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Adriana Tokar, Arina Negoiţescu

The Influence of the Water Supply Indoor Installations Pipes Wear and Clogging on Water Consumption and Hygiene and Sanitary Comfort Level

To ensure and increase the hygiene and sanitary comfort degree in buildings older than 25 years, rehabilitation and modernization of water supply indoor installations is required. The rate at which these capital repairs were made to the common facilities is very low, which explains the increasing number of commercial buildings that claims flooded basements due to rusty, clogged or broken pipes. In this regard, the paper analyzes the situation of an apartment building, located in Timisoara, which is 48 years old and to which were made only partial rehabilitation works. The solutions resulted from the performed analysis lead to the necessity of performing the rehabilitation and modernization works by replacing the installation distribution and columns that shows a high wear and clogging degree.

***Keywords**: hygiene and sanitary comfort, flow, pressure, clogging, rehabilitation*

1. Aspects regarding the design solutions of indoor systems and installations for domestic cold and hot water supply

All buildings and installations used to meet the water demand of the populated and industrial areas represent the water supply system.

The supply system consists of:

- Water capture systems that include the constructions and installations necessary for the water catchment from various natural sources;
- Transport system (supply-lines consisting of pipes and channels);
- Treatment plants (special installations for correcting water quality characteristics);

- Storage tanks required to store water reserves necessary for domestic technological and fire fighting consumption;
- Pumping stations that provide whenever it is necessary raising the water to a higher elevation and ensure the pressure inside the distribution network.

The water pressure conditions into the main pipes is established depending on the building heights, network length, flows and pressures values required at consumers. These conditions are ensured by:

- Municipal pumping stations, interconnected operating inside the system;
- Water distribution network containing main pipes and service (municipal) pipes, to which are connected the consumers branching.

In order to supply water to consumers in residential buildings, social-cultural and some industrial units there are provided water pumping stations (hydrophore stations, variable speed pump groups, pumps coupled with high tanks etc.), connected to municipal pipelines by branching pipe. Branching of indoor water installations must cover the total load losses to ensure the required hydrodynamic load and water flow in the most disadvantaged sections from hydraulic point of view.

The indoor installation for domestic cold and hot water supply contains: pipe networks, fittings mounted on network pipes, sanitary objects together with their accessories and fittings.

Hot and cold water supply for domestic consumption of apartments on each level of a vertical column is ensured through the main columns mounted in the staircase or inside the special designed rooms where the consumers will be connected.

Cold and hot water inside the indoor installations can be done in collective system or individually (per apartment). At each level there are designed special niches or prefabricated boxes within which are mounted cold and hot water metering. These metering are mounted on the pipes connections of each apartment.

The sanitary objects fittings (taps and mixing valves) can be directly connected or through some cold and hot water spreaders with main closing valves and flexible fittings which allow the water supply for each sanitary object separately. On each fitting are mounted closing valves easy to handle. For the main columns are recommended galvanized steel pipes and for the connection pipes, materials as high density polyethylene or polypropylene. For sanitary objects connection to the cold and hot water installation are recommended metal or plastic flexible tubes and special fittings of copper or stainless steel [11].

In the case of existing dwelling buildings, initially provided with collective metering, the individual metering switching is possible by mounting cold and hot water meters on the pipelines which ensure the connection between water columns and the fittings of the sanitary objects from kitchens and bathrooms. This solution requires a higher investment cost (being necessary four meters) and can be applied if there are technical conditions for mounting these meters.

2. Rehabilitation and modernization of the indoor installations for cold and hot domestic water supply

In terms of buildings and related installations, the construction sector records significant specific energy consumption. Therefore, most development strategies take into account the energy consumption reduction [10].

For the installations rehabilitation and modernization are necessary prefeasibility and feasibility studies outlining costs, financial support and work profitability. Based on these studies, there are developed technical projects and design details, in compliance with technical legislation in the field.

The installations rehabilitation involves a combination of technical and organizational measures designed to bring those installations to operate at the designed parameters, by providing the technical legal compliance.

Modernization includes the installations rehabilitation, but with the adoption of new distribution networks solutions with individual cold and hot water consumption metering and the utilization of materials and equipment with high technical performances. The installations modernization leads to the increase of reliability, water loss reduction and also the increase of hygiene and sanitary comfort in using domestic cold and hot water.

The change of the building destination or only of a part of it will have direct implications on the indoor installations used to supply cold and hot water for consumption. Thus, are required modifications of the network geometric configuration, separation of consumption hot and cold water metering system, provision of additional branches of the main distribution pipes, columns and new derivatives, etc. All these changes involve the pipeline network resizing and flow and pressure determination in the pipe section (supply line) to ensure the installation safe operation [11], [12].

3. The current state of public water supply installations in Timisoara

At present, in Romania most apartment buildings are older than 25 years, but there are cases where condominiums age exceeds 40 years. Because of the length of joint facilities in the buildings, very often, occur situations that affect the quantity and quality of drinking water supplied to the consumers.

In most of the cases, distribution pipes and columns with high wear, clogged or broken do not provide the pressure and flow necessary to ensure the hygiene and sanitary comfort degree.

In order to establish the strategy for Timisoara water supply was taken into account, firstly, the water supply safety. Therefore, water sources are safe, that is sufficient both quantitatively and of appropriate quality [3].

Through the strategy plan for the period 2009 -2030, the main objectives of local authorities were: increasing quality and efficiency, utilities (water, sewer, wiring) development, improvement and/or modernization.

The city water supply network is ring-radial type and at present provides both the necessary pressure and the flow to most of the consumers.

The Timisoara main water supply sources are:

- The in-depth source which represents about 35% of the total amount distributed in the city public water supply network;
- The surface source (Bega River) which represents the difference of about 65% of the total amount distributed in the city public water supply network.

Another priority is the replacement of the distribution network sections that are made from materials that are inappropriate or have a high degree of wear. Mainly, the sections made of steel show a high degree of wear due to inadequate materials, stray current and bacterial actions [4].

In Timişoara, the water supply network still contains in a proportion of 20% pipe sections older than 50 years.

For this reason, their aging creates problems not only through the advanced physical wear but also by pipes' material shearing and breaking. On the other hand, the recent city development had caused problems in terms of ensuring the necessary flow for new customers, so the rehabilitation and expansion works have been and still are needed.

The percentages of materials of which is made the water supply network structure are shown in Table 1.

In Timisoara, water metering is satisfactory. It can be appreciated that the rate of water loss on the distribution network, due to lack or inadequate metering, has considerably decreased. Therefore the effectiveness of these measures is quantified by the average specific water consumption reduction to about 115 l/ person/day [4].

On the other hand, the differences recorded between the supplied water amount measured at the branching water meter having accuracy class C (high precision) and the water amount recorded by each apartment meter characterized by A, B and C accuracy class (with smaller exactity) are justified. It is known that A class water meters are designed to start correct recording from 60l/s, the class B from 30l/s, and class C from 15l/h. Thus, inside the apartments in which are mounted such water meters, any water consumption smaller than 60l/h, 30l/h and 15l/h is not correctly recorded by the apartment indoor meter, but is recorded by the branching meter [3].

At present, from the hot/cold water supply indoor installations point of view, there are still many buildings with old and clogged facilities that significant record significant domestic water losses and justify the concern for the home indoor facilities rehabilitation.

Table 1. The percentages of water supply network structure materials

Material	Quantity [%]
Steel	41
Cast-iron	29.84
Asbestos cement	4.97
Polymerized vinyl chloride	3.27
Ductile iron	49
Compressed concrete	215.92
HDPE	1.49
Polyester reinforced with fiber HOBAS	0.19

4. The comparative analysis of the required water flows versus consumed water flows

The indoor installations operate under municipal water pipe pressure, which was deemed to be sufficient and permanent ensure the normal operation of all consumption points. The installation is direct branched to the municipal network (Figure 1), being adopted the inferior branched distribution. The solution was adopted by taking into account the constructive characteristics, building destination, nature and water consumption.

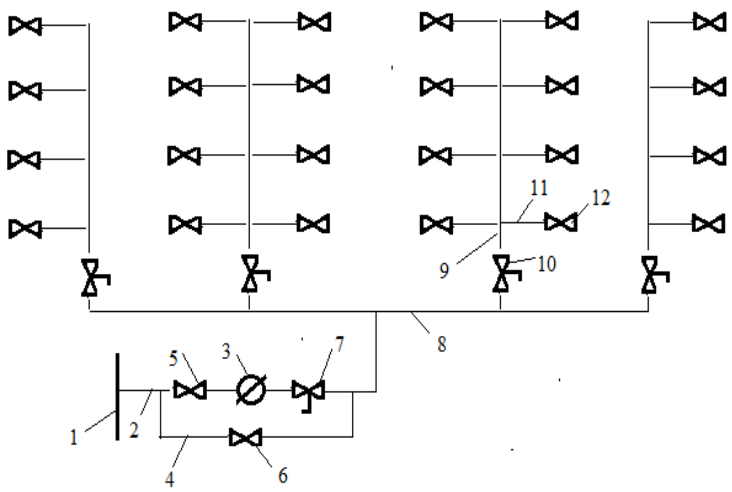

Figure 1. The scheme of cold water distribution indoor installation

1- municipal pipe, 2-branching pipe, 3-water meter, 4-bypass pipe, 5, 6-closing valve, 7-discharge valve, 8-inferior distribution pipe, 9 - column, 10 - discharged on the column valve, 11-connection pipe to sanitary objects, 12-closing valve on the connection pipe.

From the service pipes of the water supply network, made of cast iron, through the iron branching pipe and indoor network made of galvanized steel pipes, cold water is distributed to the consumer points as it follows:

- By a lower horizontal distribution, mounted into the technical unvisited channel;
- Through vertical columns mounted in closed housings;
- By links to sanitary objects mounted into walls / plaster.

For the water supply common installation of the considered building there were made no repairs, but only partial rehabilitation works by replacing a column.

The claimed problems are related to insufficient water flow and low water pressure at the top level consumers. The effects occurred after the collective disconnection from the hot water supply municipal network as a result of individual preparation of hot water by central heating.

Given that both the required of cold water and heating is provided by common installation designed for cold water supply, the resizing of this installation is necessary.

On the other hand, considering the installation age, the absence of rehabilitation works has led to increased water consumption which involving energy consumption and unmet the sanitary conditions to the consumer.

Pipes pressures control was performed by measuring periodically the pressures at characteristic points (before entering the branching valve and to consumers on the top floor) at times of maximum consumption by using gauges.

As a result of the pressure measurements carried out at the entrance of the branching valve it was recorded with a pressure gauge a pressure of 2bar (satisfactory). On the branching pipes to consumers on the top floor the pressure varies between 0.8-1.0bar. To ensure the sanitary comfort, it is necessary from the point of view of pressure, a minimum water pressure of 0.5bar at the most disadvantaged consumer. It is recommended that this value to be higher than 0.8-1.0bar [6]. Thus, if on the branching pipe between sanitary objects and the main column is recorded a pressure of 0.8-1.0bar, than on the most disadvantaged consumer often occur issues in terms of ensuring a pressure of minimum 0.5bar.

The correlation between the water pressure at the consumers and pressure at the ends of the network revealed the places with low water flowing inside the system pipes. Thus, it was concluded that the insufficient flow to the consumer is the main problem. On the other hand, insufficient water flow causes problems in hot water production by the boilers inside the apartment.

Visual inspection of the valve pipe connection and distribution revealed a high clogging and a strong inner and outer pipes wear. The images are shown in Figure 2.

Inside the pipes there are occurred incrustations that changed the roughness coefficient, negatively influencing the main flow hydraulic parameters: flow and pressure.

a b c d

Figure 2. The wear and clogging status of cold water supply system
a-external corrosion degree inside the branching pipe, b- clogging degree of the branching valve, c- external corrosion degree inside the pipe distribution, d-clogging degree of the distribution pipes

It is known that any change in the flow mode leads to the incrustations dislocation and changes in the water color which requires the pipes flushing in order to eliminate the suspensions [5]. For this reason the negative impact on consumer perceptions in the analyzed building in terms of water quality, is fully justified.

An inspection made on the indoor installation concluded that large iron oxide and limestone deposits on the pipe inner wall caused an aggressive corrosion from inside to outside. On the visibly corroded pipe sections and outer pipe wall the corrosion was produced from the outside to inside as a result of fuel cell formation due to unevenness of the material composition.

By analyzing Figure 2d, it can be observed that the problems claimed by consumers in terms of lower pressure and especially the flow rate are obvious. The difference the between pipe diameter of 35mm and D_{pipe} = 50mm, and clogged pipe diameter $D_{clogged\ pipe}$ = 15mm explain low water flow to consumers on the top floor, and especially to those who are still connected to the main columns that have not been replaced.

All these problems can be eliminated by replacing the indoor installations and using modern materials which do not alter the water physical-chemical properties with beneficial effects in terms of the installations life, costs reduction and especially transported water quality maintenance.

4.1. The determination of flow through the analyzed building sanitary installations

In order to obtain the water quantity required to ensure the hygienic and sanitary comfort it was performed the calculation for establishing the characteristic flows which will be compared to those flows effectively consumed.

The building contains 12 apartments , two of them located on the ground floor and the rest of them on the other floors. Each apartment has two rooms, 1 bathroom and 1 kitchen. The bathroom has one bathtub, 1 washing basin and 1 toilet bowl, and in the kitchen there is 1 simple lavatory.

In conclusion, the building technical-sanitary installation contains 12 pieces of: bathtubs, toilet bowl, simple lavatory, washing machine.

The cold/hot water supply indoor installation was adjusted for 36 persons.

By taking into account the Standard SR 1343-1 – 2006 recommendations regarding the water flows specific to household needs (q_s=150-180l/pers/day for hot water centralized preparation and q_s=100-120l/pers/day for hot water individual preparation), there were calculated the characteristic flows (average daily flow, maximum daily flow and maximum hourly flow) of the water required, for two different versions:

- the water requirement determination for areas with apartment buildings containing cold/hot water installations and sewerage, with centralized hot water preparation;
- the water requirement determination for areas with apartment buildings containing cold/hot water installations and sewerage, individual hot water preparation.

These flows were calculated depending on the maximum values of the specific flows and maximum number of persons, with the following relations:

$$Q_{daymed} = \frac{1}{1000} \cdot \sum_{k=1}^{n} \left[\sum_{k=1}^{m} N(i) \cdot q_s(i) \right] \ \left[m^3/day \right] \quad (1)$$

$$Q_{daymax} = \frac{1}{1000} \cdot \sum_{k=1}^{n} \left[\sum_{k=1}^{m} N(i) \cdot q_s(i) \cdot k_{zi}(i) \right] \ \left[m^3/day \right] \quad (2)$$

$$Q_{hmax} = \frac{1}{1000} \cdot \frac{1}{24} \sum_{k=1}^{n} \left[\sum_{k=1}^{m} N(i) \cdot q_s(i) \cdot k_{zi}(i) \cdot k_{or}(i) \right] \ \left[m^3/h \right] \quad (3)$$

where:

Q_{daymed} [m^3/day]- average daily flow;

Q_{daymax} [m^3/day]- maximum daily flow;

Q_{hrmax} [m^3/h]- maximum hourly flow;

$N(i)$ [pers]-number of persons;

$q_s(i)$ [l/pers/day]-specific water flow;

k_{day} – daily variation coefficient;

k_h – hourly variation coefficient;

The obtained values are presented in Table 2.

Table 2. Characteristic flows for a maximum number of persons

The hot water preparation version	N(i) [pers]	$q_s(i)$ [l/ pers/ day]	k_{day}	k_h	Q_{daymed} [m^3/ day]	Q_{daymax} [m^3/ day]	Q_{hmax} [m^3/ h]
Centralized	36	180	1.35	1.25	6,48	11.66	0.61
Individual	36	120	1.4	1.25	4.32	6.05	0.32

The data calculated for the real number of residence persons are presented in Table 3.

Table 3. Characteristic flows for the real number of persons

The hot water preparation version	N(i) [pers]	$q_s(i)$ [l/ pers/ day]	k_{day}	k_h	Q_{daymed} [m^3/ day]	Q_{daymax} [m^3/ day]	Q_{hmax} [m^3/ h]
Individual	21	120	1.4	1.25	2.52	3.53	0.18

4.2. The calculation of the design flows for the analyzed building cold water installation

According to STAS 1478/90, in order to design the cold water distribution pipes for domestic purpose inside the dwelling buildings, the design flow was calculated with the relation:

$$q_c = b(0.15\sqrt{E} + 0.004E) \tag{4}$$

b – The flow coefficient (*b*=1 for the distribution pipes of cold water to the consumer points);

E – The sum of the consumer points equivalents supplied by the considered pipe, determined with the relation:

$$E = 0.7E_1 + E_2 \tag{5}$$

where:

E_1 – the sum of the mixing cold and hot water batteries equivalents;

E_2 – the sum of the cold water valves equivalents.

and:

$$E_1 = \sum_{j=1}^{n} e_{bj} n_{bj} \;\; ; \;\; E_2 = \sum_{j=1}^{n} e_{rj} n_{rj} \tag{6}$$

in which:

e_{bj} – the equivalent of a certain battery type *j*;

n_{bj} – the number of the same *j* type batteries;

e_{rj} – the equivalent of a type *j* valve;

n_{rj} –the number of the same *j* type valve.

In Table 4 and Table 5 are presented the calculation results regarding the design flow q_d for the entire building and also for an apartment located on the last floor, in which there are problems concerning both the low flow and pressure.

In order to assess the water quantities consumed inside the considered building, there were centralized the water consumptions data for a few apartments between September 2012 and June 2013.

Table 4. The design flow q_d calculation for the entire building

Sanitary object	**Flow Equivalent, *e***	**Quantity**	**E_1**	**E_2**	**E**
Washing basin	0.35	12	4.2	0	2.94
Toilet bowl	0.5	12		6	6
Bathtub	1	12	12		8.4
Simple lavatory	1	12	12		8.4
The flow equivalents			28.2	6	25.74
The design flow			**q_d=0.86l/s**		

Table 5. The design flow q_d calculation for an apartment

Sanitary object	**Flow Equivalent, *e***	**Quantity**	**E_1**	**E_2**	**E**
Washing basin	0.35	1	0.35	0	0.245
Toilet bowl	0.5	1		0.5	0.5
Bathtub	1	1	1		0.7
Simple lavatory	1	1	1		0.7
The flow equivalents			2.35	0.5	2.145
The design flow			**q_d =0.23l/s**		

Thus, in Figure 3 is shown the total consumption variation for five apartments. All the apartments are still branched to the old distribution installation which has not been rehabilitated.

The apartments 4, 8, and 10 are branched to old columns with high clogging degree (Figure 2). Apartments 4 and 11 are branched to the new column made of copper pipes with diameter of 22mm.

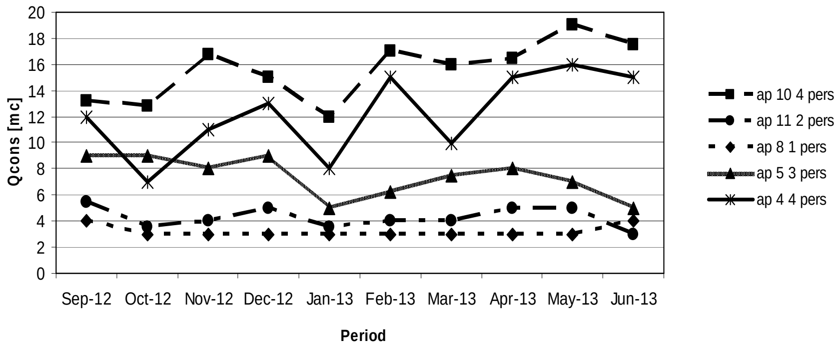

Figure 3. The water total consumption variation

Even that the indoor installation distribution column for water supply has not been replaced (has high clogging and wear degree), from Figure 3 it can be observed the difference between the cold water consumption at the consumers that were branched to the steel pipes and at those who are branched to the new copper pipes.

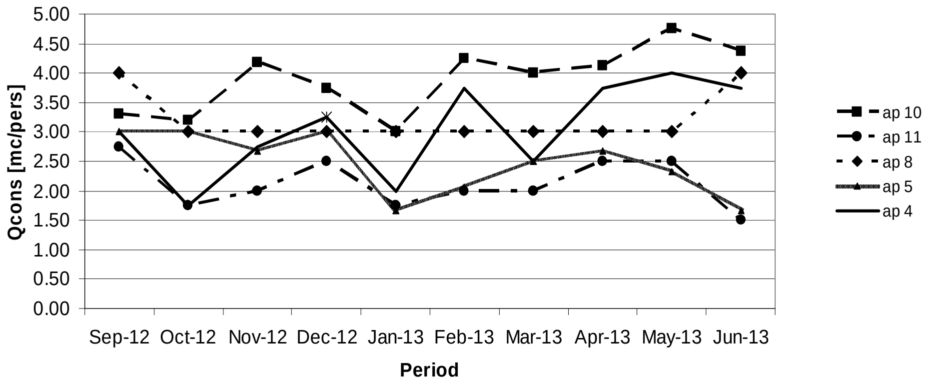

Figure 4. The water consumption variation/pers

The graphic representation of single person consumption was made in order to highlight the increase of the water consumption in the apartments located on the last floor in comparison with those located on the inferior floors (Figure 4). It can be observed that for the replaced columns case, the water consumption at the last floor is lower comparative to the one from the inferior floors.

Significant differences can be noticed if the water consumption per person is compared. Thus, water consumption per person recorded in apartment 11 on the 3rd floor (branched to the copper pipe) is smaller then the one recorded in apartment 8 on the 2nd floor and apartment 4 on the 1st floor (branched to the old steel pipe).

5. Conclusions

From the recorded data analysis regarding the water consumption within the period of time September 2012- June 2013, it can be observed that the water consumption is with 46% lower for the cases in which the pipes were replaced in comparison with those cases in which the water pipes are still those old. It is well known the fact that in Romania, for supplying water to the consumers there are consumed 0.4-1.0 kWh/m^3 [9].

Therefore, by taking into account the total water quantity consumed in the analyzed apartments located at the last floor (apartment 10-rehbilitated pipe and apartment 10-not rehabilitated pipe) there has been calculated the additional energy consumption required for the water supply. The value of this energy consumption is between 45.28kWh and 113.2kWh.

In conclusion, the rehabilitation of the indoor water supply installations inside the old buildings is absolutely required.

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Addresses:

- Lect. Dr. Eng. Adriana Tokar, Faculty of Civil Engineering, University "Politehnica" Timişoara, 2 Traian Lalescu Street, 300223 Timişoara, adriana_tokar@yahoo.com
- Lect. Dr. Eng. Arina Negoiţescu, Faculty of Mechanics, University "Politehnica" Timişoara, 1 Mihai Viteazu Blv., 300222 Timişoara, arina.negoitescu@yahoo.com