatment plants, water tanks, pumping stations, repumping pressure stations, systems of valves and hydrants, the end user (small consumers – households, large consumers – industrial and administrative buildings, companies, elements of the state's technical infrastructure). The mentioned facts make it clear that thus complex organizational and technological system demands unified management that enables unity and coordination of control measures leading to reduction of potential emergencies or operative control for minimizing harmful consequences in case of emergency. This unification can be achieved by establishment and usage of a unified control centre, i.e. a water supply control centre [5].

The designed control system must enable remote monitoring and management of the water mains and the fundamental waterworks facilities such as the treatment plant, pumping stations, water tanks, etc. from a single point, i.e. the water supply control centre. The system has to operate in an automatic mode according to pre-programmed control algorithms, where the system operator executes only remote monitoring of the water supply system and performs operative corrections of flaws insignificant for water distribution within the specified productional and distributional indicators, or operating conditions of the scheduled repairs. In this case, we refer to the control as the standard operating condition.

In case of an emergency threatening with limitation of water distribution or reduction of the demanded qualitative and distributional parameters, the system operator controls the water supply system personally through a telemetric control system, following methodology specified in plans of crisis preparedness [6] or commands issued by the management and crisis staff of the waterworks company. The telemetric control system, i.e. the monitoring and control system, is an essential tool for management of the water supply system in case of an emergency.

To fulfil its basic work in management of the water supply system in an emergency mode, the system must secure collection and visualization of basic technological and operating data and the following basic control functions:

– the current online information on production and supply of water from a higher water supply system or its own sources in $l.s^{-1}$,

– the amount of water entering the individual water tanks and flowing out into the distribution system in $l.s^{-1}$,

– monitoring of selected technological data:

– information on basic operating modes of the essential units such as the pumps, the valves, operation of the chlorinating equipment, etc.,

– information on quality parameters of the produced and distributed water,

– information on the amount of water entering the individual pressure zones and leaving them in $l.s^{-1}$ in $m^3/24$ h,

– visualization of the preset and the demanded values of technological data with the real situation,

– visualization of information in the form of tables and charts on the water flows through the individual parts of the system, water levels in the water tanks, the pressure circumstances, the minimum offtake, etc.,

– safety information on entry and movement of persons in protected waterworks objects,

– operative solution of failures in water production and distribution,

– indication of hidden faults in the network by a night flow analysis,

– regulation of the pressure and flow circumstances in the distribution network,

– control of water pumping from underground sources in relation to the quality and amount of pumping,

– control of individual technological devices,

– archiving of data and their retrospective visualization.

In the mode of:

– local management according to preset control algorithms,

– remote control by the system operator or preset control algorithms on the level of the water supply control system and management.

In case of an emergency in potable water production and distribution, the control centre is incorporated in organizational structure of the

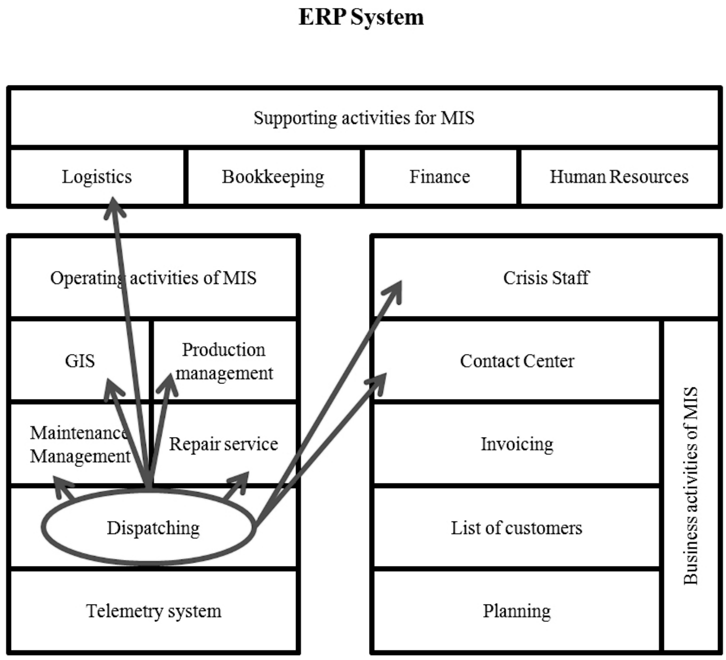

Fig. 2. Organization of the control centre in case of emergency

Rys. 2. Organizacja centrum kontroli w przypadku stanu wyjątkowego

waterworks company in relation to emergency management by the crisis staff. The proposal is given in Fig. No. 2.

Proposal for a water treatment process control

The Management Information Control System for emergency management, the MISMI, has been designed for management of a water supply system where water treatment is the fundamental component. It is a SW information module superior to the SCADA control system, which allows management of the water supply system in case of an emergency.

The module uses data from the telemetric SCADA system, filters it and compares it with the demanded preset conditions, executes potential calculations, evaluates exceeding of specified limits or demanded conditions. If it detects a deviation, it calls an alarm, offers output reports in comparison with the current and demanded conditions, printing maps and topology of the problematic part of the water pipeline, a technological chart of the equipment, a list of devices, spare parts, enumeration of potential defects and proposals for their solutions, a list of technical subjects with information on the minimum needs for potable water.

It thus provides an expert proposal for management during an emergency. This proposal is based on an executed analysis of critical parts of the water supply system, an analysis of the necessary relevant technological information, which will be obtained automatically directly from the technological process of water production and distribution or provided manually in relation to the level of automation of the given waterworks company and potentialities of its automation. Thus obtained data will be incorporated in the SW application, which represents a separate SW data module working above the existing SCADA control database.

The following systems will work within the MISMI module:

– LDS (the Leak Detection System)
– FIS (Failure Identification System),
– MIS (Mayor Interface System).

The system's output will come as a set of data and reports from the water supply system, assisting the waterworks managers with solving potential shortage of water in the water supply system and, in particular, with a speedy and correct reaction to removal of the emergency, thus reducing harmful effects, i.e. maintaining water supply to dedicated technical subjects or potentially the public.

A serious change in the quality of raw water, especially due to contamination by hazardous or extremely hazardous substances can put the water treatment plant out of service. The risk of an unexpected elimination is reduced by online monitoring [8]:

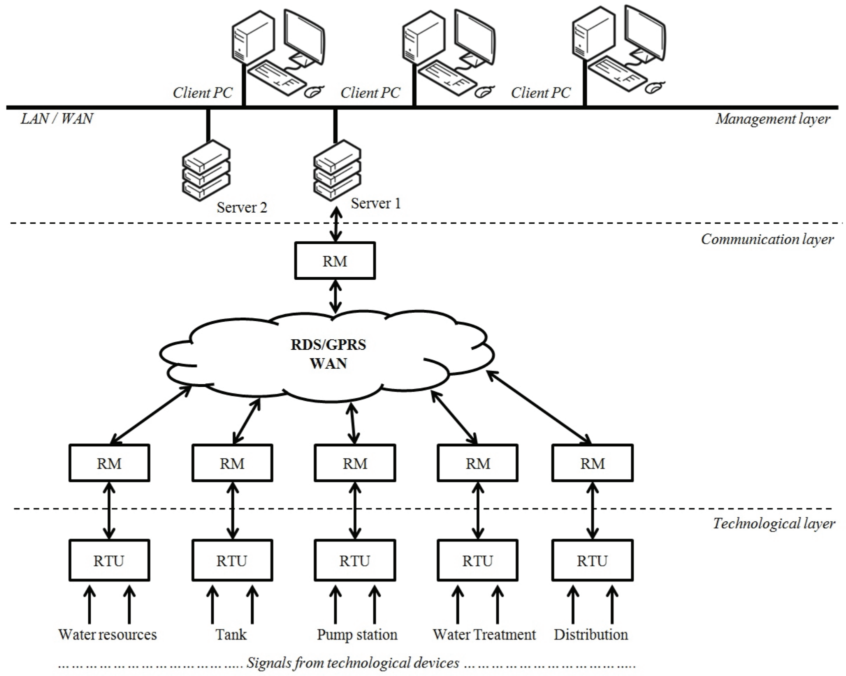

Fig. 3. Structure of the water supply management

Rys. 3. Struktura zarządzania zaopatrzeniem w wodę

– the quality of raw water from the source to the treatment plant including online information on the water inflow to the treatment plant in l.s-1,

– complex monitoring of the treatment process from raw to potable water,

– monitoring of output parameters of the flow, pressure and health safeguarding of potable water before its entering the distribution system.

Water for treatment (to the collector well) is pumped from boreholes; the pumping is usually controlled by a local automatic system according to the amount of pumped water.

Information on replenishing of the collector well is conducted to the control system from the level in the collector well. Before the collector well, the water is chemically treated by special equipment. This equipment works autonomously. It dispenses a chemical compound (aluminium sulphate) by a dosing pump whose operation is monitored. The dosing pump works in a local autonomous mode with a constant preset dose. When the collector well is replenished, the local automatic system starts the dosing pump (by a signal for replenishing the collector well).

In the water treatment plant, the water is filtered through cased sand filters. Operation of the filters is entirely autonomous. The filters are washed manually by the operator according to the technological procedure. Modifications for implementation of automatic filtration are based on replacement of manually controlled valves with motor-actuated valves.

Pumping of water to the water tank is controlled by a local automatic system, which is based on measurement of water level in the collector well. The pumping is blocked by the maximum level in the water tank; this, however, demands transfer of this information to the pumping station by a cable or radio through the control centre.

The control system will monitor signals for operation and failure of the pumps and the maximum level in the water tank.

The amount of consumed water will be measured in the water treatment plant. The signal from an optical sensor located on the water tank is conducted to a frequency converter whose output is an impulse signal announcing the total amount of water and an analogue output for the immediate flow. A water meter for measurement of the total amount of wash water is located behind a hand-controlled valve on the discharge pipe to the water tank.

The other values monitored and transferred to the control centre include loss of voltage in the low-voltage switchboard, entry into the object, confirmation of the entry and defect of the overcurrent protection.

The chlorine is automatically dispensed to the pipeline in front of the filters. The dosing pump works in a local mode with a constant preset

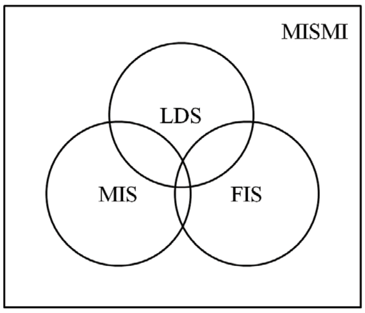

Fig. 4. Proposal of the MISMI module's SW structure

Rys. 4. Propozycja struktury SW modułu MISMI

dose. The dosing pump is activated together with pumps on the discharge to the water tank. Impulses of the individual dosages (the actual amount) by the dosage pump will be monitored through a flowmeter. Failure of the dosing pump will be evaluated by SW applications as follows: a correct operation will be evaluated if the input of the system receives regular impulses for individual doses while the pumping is activated; a failure will be evaluated if no impulses for individual doses are registered within a precisely defined period.

Consumption of electric power can be measured if an electric meter with an impulse outlet and a separating circuit is installed, connected to output impulses on binary inputs of the telemetric station. The following values can be measured: active operation in the high and low tariff, 1/4-hour maximum and other.

Measurement of electric power represents a value, which, if long-lastingly monitored and evaluated together with other values (pressure, operating hours, etc.), provides sufficient information for evaluation of the technological equipment as regards its wear.

The data are transferred to the control centre by a radio modem located in the automatic control system and a telemetric station, which, in addition to processing of the signals, secures communication between the water treatment plant and the control centre. The transfer antenna is located on a mast. The antenna is connected with the radio modem by a coaxial cable.

A detailed description of a control system for the water treatment plant would largely exceed the scope of this work, so it is not included. However, included are values essential for successions of the water treatment plant to the other objects and controls during an emergency. There are two types of values:

– technological values,

– operating values.

The most frequent technological values are heights of levels in collector tanks and accumulating tanks. They are used for automatic control of pumping to the water tanks and informing the system operator about readiness of the water supply system for distribution of the water. The technological values also include hydraulic pressures, which are used for controlling the pump units on the discharge pipeline to the water tank. The pressure values are also transferred to the control centre.

The operating values can be divided into:

– values entering the water treatment process (input)

– values leaving the process (output).

The input values include: the amount of raw water, amount of the individual chemical substances, the amount of gases (oxygen), consumed electric power and the amount of wash water. All of the mentioned values are monitored and related to a certain period of time.

The output value represents the amount of treated water pumped to the water tanks.

Conclusion

Public water supply systems in the Czech Republic supply potable water to ca 93% of the population and the value of the water supply infrastructural property has reached 1,000 billion crowns [9]. The strategic importance of water supply systems has to correspond to the legislative protection and protection of the water supply systems in real practice. Public water supply systems, as a component of the state's public infrastructure, are thus one of the state's infrastructures with a high importance for maintaining numerous emergency services to the population many social, health and technical subjects. Damage or elimination of production and distribution of potable and fire water will significantly reduce living standard of the population, but also threaten activity of health facilities, food processing and fire safety in built-up areas.

As the risk of interrupted supply of potable water for natural or anthropogenic reasons cannot be eliminated, it is necessary to at least minimize negative impacts on the consumers.

This article comments on the difficulty of this task in real conditions of water supply systems when providing at least the minimum amount of water during crises at least to the strategic consumers.

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Zarządzanie oczyszczalniami ścieków podczas stanów wyjątkowych

Publiczne systemy zaopatrzenia w wodę stanowią składnik środowiska o dużym znaczeniu dla zachowania wielu służb kryzysowych w przypadku awarii. Zniszczenie lub likwidacja produkcji wody pitnej i przeciwpożarowej, jak również jej dystrybucji może znacząco zredukować standardy życia populacji, ale, co jest jeszcze ważniejsze, narazić na niebezpieczeństwo działalność ośrodków zdrowia, przetwórstwa żywności oraz bezpieczeństwa pożarowego w rejonach budowy. System zaopatrzenia w wodę związany jest z oczyszczalniami wody, które znacząco wpływają na jakość produkowanej wody. Ponieważ ryzyko związane z zanieczyszczeniami wody z powodów naturalnych lub antropogenicznych nie może być wyeliminowane, konieczne jest aby przynajmniej zminimalizować negatywny wpływ odbiorców [1]. Artykuł ten oferuje rozwiązanie tego skomplikowanego zadania w warunkach rzeczywistych oczyszczania wody i zapewnienia potrzebnej ilości wody pitnej podczas stanów wyjątkowych, przynajmniej dla ważnych i strategicznych odbiorców.

Słowa klucze: system zaopatrzenia w wodę, oczyszczanie wody, stan wyjątkowy, awaria, analiza ryzyka, monitoring, controlling