THE INFLUENCE OF CONSTRUCTIVE PARAMETERS CONCERNING THE OPERATION OF WATER TREATMENT PLANTS

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Abstract: The aim of the work is finding ways to upgrade water plant Chirita in Iasi, Romania. The researches have like result to correlate the functional parameters of pumping station with the quality parameters of water. The followed result is the producing of good quality of drinkable water with minimum cost. Operating modes are analyzed for all channels - weir – hydraulic ram to feed all four canals of the wastewater treatment plants. The supply flow aeration tanks in the left and right side of the hydraulic ram variations are strongly influenced by the loss head Z and canal bottom slope. Water quality obtained after biological step depends on geometrical and functional parameters chosen for the aeration basins.

Key words: drainage canal, flow module, hydraulic ram, pump, weir.

1. INTRODUCTION

The coagulants for the coagulation process are selected for a maximum global efficiency. The choice reagents and the work conditions of coagulants must be accurately established. The advanced coagulation represents the reduction process of the natural organic substances in the water's treatment channel.

Seepage and evaporation are the most serious forms of water losses in an irrigation canal network. Seepage loss depends on the channel geometry, whereas evaporation loss is proportional to the area of the free surface. In this investigation, a methodology has been devised which describes the optimal canal dimensions to convey a particular discharge. The objective nonlinear water loss function, for the canal, which comprises seepage and evaporation losses, is developed. Two constrains, minimum permissible velocity as a limit for sedimentation and maximum permissible velocity as a limit for erosion of canal, have been taken into consideration in the canal design procedure. Using Lagrange's method of undetermined multipliers, the optimal canal dimensions are obtained which give the least water loss. Using a random search method, a simple computer program was developed to carry out design calculation and provide the optimal canal dimensions. A set of design charts has been prepared by plotting the results. The proposed charts facilitate easy design of the optimal canal dimensions guarantying minimum water loss and computation of water loss from the canal section without going through the conventional and cumbersome trial and error method. A design example with sensitivity analysis has been included to demonstrate the simplicity and practicability of the proposed method, (Ghazaw, 2010).

Studies of canal design for minimum water loss have been carried out by several investigators. These studies besides their difficulties to be applied by the practicing engineer, no attention has been made to consider the side slope constrain, (Chahar, 2007).

A study was conducted for the treatment of canal water using coagulation-flocculation-sedimentation process. Different coagulants i.e. alum, ferric sulfate and ferric chlorides were used. The effect of pH and mixing condition i.e. rapid mixing energy and time and slow mixing energy and time on the performance of coagulants were studied. The results of the study demonstrated that pH and mixing conditions affect the efficiency of the coagulant and there exist particular conditions for achieving maximum efficiency of a coagulant at an economical cost. Among different coagulants tested, alum was found to be a suitable coagulant for canal water on the basis of removal of turbidity and cost of treatment. The optimum dose of alum was found to be 12 mg/l at an optimum rapid mixing energy of 100 sec^{-1} and mixing time of 1 minute and slow mixing energy of 35 sec-1 and mixing time of 20 minutes and 30 minutes of sedimentation time. At the optimum dose, alum removed 99.5% turbidity and 94.4% fecal coliforms. Sludge production at optimum dose of alum was 2.4 mg/l, (Haydar et al., 2010).

The present drinking water purification system in Egypt uses surface water as a raw water supply without a preliminary filtration process. On the other hand, chlorine gas is added as a disinfectant agent in two steps, pre- and post-chlorination. Due to these reasons most of water treatment plants suffer low filtering effectiveness and produce the trihalomethane (THM) species as a chlorination by-product. The Ismailia Canal represents the most distal downstream of the main Nile River. Thus its water contains all the proceeded pollutants discharged into the Nile. In addition, the downstream reaches of the canal act as an agricultural drain during the closing period of the High Dam gates in January and February every year. Moreover, the wide industrial zone along the upstream course of the canal enriches the canal water with high concentrations of heavy metals. The obtained results indicate that the canal gains up to 24.06×106 m3 of water from the surrounding shallow aquifer during the closing period of the High Dam gates, while during the rest of the year, the canal acts as an influent stream losing about 99.6×106 m^3 of its water budget. The reduction of total organic carbon (TOC) and suspended particulate matters (SPMs) should be one of the central goals of any treatment plan to avoid the disinfectants by-products. The combination of sedimentation basins, gravel pre-filtration and slow sand filtration, and underground passage with microbiological oxidation-reduction and adsorption criteria showed good removal of parasites and bacteria and complete elimination of TOC, SPM and heavy metals. Moreover, it reduces the use of disinfectants chemicals and lowers the treatment costs. However, this purification system under the arid climate prevailing in Egypt should be tested and modified prior to application, (Geriesh et al., 2008).

A conventional flow monitoring and control system is discussed for the following problems (Dolezilek et al., 2013):

- An analogy of the water system to the power system.
- A dynamic, efficient, and multifunctional automation system for the monitoring and control of water flow through open channels and the associated power consumed by the process.
- How radios in a dual-ring loop topology allow a differential water flow calculation, similar to a differential current calculation.
- The high-speed detection of channel leakage, overflow, and blockage conditions.
- The featured benefits of a modern water delivery solution.
- Future research opportunities that include the optimization of water and energy usage in fields by combining climate information.

2. PROBLEM DEFINITION

Data were analyzed the water quality of the River Prut, in Section Tutora, Iasi, Romania, Fig. 1. The conclusions drawn from experimental data are, (Megelea, 2008):

1. Water shows large variations in turbidity and poorly colored. Suspension concentrations are variable.

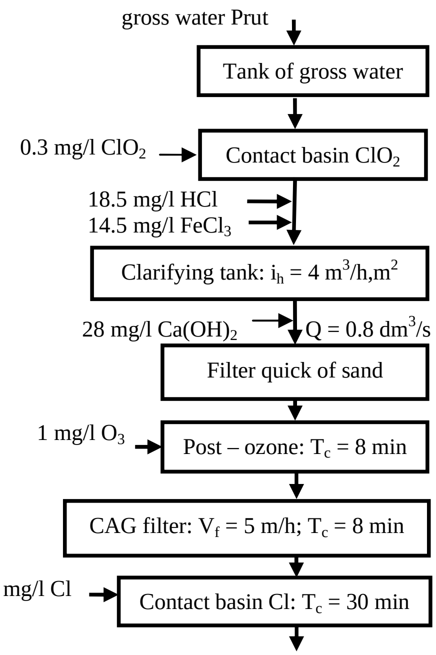

Fig. 1. The treatment way of Prut water, Romania, (Megelea, 2008); CAG - granulated active coal

2. The pH is the basic of (8.06 ÷ 8.16) pH units. Total alkalinity is included in the limits (3 ÷ 3.5) mequivalent/l.
3. The indicators of mineralization (fixed residue and conductivity) have values corresponding average mineralized waters, mineralization being especially carbonates and calcium sulphates.
4. Concentration of organic substances determined by potassium permanganate method CCO-Mn was in the range (10 ÷ 26) mg $KMnO_4$/l, and the concentration of organic substances determined by potassium dichromate method CCO-Cr was (12 ÷ 15) mg O_2/l. These values are high and can lead to difficulties in water treatment.

The concentration of pesticides in source water has deposited of (5 ÷ 10) higher allowable concentration for drinking water.

Consistent with laboratory coagulation tests effectuated and source water quality was adopted following chain of water treatment:

- Pre-oxidation with chlorine dioxide.

- Advanced coagulation with ferric chloride (14.5 mg/l) and raw water acidification with a solution of 2.5 HCl (18.5 mg/l).
- Rinse the decanter with dynamic layer concentrated to hydraulic loads $i_h = 4$ m^3/h,m^2.
- The adjustment pH with lime water (dose of 28 mg/l).
- Rapid filtration on layer of quartz sand, filtration speed is $V_f = 60$ m/h.
- Post - oxidation with ozone (1 mg O_3/l) after rapid filtration on sand.
- Granular activated carbon filtration; filtration apparent speed $V_f = 5$ m/h, for a time $t_c = 8$ minutes of action.
- Final disinfection with sodium hypochlorite (chlorine dose 1 mg/l).

One of the parameters that analyze the mechanisms of rejection electrostatic forces decrease is the electrokinetic potential E_P, defined by the formula, (Green, 2009):

$$E_P = \frac{4 \,.\, \pi \,.\, \eta . v}{\varepsilon \,.\, E}, \qquad (1)$$

where: E_P - potential gradient, η - dynamic viscosity, ε - dielectric constant, v - electrophoretic mobility in an electric field. The potential cancellation P corresponds to the situation that can perform optimal reactions coagulation - flocculation.

The coagulation is a complex process in which the colloidal particles are aggregated into particles small enough weight to be removed. It can be considered as clotting process includes coagulant injection, chemical destabilization of particles and physical contact between particles. Coagulation process results in the overall process of aggregation of particles in the water to be treated.

The process known as "advanced coagulation" occurred as a result of reduction targets need natural organic matter (MON) in treatment streams. The systematic analysis of substances that lead to the formation of by-products from chlorination reaction, (Megelea, 2008) have demonstrated a linear relationship between organic carbon content and the amount of by-product water formed by applying disinfectant. It is a linear relationship between DOC and byproduct chlorinated, for groundwater and surface water:

$$THMFP = 43{,}78 \;.\; TOC^{1{,}248}, \; [\mu g/l], \qquad (2)$$

where: $THMFP$ – formation potential of trihalomethanes; TOC – organic carbon concentration total, [mg C/l].

The reducing concentration of organic substances in the water before applying the disinfectant can lead to a decrease in the concentration of by-products.

In table 1 are showed the allowance's requirements of the TOC and the gross water's alkalinity, that have to accomplished for the advanced coagulation, (condition 1), (Moss, 2008).

Table 1. Condition 1: Punctual allowance of organic carbon concentration total TOC

TOC, [mg C/dm^3]	Gross water's alkalinity, [mg/l $CaCO_3$]		
	0 ÷ 60	60 ÷ 120	120
2 ÷ 4	35 %	25 %	15 %
4 ÷ 8	45 %	35 %	25 %
> 8	50 %	40 %	30 %

The quality of the gross water from Prut River in period of the experimentations is showed in Table 2.

Table 2. The quality of the gross water (average values), (Megelea, 2008)

Indicator	Turbulence	pH	Organic substance	CCO-Cr	TOC	Alkalinity	Conductivity	TDS
M. U.	NTU	-	mg $KMnO_4$/l	mg O_2/l	mg C/l	mechiv/l	µS/cm	mg/l
Values	15÷26	8.08÷8	15.95÷18.92	12.88÷13.44	17.92	3÷3.4	536÷562	305÷315
Indicator	Hardness	Calcium	Magnesium	Bicarbonates	Chloride	Nitrates	Ammonium	Sulfates
M. U.	^{o}d	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Values	10.9÷12.32	48÷53.71	20.9÷24.30	183÷207	24.9÷30	3.2÷6.7	0.2÷0.34	90÷92

The adjutants are substances coagulation natural or synthetic used to enhance the performance of the coagulation process in the sense of obtaining large floaters higher shear strength.

The adjuvant doses of coagulation should be determined accurately by coagulation-flocculation tests and if necessary the resulting slurry tests (sedimentation coefficient of determination and cohesion), (Sundari, 2012).

A significant influence on efficiencies induced by additions of the polymers has time between injections of the coagulant and coagulation adjuvant. The polymers can lead to high effective only if injected after micro-flocculation phase is complete. This time is influenced by the water composition and temperature. The time must be established by experimental determinations for each case. Using flocculants lead besides increasing the coagulation efficiency, lower sludge volumes, (Haydar, 2010).

The doses of ClO_2, HCl, $FeCl_3$, $Ca(OH)_2$, O_3, Cl needed a year were correlated with the hydraulic and geometric parameters of drainage channels in the biological stage of water plant Chirita, in Iasi , Romania. The operating modes are analyzed for all channels - weir – hydraulic ram to feed all four channels of the wastewater treatment plants, Fig. 2.

In the treatment plant is necessary to correlate the volume of water transported charge Q under load H, (Fig. 3), with geometric and hydraulic parameters for biological stage aeration canals. These analysis underline of the optimization problem with two objective functions: total efficiency of treatment plant (must be maximum) and total electricity consumption for water treatment (should be minimum). For optimization method the authors have developed a computer programs TRIOPMCEETV for MATLAB protected to the Romanian Office for Copyright ORDA, certificate of registration in the National Register of Computer Programs S500 Series 1351 no. 04518/30.11.2010.

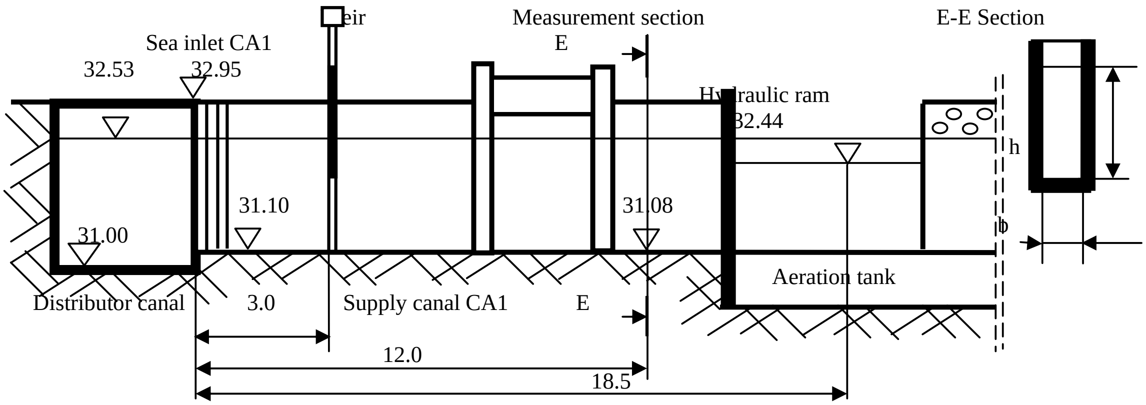

Fig. 2. Scheme for the hydraulic calculation at the supply CA1 of the aeration tanks for the biological tread, (plant Chirita).

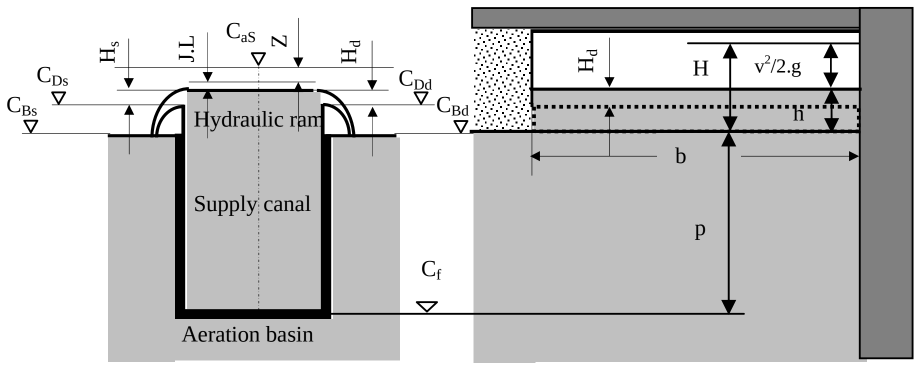

Fig. 3. Flow over the hydraulic ram scheme of supply canals in biological stage aeration basins

The hydraulic ram of aeration tank has rectangular section, Fig. 2. The dimensions for hydraulic ram are: h – water's depth in canal, [m]; b – breadth, [m]; p – height threshold, [m].

The canals are dimensioned for the biological stage in equable motion. Consider a hydraulic slope J of equation, (Chahar, 2007):

$$J = \frac{Q^2}{A^2 \,.\, C^2 .\, R} = a_1 + a_2 .Q + a_3 \,.\, Q^2 \;; \qquad R = \frac{A}{P};\; C = \frac{1}{n} \cdot R^{\frac{1}{6}}, \qquad (3)$$

where A - wetted area; C – Chezy coefficient; R - hydraulic radius; P - wet perimeter; n – roughness; a_1, a_2, a_3 – constants.

The head at hydraulic ram H_o depend on the transport flow Q and the specific flow q using the equation, (m - hydraulic ram flow module), (Chahar, 2007):

$$H_o(Q) = \sqrt[3]{\frac{q^2}{2 \,.\, g \,.\, m^2}} = \sqrt[3]{\frac{Q^2}{2 \,.\, g \,.\, m^2 .\, b^2}} \quad . \qquad (4)$$

The head at hydraulic ram H_o depend on height threshold p, hydraulic ram head H and transport flow Q through following formula:

$$H_o(H, p, Q) = H + \frac{Q(H, b, p)}{2 \,.\, g \,.\, b^2 .\, (p + H)^2}. \qquad (5)$$

The depth of the concerted h_c is calculated from following formula:

$$q(H, h_c) = \varphi .\, h_c .\, \sqrt{2.\, g.\, \left[p - h_c + H_o(H)\right]} \;. \qquad (6)$$

In Eq. (6) are used the following notation: φ = flow coefficient; h_c - depth of contracted area, [m].

3. EXPERIMENTAL RESULTS

Using TRIOPMCEETV for MATLAB computer program is calculated the hydraulic ram flow mode m depending on head H and height threshold p for a maximum rated capacity of the Chirita treatment station with the following form:

$$m(p,H) = \left(0{,}405 + \frac{0{,}0027}{H}\right).\left[1+\frac{0{,}55\,.\,H^2}{(H+p)^2}\right]. \quad (7)$$

General considered for calculation are as follows: g = 9.81 m/s^2; b = 1.98 m; b = 1.96 m; p = 0.5 m; h = (0.01…2) m; H = (0.01; 0.02…1) m; n = 0.015; J = 0.0018.

Using TRIOPMCEETV for MATLAB computer program is calculated the depth of the concerted h_c depending on the specific flow q:

$$hc = -\,0.03177 + 0.35552\,.\,q - 0.06892\,.\,q^2, \quad (8)$$

and the head at hydraulic ram H_o depend on the specific flow q:

$$Ho = 0.14791 + 0.60568\,.\,q - 0.09269\,.\,q^2. \quad (9)$$

Fig. 4 shows the concentrations variation for organic carbon concentration total TOC, concentration of organic substances determined by potassium permanganate method CCO-Mn and concentration of organic substances determined by potassium dichromate method CCO-Cr depending on treatment step of Chirita plant. This analysis shows the following aspects:

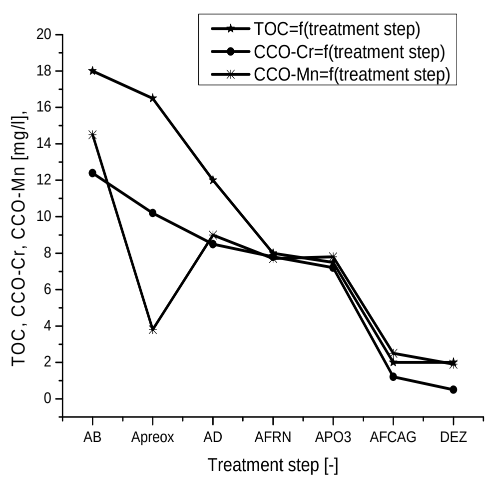

Fig. 4. The concentrations variation for organic carbon total TOC [mg C/l], organic substances CCO-Cr [mg O_2/l] and CCO-Mn [mg $KMnO_4$/l] depending on treatment step

-The organic substances concentration in the classical way of treatment (settling - sand filtration) has lessened to 14.44 mg $KMnO_4$/l in raw water at 7.57 mg $KMnO_4$/l in filtered water on quartz sand (efficiency reduction of 47.6%).

-The organic content has increased slightly by after ozone due to oxidative transformation of hard substances oxidized CCO-Mn method.

-The organic substances concentration has decreased after granular activated carbon adsorption values of 1.7 mg $KMnO_4$/l in water disinfected (values of total organic carbon concentration below 2 mg/l in water according to the concept of bio-stable).

-The hardly oxidable organic substances concentrations were determined by the CCO-Cr, or total organic carbon TOC on the treatment way analysis.

Fig. 5 shows the formation potential of trihalomethanes THMFP variation depending on treatment step for Chirita plant, using Eq. (2).

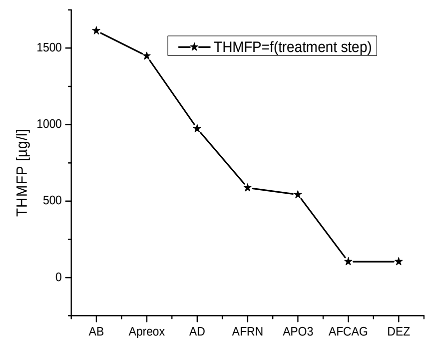

Fig. 5. Formation potential of trihalomethanes THMFP variation depending on treatment step

The notations used in Fig. 4 are: AB – gross water; Apreox. - ahead of oxidation with ClO_2; AD – decanted water; AFRN – filtered water on sand; APO_3 - after ozonized water; AFCAG - filtered water on granular active coal.

It is analysed the variation between the necessary of mass by day for the substances used fot the treatment steps in Chirita plant depending, on the hydraulic slope J for height threshold p = 0.5 m, Fig 6 and p = 0.9 m, Fig. 7.

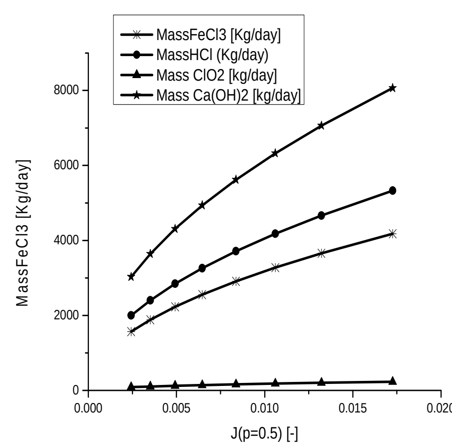

Fig. 6. Mass $FeCl_3$, Mass HCl, Mass ClO_2 and Mass $Ca(OH)_2$ variations depending on hydraulic slope J for height threshold p = 0.5 m

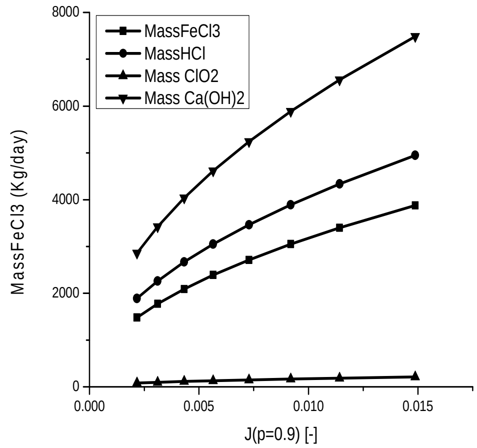

Fig. 7. Mass $FeCl_3$, Mass HCl, Mass ClO_2 and Mass $Ca(OH)_2$ variations depending on the hydraulic slope J for height threshold p = 0.9 m

Fig. 8 shows the head at hydraulic ram H_o and the depth of the concerted h_c variations depend on the specific flow q, using Eq. (8), respectively Eq. (9).

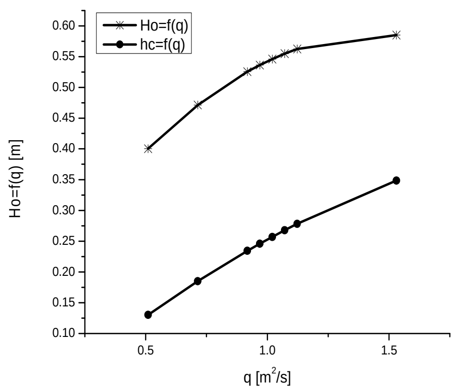

Fig. 8. Head at hydraulic ram H_o and the depth of the concerted h_c variations depend on the specific flow q

4. CONCLUSIONS

The results shown in Figures 6 and 7 indicate the following:

-Similar behaviour for all indicators examined: CCO-Mn, CCO-Cr, TOC, (Megelea, 2008).

-The reduction of COD, up to values of 8 mg O_2/l in rapidly filtered water on sand layer and disinfected, respectively 0.5 mg O_2/l in the GAC filtered water and disinfected.

-The reducing TOC values of up to 8.06 mg C/l in the filtered water quickly on sand layer (reduction efficiency 55.7%), respectively 2.16 mg C/l in the filtered water (removal efficiency of 88%).

The results indicate a high efficiency of the way adopted (advanced coagulation - settling - pH correction - rapid filtration on sand – after ozone - CAG filtration - disinfection).

The geometrical dimensions of the drainage channel at the biological stage strongly influence hydraulic parameters of treated water.

The quantities of the substances used in water treatment steps depend on drainage channel geometry and hydraulic parameters variation.

Rehabilitation treatment is required by the design Chirita treatment ways, in particular those of coagulation - flocculation as priority processes and establish objective criteria for the choice of the product performance in manufacturing of water intended for human consumption.

5. REFERENCES

1. Chahar, B. R., (2007), *Optimal Design of a Special Class of Curvilinear Bottomed Channel Section*, *J. Irrig. Drain. Eng.,* 133 (3), pp. 571-576.

2. Dolezilek, D., Amandeep Kalra, A., (2013), *Power Management and Automation Scheme for Water Canal Networks*, Pb. Schweitzer Engineering Laboratories, Inc, pp. 1 - 8.

3. Geriesh, M. H., Balke, K. D., El-Rayes, A. E., (2008), *Problems of drinking water treatment along Ismailia Canal Province, Egypt*, Journal of Zhejiang University SCIENCE B, 9(3), pp. 232-242.

4. Ghazaw, Y. M., (2010), *Design Charts of Optimal Canal Section for Minimum Water Loss*. Journal of Engineering and Computer Sciences, Qassim University, Vol. 3, (2), pp. 73-95.

5. Green, P. C., (2009), *Modelling water and sediment chemistry in urban canals using chironomid pupal exuviae*, PhD Thesis, University of Birmingham.

6. Haydar, S., Ahmad, H., Aziz, J. A., (2010), *Optimization of coagulation-flocculation in the treatment of canal water*, Environmental Engineering and Management Journal, November 2010, Vol. 9, No. 11, 1563-1570.

7. Megelea, E., (2008), *The Optimizing chemical coagulation - flocculation in water treatment*, PhD Thesis, Technical University of Civil Engineering of Bucharest, Romania.

8. Moss, B., (2008), *The Water Framework Directive: total environment or political compromiso*, The Science of the Total Environment, No 400, pp. 32–41.

9. Sundari, T., Kulandaivel, A.R., (2012), *Water Quality Assessment of Kalingarayan Canal*, Coromandal Journal of Science, Vol. 1, No. 1, pp. 20 - 21.

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