[1]Goran VUJNOVIĆ, [2]Jasmina PERIŠIĆ, [3]Marina MILOVANOVIĆ, [4]Ljiljana RADOVANOVIĆ

USING SCADA APPLICATIONS IN WATER SUPPLY SYSTEM

[1-3]UNION University "Nikola Tesla", Faculty of Entrepreneurial Business and Real Estate Management, Belgrade, SERBIA
[2]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, SERBIA

Abstract: The application of information technology has made it easier to apply all other technologies in everyday life. In this paper, the application of SCADA applications in the Pljevlja plumbing system is explained. Its main role is to utilize certain parameters for dosing chlorine in water. In this way, the primary aspect of this work is placed on the ecological aspect and on the preservation of human health. All other factors that are obtained by applying these applications are secondary, and among other things there is a reduction in error options, a reduction in the number of employees and savings. They are based on one or more implementation principles. Also, the paper describes methods, techniques and devices that allow the automated process of chlorine dosing in the water supply system.
Keywords: SCADA, water supply system, water treatment plants

INTRODUCTION

Water supply systems use water that needs to be processed to be used as potable. The most commonly needed processes are: sedimentation, filtration, disinfection [7]. The most common form of water disinfection is chlorination [22]. The parameters that are monitored during the treatment of water are variable and depend on the quality of the incoming water in the water treatment plant [14], [17]. The parameters that are monitored are physicochemical and microbiological water treatment plants are automated and the parameters are monitored and recorded continuously [8], [15], [20]. If such a change in the quality of the inlet water occurs, the water treatment devices cannot process it to the level of the quality of the drinking water, the probing devices send analogue or digital impulses to PLC ie. programmable logic controller. PLC is a device that is currently stopping water production in order to avoid complications related to the contamination of drinking water [4], [10], [18].

One of the most commonly used methods for water disinfection is the insertion of chlorine (or some chlorine compound) as a strong oxidizing chemical agent. In the water supply facilities, besides dosing various other chemicals for water preparation, chlorine is added as one of the usual disinfectants. The addition of chlorine can be in the form of gas (Cl_2) or in the form of a liquid when one of the chlorine compounds is added. After the addition of chlorine, one part is spent on initial disinfection of water in the water supply and the other part remaining in water distributed to consumers. This residual amount of i.e. residual is controlled and maintained at a predetermined level, typically from 0.2 to 0.5 mg / l of chlorine that is in accordance with the officially legislation [6], [21]. Automation of the chlorination process greatly reduces the influence of the "human error" present during manual regulation. A well-tuned machine maintains an uninterrupted level of residual chlorine in the water, always at a given level, without the intervention of a human being. PLC Controller based on the continuous measurement of chlorine residual in water (using chlorine analyzer) increases or decreases chlorine dosing. This method of operation is called "Residual Management". There is also a different kind of management that is used if the amount of chlorinated water is variable. Less chlorine is added to the smaller amount of water, and in larger, proportionately more. The necessary information about the current flow of the controller is obtained from the appropriate flowmeter, and based on this increases or decreases the dosage. This type of management is called "Flow Control". The most complex management method is used if the water has variable chemical properties over time (and hence chlorine demand) and at the same time, variable flow. Then, "Flow and residual management" is performed, or combined management. Various machines used up to the last ten years have been designed as electromechanical or electronic circuits on an analogous principle of operation. Today, modern, digital, microprocessor devices are used in this field. In addition to the unlimited possibilities of programming and adjustment of the chlorine problem solving, they also enable remote communication with other computer devices, thus increasing the possibilities of automating and managing all devices on one water supply from a single command center SCADA ie. supervisory control and data acquisition system [4], [9]. Steel chlorine cylinders as well as dosing devices must be placed in a separate room (chlorine station) with forced ventilation, shower and drainage by sewage connection. On the outside of the chlorine station there is a cabinets with a gas mask and shower drain.

MATERIAL AND METHODS

Water disinfection ie. chlorination: involves the removal or destruction of pathogenic and optionally pathogenic microorganisms. In the course of disinfection or sterilization of water in microorganisms, gross disorders of the colloidal balance (due to the effects of physical, physical-chemical and chemical agents), and the disturbances of the balance of their fermentation system occur.

Irreversible physico-chemical changes of breathing fingers and other ferments of the metabolism of microorganisms are expressed in particular, which leads to inactivation and cell death. Water disinfection can be achieved in several ways: physical (prokating, ultraviolet rays - UV, ultrasound), chemical agents (lime, electrolytic silver, ozone, iodine, persistent acid and chlorination) [1], [3], [12], [16]. All the listed methods and agents, other than chlorination, are either expensive or inappropriate, and are rarely considered for the disinfection of large quantities of drinking water. Water is most often disinfected by using Sodium Hypochlorite or by using preparations that release a certain amount of active chlorine in water [13].

Disinfectant based on chlorine, in most cases, is introduced into the water in the form of a solution - dosing or injection. On the supply line through which water enters the facility, there is a pulse water meter, which, depending on the flow of water, sends an electrical impulse to the dosing pump, which disinfects (sputter) a disinfectant into the same tube from the tank with chlorine solution, in the position on which the device is located. The dosing pump is considered to be in the installation to dosage a certain amount of chlorine in the water [19]. Using the digital photometer or some other (less reliable) method at the end of the object, the index of residual chlorine in the tubes is checked. Chlorine acts destructively on the cells of all organisms, especially on microorganisms, because they do not tolerate even very small amounts of chlorine that the human organism does not respond to. The bactericidal effect of chlorine is very fast. Already within minutes or two, this gas inactivates most fermenting microorganisms in their metabolism. Chlorine is a particularly sensitive SH-fermenting microbial. In addition, it acts destructively and on protoplasm. Spores, algae, protozoa and cysts are relatively resistant to the effect of "normal chloride doses". Water chlorination is a cheap, reliable, highly efficient and tried process for water disinfection [5].

The success of chlorination of water depends on:

- » Types of chlorine preparations.
- » Biological peculiarities of microorganisms - less or higher sensitivity of wet organisms to chlorine. The residual chlorine value was determined at the earliest 30 minutes from the beginning of chlorination.
- » Homogenization and contact of the chlorine preparation with water.
- » Temperature - at lower temperatures, water disinfection is slower. At 10°C it is necessary to double the amount of chlorine at 20°C.
- » Meteorological conditions - sunlight accelerates the process of disinfection and the loss of active chlorine from the water.
- » pH value of water - The optimum pH of water for chlorination is 6.2 to 6.5 [6], [21].
- » Water miscibility - reduces the efficiency of chlorination, and the water must always be cleaned and filtered.
- » Organic matter - consumes a certain amount of chlorine, so the dose must be increased. That is why "chlorine test" is performed, that is, the "chlorine demand - chlorine number".

Figure 1 shows the screen in the control room of the city Pljevlja water supply, which monitors all wells in the city and their parameters (amount of water, etc.) on-line.

Figure 1. The on-line monitoring wells parameters

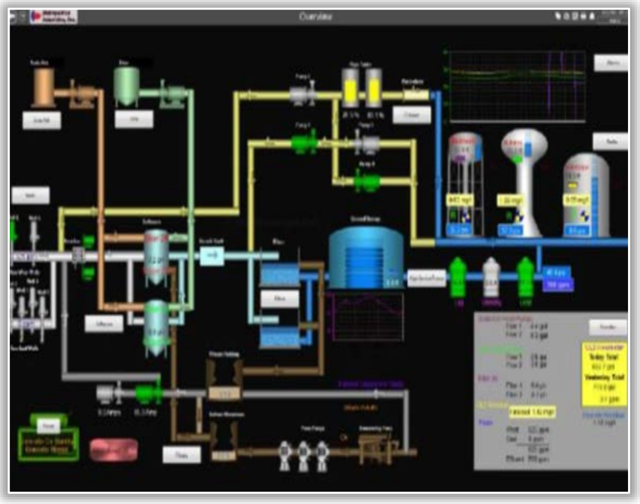

Figure 2. A functional scheme for drinking water

In Figure 2 is presented a functional scheme for drinking water. The icons inserted as a parameters are measured within the given devices. The parameters that are measured and monitored are following:

- » the amount of raw water entering the system,
- » voltage of well pumps (working and spare),
- » the acidity of the flywheel (water and chemicals to be dosed),
- » new in tanks (water and chemicals),
- » the water's water content and the amount of chlorine in the residual,
- » the valve position on-off.

Based on the parameters of the system as it automatically corrects itself. The boundaries of the parameters that are monitored can be in permitted intervals or may jump out of the allowed intervals. Upon receipt of signals that the PLC system recognizes and if the associated parameters are equal to the allowed limits, a certain alarm is activated. After that, the system switches to a higher degree of protection.

It is important to note that the complete PLC system can also be connected with mobile devices. Figure 3 shows the hardware connection with back-up data because the system is in on-line mode and it is necessary to have stored data for a certain period. There is also monitoring one of the wells with data tracking with included data transfer to the mobile device with the android system.

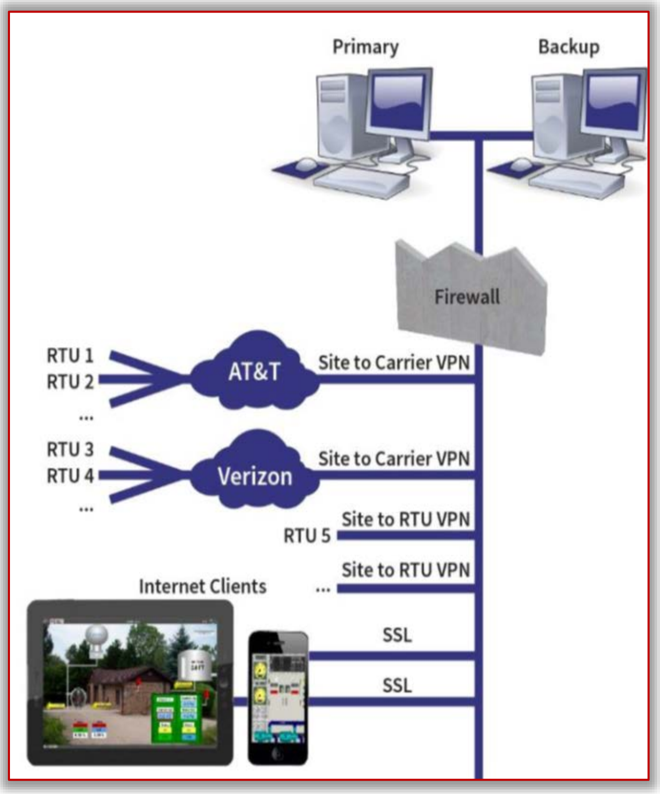

Figure 3. The hardware connection with back-up data

PRESENTATION AND DESCRIPTION OF THE AUTOMATED CHLORINE DOSING SYSTEM IN DRINKING WATER

The automatic gassing dosing system consists of the following elements:

- bottles with laced chlorine,
- collecting lines for bottles with chlorine valves, carriers,
- two doses - vacuum regulator mounted on bottles and connected to an automatic switch an automatic switch whose function is that once a bottle is emptied, the chlorine is automatically switched over and the chlorine dosage from the other bottle,
- flow meter - rotameter (measuring tube with dosing valve) showing flow in gr / h of chlorine,
- injector from mixing hose,
- pump for increasing the water pressure for securing the formation of a vacuum,
- PLC Device and control valve.

A scheme for chlorination of water with neutral chlorine gas chloride is shown in Figure 4.

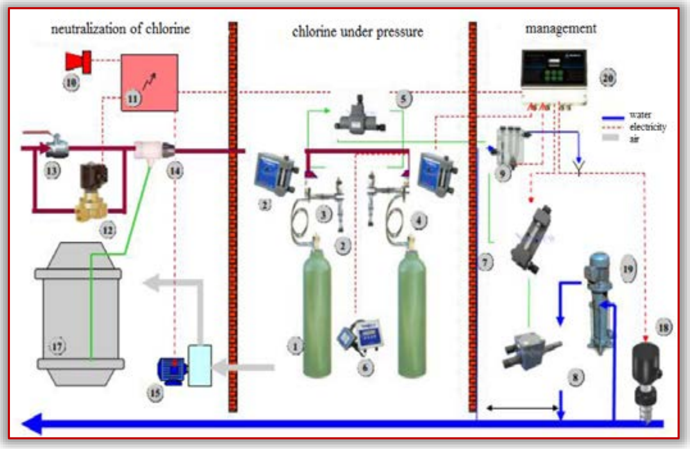

Figure 4. A scheme for chlorination of water with neutral chlorine gas chloride

1- bottles for chlorine; 2- gas vacuum regulators; 3- collecting line with pressure gauge; 4- flexible tube; 5- automatic vacuum switch; 6- the chlorine detector probe in the air; 7- electromotor valve with rotameter; 8- coupling; 9- measuring cell of chlorine in the residual, EMEC; 10- signal trumpet; 11- electrical cabinet; 12- electromagnetic valves; 13- globe valve manually; 14- coupling for neutralization; 15- centrifugal valves; 16- diffusers; 17- Reservoir neutralization solution V = 200l; 18- prick flowmeter; 19- pump for pressure boosting; 20- PLC

PLC controller is an Electronic Microprocessor Device. It has its inputs to which electrical information is given on the state of the process, and exits through which it commands the process. Communication with a person is done through the Operational Panel, or a remote digital connection with a PC.

Boils with chlorine and dosing equipment must be stored in a separate room (chlorine station) with forced ventilation, shower and drainage with sewage connection. On the outside of the chlorine station there is a cabinet and a switch to turn on the fan. In the room, the free chlorine indicator is connected to the alarm device (chlorine detector), which activates the neutralization system in case of chlorine expulsion.

The floor in the chlorine station must be carried out with the fall towards the drainage in the drain. If accidentally, due to some malfunction, the gas chlorine emitted into the atmosphere would result, an environmentally very dangerous situation would occur. The presence of chlorine in the air is controlled by an electronic device - chlorine detector.

Special electrochemical probes are used to measure the concentration of chlorine in the air, and the electronic device includes a chlorine neutralization plant from the air. The ejector within the device compulsorily inserts contaminated air through a filler that discharges with the neutralization liquid that is driven by the recirculation pump. In such a forced movement of polluted air and neutralizing liquid, and neutralizing chlorine from the air.

This process lasts until the concentration of chlorine in the air drops below the given level. All activities are recorded by PLC device and send it to the database server and auto-record is done. PLC in addition to data transfer, the device also provides the ability to download data with USB flesh, as shown in Figure 5.

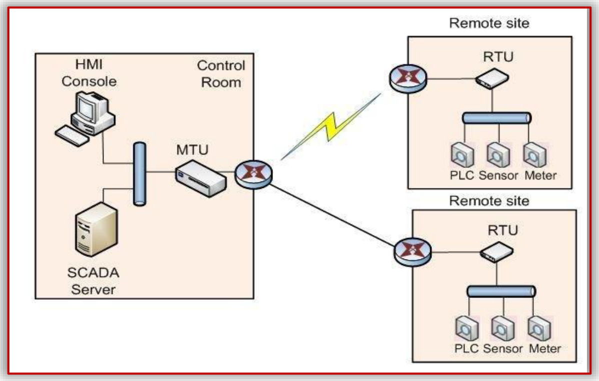

Figure 5. Data transfer and storage

RESULTS AND DISCUSSION

Water entering the city water supply network should be chlorinated continuously, in order to prevent secondary infections. The effective dose of chlorine is determined by experiments. The adjusted concentration is independent of the amount of water flow, because the regulation system automatically maintains a constant concentration of the active chlorine.

In the city Pljevlja core supplied with drinking water from the water supply system there are about 19,000 consumers. The water is provided from the Otilovići Reservoir, the river Cehotina and Breznica and several sites. Considering that Pljevlja is surrounded by mountains in the period from February to May, there is snow melting and accumulation of larger quantities of water. This leads to water blur and deterioration of quality. Then special attention is paid to the water treatment system and quality control.

Raw water is collected in wells. Well pumps pump water into the precipitator. In the precipitator, physical impurities are deposited and aeration is performed. Water meters are installed in the precipitator. Measurement level meters are level ultrasonic or float system. When water is precipitated and reaches a certain level of water, the water is transferred to the filtration. From the filter fields, water is pumped into the reservoirs via filter pumps. Disinfection of water is carried out in the reservoirs and sent via the water supply system to consumers.

The work of well and filter pumps, water level measurement and automatic process control are carried out by PLC [2]. Everything is controlled and monitored in the main control room of the water supply system where the SCADA system for control and data transmission is installed [9]. Also, the main operatives, quality managers, laboratory heads, technical directors have the ability to receive signals over a mobile network [11].

Special attention is paid if parameters that deviate from the given parameters, then the system reports an error and sends the alarm signals. In the plant and control room, signal lights and sirens have come down. All employees who have the authorization to monitor and control the value of SMS messages on mobile devices. The most important parameters whose measurement is monitored are:

- chlorine in the water,
- temperature,
- pH value,
- flow,
- chlorine in the air,
- pump working,
- the system of neutralization.

The measured values are stored in the database. Chlorine is dosed with a vacuum system in the reservoir. In the tank after the dosing and disinfection of the chlorine volume measurement probe in the residual measured value, it sends the signal 04-20m. PLC. a controller that opens / closes the electromotor valve on chlorine bottles.

The dosage is also carried out according to the flow of water by applying to PLC the device programmates chlorine dosing through the openness of the electromotor valve. According to the standards it is desirable that water goes to consumers with 0.5 g Cl2 / m3 to consumers. Without the pump, the system could not function. Two pumps are always installed [19]. One pump is working and the other is a spare pump. PLC the screen is monitored which pump is on, the number of hours of operation and the number of pumps turning on.

CONCLUSIONS

Processing information about input water quality includes measurement activities: input, processing via PLC, output, storage and control. An input as a data resource is an activity that determines the operation of an automated system that, with its activities, brings the measured values to an acceptable level. All input and output parameters are stored on the main database every day in real time which is in accordance with the work of author [14].

Within the SCADA system, applications are integrated: hardware, software, databases, procedures and frames - CASE technology. Also in process discussed in this work, there is an exchange of data exchange among employees and the possibility of common tool access, which allows employees to call a number of different tools in the same way, from the menu and compare the outputs of chemical dosing, pump operation, opening filter the fields in the way they need. In this way, the primary aspect of this work is placed on the ecological aspect and on the preservation of human health. All other factors that are obtained by applying these applications are secondary, and among other things there is a reduction in error options, a reduction in the number of employees and savings.

Note

This paper is based on the paper presented at 7th International Conference Industrial Engineering and Environmental Protection 2017 – IIZS 2017, organized by University of Novi Sad, Technical Faculty "Mihajlo Pupin", in Zrenjanin, SERBIA, 12 – 13 October 2017.

References

[1] Astuti, M.P., Xie, R. and Aziz, N.S., Laboratory and pilot plant scale study on water dechlorination by medium pressure

ultraviolet (UV) radiation, In MATEC Web of Conferences (Vol. 101, p. 02003), EDP Sciences, 2017.
[2] Bayindir, R. and Cetinceviz, Y., A water pumping control system with a programmable logic controller (PLC) and industrial wireless modules for industrial plants—An experimental setup, ISA transactions, Vol. 50, No. 2, pp.321-328, 2011.
[3] Cheremisinoff, N.P., Handbook of water and wastewater treatment technologies, Butterworth-Heinemann, 2001.
[4] Dhiman, J. and Kumar, D.. Hybrid method for automatically filling of the chemical liquid into bottles using PLC & SCADA. International Journal of Engg. Research & General Science, Vol. 2, No. 6, pp.1000-1007, 2014.
[5] Du, Y., Lv, X.T., Wu, Q.Y., Zhang, D.Y., Zhou, Y.T., Peng, L. and Hu, H.Y., Formation and control of disinfection byproducts and toxicity during reclaimed water chlorination: A review, Journal of Environmental Sciences, 2017.
[6] EU Directive 98/83/EC, 1998, Council Directive of 3 November 1998 on the quality of water intended for human consumption. Official Journal of the European Union L330/32 5/12/1998. http://www.nmw.co.rs/downloads/Directive_98-83EC.pdf
[7] Favero, C. and Taylor, A.E., SPCM Sa, Functionalized cationic polyamines and their use to reduce the NDMA formation during the treatment of aqueous systems, and applications in the water treatment industry, including wastewater and drinking water treatment processes. U.S. Patent 9,656,888, 2017.
[8] Fuhs, G.W. and Chen, M., Microbiological basis of phosphate removal in the activated sludge process for the treatment of wastewater. Microbial Ecology, Vol. 2, No. 2, pp.119-138, 1975.
[9] Gray, A.D., Pisica, I., Taylor, G.A. and Whitehurst, L.,A Standardised Modular Approach for Site SCADA Applications within a Water Utility. IEEE Access, 2017.
[10] Khan, N.H., Sohail, S. and Nasim, S., Implementation of Water Distribution Monitoring Framework Using PLC, Journal Of Information Communication Technologies And Robotics Applications (JICTRA, formally known as Journal of Computer Science of NICE)., Vol. 7, No. 1, pp.39-44, 2017.
[11] Kim, T.H., SCADA architecture with mobile remote components. WSEAS Transactions on Systems and Control, Vol. 5, No. 8, pp.611-622, 2010.
[12] LeChevallier, M.W. and Au, K.K., Water treatment and pathogen control, Iwa Publishing, 2004.
[13] Lin, H., Zhu, X., Wang, Y. and Yu, X., Effect of sodium hypochlorite on typical biofilms formed in drinking water distribution systems. Journal of Water and Health, Vol. 15 No. 2, pp.218-227, 2017.
[14] Meseguer, J. and Quevedo, J., Real-Time Monitoring and Control in Water Systems. In Real-time Monitoring and Operational Control of Drinking-Water Systems, Springer International Publishing, pp. 1-19, 2017.
[15] Makris, K.C., Harris, W.G., O'Connor, G.A., Obreza, T.A. and Elliott, H.A., Physicochemical properties related to long-term phosphorus retention by drinking-water treatment residuals. Environmental science & technology, Vol. 39, No. 11, pp.4280-4289, 2005.
[16] Montemayor, M., Costan, A., Lucena, F., Jofre, J., Munoz, J., Dalmau, E., Mujeriego, R. and Sala, L., The combined performance of UV light and chlorine during reclaimed water disinfection. Water Science and Technology, Vol. 57, No. 6, pp.935-940, 2008.
[17] Ostfeld, A. and Salomons, E., Optimal layout of early warning detection stations for water distribution systems security, Journal of Water Resources Planning and Management, Vol. 130, No. 5, pp.377-385, 2004.
[18] Ormsbee, L.E. and Lansey, K.E.,Optimal control of water supply pumping systems, Journal of Water Resources Planning and Management, Vol. 120, No. 2, pp.237-252, 1994.
[19] Park, S., Kim, Y., Kim, K. and Han, K., Development of computational algorithms for pump operations and their applications to the system dynamics modelling of a water supply system, Civil Engineering and Environmental Systems, pp.1-22, 2017.
[20] Petrović, T.M., Zlokolica-Mandić, M., Veljković, N., Papić, P.J., Poznanović, M.M., Stojković, J.S. and Magazinović, S.M., Macro and microelements in bottled and tap waters of Serbia. Hemijska industrija, Vol. 66, No. 1, pp.107-122, 2012.
[21] Sl. list SRJ br.42/98 i 44/99: Pravilnik o higijenskoj ispravnosti vode za piće. http://www.zjz.org.rs/wp-content/uploads/2013/04/pravilnik-o-higijenskoj-ispravnosti-vode-za-pice.pdf
[22] Yu, Y. and Reckhow, D.A., Formation and Occurrence of N-Chloro-2, 2-dichloroacetamide, a Previously Overlooked Nitrogenous Disinfection Byproduct in Chlorinated Drinking Waters. Environmental science & technology, Vol. 51, No. 3, pp.1488-1497, 2017.

ACTA TECHNICA CORVINIENSIS BULLETIN OF ENGINEERING
ISSN: 2067-3809