

The Efficiency of Resita Town Water Treatment Plant

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The main source of water supply for the residents of Resita town is Bîrzava River. Water is extracted from the settling basin of Crăinicele Hydroelectric Power Plant located on Bîrzava River, upstream of Resita town. The water treatment station, with 1 m³/s discharge contains in its technological line the following items: kitchen reagents, reaction tanks, clarifiers, filters, chlorine disinfection and storage tanks. Water quality measurements, at the entrance and exit of water treatment plant were made for a two year period (2010 - 2011). Analyzed quality parameters in this paper are: water turbidity, pH, water oxidation, ammonium, nitrate concentrations. The average yield reduction of presented parameters was between 1.93 (for pH), and 49.61 (for ammonium). The comparison of values from analyzed parameters at the exit of water treatment plant with the current regulation ones for drinking water allowed us to conclude that the supplied water to residents of Resita town corresponds in terms of quality, to a good quality drinking water.

Keywords: drinking water, water treatment plant, quality parameters, technological line, Bîrzava

The technology used at Reșița water treatment plant

The water source for drinking water of town Reșița, subject to purification at the water treatment plant is situated at the surface. Water from the calming pool of Hydroelectric Power Plant Crăinicele is pumped to the water treatment plant (fig. 1).

Water Treatment Plant Reșița produces 1 m³/s drinking water. Ground level at which the plant is located is between 300 and 315m.

The plant is composed of reagent dosing installations, mixing chamber, sedimentation tanks and filters. Water disinfection is made by chlorine gas in the contact tanks.

Reagent dosing is made by a line for lime and another for aluminium sulphate used for coagulation.

The lime line is composed of a lime deposit, a pool of 1 m³ used to slack lime, pumps which send "milk" lime into two containers of 2.5 m³ for diluted suspension, and 1+1 recirculation pumps towards the containers with dispensing nozzles.

Sulphate aluminium line comprises a pool of approx. 30 m³, decanting pumps of the concentrated solution in two dilution containers of 2.5 m³ from where the diluted solution is pumped into containers with dispensing nozzles and recirculation of excess solution.

At the reagents household floor we find the analysis laboratory, reagents storage, a locker and bathroom.

The mixing chamber has a volume of 42 m³ and provides a contact time of 42 sec.

The two sedimentation tanks with a diameter of 32 m and a volume of 4800 m³ each, ensuring a flow rate of 500 l/s with a settling time of 2.6 h.

The Plant is equipped with 24 sand filter tanks with a total area of 572 m².

Purified water is stored in tanks inside the treatment plant, with a total capacity of 5000 m³.

At a flow rate of 1 m³/s the time it takes the water to pass through the treatment plant reservoirs is 1.25 h.

Treatment plant analysis laboratory

The treatment plant analysis laboratory is structured in 3 units with different functions:

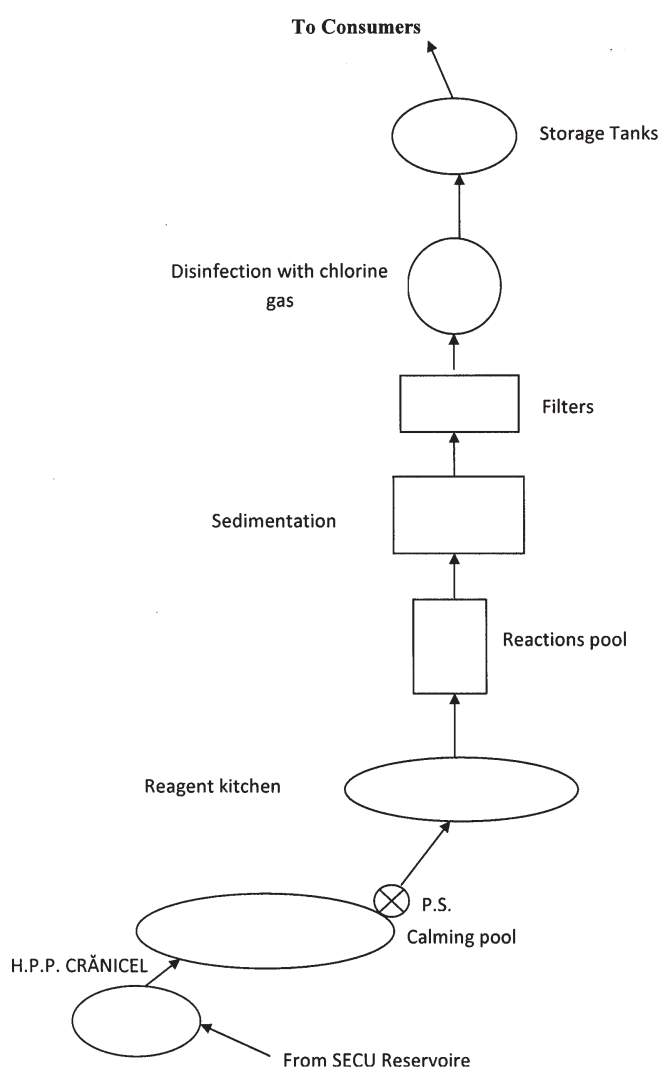


Fig. 1. Water Treatment Plant of Resita Town

Technological Laboratory of physico-chemical raw and decanted water- wherein quality indicators are determined for raw water to properly establish reagents dosage, as well as quality indicators for the technological steps in order

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Value	TURBIDITY (UNT)		pH (U pH)		OXIDISABILITY (mg O ₂ /l)		AMMONIA (mg/l)		NITRITE (mg/l)	
	RAW WATER	PURIFIED WATER	RAW WATER	PURIFIED WATER	RAW WATER	PURIFIED WATER	RAW WATER	PURIFIED WATER	RAW WATER	PURIFIED WATER
maximum	710,00	63,40	7,95	7,86	7,99	7,04	1,895	0,487	0,014	0,008
minimum	0,91	0,50	6,51	6,19	1,28	0,96	0,010	0,002	0,001	0,001
average	6,213	2,903	7,171	7,031	2,256	1,565	0,080	0,040	0,003	0,002

Table 1
THE MAXIMUM,
MINIMUM AND AVERAGE
VALUES (2189
MEASUREMENTS)

Maximum permissible values					
Turbidity	Colour	pH	Oxidisability	Ammonia	Nitrite
65 turbidity units	Acceptable to consumers and no abnormal change	9,5 pH units	5,0 mg O ₂ /l	0,50 mg/l	0,50 mg/l

Table 2
LIMIT VALUES OF LAW 458/2002
SUPPLEMENTED WITH LAW 311/
2004

to optimize process flow. This Laboratory is equipped with: turbid meter, pH meter, test device for Jarr test, zeta meter.

Physico-chemical Laboratory for filtered water – purified water which will be distributed to consumers. Test results from this laboratory are used to properly modify filters operation, dosage adjustment of chlorine, as well as monitoring water from the distribution network. This Laboratory is equipped with: turbid meter, pH meter, oxygen meter, UV-Vis spectrometer, oven, distilled-bidistilled device, analytical balance, technical balance, conductivity meter, water bath.

Bacteriology Laboratory which is performing bacteriological analysis of raw water, decanted water, filtered water, drinking water which will be distributed to consumers as well as the water from the distribution network. The decisions of washing-disinfection of installations as well as modifying residual chlorine level in order to ensure quality requirements of legal norms are based on these test results. This Laboratory is equipped with: autoclave, two thermostats, two ovens, microscope, centrifuge, water bath, Millipore filter installation, microbiological hood, colony counter.

Harvesting program of water samples

Sampling and analyzes are made in several sections. Sections from which sampling and analysis are made:

- At the station entrance raw water is harvested from the water outlet. Hourly turbidity is performed. Three times a day, at 8 am, 3 and 11 pm, determinations are performed for temperature, smell, colour, pH, organic matter, alkalinity, total hardness, temporary hardness, permanent hardness, oxidisability, ammonia, nitrates, nitrites as well as bacteriological analysis (number of bacteria, total coliforms, faecal coliforms, faecal streptococcus). Once a day dissolved oxygen and conductivity is measured.

- At the sedimentation tanks spillway the following analysis are performed three times a day for temperature, turbidity, pH, organic matter and weekly number of bacteria, total coliforms, faecal coliforms, faecal streptococcus. Three times a day samples from two filters are taken for analysis of pH, turbidity, organic matter. Once a week bacteriological analysis regarding bacteria number, total coliforms, faecal coliforms, faecal streptococcus is made.

- At the station exit samples from drinking water reservoirs is taken. Analyses are performed three times a

day at 8 am, 3 and 11 pm, when temperature, smell, colour, taste, pH, turbidity, organic matter, residual chlorine, alkalinity, total hardness, temporary hardness, permanent hardness, oxidisability, ammonia, nitrates, nitrites are determined. Once a day, determination for aluminium, dissolved oxygen, conductivity is made, and twice a day for bacteria number, coliform bacteria, E. coli, faecal streptococcus.

The results of physico-chemical and bacteriological analyses are underlying the efficiency calculations performed on the technological process by treatment steps as well as monitoring the quality of water in the distribution network.

Frequency of analyses is increased whenever necessary, both in terms of number and sampling locations in the technological flow and distribution network.

Statistical analysis of measurements

The initial set of measurements comprises a volume of 2189 simultaneous measurements performed at the stations entry and exit between 1.01.2010 and 31.12.2011. Of all the water quality indicators determined at the Treatment Plant of Resita town only a few of them are being analysed in terms of statistics, and they are: turbidity, pH, oxidisability, ammonia, nitrite.

The maximum, minimum and average values for the intended parameters are given in table 1, the quality limits allowed by the Law 458/2002 supplemented by Law 311/2004 are present in table 2.

Detection and elimination of outliers from the initial set of measurements was made according to STAS 11278-79, using Grubbs-Smirnov. For each set of tracked parameters, the following calculations were made:

- arithmetic average value for data string, with equation (1):

$$\bar{x} = \frac{x_1 + x_2 + \dots + x_n}{n} = \frac{\sum_{i=1}^n x_i}{n} \quad (1)$$

- standard quadratic deviation (standard deviation) with relation (2):

$$s = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}} \quad (2)$$

Checking if a measurement is anomalous or not was made using the relations (3), (4) for the minimum value, respectively for the maximum value in the string:

$$u_n = \frac{x_n - \bar{x}}{s} \quad (3)$$

$$u_1 = \frac{\bar{x} - x_1}{s} \quad (4)$$

Decision on retention or removal of a string value is made by comparing u_n , respectively u_1 , with the standard value h (STAS 11278-79, table 4), determined according to the number of data in the string and the level of significance chosen. For the large volume of existing data in the string and a degree of significance $\alpha=0,001$, table 4 showed the value $h = 4.607$.

Values from the string which $u_1 < h$, $u_n < h$ were kept, those who were $u_1 > h$, $u_n > h$ were eliminated from the string.

Applying this test resulted in eliminating:

-77 measurements regarding turbidity of raw water entering the station and 12 values regarding turbidity of water at the output;

-3 measurements regarding water pH entering the station and 2 values regarding water pH at the station output;

-16 measurements regarding water oxidisability entering the station and 22 values regarding water oxidisability at the station output;

-70 measurements regarding water ammonium content entering the station and 25 values regarding water ammonium content at the station output;

-18 measurements regarding water nitrite content entering the station and 27 values regarding water nitrite content at the station output;

The stations yield was calculated for the following parameters, resulting in eliminating of values from the string which corresponded to a negative yield:

-5 measurements regarding water pH;

-1 measurement regarding waters oxidisability;

-5 measurements regarding waters ammonium content;

Table 3
MAXIMUM, MINIMUM, AVERAGE AND YIELD VALUES (2040 MEASUREMENTS)

SPECIFICATION	TURBIDITY			pH			OXIDISABILITY		
	(UNT)			(U pH)			(mg O ₂ /l)		
	Val. max.	Val. min.	Val. avg.	Val. max.	Val. min.	Val. avg.	Val. max.	Val. min.	Val. avg.
RAW WATER	22,90	0,91	4,229	7,70	6,60	7,170	4,00	1,28	2,219
PURIFIED WATER	11,90	0,50	2,903	7,78	6,48	7,031	2,40	0,96	1,530
YIELD	87,15	0,93	33,360	12,82	-1,51	1,930	60,29	-4,55	29,010

Continuing

SPECIFICATION	AMMONIA			NITRITE		
	(mg/l)			(mg/l)		
	Val. max.	Val. min.	Val. avg.	Val. max.	Val. min.	Val. avg.
RAW WATER	0,230	0,010	0,067	0,008	0,001	0,002
PURIFIED WATER	0,160	0,002	0,037	0,004	0,000	0,001
YIELD	95,890	566,670	48,320	100	0	37,53

On table 3 the maximum, minimum average and yield values are presented for our tracked parameters after applying Grubbs-Smirnov test, again in table 4 maximum, minimum, average and yield values are presented for our tracked parameters after eliminating negative values of yield.

Table 4
MAXIMUM, MINIMUM, AVERAGE AND YIELD VALUES (2029 MEASUREMENTS)

SPECIFICATION	TURBIDITY			pH			OXIDISABILITY		
	(UNT)			(U pH)			(mg O ₂ /l)		
	Val. max.	Val. min.	Val. avg.	Val. max.	Val. min.	Val. avg.	Val. max.	Val. min.	Val. avg.
RAW WATER	22,90	0,91	4,11	7,70	6,60	7,17	4,00	1,28	2,19
PURIFIED WATER	11,40	0,50	2,47	7,39	6,19	7,03	2,40	0,96	1,53
YIELD	87,15	0,93	33,36	12,82	2,64	1,93	60,29	3,85	29,02

Continuing

SPECIFICATION	AMMONIA (mg/l)			NITRITE (mg/l)		
	Val. max.	Val. min.	Val. avg.	Val. max.	Val. min.	Val. avg.
RAW WATER	0,230	0,010	0,068	0,008	0,001	0,002
PURIFIED WATER	0,151	0,002	0,036	0,004	0,000	0,001
YIELD	95,890	2,040	49,610	100	0	37,5

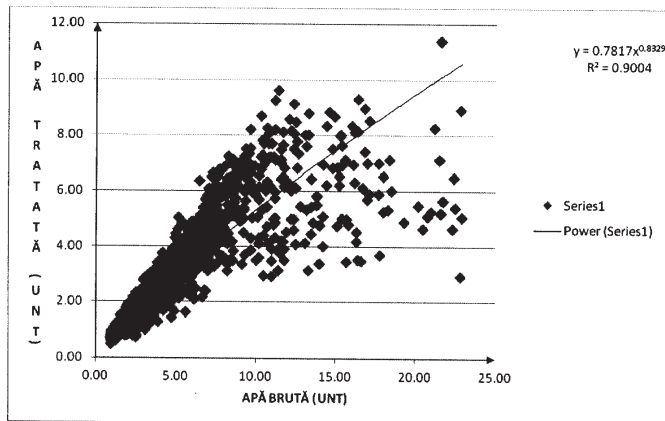


Fig. 2. Correlation between purified water turbidity (y) and raw water turbidity (x) recommended practice

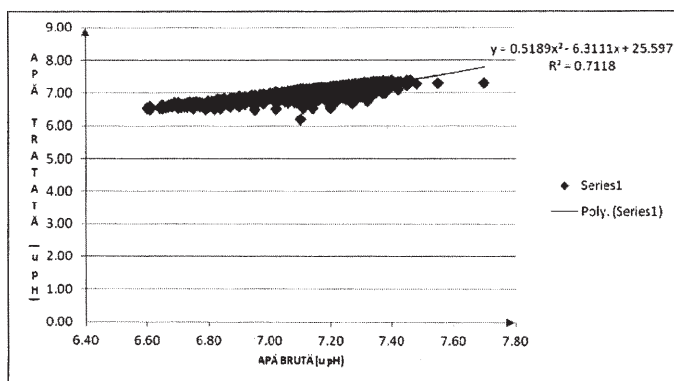


Fig. 3. Correlation between purified water pH (y) and raw water pH (x) recommended practice.

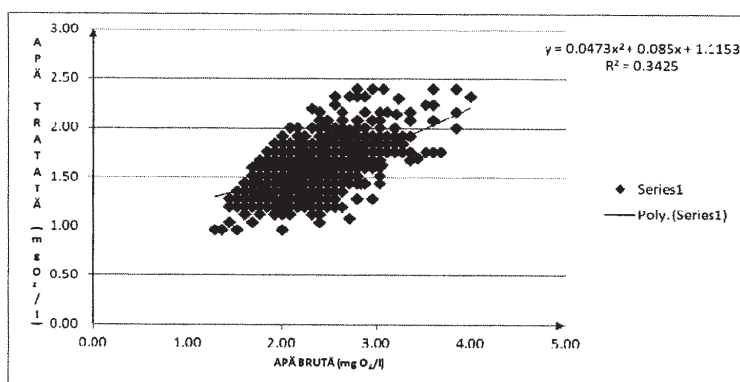


Fig. 4. Correlation between purified water oxidisability (y) and raw water oxidisability (x) recommended practice

Obtained correlations

For the remaining 2029 string of measured data correlations where established between values from entry and exit of water treatment station. The expressions of

Table 5
CORRELATION BETWEEN PURIFIED WATER TURBIDITY (y) AND RAW WATER TURBIDITY (x)

Function	R ²	y
Exponential	0,697	1,073 e ^{0,148x}
Linear	0,758	0,427x+0,716
Logarithmic	0,803	2,181ln(x)+0,050
Polynomial	0,860	-0,026x ² +0,847x-0,212
Power	0,900	0,781x ^{0,832}

Table 6
CORRELATION BETWEEN PURIFIED WATER pH (y) AND RAW WATER pH (x)

Function	R ²	y
Exponential	0,703	2,404 e ^{0,149x}
Linear	0,702	1,042x-0,441
Logarithmic	0,699	7,365ln(x)-7,476
Polynomial	0,711	0,518x ² -6,311x+25,59
Power	0,701	0,875x ^{1,057}

Table 7
CORRELATION BETWEEN PURIFIED WATER OXIDISABILITY (y) AND RAW WATER OXIDISABILITY

Function	R ²	y
Exponential	0,321	1,002 e ^{0,191x}
Linear	0,339	0,309x+0,857
Logarithmic	0,330	0,698ln(x)+0,995
Polynomial	0,342	0,047x ² +0,085x+1,115
Power	0,318	1,087x ^{0,437}

Table 8
CORRELATION BETWEEN PURIFIED WATER AMMONIUM CONCENTRATION (y) AND RAW WATER AMMONIUM CONCENTRATION (x).

Function	R ²	y
Exponential	0,680	0,010 e ^{14,81x}
Linear	0,794	0,618x-0,006
Logarithmic	0,692	0,042ln(x)+0,155
Polynomial	0,794	-0,065x ² +0,631x-0,007
Power	0,743	0,728x ^{1,149}

tested functions as well as square correlation coefficient are presented in tables 5 to 9. In practice function expressions that correspond to the highest square correlation coefficient value are recommended.

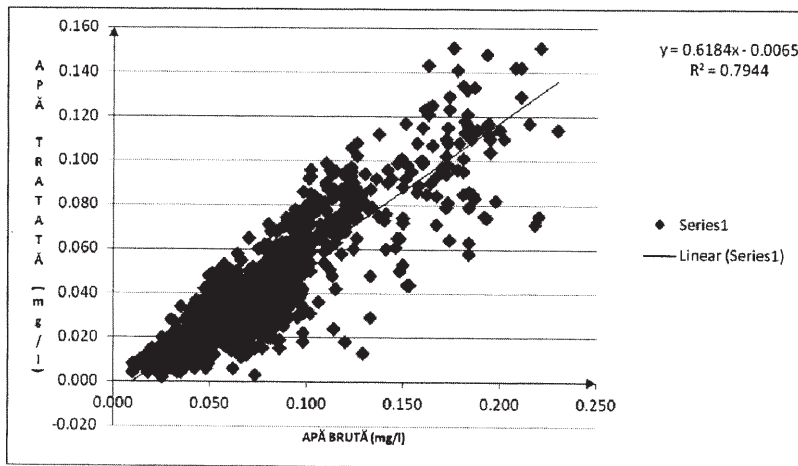


Fig. 5. Correlation between purified water ammonium concentration (y) and raw water ammonium concentration (x) recommended practice

Function	R ²	y
Exponential	-	-
Linear	0,643	0,409x+0,0001
Logarithmic	0,510	0,0001ln(x)+0,006
Polynomial	0,657	36,60x ² +0,188x+0,0001
Power	-	-

Table 9
CORRELATION BETWEEN PURIFIED WATER NITRITE CONCENTRATION (y) AND RAW WATER NITRITE CONCENTRATION (x).

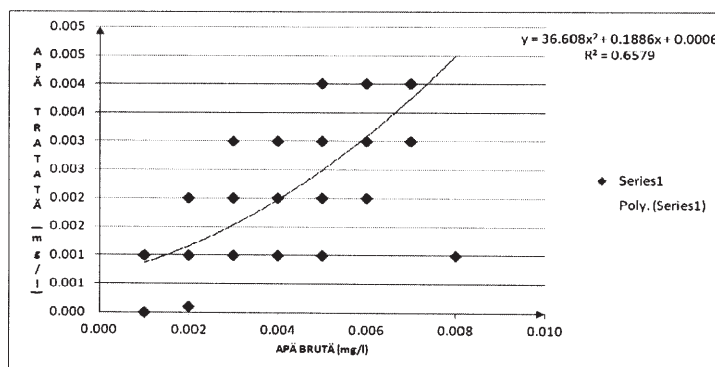


Fig. 6. Correlation between purified water nitrite concentration (y) and raw water nitrite concentration (x) recommended practice

Conclusions

At recommended correlations, square correlation coefficient (R²) was between 0.900 (power function) for water turbidity and 0.342 (polynomial function) for water oxidisability. For the considered data string values (2029 measurements) and for the obtained square correlation coefficient values, we believe that the proposed mathematical functions describe strong connections between these quality indicators of our analysed water parameters.

Quality parameter values at the exit of the water treatment plant are below limits imposed by legislation and indicate a good quality for drinking water supplied to consumers of Re'ia Town.

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9. *** - SR ISO 7887/97 privind determinarea culorii.

10. *** - SR ISO 10523/97 privind determinarea pH-ului.

11. *** - STAS 3002/85 privind determinarea oxidabilității.

12. *** - STAS 3048/2-96 privind determinarea nitriților.

13. *** - STAS 6323/88 privind determinarea turbidității.

14. *** - STAS 6328/85 privind determinarea amoniului.

15. *** - STAS 11278-79 privind identificarea rezultatelor aberante ale măsurătorilor

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