Effects of Quantitative Changes on Drinking Water Quality Indicators of Urban Distribution Networks

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In this paper are shown quantitative and qualitative changes in the drinking water distribution system, occurring in an urban locality with about 200 000 inhabitants in which water consumption over the past decade have been reduced by 50%. In relation to consumer debts are highlighted oscillations related to water pressure in the system and residual chlorine concentration on pressure zones. Hydraulic modeling of the water distribution system was performed using computer programming software, EPANET type, program that performs hydraulic simulations and water quality in pressure pipeline network. After analyzing and interpreting the results of hydraulic simulations performed in different operational situations (consumption 100; 75; 50%) resulted in areas where residual chlorine levels fall well below the limits imposed by the laws and regulations in force. In this situation are required corrective measures on water quality by reducing or eliminating water stagnation by increasing the velocity of the water circulation pipe sections affected. The book is useful for units or operators that use water networks in areas with significant debt fluctuations where by reducing travel speeds on sections of pipeline in areas where residual chlorine drops below the limits, favoring the formation of ecosystems biological and thereby triggering internal processes of auto-pollution reflected in the degradation of water supplied to consumers.

Keywords: disinfection, residual chlorine, stagnation, water demand, pressure

The economic downturn triggered by the '90s, following the change of social system, the transition from centralized economy to a free economy, market, generated important changes in all spheres of activity, including public service, namely that of producing and distribution of drinking water in most localities of our country. Substantial reduction in potable water consumption due to the reduction or stopping of industrial activities in centers of population, changing production profile of most businesses, real consumption of each consumer metering and even temporary reduction in departures or migration of consumers in other areas and the water price increase, along with other influential factors prompted radical changes in both parameters of water production and especially in those related to the distribution of drinking water on the site of many towns. Distribution networks in these collectivities were sized by ensuring the necessary water pressure and service in every consumer. Hydraulic calculation of the distribution networks was based on water demand and economic to transport speed in each of the specific areas of the village. The transition to a new operating schedule distribution system or network pumping water by drastically reducing water demand respectively volumes of water pumped (Q, v H max reduced by 50 ÷ 70%) and the leaving the water pressure pumping stations using existing distribution network, give rise to new situations related to ensuring the appropriate operation and maintenance service for water quality distributed to every consumer, especially in terms of operational safety by avoiding risk auto-pollution of water in water networks, reflected by substantially reducing residual chlorine and flow rates well below the permissible limits. The degradation of water quality in distribution systems is determined by the following: formation and development of biological ecosystems; Network stagnation of water more than 7 days Excessive reduction of residual chlorine; formation of deposits or sediments; accidental contamination; quality materials forming the network [9].

Damage due to water bio-stability and discharges of biodegradable compounds in plastic pipes (PE-HD and PVC) that are not subject to corrosion processes may influence water quality due to used manufacturing additives. Bacterial biofilm that grows in the water and on the inner walls of the pipes can be eliminated by providing chlorine residual in all points of consumption or by washing and disinfection of piping where flow rates are below the limits, especially at the ends of piping network [2, 3, 11]. Uniform pressure and residual chlorine in distribution networks populated centers can be achieved by feeding the system from two or more sources of water, in order to avoid over-chlorined peripheral areas where water supply from a single source [8]. In the case of centralized water supply network of high quality, and land located in areas clean, unpolluted, disinfection with chlorine or other chemical reagents can be substantially reduced and even eliminated, thus reducing the danger of forming compounds carcinogenic organo-chlorine, regarded as particularly hazardous or harmful to human health [5].

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Theoretical Aspects

Chlorine is a residual disinfectant action which will react when placed in water distribution system with mineral and organic compounds, as well as bacteria and microorganisms existing in water which develops on the inner walls of pipes [2, 4, 5, 10]. The side chain of the consumption of chlorine water is dependent on temperature, the compounds that react with chlorine (HOCl or Cl_2O), the concentration of chlorine is introduced into the water but also the concentration of the reaction mixture [4, 7, 8]. In figure 1 is shown chlorine concentration at intersections / junctions / nodes, depending on the number of pipes that enter the node.

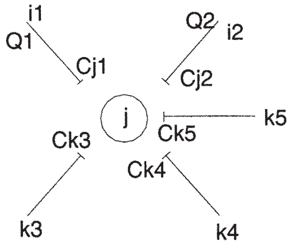

Fig. 1. The concentration of chlorine in intersections / junctions / nodes, depending on the number of pipeline entering the junction

Figure 2 shows the chlorine consumption between two consecutive nodes of a pipe section (ij) length (l). The chain reaction can be written as follows:

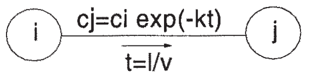

Fig. 2. Chlorine consumption between two consecutive nodes

Since the CK3 = Ck4 = CK5 = Cj, then the concentration of chlorine in the junction (j) is calculated as a weighted average formula (1):

$$C_j = \frac{C_{j1}Q_1 + C_{j2}Q_2 + ...}{Q_1 + Q_2 + ...} = \frac{\sum C_{ji1} \cdot Q_i}{\sum Q_i} \quad (1)$$

On each portion (ij) are two unknowns (Ci, Cj) which is the concentration of chlorine in the parts (p). If we know the initial chlorine concentration of the parts (p), the number of unknowns is equal to the number of available relationship (p + n) (n - the number of junctions), and may thus be defined by the hydraulic scheme of operation of the network and also through kinetic constant (k) network or portion. The kinetic constant (k) can be calculated by the method proposed by Wable (1992). In this method, the constant (k) can be determined for each portion of the distribution network, according to the scheme shown in figure 3.

By bypass the node "i" is the portion of the chlorine Ci and Pi sampler that studies the consumption of chlorine reaction kinetics But that water will cross the section of the pipeline "ij". The by-pass the node (j) Pj sample is collected by studying the kinetics of the reaction is dose-chloral but with the water passing through the "ij". Chlorine consumption difference (Δc) between samples Pi and Pj,

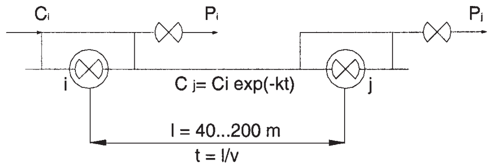

Fig. 3. Scheme for calculating the kinetic constant k

for the same period of time, is reduced free chlorine pipe wall. Size speeds conduits conditional residence time of the water distribution networks.

Modeling water distribution system for an urban area

System description

Urban P, consisting of approx. 200,000 inhabitants, which is the subject of the case study is a settlement with a geodesic significant difference of approx. 50 m to the north - south. Water supply system of this settlement has existed for over 100 years, being fed by gravity (approx. 30 to 35%) from a surface source and pumped (approx. 65 ÷ 70%) from three underground sources.

Headrace of water sources is made of ductile iron pipes, steel and PREMO and distribution network, mostly in a mood ring was fitted with diameters between DN 100 mm and DN 1000 mm, cast iron ductile, steel, cement, GRP, PE-HD, with roughness between 0.5 mm and 3.0 mm, depending on material type and age of the pipes. Share diameters and roughness on the water supply network of the town analyzed are shown in sigures 4 - 6.

In figure 5 is shown scheme of water supply system with the arrangement surface source with chlorine injection point (SCL0) and three underground fronts A, B and C, with associated points chlorine injection (SCL1, SCL2 and SCL3) pumping stations (SP1 and SP2), pumping stations (SRP1 ÷ SRP7) and water pump stations (SH1 ÷ SH7).

Figure 6 shows the share of roughness in pipes distribution system and their proportion in relation to the different degrees of roughness assessed by measurements made on various samples.

Number of contacts with the roughness large (2-3 mm) have a significant share (71.4%) were on cast iron and steel pipes. The gradual rehabilitation of the distribution system with new pipes from PE-HD and GRP will increase the share of roughness in pipes under 0.5 mm. Roughness on the inner walls of the pipes are caused by sediment and debris from water supply sources, and increased hardness (for upper limit) groundwater to consumers.

The water supply system model

Hydraulic modeling of the water distribution system was performed using computer programming software, EPANET type [6]. The water supply system in the urban area P is formed, according to figure 5, a surface source and capture the three fronts groundwater, four chlorination stations for water disinfection (SCL0, SCL1, SCL2 and SCL3)

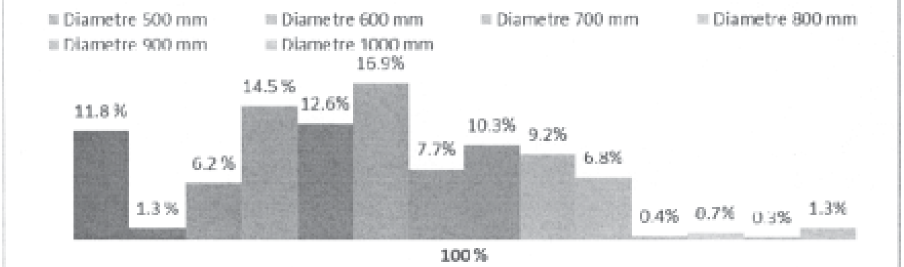

Fig. 4 .Share diameters of the water supply network

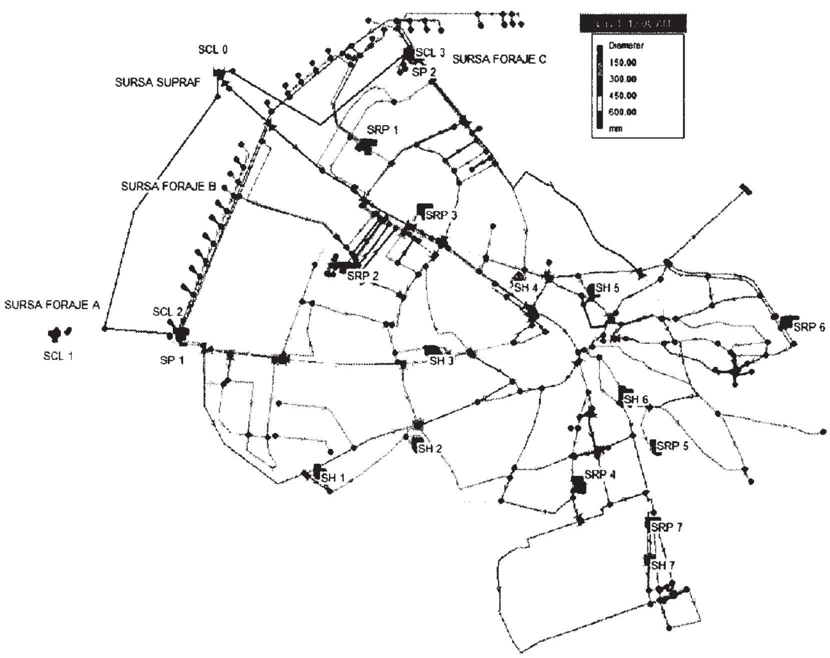

Fig. 5.Scheme of water supply system with the arrangement of water sources, chlorination stations, pumping stations and pumping, water pump installations and pipe diameters

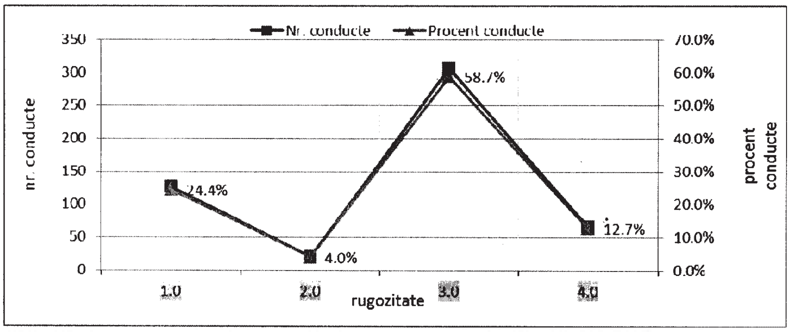

Fig. 6. .Share roughness in pipes distribution network

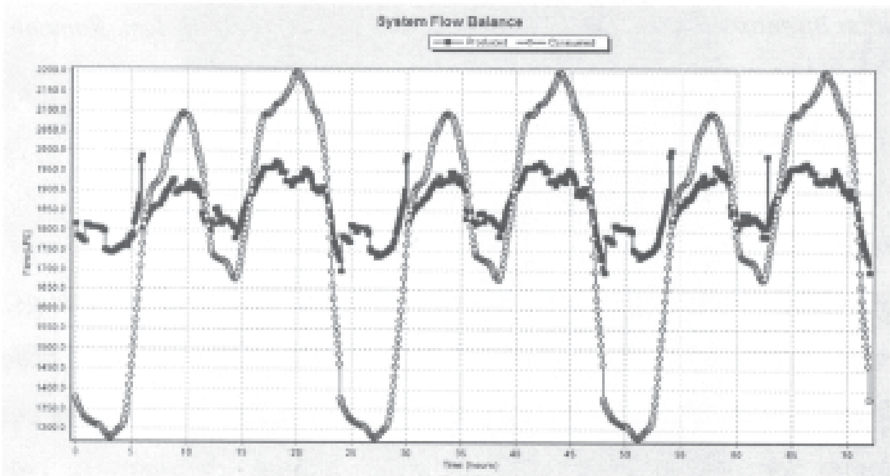

Fig. 7. Changes in the flow of food and consumer hearth village

two pumping stations (SP1 and SP2) seven pumping stations (SRP1 ÷ SRP7) and seven water pump stations (SH1 ÷ SH7) and a distribution network with a total length of approx. 150 km consisting of 520 sections of pipe with diameters between 100 mm and 1000 mm without being included distribution and branching pipes with diameters up to 100mm. Compared to the previous period in which the 90 pumping stations (7 units) and water pump stations (7 units) had an important role in ensuring the necessary pressure in the deficit areas and especially on the top floors of housing blocks, now they do not are used only in small measure due to reduced consumer debt actually decreased activity caused by industry and changing production profile, the rehabilitation process-optimizing network and metering progressive hydraulic consumers. Thus, due to reduced water consumption, current flows through a network carried mostly oversize diameters in terms of existing / rehabilitated all speeds lead to lower direct negative repercussions on water quality results during transit and stagnation distribution network through pipelines. To simulate the evolution of water quality in the distribution system, the chlorine dosing was done through the four stations disinfection in relation to the weight flow delivered by each of the sources captured [1, 2].

In figure 7 “flow balance system” is given the change in power flows and the consumption of hearth village, analyzed in 2000, for an average flow rate of approximate 1800 L / s.

Source surface covering 38 ÷ 40% of water and three underground sources cover the difference of 60 ÷ 62%, of which 12% is underground source (A); 36 ÷ 38% is underground source (B) and 12% is underground source (C).

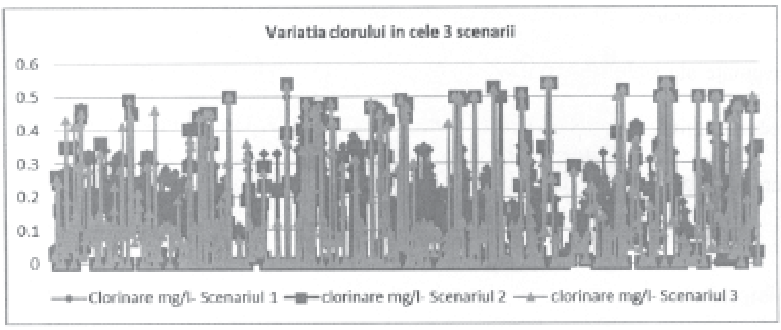

Fig. 8a. Change in residual chlorine in the three scenarios

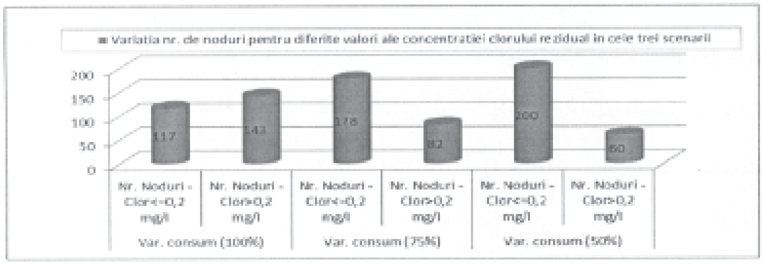

Fig. 8b.Variation of the number of nodes for different values of residual chlorine concentration in the three scenarios

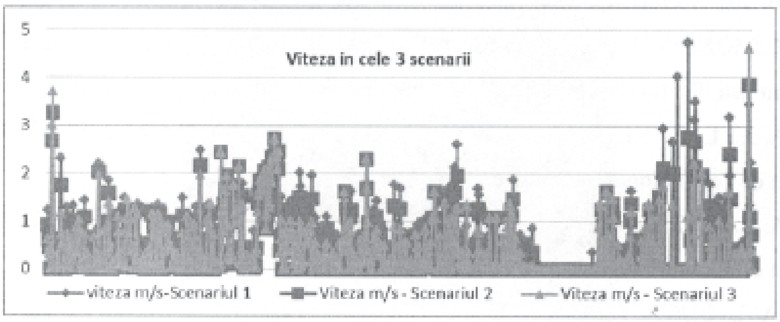

Fig. 9a. Change in velocity distribution networks in three scenarios

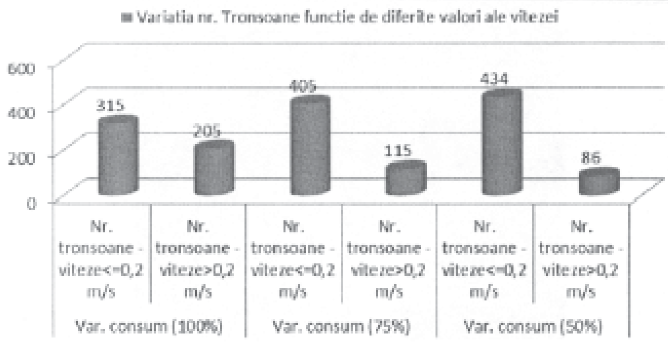

Fig. 9b. Change in the number of sections for different speed values in three scenarios

Fig. 10.a. The percentage of residual chlorine in the distribution network - Scenario 1 (100% consumption)

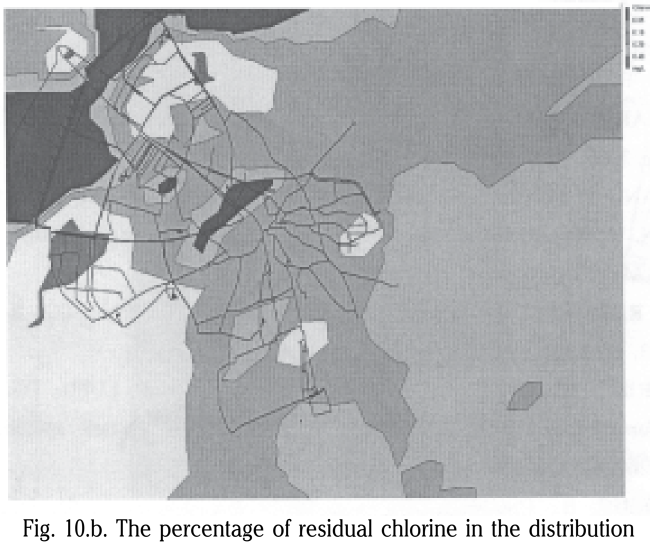

Fig. 10.b. The percentage of residual chlorine in the distribution network - Scenario 2 (consumption 75%)

Process flow modeling results

Modeling and data processing was performed for three scenarios as follows: Scenario 1 in the initial variant for consumption of 100%; Scenario 2 variant with a consumption of 75%; Scenario 3 variant with a consumption of 50%. Feed rate initially considered 1800 L/s. The calculation algorithm to simulate the evolution of

Fig. 10.c.The percentage of residual chlorine in the distribution network - Scenario 3 (50% consumption)

Fig. 11b. The weight for age water distribution network pipes - Scenario 2 (consumption 75%)

Fig. 11a. The weight for age water distribution network pipes - Scenario 1 (100% consumption)

Fig. 11c. The weight for age water distribution network pipes - Scenario 3 (50% consumption)

chlorine in water distribution networks consists of: water speed in distribution network pipes and its stop time in the network; Free residual chlorine concentrations at intersections and at the ends of the distribution network. Chlorine residual flow rates through pipes distribution network were represented at t = 44 h from start simulations and water for age were taken into account a maximum duration of 7 days. In figures 8a and 8b are shown variations in junctions residual chlorine and varying the number of nodes for different margins of residual chlorine concentration in the three scenarios.

In figures 9a and 9b are shown changes of flow rates in pipes distribution network and the variation in the number of sections for beach gear in the three scenarios considered.

In figures 10a-c are shown variations all over town residual chlorine resulting in differentiated areas of residual chlorine concentration in the three scenarios.

In figures 11a-c are represented the water variation age (stagnation period) all over town differentiated areas resulting in three scenarios.

Conclusions

The paper highlights the effects of lower water consumption on water quality carried through distribution networks. Simulations performed using EPANET program for the three scenarios and reveal areas where pipe sections residual chlorine was reduced far below the permissible limit set by regulations (figs. 10a-c). This is a reflection of the decreasing flow rates well below the permissible limits causing an increase in the duration of stagnant water in pipes. Water stagnation during more than 7 days can lead to the development of biological ecosystems and thus increase the risk of auto-contamination (figs. 11a -c).

To combat training biological ecosystems in water distribution networks in population centers, it is recommended the following measures: washing, regular cleaning and disinfection of piping sections that are not self-cleaning secured minimum speeds and minimum permissible residual chlorine concentrations; Regular opening / weekly fire hydrants at the ends of pipes with low consumption to avoid water stagnation on longer than 7 days; public fountain continuous operation; regular supervision of the operation and status of pipes, fittings and measuring and control equipment; detecting and combating water losses greater than 20%; highlighting areas and pipe sections to ensure doses are not permissible residual chlorine. Water losses in distribution networks allowed by the technical regulations constitute an additional measure to combat the formation of biological ecosystems, thereby reducing the risks of auto-pollution / auto-degradation distributed drinking water to human beings. It is recommended, as well as rehabilitation of water distribution in advance conduct an analysis to resize depending on consumption rates distributed and localized mainly based on data derived from metering flows, and the values of residual chlorine in the distribution network, identifying vulnerable areas at high risk of degradation, so after pipe rehabilitation to reach the miscarriage usually linear up to 5 m / km pipeline and residual chlorine values especially in the outskirts of network permissible limits 0.1 to 0.3 mg / L.

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