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New Type Filtration, Ion-Exchange, Sorption Small Multi Process Water Conditioning Device Used as a Multi Cell Water Deionizer

Angel Zvezdov and Dilyana Zvezdova
*Prof. Dr. Asen Zlatarov University of Bourgas,
Department of Water treatment Technology, Bourgas,
Bulgaria*

1. Introduction

Sand filtration, ion-exchange and sorption methods are often used in the design of small water treatment devices. Such designs are suitable for use in the technological water conditioning plants before small ultra-pure water point-of-use systems, typical laboratory application, a feed to autoclaves, and environmental cabinets. Present work is an attempt to create a simple and easily used water treatment device for the cost effective production of general laboratory grade water (Catalog ELGA Co.,2008; Catalog Purity Ltd., 2007). This trend utilizes a combination of technologies including membrane processes, ion-exchange, adsorption, sanitization etc. (Adjarov G.,1998). That sets our device apart is the unique process which provides a constant supply of high purity laboratory water and is more cost-effective and convenient for the user. Usually, small water treatment deionization systems include ion-exchange cartridges, the ion-exchange capacity which is exhausted during the working period has to be regularly regenerated for continued use. Some producers (Catalog ELGA Co.,2008; Catalog Purity Ltd., 2007; Catalog CHROMSERVISE s.r.o.-Chehia, 2003) accept as a more cost-effective and convenient solution the replacement of ion-exchange cartridges with ready regenerated cartridges by specialized work departments. Purchasing ready made replacement cartridges supplied by specialized dealers, requires the user to be a subscriber to this department. Other producers design ion-exchange plants with regeneration systems (reagent vessels, pumps, valves, tubes etc.). It enables local regeneration procedures to be completed by the user (Plehov G.,1997 ; Zvezdov A., et.al).The decision on which kind of design should be purchased to equip the laboratory depends on many considerations: distances and transport prices; manual service expenses; operative procedures and their complication; personal qualification etc. On the basis of the above mentioned items it should be concluded that there is a necessity to research and enhance the activity for creation of new designs for small water deionization plants. The researchers and designers are looking for a simple, cheaper laboratory water treatment system. These research works are typically important in hard water areas where ion-exchange cartridges are replaced frequently. It is important as a cost-effective choice for labs that require higher

volumes of water, as well. The purpose is to create and evaluate a multi cellular small water treatment ion-exchange and sorption device with a simple, cost-effective and user friendly design. The design should allow the regeneration of exhausted ion-exchange and sorption beds to be made locally by the user. From a scientific point of view it is important to clarify the influence of the physical (pore) structure of ion-exchange resins and adsorbents used. The ability to be effectively regenerated and washed to remove the organic humus substances retained into their pore structure during the working functional period of deionized water production.

2. Experimental

As an example for its different functionality, the multi process small water treatment filtration device has been designed to provide uncompromising deionized water quality while still being affordably priced. The device consists of three separated vertical cells which could be loaded by different filtration and sorption materials. It has only three valves for treated water and regeneration flows regulation (Fig.1). In the researched case, the three cells filtration body was loaded by ion-exchange resins and active carbon sorption material. The unit is evaluated as a device to produce deionized and sorption purified water. It produces secondary grade purified water in accordance with standards (BDS ISO 3696, 1993) from a potable source in a wide range of volumes for laboratory and small industrial applications. The device created can handle most laboratory water needs, from reagent preparation and glassware washing to sensitive instrumentation analyses. The ion-exchange and sorption methods have been researched are incorporated in an innovative design of a three cellular one body small water deionizer. It could be localized on a mobile fundamental frame and can be moved easy if it is necessary. A flow type conductance apparatus is included to the design for a continuous monitoring and control of the deionized water quality. The device could operate from a range of tap water pressure between 0,2 to 0,6 MPa. The flow rate of the deionized water produced was up to 200 dm³/h. The continuous water monitoring was achieved by means of a flow conductance control apparatus which is situated on the front panel.

The regeneration of the exhausted ion-exchange and sorption beds could be accomplished on the basis of gravitation phenomenon (by means of reagent containers localized to a suitable height), locally by the user. For greater convenience there is a choice of bench, under bench and wall mounting options to best suit the layout of the laboratory or site. A major technological contribution was possibility to realize five processes into one filtration body with just three valves for flow rate controlling included in the construction (Fig.1). During the water deionizing experiment, we loaded the three chambers as follows:

- layer of weak acid cation-exchange resin (Dowex MWC-2) H-R_w (hydrogen form) and a layer of strong acid cation-exchange resin (Dowex MSC-1) H-R_{str} (hydrogen form) in the chamber between walls 1 and 2;
- layer of weak base anion-exchange resin (Dowex MWA-1) R_w-OH (hydroxyl form) and a layer of strong base anion-exchange resins (alternative: Dowex MSA-1, Dowex MSA-2, Amberlite IRA-938) R_{str}-OH (hydroxyl form) in the chamber between walls (2) and (3). This chamber was loaded with polyreticular (Dobrevsky Iv.& A. Zvezdov, 1999) true porous (Kunin R., 1968) ion-exchange resins to be able to reduce humus natural organic impurities from the water treated (Einsatz und Schaltung Leverkusen, Bayer-AG, 1970);
- layer of active carbon or bioadsorbent hitosan sorption material in the central chamber.

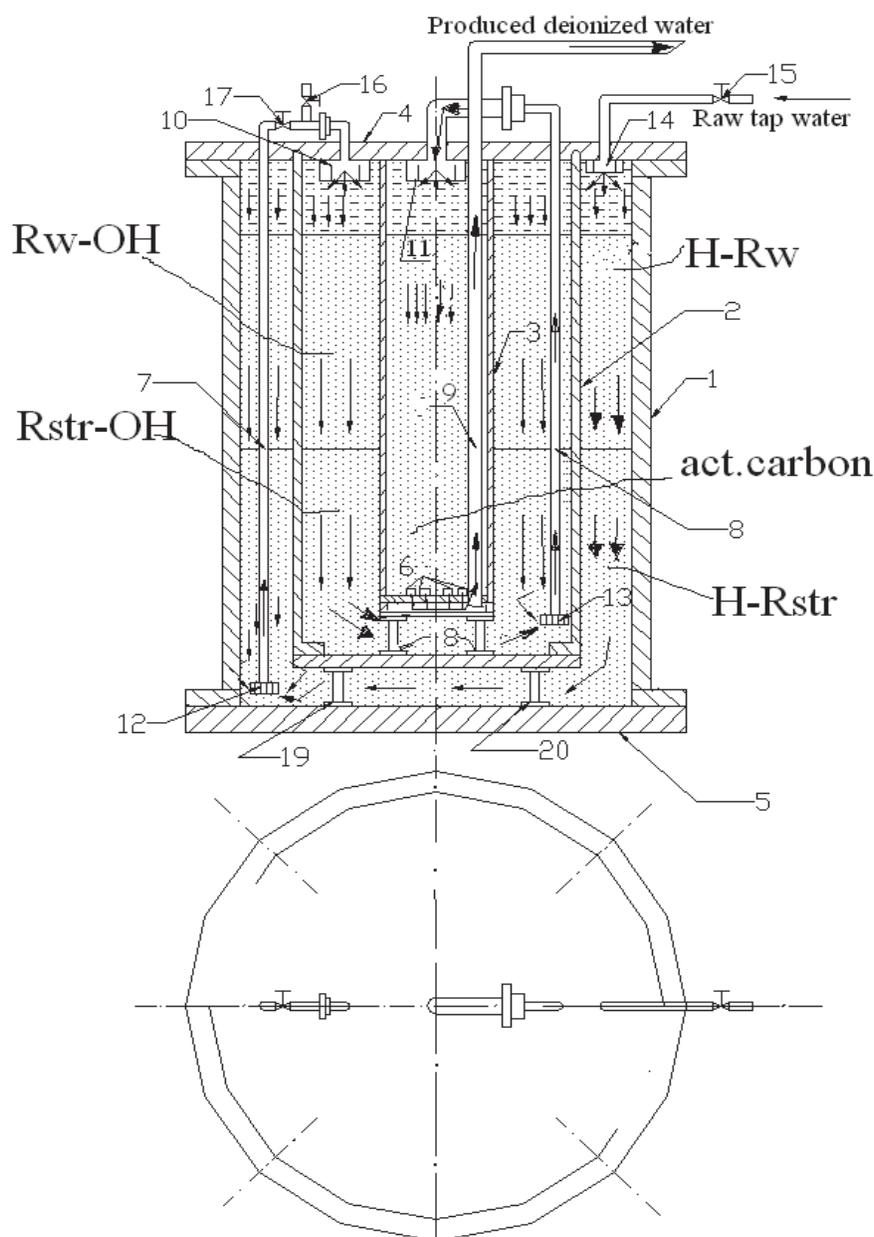


Fig. 1. Design of Multi process ion-exchange and sorption small water conditioning device: 1-outside body; 2,3- inside bodies; 4- upper cover; 5- bottom; 6,10÷14-scatter nozzles; 15÷17 - valves; 18÷20-bearings; H-R_w-weak acid cation-exchanger (hydrogen ion form); H-R_{str}-strong acid cation-exchanger hydrogen ion form); R_w-OH-weak base anion-exchanger (hydroxyl ion form); R_{str} -OH - strong base anion-exchanger (hydroxyl ion form)

One very important role was weak base anion-exchange resin (Dowex MWA-1). The importance was due to the sorption-desorption ability of this resin. Actually it possesses an ability to realize an adsorption process of natural humus insoluble substances on its surface area during the working period, purifying the treated water flow. Then it was able to clean its porous structure and surface area, respectively from this organic natural substances during the period of reagent regeneration process by sodium hydroxide. This resin did play an important protection role to the strong base anion exchange resin against an irreversible poisoning of the ion-exchange functionality (Dobrevsky Iv.,1991).

In order to clarify the effect of physical structure of the filtration materials loaded in the device on the technological behaviour of water treatment device, their physical structure was investigated by means of electron scanning microscope and mercury intrusion apparatus („POROSIMETER-1500“ CarloErba-Strumentazione-Italy). The physical structures of adsorption active carbon materials are shown in (fig.2-5). Pore size distribution curves of ion-exchange resins used are shown in Fig. 6, 7.

The electron scanning microscope photographs for active carbon physical structure show uniformity of pore sizes. Actually it is an identity pore channel physical structure. Average size of both types active carbon pores is approx. 13-14 μm . It is a suitable pore sizes for a sorption process to remove the organic colloidal natural impurities that possess sizes between 0,10-0,001 μm (Alekin.O.A., 1970).

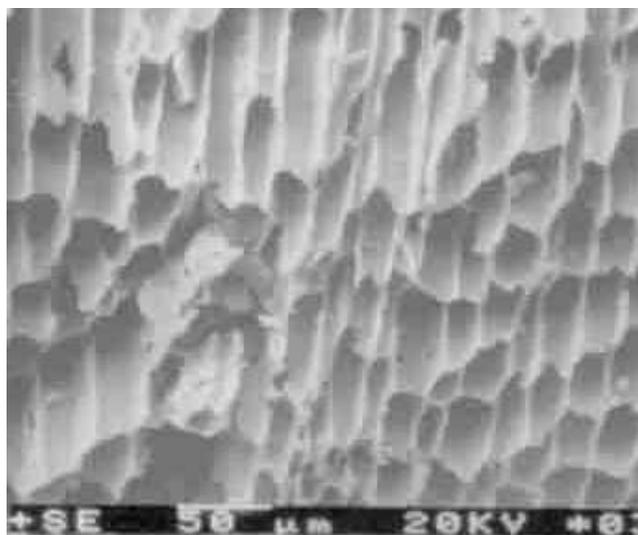


Fig. 2. Electron scanning microphotography of active carbon "AP-4-60" (magnified 10⁴times)

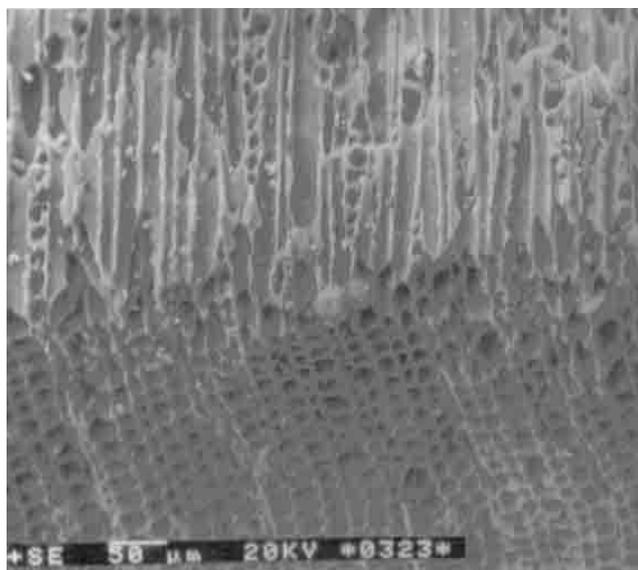


Fig. 3. Electron scanning microphotography of active carbon AC-Luise (magnified 10⁴times)

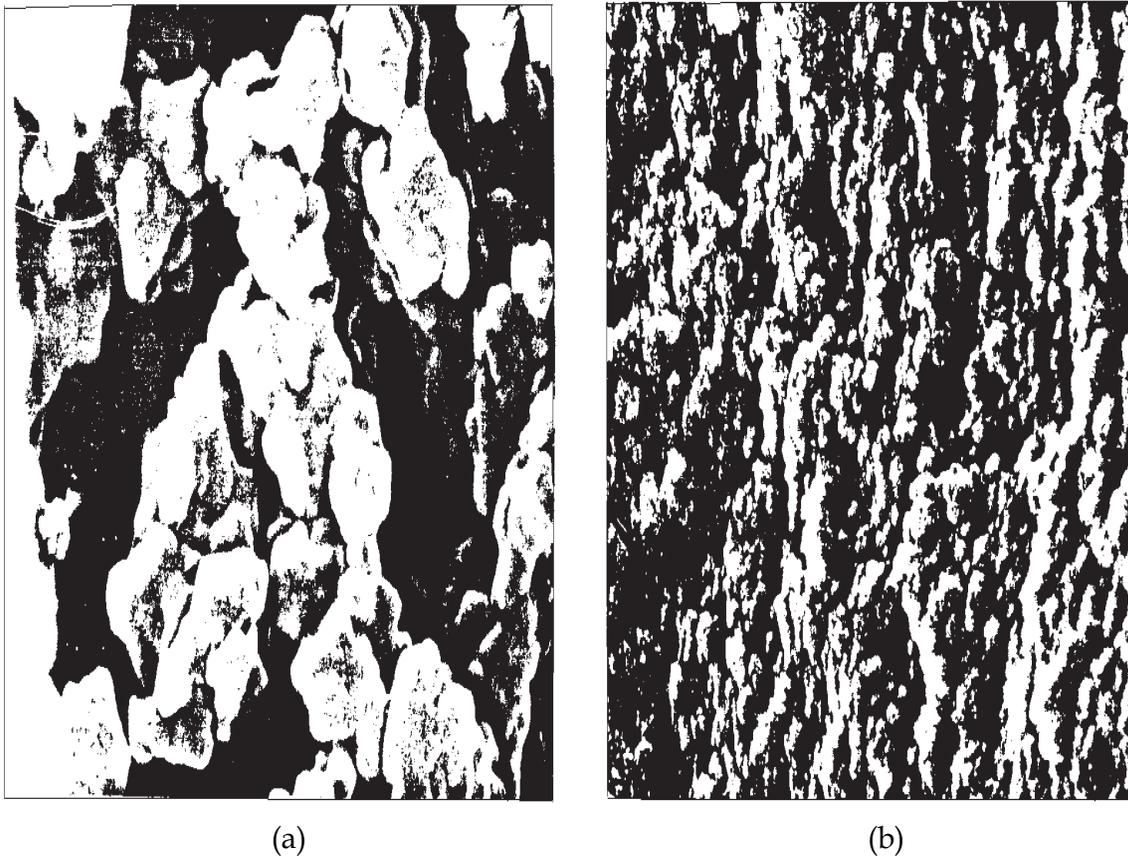


Fig. 4. Electron scanning microphotography of strong base anion exchangers: a) Amberlite IRA-938; b) Dowex MSA-1 (magnified 10^4 times)

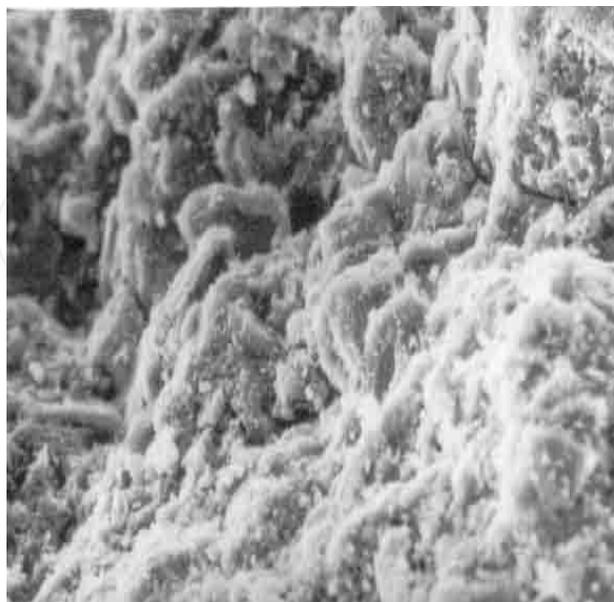


Fig. 5. Electron scanning microphotography of weak base anion-exchange Dowex MWA-1 (magnified 10^4 times)

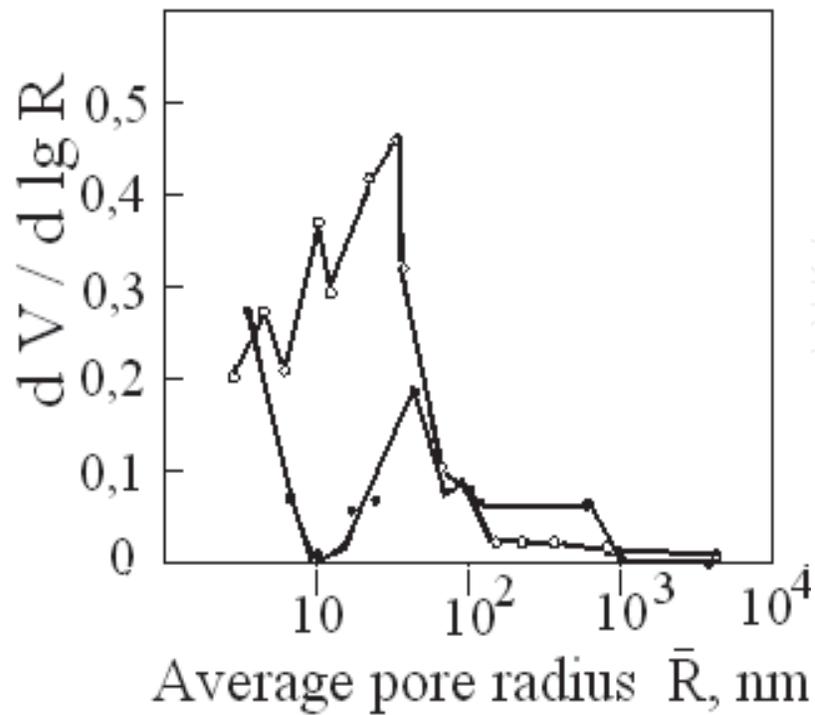


Fig. 6. Differential pore size distribution curves of weak base ion-exchange resins: **o-o-** Dowex MWA-1 (weak base anion-exchanger); **•-•-** Dowex MWC-2 (weak acid cation-exchanger)

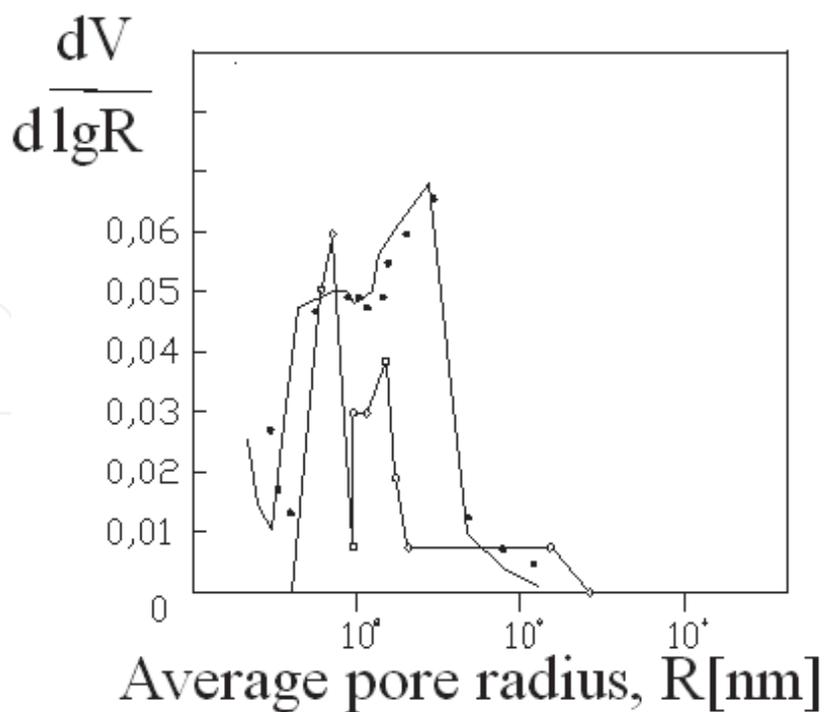


Fig. 7. Differential pore size distribution curves of strong base anion exchange resins: **o-o:** Dowex MSA-1; **•-•:** Dowex MSA-2

Pore size distribution curves of ion-exchange resins used, show the average pore size of predominated pores as follows:

- strong base anion exchanger Amberlite IRA-938: $R_{\text{average}}=7500$ nm
- strong base anion exchanger Dowex MSA-1: $R_{\text{average}}=6-13$ nm
- strong base anion exchanger Dowex MSA-2: $R_{\text{average}}=5-45$ nm
- weak base anion exchanger Dowex MWA-1: $R_{\text{average}}=5-50$ nm;
- weak acid cation exchanger Dowex MWC-2: $R_{\text{average}}=5-60$ nm;

The physical pore structure properties of adsorption and ion-exchange filtration materials loaded in the small water treatment device researched explain the significant reduction of permanganate demand value of raw natural water treated (from $P = 3,2 \text{ mg O}_2 / \text{dm}^3$ to the values shown in Table 3).

The multi process ion-exchange and adsorption small water conditioning device functioned as follows:

2.1 Working functional period

The raw tap water (Table 1,2) was fed through the valve (15). It was processed with the following:

- layer of weak acid cation-exchange ($H-R_w$);
- layer of strong acid cation-exchange resin ($H-R_{\text{str}}$); a weak base anion-exchange resin ($R_w\text{-OH}$) layer;
- layer of strong base anion-exchange resin ($R_{\text{str}}\text{-OH}$) layer;
- layer of active carbon layer (central cell). Actually in the central (last) chamber was realized a sorption process, but in the surrounding besides chambers before the sorption process were realized four ion-exchange processes as follows:
- weak acid cation-exchange process and strong acid cation-exchange process in the first two layers [ion-exchange chamber between walls (1) and (2)];
- weak base anion-exchange and strong base anion-exchange processes in the second two layers [ion-exchange chamber between walls (2) and (3)].

In the first cation-exchange chamber was realized a cation-exchange removal process and by this process H -ions from cation-exchanger's polymer matrix were changed with all cations included in the treated raw tap water. All the mineral salts dissolved in the water treated were transformed to acids. Then the acids contents water flow goes in the second anion exchange two layers chamber between walls (2) and (3). This chamber was loaded by weak base and strong base anion-exchangers in OH -ion form ($R\text{-OH}$). By the contact with anion-exchange resins loaded there, all these acids were transformed to equivalent new water molecules. Such a way the salty raw tap water became to be desalinated. Then the water flow was going through the central adsorption chamber (3) and it contacts the active carbon to be purified from organic halogen, natural humus organic impurities and partially from heavy metals compounds. Finally the purified water flow product went out by a special situated (Zvezdov A., 1999) suitable pipe to be used by a user.

2.2 Scarify backwash functional period

Functioning as a scarify backwash water flow, the feeding raw tap water did enter through the tube (9), carbon bed, tube (8), nozzles (13), (10), valve (17), nozzles (12),(14), valve (15) and the flow was going out to the drainage waste water communication of the building for approx. of 10 minutes.

2.3 Reagent regeneration periods

2.3.1 Acid reagent regeneration period

Above the water treatment device was situated reagent tank connected by reinforced hose to valve (15). During the first regeneration step it was filled with 10 % HCl solution. On the basis of gravitation phenomenon, the opened valves (15) and (17) did allow the acid regeneration solution to pass through valve (15), nozzles (14,12,10,13,11,6) contacting the weak acid cation-exchange, strong acid cation-exchange, weak base anion-exchange, strong base anion-exchange resins and active carbon beds. Such a way the acid solution did transform (regenerate) to hydrogen ion-form of the functional ion-exchange groups into the polymer matrix of weak and strong acid cation-exchange resins ($H-R_w; H-R_{str}$) (Dobrevsky Iv.,1991). In parallel it exhausted the functional ion-exchange groups into the polymer matrix of weak and strong base anion exchange resins. Passing through the active carbon adsorbent bed, the acid solution did remove from its porous sorption structure the impurities which are soluble at $pH < 7$ (it is called acid activation process).

2.3.2 Washing period for $H-R_w$ and $H-R_{STR}$ filtration beds

A. Slow washing process

A feeding row tap water was going in through the same flow way (opened valves 15, and 17) as the reagent regeneration period, but slowly with approximately same linear velocity as the reagent regeneration period (10 minutes).

B. Fast washing process

A feeding row tap water was going in through the same flow way (opened valves (15) and (17) as the reagent regeneration period. It was faster than during the slow washing process (for 30 minutes with approximately same linear velocity run like during the working functional period).

2.3.3 Alkaline reagent regeneration period

After the washing processes, the situated above the water treatment device reagent tank was connected by reinforced hose to opened valve (16) (but valve 17 was closed). To perform the second regeneration step reagent tank was filled with 5 % NaOH solution. The opened valves (16) and produced water output did allow the alkaline regeneration solution to pass through nozzles (10, 13, 11, 6) to contact the weak base anion-exchange, strong base anion-exchange, and active carbon beds. Such a way the alkaline regeneration solution did transform (regenerate) to hydroxyl ion form the functional ion-exchange groups into the polymer matrix of weak and strong base anion exchange resins ($R_w-OH; R_{str}-OH$). Passing through the active carbon adsorbent bed, the alkaline regeneration solution did remove from its porous sorption structure the impurities which are soluble at $pH > 7$ (it is called alkaline activation process).

2.3.4 Washing period for R_w-OH and $R_{str}-OH$ filtration beds

A. Slow washing process

The feeding row tap water was connected by reinforced hose to valve (16). It went through the valve (16) nozzles (10,13,11) and (6) to wash the weak base anion-exchange, strong base anion-exchange, and active carbon beds (for 20 minutes with same flow way and flow rate as the reagent regeneration period).

B. Final washing process

The feeding raw tap water went through the valve (15), weak acid resin $H-R_w$ layer; strong acid cation-exchange resin $H-R_{str}$ layer; weak base anion-exchange resin R_w-OH ; strong base anion-exchange resin $R_{str}-OH$; active carbon bed (same flow way and approximately same velocity as working functional period, but the flow was dumped to the building drainage system until the flow conductance apparatus indicates the necessary water electric conductivity (after approx. 30÷40 minutes). Then the working functional period producing deionized water began again.

To achieve a better quality of deionization water processes the module could be doubled (fig. 10.).

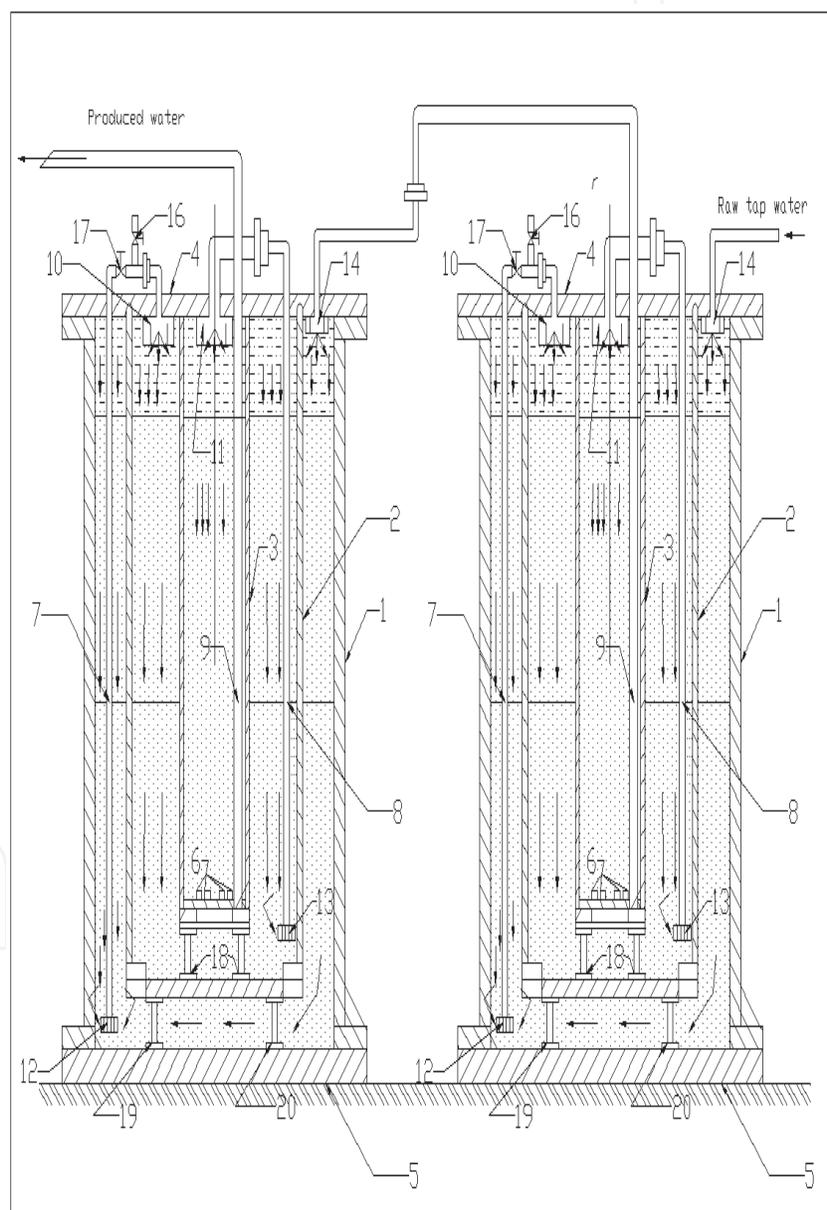


Fig. 10. Duplex module deionization bench scale tap water treatment device for laboratory grade water production according BDS ISO 3696: 1- outside body; 2,3- inside body; 4- upper cover; 5- bottom; 6,10 -14 - scatter nozzles; 15-17 - valves; 18-20 - bearings

The water treatment device had not automation. It was reasonable because the quantity of deionized water produced between two regeneration procedures was approx. 2000 dm³ (depending on the size of filter body and raw tap water salt content, the productivity could be increased or decreased). This quantity was consumed by the laboratory approximately during 150÷200 days. It means that for laboratory use, two times a year (maximum) was necessary to change the flow directions using regeneration solutions. The regeneration procedures could be easily done by means of two manually turned valves, without necessity of electronic automation. A broad range of optional accessories were also available to further complement deionization device: remote display; full range of water storage reservoirs with an availability for water produced level governor etc. (if it was defined like necessity).

3. Results and discussion

A series of pilot experiments have been carried out. The R-H and R-OH ion-exchange beds were loaded by polyreticular [10] ion-exchange resins to be able to reduce humus natural organic impurities from the water treated (Kunin R., 1968; Dobrevsky Iv., 1991). The specific electrical conductivity of the water produced was measured by a flow conductivity meter apparatus. Two working filter cycles were performed:

- The first working cycle was carried out and 2300 dm³ deionized water was produced. It is ended when the conductivity meter showed $\chi \geq 5 \mu\text{S}/\text{cm}$. For the initial 1900 dm³ the specific electrical conductivity was 1 to 2 $\mu\text{S}/\text{cm}$ and then slowly increased up to 5 $\mu\text{S}/\text{cm}$.
- The second working cycle was with the duplex module device (Fig.10). The specific electrical conductivity achieved of the water produced 0,27 to 0,38 $\mu\text{S}/\text{cm}$. About 250 dm³ water was produced with this value of specific electrical conductivity.
- The analytical measurements of the properties of the deionized water obtained at a flow rate $Q = 150\div 200 \text{ dm}^3/\text{h}$ have been carried out in accordance with the parameters required by BDS ISO 3696 provides pure water to ISO 3696 and BS and ASTM D1193-99. The results obtained are presented in Table 3.

The results in Table 3 show that the properties of the water produced by the small water deionization device comply with the requirements for water with primary or secondary degree of purity (BDS ISO 3696, 1993; ASTM D 1193-99, 1999). Therefore, it is concluded that the product can be used for usual laboratory needs, as well as for more high quality laboratory needs, instead of the expensive water prepared by electrical distillers (Petkov K., et al., 2007; Petkov K. & A. Zvezdov, 2007).

An example for ultra pure water production by small local water treatment plant used for high quality urea solution AUS 32 defined by DIN 700070 is shown in next text. On the base of design and results discussed above a small local water treatment plant for high quality urea solution AUS 32 defined by DIN 700070 is created. The technological parameters of this plant are researched during the ultra pure water production used as a solvent for urea solution AUS 32. A very salty under-ground water was treated to get a deionized ultra pure water with specific electric conductivity $\chi \leq 1 \mu\text{S}/\text{cm}$. It was used as a solvent during the automotive grade urea solution (AUS 32) production. The product obtained was according to quality requirements of DIN 700070. The role and use of deionized ultra pure water addressed to quality assurance guidance document (QAGD) is discussed.



Fig. 8. Photography of a pilot one body multi stage multi cell water deionization filtration device



Fig. 9. Photography of a flow distributing and conductivity measuring part of the pilot one body multi stage multi cell water deionization filtration device

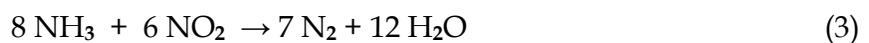
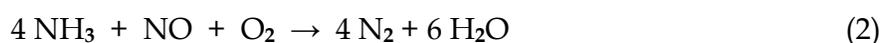
After evaluation different concepts to meet the Euro IV (10/2006) and Euro V (10/2009) standards for heavy-duty vehicles, the automotive industry has decided to use the Selective catalytic reduction (SCR)-technology with AUS 32 (Quality assurance Guidance on AUS 32, 2005) as a reducing agent for most of these vehicles. The SCR-technology has demonstrated the capability to reduce nitrogen oxides emissions from heavy-duty trucks in test cycles and in on the real road operation. The combination of fuel-economy-optimized engines with low particulates and SCR is able to meet the Euro IV and Euro V regulation. The mentioned above technology with AUS 32 as a reducing agent has already been applied successfully to stationary applications, waste incinerators, power plants and to mobile Diesel engines in application such as ships and locomotives.

The basic chemical reaction (Quality assurance Guidance on AUS 32, 2005) of the urea SCR-process is as follows:

AUS 32 is injected into the hot exhaust gas and is hydrolysed above approx. 180 °C forming ammonia (NH₃) according the following reaction equation:



At the homogeneous extruded, base metal SCR catalyst the following reaction takes place to convert nitrogen oxides with NH₃ from the hydrolysis reaction to nitrogen and water (very positive ecological waste products).



On the base of the design discussed above, a small local water treatment technology plant was researched for this purpose. This paper describes the technological scheme, its components and recommended production parameters in producing a ultra pure deionized water to get 32.5% aqueous urea solution AUS 32 DIN 70070 grade, to preserve the quality of the solution from production via storage, handling and distribution to the enduser. A water as a solvent plays very important role to be obtained necessary quality of the product and additionally the water properties are important also for washing procedures of product handling, storage reservoirs, distribution pipe system etc. A water takes a great deal to environmental protection aspects also. Its purity deals all participants in the distribution chain, producers of AUS 32, logistics partners, public filling and truck stations. They should draw their attention to common guidelines concerning producing, handling in such a way that the intended high quality of AUS 32 will be maintained from the point of production to the point of enduse.

The water treatment plant is designed as a combination of different water technology methods (percolation; ion-exchange softening (Type DMEaWZD); reverse osmosis; ion-exchange deionization) (Fig.11).The technological scheme is created on the base of raw water properties (Table1,2). It is a suitable decision, because of relatively high salinity of this underground water.

Because of very serious probability to obtain a dangerous scaling phenomenon on the reverse osmosis membrane surfaces, a first module on the raw water treated line is a softening module (DMEaWZD). It is an automatically controlled duplex type ion-exchange softening plant (Fig.11). After that, the water flow is treated by reverse osmosis module and then is finally conditioned by a filtration trough multi process mixed-functioning module (H-cation exchange / OH-anion exchange; adsorption processes). This module has a design (Zvezdov A.,1997) shown on (Fig. 1, 8,13)

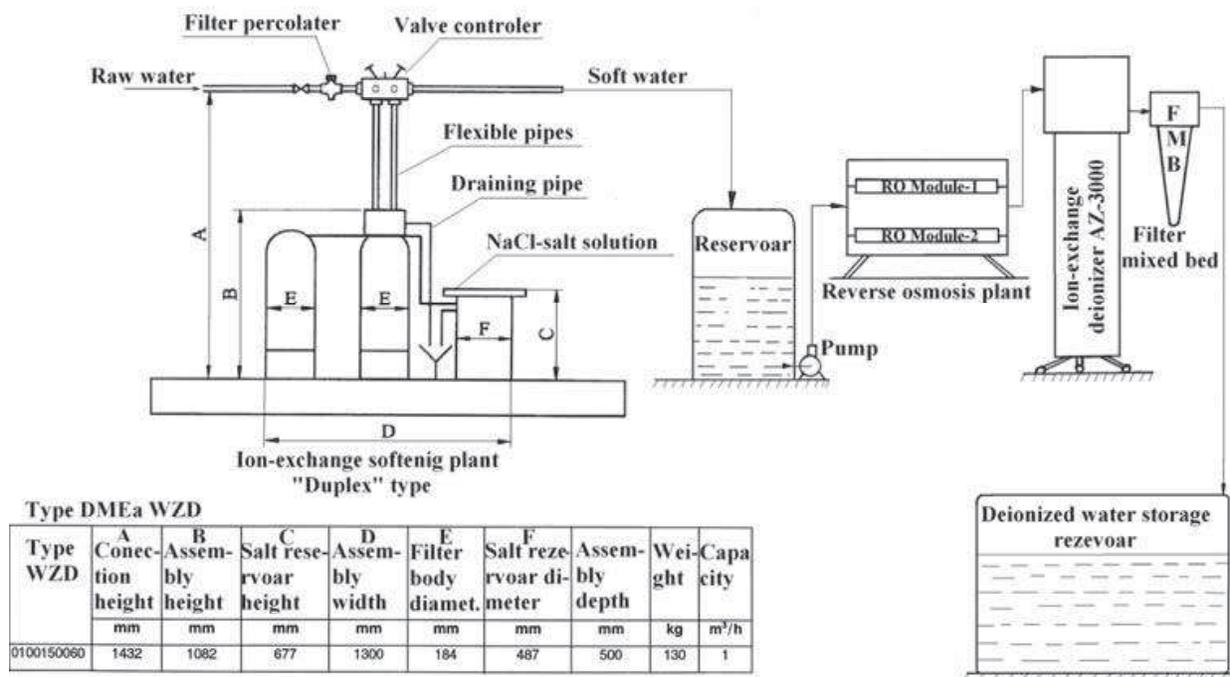


Fig. 11. A technological scheme for ultra pure deionized water production used as a solvent for 32.5% aqueous urea solution AUS 32 DIN 70070 grade

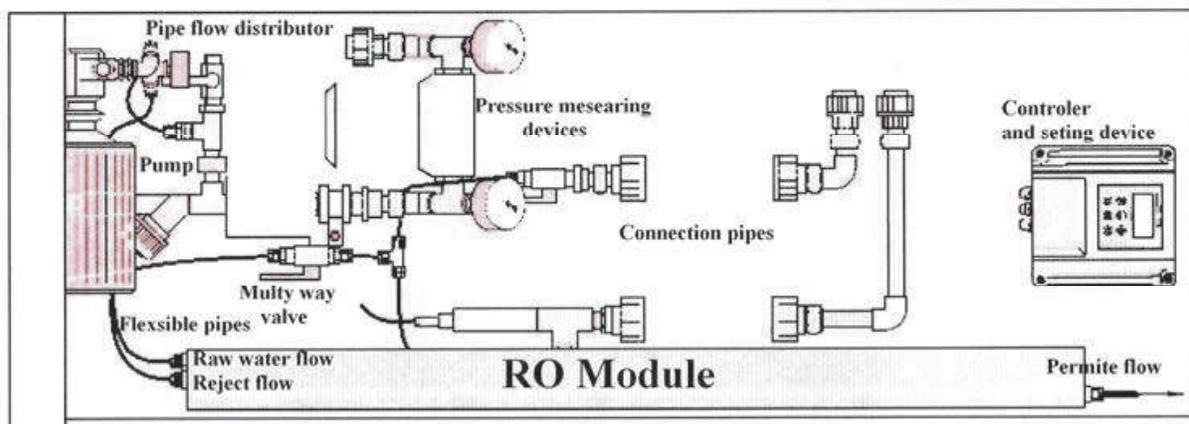


Fig. 12. Reverse osmosis module included into the technological scheme for ultra pure deionized water production

Such designs are suitable for use in the technological water conditioning plants after membrane water treatment modules as a point-of-use final systems (typical finally used module for a deep deionized water-product). Present investigation is an attempt to include a simple and easily used ion-exchange water treatment device in the technological plant for cost effective production of aqueous urea solution AUS 32 DIN 70070 grade 32 (Quality assurance Guidance on AUS 32, 2005). This trend utilizes a combination of technologies including membrane processes, ion-exchange, adsorption, etc. That sets our device for the unique process which provides a constant supply of high purity deionized water and is more cost-effective and convenient for the user.

The properties of raw water used for a production of solvent in AUS 32 production processes are presented in Tables 1 and 2. The schemes for water treatment plants are shown on Fig.11 and 12 with all main technological components. The water treatment plant includes the created new type small ion-exchange water deionizer (Zvezdov A.,1997; (Zvezdov A.,1999) (fig.1, 13).The regular reagent-regeneration processes of ion-exchange beds into main filtration deionizer body are necessary. The reagent flows pass through the filter under gravitation (see Fig.1).The presence of an operator, control or monitoring are not necessary during this process. The device is designed and constructed so as the reagent hydrostatic pressure from the regeneration reservoir drives the two regenerating solutions through the ion-exchange beds at linear velocities suitable for the kinetic of regeneration processes and the flows are drained after their mixing in a neutralizing collection module (it was explained above). Technological project calculations were carried out and then a technological scheme for ultra pure deionized water production was realized. A pilot experimental water treatment plant was made and series of pilot experiments were carried out in two alternative ways : with one or with two FMB modules. The deionized water produced was used as a solvent for 32.5% aqueous urea solution AUS 32 DIN 70070 grade. The R-H and R-OH ion-exchange modules and FMB modules were loaded with polyreticular ion-exchange resins to reduce humus and natural organic impurities from the treated water. The specific electrical conductivity of the water produced was measured by a flow type conductance measuring apparatus equipped with two sensors. When the capacity of the device is exhausted, its functionality as a deionizer is recovered by treatment of the ion-exchange beds with reagent regeneration solutions as follows (see Fig.1, Fig 8 and Fig.13):

- a solution of 5÷8% hydrochloric acid is passed through the exhausted ion-exchange R-H beds;
- a solution of 5÷6% sodium hydroxide is passed through the exhausted ion-exchange R-OH beds;
- the FMB module is filled with a mixture of a strong acid cation-exchanger and a strong base anion-exchanger(type MB), preliminarily regenerated into H⁺ and OH⁻ ion forms, respectively *;
- a possible alternative is to use the central cell of main filtration body as a sorption module charged with active carbon (Fig.1) in order to achieve the requested value of permanganate demand of the water obtained required by BDS ISO 3696 and DIN 70070 (there is such option instead of additional adapted separate module after mixed bed (FMB) ion-exchange module).

When the periods of washing fillers from the residual reagents and waste regeneration products are completed, the ion-exchange device switches to working period (according to technological requirements - when the target specific electrical conductivity measured by the flow conductivity meter is reached). The results obtained are presented in Table 3.

The results in Table 3 show that the properties of the water produced by the small water deionization device comply with the requirements for water with primary or secondary degree of purity (BDS ISO 3696,1993;ASTM 1193, 1999; DIN 70070) Therefore, it was concluded that the product can be used as a solvent of urea to produce AUS 32; for usual laboratory needs, as well as for more precise laboratory analyses both for laboratory and small industrial purposes.



Fig. 13. Photography of a multi process ion-exchange and sorption small water conditioning device (Zvezdov A.,1997; Zvezdov A.,1999; Zvezdov A., et al.2006)

No	Parameter	Dimention	Stand. method	Results obtained	Decree 9/2001
Gustatory properties					
1	Smell	-	BDS 8451-77	absent	acceptable
2	Appearance	-	BDS 8451-77	Visually clear	acceptable
3	Transparency	-	ISO 7026603	38 cm	Acceptable
Physical and physico-chemical properties					
4	Taste	-	BDS 8451-77	no bad taste.	acceptable
5	COLOUR		BDS 8451-77	acceptable	acceptable
6	Temperature			20,4°C	
7	pH	pH units	BDS 3423-81	7,6	6,5÷9,5
8	Turbidity	mg/dm ³	ISO70266-03	2,4	acceptable
9	Plug. ability	-	-	K= 0,12(weakly)	-
10	Perm. demand	mg O ₂ /dm ³	BDS 3413-77	3,2	≤5,0
11	Dry rest	g/dm ³	BDS171408-77	0,76	≤0,030

Table 1. Data on gustatory properties, physical and physico-chemical properties of raw water dealing technological creation of water treatment plant

No	Parameter:	Dimension	Stand. method	Results obtained	Decree 9/2001
Cation content:					
1	Total hardness	mg-eq/dm ³ (°H)	BDS ISO 6059-02	8,87 (24,84)	≤ 12 mg-eq/dm ³
2	Carbonate hardness	mg-eq/dm ³ (°H)	BDS ISO 6059-02	4,8 (13,44)	-
3	Noncarbonate hardness	mg-eq/dm ³ (°H)	BDS ISO 6059-02	4,07 (11,4)	-
4	Ca ²⁺	mg-eq/dm ³ (mg/dm ³)	BDS ISO 6058-02	6,83 (136,87)	≤ 150 mg/dm ³
5	Mg ²⁺	mg-eq/dm ³ (mg/dm ³)	BDS ISO 6059-02	2,04 (24,83)	≤ 80 mg/dm ³
6	Na ⁺ +K ⁺ cations	mg-eq/dm ³ (mg/dm ³)	-	1,98 (45,53)	-
7	Total Fe	µg/dm ³	ISO 6332-02	0,11	200 µg/dm ³
8	Mn ²⁺	µg/dm ³	ISO 6333-02	UMAL ¹	≤ 50 mg/dm ³
9	Cu ²⁺	mg/dm ³	BDS 3770-80	UMAL ¹	≤ 2,0 mg/dm ³
10	NH ₄ ⁺	mg/dm ³		UMAL ¹	≤ 0,5 mg/dm ³
11	TCC ²	mg-eq/dm ³	-	10,85	-
Anion content:					
12	HCO ₃ ⁻	mg-eq/dm ³ mg/dm ³	M3-85	4,8 (292,9)	-
13	CO ₃ ²⁻	mg/dm ³	-	UMAL ¹	-
14	SO ₄ ²⁻	mg-eq/dm ³ mg/dm ³	BDS 3588-77	1,79 (85,97)	≤ 250 mg/dm ³
15	Cl ⁻	mg-eq/dm ³ mg/dm ³	BDS 3414-80	3,21 (113,89)	≤ 250 mg/dm ³
16	NO ₃ ⁻	mg-eq/dm ³ mg/dm ³	BDS 3758-85	0,049 (3,04)	≤ 50 mg/dm ³
17	NO ₃ ⁻	mg-eq/dm ³ mg/dm ³	BDS EN 26777- 97	UMAL ¹	≤ 0,5 mg/dm ³
18	HSiO ₃ ⁻ as SiO ₃ ²⁻	mg-eq/dm ³ mg/dm ³	-	0,78 (23)	-
19	F ⁻	mg-eq/dm ³ mg/dm ³	-	UMAL ¹	≤ 1,5
20	PO ₄ ²⁻	mg-eq/dm ³ mg/dm ³	BDS EN ISO 6878-04	UMAL ¹	≤ 0,5
	TAC ³	mg-eq/dm ³	-	10,779	-
	TDS ⁴	mg/dm ³	-	731,32	-
4	Spec. el. cond.	µS/cm	BDS 27888-93	898	≤ 2000

¹ UMAL-under minimal analytical level; ² TCC-total cation content; ³ TAC-total anion content;

⁴ TDS-total dissolved salts;

Table 2. Data on chemical properties and salt content of raw water

Parameters	Purity			Purity									
	By BDS ISO 3696			With one FMB modules, bed vol.					With two FMB modules, bed vol.				
	I	II		I	II		I	II		I	II		I
pH at 25°C	Not incl.	Not incl.	pH at 25°C	Not incl.	Not incl.	pH at 25°C	Not incl.	Not incl.	pH at 25°C	Not incl.	Not incl.	pH at 25°C	Not incl.
Spec.electric conductivity, $\mu\text{s}/\text{cm}^3$	0,1	1	5	0,53	0,49	0,51	0,6	0,46	0,12	0,09	0,10	0,08	0,09
Permanganate oxygen demand, ¹ mgO_2/dm^3	Not incl.	0,08	0,4	0,08	0,07	0,07	0,06	0,07	0,06	0,06	0,07	0,06	0,06
Absorption at 254 nm cuvette - 1 cm	0,001	0,01	Not incl..	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
Dry residue at 110°C, mg/dm^3	Not incl.	1	2	0,9	0,9	0,9	0,9	0,9	0,8	0,8	0,9	0,7	0,8
$\text{SiO}_2\mu\text{g}/\text{dm}^3$	10	20	Not incl.	14	16	15	16	12	8	9	17	19	11

¹ Permanganate demand of the water produced was measured by samples taken from the flow after the final adsorption module charged with active carbon

Table 3. Data on standard parameters and purity of deionized water produced dealing technological functionality of water treatment plant created

4. Conclusion

A water treatment device is designed to realize different processes in one filtration body. It is a multistage multiprocess filter. It can be used for different processes (filtration, ion-exchange, active carbon sorption, biopolymer-chitosan sorption, etc.) Experimentally, the device is researched for a deionized water production using ion-exchange resins and active carbon sorption methods in one body.

The device's features and price are minimized, but the technological behaviour of the device is very good. It produces secondary and third grade deionized water in accordance with BDS ISO 3696; ASTM D 1193-99; DIN 70070 from a potable source for laboratory and other small industrial applications.

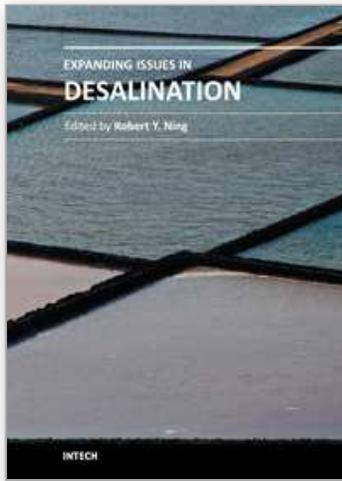
A small local water treatment plant for high quality urea solution AUS 32 defined by DIN 700070 is also created. The technological parameters of this plant are researched during the ultra pure water production used as a solvent for urea solution AUS 32. The water treatment plant is designed as a combination of different water technology methods (percolation; ion-exchange softening; reverse osmosis; ion-exchange deionization).

The properties of the deionized water produced are monitored and controlled by two built-in flow sensors providing signals to conductometric digital gauge measuring the specific electrical conductivity of the product after the main ion-exchange module or after the mixed bed (FMB) module, depending on the user's wish.

The cost of the device is much cheaper than the market available deionizers, but the operating expenses are much lower and the device allows easy control of the processes, technological maintenance and repair, as well as much longer technological life.

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Expanding Issues in Desalination

Edited by Prof. Robert Y. Ning

ISBN 978-953-307-624-9

Hard cover, 412 pages

Publisher InTech

Published online 22, September, 2011

Published in print edition September, 2011

For this book, the term “desalination” is used in the broadest sense of the removal of dissolved, suspended, visible and invisible impurities in seawater, brackish water and wastewater, to make them drinkable, or pure enough for industrial applications like in the processes for the production of steam, power, pharmaceuticals and microelectronics, or simply for discharge back into the environment. This book is a companion volume to “Desalination, Trends and Technologies”, INTECH, 2011, expanding on the extension of seawater desalination to brackish and wastewater desalination applications, and associated technical issues. For students and workers in the field of desalination, this book provides a summary of key concepts and keywords with which detailed information may be gathered through internet search engines. Papers and reviews collected in this volume covers the spectrum of topics on the desalination of water, too broad to delve into in depth. The literature citations in these papers serve to fill in gaps in the coverage of this book. Contributions to the knowledge-base of desalination is expected to continue to grow exponentially in the coming years.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Angel Zvezdov and Dilyana Zvezdova (2011). New Type Filtration, Ion-Exchange, Sorption Small Multi Process Water Conditioning Device Used as a Multi Cell Water Deionizer, Expanding Issues in Desalination, Prof. Robert Y. Ning (Ed.), ISBN: 978-953-307-624-9, InTech, Available from:
<http://www.intechopen.com/books/expanding-issues-in-desalination/new-type-filtration-ion-exchange-sorption-small-multi-process-water-conditioning-device-used-as-a-mu>

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InTech Europe

University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China

Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

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