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APPLICATION OF PERFORMANCE INDICATORS OF WATER QUALITY IN SPECIFIC WATER SUPPLY SYSTEMS

UPORABA KAZALCEV USPEŠNOSTI ZA KAKOVOST VODE V SPECIFIČNIH SISTEMIH OSKRBE Z VODO

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Abstract

This paper deals with the management in the area of water quality in systems characterized by uneven seasonal water production and consumption. We present a model for managing water supply systems in terms of monitoring water quality, while introducing performance indicators (abbreviated PI) containing variables directly or indirectly related to water quality. In the discussion section, we explain each individual group of indicators and give reasons for their use. We present results of setting an IP matrix related to the issue of improving water quality in the system. The main aim is to establishing a methodology to improve efficiency, effectiveness and cost-effectiveness of a water system with a seasonal customer boom when resources and the total quantity of water in the system are at a minimum, by applying IPs.

Keywords: performance indicators, microbiological quality of water, chlorination, water cuts, Montenegro.

Izvleček

Študija se ukvarja z upravljanjem na področju kakovosti vode pri sistemih s sezonsko neenakomerno proizvodnjo in porabo vode. Predstavljamo model upravljanja vodovodnega sistema s pomočjo monitoringa kakovosti, z uporabo kazalcev uspešnosti (KU), ki vsebujejo spremenljivke, ki se posredno ali neposredno nanašajo na kakovost vode. V diskusiji razložimo vsako posamezno skupino kazalcev in razložimo njihovo uporabo. Predstavljeni so izidi matrice kazalcev uspešnosti, ki se nanašajo na vprašanje izboljšave kakovosti vode v sistemu. Cilj študije je določitev metodologije s pomočjo KU za izboljšanja učinkovitosti vodnega sistema, ki ima sezonsko povečano število potrošnikov, kadar so viri in skupna količina vode v sistemu najmanjši.

Ključne besede: kazalci uspešnosti, mikrobiološka kakovost vode, kloriranje, prekinitve, Črna Gora.

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1. Introduction

Water utilities in Montenegro have gradually been applying a benchmarking technique since 2004. Actually, the use of benchmarking is not yet fully developed in all the technical-operational and financial-economic sectors. For the time being, it works solely in the domain of operational and economic factors. There is a database at the Institute of Public Health in Podgorica on the quality of potable water in the public supply systems in Montenegro. However, except for certain activities within municipal systems where performance indicators exceed allowable limits for potable water parameters, there is still no state program to monitor chemical and microbiological water quality that would have a task to coordinate activities in the field of sanitary-epidemiological and technical parameters. In other words, there are regular water quality analyses (qualitative and quantitative analyses) regulated by law, but this does not include all other indicators that would control the quality of water being delivered to customers particularly in the summer.

Therefore, special or additional analyses of water quality are carried out as interpolation of selected sampling points, and in additional time periods. The coastal region of Montenegro, as a tourist region, with the municipalities from Herceg Novi to Ulcinj, covering an areal of only 100 km net length, has commenced implementation of a programme of systematic improvement of the state of water utilities, with a task of reducing water lossess in the systems, better collection and quantitative and qualitative water serving toward the customers.

Figure 1: *Coast of Montenegro that is the subject area of this paper, and Herceg Novi municipality as a representative example.*

Slika 1*: Predmet te študije je obalno območje Črne Gore in občina Herceg Novi kot reprezentativni primer.*

Out of a total of six water utilities, i.e. public water supply systems, in the coastal area of Montenegro, (see Figure 1. presenting the map of the Montenegro coastal area with municipalities Herceg Novi, Tivat, Kotor, Budva, Bar, and Ulcinj) one is selected as a representative utility that will serve as a benchmark; anomalies of the current management and the need for improvement by introducing benchmarking and IPs will be presented on this utility. The sample water system is the water supply system of Herceg Novi (Figure 2).

2. The goal, task and basic hypotheses

Application of integrated management of water supply systems is based on the principle of management towards objectives. This means that the general direction of development is managed in accordance with individual objectives, using the *"Balanced Scorecard"(COST C18*). The *"Balanced Scorecard"* is a tool to achieve a balance between several selected regions in the focus of research or observation. In accordance with the *"Balanced Scorecard"* the main target areas that need to be balanced are the following: customers, environment, work staff, internal efficiency, cost-effectiveness and development. One of the priority tasks of Integrated management (per COST C18 *European Concerted Research Action designated as COST Action C18 «Performance assessment of urban infrastructure services: the case of water supply, wastewater and solid waste»)* for one city, i.e. its water system, is to establish a direct connection between the control system and financial processes of water utility (system of sale and collection of the water consumed), with the task of continuous, ongoing improvement of water supply system operation.

The task related to the quality of water delivered to consumers is defined by modern principles of system management. These principles are compiled in the so-called "Performance assessment system" - PAS and imply the relation: *cost – efficiency* with the application of specific indicators of the condition, i.e, performance indicators (PIs). Each PI consists of a value obtained as a result of the evaluation by the processing rule, and it is expressed in specific units and with the level of confidence, indicating the quality of the data being presented by that indicator.

During the summer tourism season, water resources are at the minimum level, while the unit consumption per person and the total, cumulative water consumption, are increased by two to three times compared to the off-season period. In this period the water system suffers a significant burden in almost all sectors, and especially in the technical and functional ones. Level of the system operation is increased by the increased mobility of technical department, so as to enable that the changes in the level of service and quantity of water supplied to customers remain as little noticeable as possible and have no negative impact on the tourist market. Water quality, i.e. its physical-chemical and microbiological properties, depends closely on the various parameters of technical-technological procedures, from water intakes, through the pipeline flow, control points for sampling and analysis, and direct delivery to customers. Despite regular, rigorous analyses of water quality and the implementation of precautionary measures, it occurs that water quality in the system still does not meet the required level. This refers only to some control points, and there is no continuity, either seasonal or annual. Water quality analysis, conducted for the period from 1 July 2010 to 1 July 2011 has shown that a total of 138 water samples from 6 positions were taken for the entire public water supply system of Herceg Novi. Of that number, 17 or 12.3% of the analysed samples were non-compliant. Data show that for the sampled water from the site Djenovići there were 5 non-compliant samples of a total of 23, containing 25-112 aerobic mesophilic bacteria/ml, and this is explained by the lack of residual chlorine in the distribution pipeline.

At the site Kamenari, which is quite far from the point of chlorination in the zone of eastern end of the system, 8 of the 21 samples taken were non-compliant. The cause of unsatisfactory samples is the appearance of mesophilic bacteria, and there are 22-280 p/ml of mesophilic bacteria in 1ml of water (in several samples). Mesophilic bacteria are one of the indicators of the water age, i.e., they are a result of low flow and pressure, occuring when the pipeline is not full of water, that is when the flows are reduced, and when there are water restrictions in the system. In the analysed period there were 4 non-compliant samples out of a total of 23 taken in the settlement Bijela, while the number of mesophilic bacteria ranged from 16 to 299. 82.8% non complying samples were registered in the summer period, between 1 June and 15 September, a period with registered increased water temperature in the system supply, particularly in the main water pipeline from Igalo to Kamenari, i.e. from the local spring Opacica to Kamenari. Along with climate conditions, this is also the period that is significantly different from the other part of the year because of increased consumption and reduced amount of water in the system. Water temperatures, shown in Table 1, showed a significant increase in the summer period, on all the longer pipeline sections, where there are no reservoirs (where water temperature is significantly lower). Temperature is an important feature of the distribution system, both because of its significant reflection on the development of colonies of thermotolerant bacteria, or the decay of others, and from the standpoint of action of residual chlorine. It is known that high temperatures, with a relatively high amount of biodegradable organic carbon and low residual concentrations of chlorine, can support the growth of some parasites, opportunistic pathogens, as well as other undesirable organisms during water distribution. This paper deals with such microorganisms.

Table 1: *Measured temperatures of sampled water.*

Preglednica 1:*. Izmerjene temperature vzorčene vode.*

	Temperature (˚C)					
Date/Location	**Opačica**	**Kumbor**	**Đenovići**	**Baošići**	**Bijela**	**Kamenari**
27.06.	15,5	17	18	23	22	23
11.07.	15,5	19	22	22	20	22
18.07.	15,5	17	16	21	20	21
25.07.	16	17	17	22	19	20
02.08.		/	22	23	22	23
29.08.		20	22	23	21	22
Location	**1**	**2**	**3**	**4**	**5**	**6**

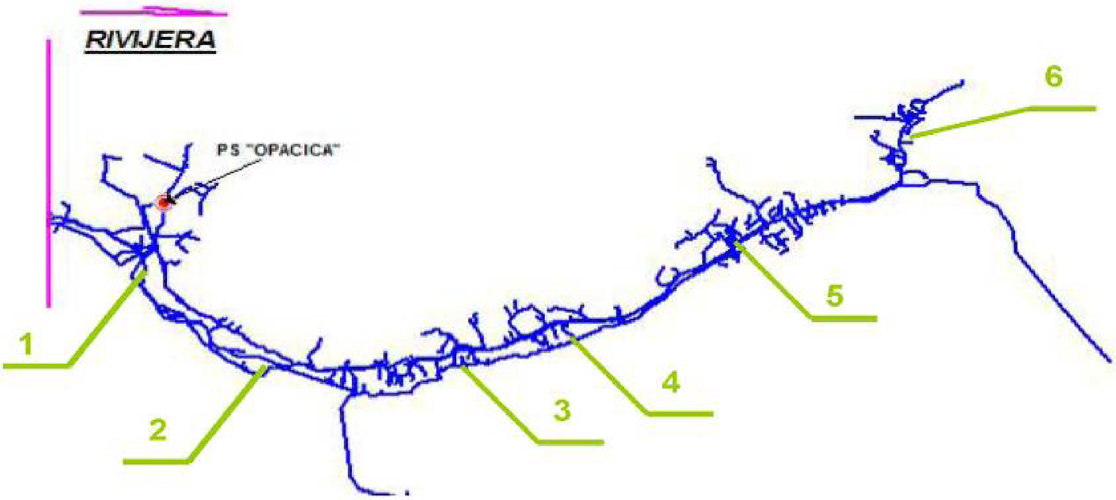

Figure 2*: Water supply network with marked sampling locations.*

Slika 2*: Mreža oskrbe z vodom z označenimi lokaci-jami vzorčenja.*

***Table 2**: Number of consumers, total number of samples and number of non-compliant samples (in brackets).*

***Preglednica 2**: Število uprobnikov, skupno število vzorcev in število neskladnih vzorcev (v oklepaju).*

Settl.	1	2	3	4	5	6
Population No.	1431	925	1161	1346	3691	700
No. of samp.	-	-	23 (4)	-	23 (4)	21 (6)

***Table 3:** Microbiological criteria for drinking water (Rulebook on detailed requirements for the safety of drinking water Official Gazette of Montenegro, 24/12.*

***Preglednica 3**: Mikrobiološka merila za pitno vodo (Uredba za varnost pitne vode, Uradni list Črne Gore, 24/12).*

Parameter	Drinking Water Unit	MAC*
Escherichia coli	Number/100 ml	0
Enterococci	Number/100 ml	0
Total coliform bac.	Number/100 ml	0
Clostridium perfingens	Number/100 ml	0
No of col. at 22^0 C	number/1 ml	100
No of col. at 37^0 C	number/1 ml	20
Salmonella spp.	number/1000 ml	0
Shigella spp.	number/1000 ml	0
Vibrio cholerae	number/1000 ml	0
Parasites	number/1000 ml	0
Enteroviruses	number/5000 ml	0
Pseudomonas aeruginosa	Number/100 ml	0

*MAC – maximum allowable concentration

Table 2 presents specific water consumption in places along the Riviera, depending on the population number, the total number of samples, and the number of non-compliant ones in the brackets. EPANET hydraulic model with 48 hour operation is used for the task of identifying technical causes of unsatisfactory samples and improvingt the water supply system operation by using performance indicators. Water supply system model was created in accordance with the theoretical postulates for all elements of the system: reservoirs, pipeline network, valves, lines, lifting stations, etc. Table 1 shows water quality analyses in the area of Herceg Novi Riviera in the settlements: Zelenika, Kumbor, Djenovici, Baosici, Bijela and Kamenari and it corresponds to the initial state of the model for setting the IP matrix.

The water delivered to consumers must contain no microbes, except possibly mesophilic bacteria and not more than 10 in 100 ml of water sampled. It is a condition of sanitary-epidemiological safe water, according to the Regulation on drinking water (Official Gazette of the FRY 42/98 and 44/99).

3. Methodology

3.1 Application of PIs

With the previously given analysis of characteristic parameters of the selected water supply system, possible reasons of poor water quality will be analysed by introducing the system of PIs directly or indirectly linked to the quality of water in the system. The data obtained by water quality analysis will be compared and the results of the validity of the set matrix of indicators in the model will be discussed.

The first task is the application of PIs in the analysis of water quality in a water supply system. The ultimate goal is to come to some general conclusions for all systems in a region by the inductive method.

The PIs are defined as a quantitative measure of certain aspects of the current functionality and measures of effectiveness of the level of water supply system services. Relevant PIs are inexhaustible sources of research that lead to improvement of the water supply situation. They are featured in several IWA publications (Alegre, et al., 2000; Alegre et al., 2006) as well as technical and economic reports prepared for the World Bank and its investments in this sector (Worldbank, 1999–2000). PIs determining the area of the research are defined by applying IWA manuals.

The area of research is the quality of water delivered to consumers. As one of the postulates of the principles of public supply, water quality depends on the following factors:

- state of the water intake and quality of raw water,
- technological process of water treatment to the discharge into the public water supply system,
- qualitative state of the system facilities: reservoirs, distribution network, valves, household connections and other parts.

In the application of PIs it is important to select the relevant variables directly related to the previously stated, key items. Then the model of performance indicators corresponding to the selected variables is set.

As an example of the situation analysis, setting up a model of PIs and reaching conclusions, we will use one of the region's water supply systems, namely the system of the municipality of Herceg Novi that supplies 35,000 residents and about 65,000 individual consumers in the peak tourist season. To set up the system model we will take the basic hypotheses and set limits by certain baseline assumptions.

3.2 System analysis based on PIs

The following elements and their correlations are significant for the quality of water delivered to customers: raw and treated water (water that has undergone treatment), condition of reservoirs and the quality of water in them (reservoirs that are poorly maintained, or those with algal growth due to light, or due to long water retention in them, it is obvious that such water is of poorer quality than water in the distribution network), condition of pipelines (through cracks and ruptures dirt can enter and contaminate the water in the network), the pipe material and the quality of water inside, mixing of waters that have different chemical composition and have undergone different types of water treatment, etc. Most of these relationships have already been studied and presented in numerous papers under the auspices of the World Health Organization and in collaboration with the IWA association (Chambers et al., 2004). Naturally, for each water system and the climate and geographical area where it is located, there are many specific features. Institute of Chemistry of the Natural Science Faculty in Novi Sad (Serbia) has published several proceedings in the field of potable water quality (Dalmacija et al., 1998) that can be used as guides in investigating causes of poor water quality, as well as the consequences for human health and the environment.

Water supply network should be designed and it should ensure operation so as to enable preventive actions for eliminating anything that can have detrimental effects on water quality. Unfortunately, water supply systems are not perfect and it is not always possible to have maximum control of all activities, so that side effects are frequent (or inevitable). Anomalies, i.e. side effects in terms of chemical and microbiological water defects occur in the following cases:

- travel time of disinfectant through the network is too long,
- the network has a lot of “pockets”, loops and dead ends,
- the pipeline is in poor condition, with a number of defects, cracks and leaks,
- the system is unbalanced, and there is a point with a negative pressure in the network (suction of impurities from the surrounding soil).

It is of great importance for microbiological quality of water to minimize the travel time of water through the pipes, to eliminate low speeds and sub-pressures in the network. For this reason it is necessary for system operation to be balanced, and for us to know its "weak points" (Chambers et al., 2004).

Water is regularly analyzed at selected locations. Due to various types of contacts of substances from the air, land, and the pipeline material, different substances of organic and inorganic origin can be found in water. It is necessary for the treatment with final chlorination to eliminate the presence of microbiological impurities. However, network faults, large number of cracks, holes, openings, bad joints, valves with sealing problem, etc. result in introducing impurities from the surrounding soil. These impurities are retained for some time in the pipes and have a direct impact on water quality. The more damaged the network, the lower the pressure is in pipes, and the higher the possibility of creating “pockets” with sub-pressure. This increases the risk of microbial contamination. Despite regular sampling and testing of water from the system, and by eliminating the causes, some phenomena remain out of regular controls and depend on the state of the water supply network and the quality of water delivered to the pipe.

3.3 Model

A set of indicators describing the condition and quality of the network is a complex system that uses several types of variables accepted as relevant for determining certain sectors of water supply systems. Naturally, the use of IPs should be aligned with the ISO standard 9001. Implementation of the ISO 9001 standard is related to documents that combine the Manual of quality and Procedures for securing quality, in a single set of procedures: *user - document.* IWA concept and methodology are incorporated in this way in the international standards manual published by the Technical committee ISO/TC224 *Service activities related to drinking water supply systems and waste water system (ISO/DIS24510 from 2006 and ISO/DIS24512 from 2006 and ISO 9001 from 2008).*

For modelling the system in terms of water quality, it is necessary to know what is required and what are the key variables in a given issue. Table 2 gives systematized variables by marks of sectors that are important for the analyzed area (in this case the area of the quality of water delivered to customers) and their respective performance indicators presented in the IWA Manual (Alegre et al., 2006).

Table4*: Variables describing the water supply system according the IWA Manual of best practice from 2006 (Alegre et al., 2006).*

Preglednica 4: *Spremenljivke, ki opisujejo sistem oskrbe z vodo(Alegre et al., 2006).*

Variable	Description	No of PI
E5	No of residents (No)	3
E1	Total no of customers (No)	1
C8	Length of main pipelines (km)	15
C22	Valves (No)	1
F8	Public taps and running water points (No)	1
D54	Regular microbiological tests (No).	3
WR	Available water resources	2

The following priority parameters are important for describing the system: number of local residents, the overall population (number of inhabitants increased by the number of tourists in the summer season, the number of customers is seasonally variable), the length of the pipeline in the network, travel times of water and chlorine to customers, and the state of various plugs and valves, public taps, (from which water samples are taken for analysis) and microbiological parameters.

The methodology of PI application has to satisfy the conditions set out below, so as not to be a simple statistical counting of parameters, but to be a meaningful and important tool for further improvement of the condition of a water system:

1. separation of variables should be defined in the model (constant and seasonally-dependent),
2. the domain of PI evaluation should be defined,
3. experimental methods should be used for analysing certain PIs.

Table 5 shows the IWA PI system that will present a model of water quality in the system. These indicators are organised to serve the nature of water parameters. This classification may not coincide with the classification of the applicable legislation. However, a coherent and general classification that could be adopted by any country has to be adopted, not necessearily the easiest one to apply for particular instances. These indicators are connected to the quantity of tests. Their result, i.e. the compliance aspect, is considered in the quality of service section. The first column gives the domain of the evaluation of indicators, the second the number of bound indicators, the third gives the PI code, and the fourth column provides aims of using a specific set of indicators.

The microbiological quality of drinking water in public supply systems is directly dependent on:

- presence of microbiological agents in raw water (bacteria *Salmonella spp*., *Shigella spp*., *Vibrio cholerae* and other pathogenic microorganisms, coliforms and streptococci of faecal origin, *Proteus spp*., intestinal protozoa, intestinal helminths and their developmental stages, and vibrio bacteriophages),
- physical and chemical properties of raw water (temperature, pH, presence of chemical substances, etc.),
- concentration of disinfectant, or mode and dynamics of inserting chlorine into the system,
- some local peculiarities of sampling points.

Table 5: *IWA PI system for the analysis of the water quality in the system (Alegre et al., 2006)*

Preglednica 5: *IWA sistem kazalcev uspešnosti za analizo stanja kakovosti vode v sistemu (Alegre et al., 2006)*

Doman in evaluation	**No of PIs**	**PI code**	**Aims**
Volume of water resources	2	WR	To assess the amount of water entering the system, taking into account water losses
Quality of treated water at the exit from the plant	1	WQ	To assess the performance in terms of compliance with the criteria set out for the quality of water exiting the PTV, and the conditions of ability of produced water to meet the required quality in the point of consumption.
Inspection and maintenance	4	OI	To evaluate the speed and quality of network inspection, establish technical condition, speed, and quality of repairs
System operation	8	OS	To assess the operational indicators affecting the distribution of water to customers: quality of pipeline network, quality of welds, valves and fittings, density and coverage of customers, the value of adequate pressure in the network, continuity of supply, duration of water cuts, and the total number of supply interruptions per connection, etc.
Quality of supplied water	4	QS	To assess the status of water quality in the system taking into account the side effects

Table 6: *Indicators of the condition of water quality in the water system characterized by seasonal variability of water production and consumption.*

Preglednica 6: *Kazalci kakovosti vode v sistemu, za katerega je značilna sezonska spremenljivost proizvodnje in porabe vode.*

Water resources available PIs (WR)		
$WV_1 = Vint/V_d$	V_{int}	Volume of water delivered to customers in the cycle (the time of delay between two subsequent activations of the water system in the conditions with occasional interruptions in water distribution – water cuts, is taken into account)
	V_d	Volume of water that is supposed to be distributed during the working cycle of the system in summer period in accordance with existing possibilities (continuous distribution)
$WV_2 = Q_{int,i}/Q_{cont,t}$	Qint,i	Average flow (calculated in l/h) to customers during water cuts
	Qcont,t	Average flow (calculated in l/h) to customers during continuous distribution

Treated water quality PIs (TW)		
Ph1= A / C	A	Maximum daily volume of water being treated in a given period of time, during restrictions, calculated in m^3/day
	C	Total daily water volume being treated, calculated in m^3/day

Operational indicators PIs (OP)		
SD_1= ST/24	ST	Time of supply (h)
SD_2= ST_t/ST	STt	Time of supply over the period when the population is active (index t is related to the peak supply periods: 6:00-8:00, 13:00-15:00 and 19:00-22:00)
$BD_1=N_{t+r}/N_r$	Nt+r	Total no of customers, resident population and tourists in a certain time period
	Nr	No of resident customers
BD_2= Nt+r/Trest,h	Trest,h	Summary No of population of customers divided by relevant duration of water cuts (supply interruptions), calculated by hours
$SR_1 = V_s/V_d$	Vs	Available volume of reservoir in the network (calculated in cubic meters per customer m^3/h)
	Vd	Average water demand per customer (calculated in cubic meters per customer m^3 /h)
$SR_2 = Q_{mg}/\sum Q_{a,i}$	Qmg	Required average daily flow for urban zone (with hotels or other tourist capacities)
	Qa,i	Delivered flow from a resource (including all available water resources)
$SR_3 = N_{pr}/365$	Npr	Annual no of supply interruptions
SR_4 =Trest,y/365	Trest,y	Total annual duration of supply interruptions

To be continued / Se nadaljuje

Table 6 continued / Nadaljevanje preglednice 6

Inspection and maintenance PIs (OI)		
Op3 = (Px365)/H1/C	C	Total length of pipeline (km)
	P	Length of inspected network in a given time period (km)
	H1	Time period when the network is inspected (day)
Op4 = (P_cx365/H1)/C	P_c	Control of leakage in the pipelines in a given period (km)

Water quality PIs, QS		
QS = (D_{11}+D_{12}+D_{13})/ D_1	Total number of quality tests summarizing standards or regulations, related to the period under study	
	D_1	Total number of samples (quality tests)
	D_{11}	Tests on aesthetic (organoleptic) properties of water
	D_{12}	Microbiological tests
	D_{13}	Tests on the physical-chemical properties of water
$QS_1 = D_{11,N}/D_{11}$	$D_{11,N}$	The total number of non-compliant samples in tests on the aesthetic parameters, in relation to the total number of tests during water cuts
$QS_2 = D_{12,N}/D_{12}$	$D_{12,N}$	The total number of microbiologically non-compliant samples in relation to the total number of tests during water cuts
$QS_3 = D_{13,N}/D_{13}$	$D_{13,N}$	The total number of non-compliant samples on physical and chemical water characteristics in relation to the total number of tests during water cuts

Each microbial agent has a specific reaction to the disinfectant (chlorine), i.e. each has a different level of resistance, depending on water temperature, pH and concentration of chlorine *(US EPA, 1989).*

In addition to these standard factors, the quality of water at sampling points may be affected by the specific features of sampling points:

- quality of equipment and the sampling method,
- technical equipment and the condition of sampling point.

3.4 Model, PI matrix determining the microbiological water quality in the supply system

Proceeding from the basic parameters describing the state of a water supply system in the coastal region of Montenegro, the causes and consequences of negative phenomena in the system operation, as well as the presence of non-compliant water samples, a matrix of PIs combining variables directly associated with water quality issues in the system is set based on tables 3-5. This set of PIs is presented in Table 6.

4. Results

The presented IP application model was proven in practice, in real conditions. The selected water supply system (of Herceg Novi) has still not developed a complete benchmarking, but the model can nonetheless be applied. Permanent monitoring of conditions in the system includes technical indicators (the amount of water entering the system, water quantity registered by sector flow meters, the amount of chlorine inserted), the statistical analyses of laboratory data on quantitative and qualitative water analyses with the frequency of occurrence of specific microbes at specific points in the specified time, and the analysis of operational indicators on the state of the network, failures, repairs, etc. These are used to determine the so-called initial or zero state of the system. After determining the "zero" state of the supply system, it was possible to carry out interventions already in the first year of operation, at such places and at such a times as to improve the quality of water distributed to customers.

Comparing the values for the number of samples and the number of non-compliant ones for the Herceg Novi Riviera from tables 1 and 5, an increase in the quality of water supplied can be noticed. This improvement is seen in the reduction of the the number of non-compliant samples.

Table 7: *The total number of samples and number of non-compliant samples, and distribution of non-compliant samples on a monthly basis.*

Preglednica 7: *Število skupnih in neskladnih vzorcev na mesec.*

Settl.	1	2	3	4	5	6
Population No.	1431	925	1161	1346	3691	700
No of samples	-	-	27 (3)	-	21 (2)	19 (4)

5. Discussion

The presented model of PIs needs to be proved in practice, in real conditions. The selected water system still does not have a developed benchmarking in this domain, but the model can be applied nonetheless. In the following section we will discuss the values from Table 6.

Water resources available. Available water resources are the first point of observation of the condition expressed with PIs: amount of water, seasonal variations in quantity, chemical and microbiological quality and seasonal changes in water quality. The amount dictates the state in the network of the entire system, distribution, filling the reservoir and distributing water by altitude zones (if any). The PI implies permanent condition of measurements of the amount of water at the entrance to the system, and keeping accurate records by indicating days and hours of registered amounts of water on the flow meter. Given that this is a seasonally variable system in terms of quantity of water, it is necessary to carry out exact time division in two ways:

- On the off-season period and the official tourism season period (when the number of customers is increased by approximately 30%),
- On the period of reduced inflow compared to the average quantity or volume in the winter period by 20% (here the limit of a 20% of reduction in the water quantity on resources entering the system has been taken arbitrarily).

Treated water quality. Reducing the amount of water in the system can initiate a restrictive supply regime. What, in this case, happens to the quality of water in the system reaching the customer? A complex method of treating water at the filter station guarantees sufficient and safe water quality entering the system in general, but problems may occur in the network, due to retention of water in the pipes, especially in parts where there are "pockets" and nodes, out of reach of residual chlorine. In addition, the quality of the pipe network is of great importance to the quality of water in the system if it contains any cracks, holes or bad gaskets through which outer impurities can enter the pipe and be distributed with water to consumers. Tests of water quality have to be carried out more often during the water cut periods, i.e. during the tourist season, than in the remaining part of the year. These are tests on the organoleptic properties and chemical and microbiological properties of potable water. Analyses of the tests are statistically processed by time factor and sampling location. Given that the microbiological aspects of drinking water are the most important (according to the World Health Organization, 2001), the required level of analysis is reduced solely to them, as shown in Table 6 (QS), which refers to water quality. Statistical data analysis, especially of non-compliant samples, by itself has no importance, unless the time (day and hour) of sampling and exact location of sampling is not recorded, and an analysis of system operation with mandatory inclusion of technical parameters of the system (state of failures, repairs, opening and closing, etc.) is established. The aim i.e. detecting causes and locating problem generation by PIs, can be directly achieved by comparing tests during the restrictive supply regime with the "regular" state, i.e., by comparing the number of non-compliant samples and establishing the genesis of their origin.

Inspection and maintenance. Inspection and maintenance of pipeline network are of high importance for the entire state of the system, regardless of the period of the year. The system monitoring is carried out by regular inspection of the network and its special elements from the standpoint of leakages and identification of failures and water losses in the system. For this purpose PIs containing the basic characteristics of the pipeline network are introduced: overall length, length of pipe by various pipe diameters, daily set lengths of pipe inspection in order to establish the pipeline network. These must be inspections carried out annually, no matter if there is the so-called SCADA system of automatic control of work, or everything has to be done by on-site inspections. Control of water leakage in the field is of great importance for the process of reducing water losses in the system. Inspection and maintenance is especially important in systems with very high losses, as is the case in the local systems on the coast of Montenegro, where the percentage of losses is 50% or higher.

Operational indicators. Operational indicators are directly connected to the quality of delivered water, i.e. customer service provision. They are related to the concept of duration of water supply or water cuts, i.e. periods of restrictive supply introduced in the benchmarking process. In addition, the term of the number of consumers is introduced, since the strict division of the off-season period and the tourism season period is of great importance, when the number of customers is increased by 30-100%. In summarizing the state of the system operating under difficult conditions (during summer season), technical parameters of the water supply system are of great importance: the length of pipe network, number, distribution and volume of water reservoirs, operation of pumping systems (if any), etc. Irregular water supply provokes customer dissatisfaction and has a direct impact on the tourism industry by changing the general image of the environment for the worse. Based on the available water in the system, water is rearranged by customer zones, priorities for supply are determined and a complete reorganization is carried out, all aimed at reducing the risk of negative and harmful occurrences as well as reducing the level of customer dissatisfaction. The efficiency of the system operation at any given moment is of great significance.

PIs are aimed at improving the performance of water supply systems through better efficiency, effectiveness and cost-efficiency. Such a model is a move forward from uncontrolled and non-systematic approaches of water utilities management to a systematic and overall controlled management approach leading towards set goals.

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