WATER TREATMENT TECHNOLOGY SUPPLEMENTED BY ELEMENTS FROM INDUSTRY 4.0 – A REVIEW

David Guth[1]

[1]*Department of Mechanical Engineering, Faculty of Engineering, Czech University of Life Sciences Prague, Czech Republic*

Abstract
This review deals with the issue of water and its filtering. Among others, the effects on human health, in the case of consumption of contaminated water, are also mentioned. The main parameters are the implementation of modern elements (pH meter, flow meter, thermometer, filter pollution meter, UV lamp, reverse osmosis and cameras) to the existing water treatment plant and their subsequent use. The result should be an independent, modern treatment plant that should be able to filter clean drinking water for final consumers without bacteria or discoloration.

Key words: *water treatment plant, filtration, drinking water, industry 4.0*

INTRODUCTION
In today's modern times, the quality of drinking water is a very discussed, important and current topic, especially in the developing countries of the world was mentioned by *Sutherland, K. (2008).* Providing high-quality drinking water for the population to their homes without any pollution is a basic condition for developed countries described by *Mallik, A., & Arefin, M. A. (2018)*. In order to meet these conditions, it is required to improve the microbiological quality of the water, control of undesirable substances, chemicals and metals that may be contained in the water, reported by *Fewtrell, L. et al. (1997)*. Secondary steps are the maintenance and sufficient protection of the water pipeline and the complete system, management and control of the content and aesthetic quality of the water, which include color, hardness, smell and taste, these steps are reported by *Martynov, S.et al. (2020)*. Polluted and contaminated water is the main carrier of many water-borne diseases, including typhoid, cholera, salmonellosis, hepatitis, viral infections and many others reported by *Deflorio-Barker, S. et al. (2016)*. These diseases cause a noticeable weakening of the human organism and can lead to the complete failure of the human body, both men and women, but also children mentioned by *Momba, M. N. B. et al. (2009)*. Water industry-specific structures and functioning provide the perfect environment for improvements in efficiency, quality, and availability using Industry 4.0 principles. The water industry is represented by highly heterogeneous and geographically dispersed processes and technical solutions that are described by *Nicolae, A. et al. (2019)*. These include legacy systems and new structures that are in stringent need of connecting the digital and the physical worlds in the context of highly functional process dependencies with interoperation reported by *Nicolae, A. et al. (2019)*. In todays world, there is very many modern elements and filtration methods that are used in the water treatment plants. One of the most common used elements is reverse osmosis or UV (ultra-violet) purification which is described by *Piferi, C. et al. (2021)*. Study by *Rao, S. M. (2007)* describes that reverse osmosis process involves the use of membrane technology which allows to remove dissolved salts and other impurities in water. The radiations function by irradiating the water and piercing through the cells of the microorganisms and viruses. Study by *Pinto et al. (2012*) describes that among the generally accepted methods of purifying drinking water is the addition of chlorination to the filtration process, which results in a dramatic decrease in the amount of bacteria in the water. Study by *Liao, X., et al. (2015)* describes that filtration by dual media rapid sand filters in a drinking water plant played a primary role in shaping the bacterial community. If residents decide to draw and consume water from their own sources, ensuring sufficient filtration to prevent possible diseases is a necessary step. Drinking water filters differ according to the technologies used, filter materials and purpose. Study by *Poitelon, J. B. et al. (2010)* describes the most common are mechanical filters and filters with active carbon. Mechanical filtration can be mesh or membrane. Membrane filtration is generally more effective, but it is not suitable for drinking water. The membrane captures vital substances that the organism would miss, which is reported by *Nagakura, (2015)*. Chemical filtration is not filtration in the true sense of the word, but water treatment, where unwanted

chemical or organic substances are removed from the water. For these purposes, granulated activated carbon is most often used, which, thanks to its surface and sorption properties, can capture the entire range of harmful substances dissolved in water – from heavy metals to chlorine and other chemicals to viruses and bacteria. Granulated activated carbon absorbs or captures these substances and organisms on its surface. Based on this, it removes unpleasant odors from the water and improves its taste which was reported by *Tang, H. L., & Xie, Y. F. (2016)*. Study by *T. Eisenberg, E. Middlebrooks (1986)* describes that reverse osmosis processes can simultaneously remove hardness, color, many types of bacteria, viruses and organic contaminants. Contaminants, as agricultural chemicals reviewed the effectiveness of reverse osmosis on drinking water and reported that it can successfully remove a wide range of contaminants that are often found in drinking water which was reported by *T. Eisenberg, E. Middlebrooks (1986)*. The aim of this study is to create a water treatment plant based on industry 4.0. By combining mechanical filtration and chemical filtration, using modern elements to maximize unit self-automatization. By using pH meter, water flow calculator, thermometer, filter pollution meter and install the cameras to simply prevent a possible problem that could arise as a result of neglect. The water entering the treatment plant will undergo treatment using several modern elements, and the main goal of this work is clean treated water at the exit.

MATERIALS AND METHODS

In order to create and maximize the automatization and modernization of the water treatment plant, a treatment plant named Oaza 100 was selected. The treatment plant is equipped with a pre-filter with an ABS (acrylonitrile butadiene styrene) and nylon filter insert, composite fiberglass, reverse osmosis module and its membrane, pump and UV lamp. All the data were collected from the manual of the water treatment itself and from the articles uploaded to Web of Science, Scopus, IWA (International Water Association). A large part of the obtained data and knowledge was obtained through an interview with the creator of the water treatment plant, and its subsequent maintenance and the possibility of modernization was solved with a specialist company dealing with this issue. Other technical parameters are mentioned in the Tab.1. All the technological equipment of the water treatment plant are fixed in a stainless steel frame so that all parts of the technological unit can be easily serviced while maintaining the smallest possible space. All materials used must meet certification for contact with food, respectively drinking water. To achieve the modernization of the water treatment plant, a pH meter, flow meter, thermometer, filter pollution meter, and cameras will be purchased. All these mentioned elements will be installed on the water treatment plant and tested. The water will be entering the water treatment plant in three different flows 0,2; 0,4 and 0,6 liters per minute. Subsequently, the water values at the inlet and outlet will be compared and the efficiency of the treatment plant will be evaluated by an expert laboratory dealing with water analysis.

Tab.1 Operational **-** technical parameters

Working pressure range	6-10 bars
Optimal working pressure	7-8 bars
Permeate performance at optimum pressure	100 l/hod
Weight of the body of the treatment plant approx.	500 kg
Body dimensions (height × width × depth)	2000 × 1100 × 1720mm

RESULTS AND DISCUSSION

This review is focused on, how the treatment plant will be able to filter the water that will be admitted to the treatment plant at the entrance and will pass through all the installed elements and come out at the exit. Colored water with added bacteria and then with cyanobacteria will be fed into the treatment plant. Assuming that disinfection is sufficient in the treatment plant and suspended and colloidal solids are sufficiently removed in preceding steps, the main controlled parameters for a treatment plant are chemical stability (saturation index SI), biological stability (assimilable organic carbon AOC), disinfection by-products (bromate) and organic micro-pollutants (pesticides) which was reported by *Rietveld, L. et al. (2008)*. The expected results are that the treatment plant will be able to fully remove all undesirable elements from the water and at the exit the water will be clean and drinkable meeting WHO requirements. The process revealed that the system which combines NF and UV disinfection is ranked first for all the different stakeholder weightings reported by *Bouchard, et al. (2010)*. All three investigated flow rates should be able to filter water equally well, as they are below the limit of the maximum flow rate of the treatment plant. The most suitable filter cleaning process is the backwash, which is the most effective, which is confirmed by *Arendze, S., & Sibiya, M. (2014)*. Although it may seem that the control of the treatment plant is relatively complicated, but it is not. The treatment and its controls are set up so that even quickly trained personnel can control it easily. No same or similar works to this were found, and therefore does not have the possibility to compare the results with other works. This is one of the reasons and motivations why this topic was chosen.

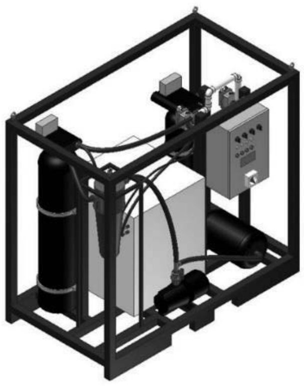

Fig. 1 Animation of Oasa 100 water treatment plant

Fig.2 Real picture of Oasa 100 water treatment

CONCLUSIONS

Water takes an essential part of human daily lives that's mostly not even being considered where it´s being sourced or the quality of the water. For many people, tap water is deemed as undrinkable. That's why it´s very important to take care of the water and filter it. The importance of water filtration is that it gives people access to clean water that is free of contaminants, that tastes good, and is a reliable source of hydration. The implementation of the modern elements into the water treatment plant would bring lots of benefits. Using the elements mentioned above would save time on operating the water treatment plant. Some of the negatives of implementing the modern elements into the water treatment may be reflected in the purchase price of the water treatment. The main positives of implementing the modern elements based on industry 4.0 into the existing water treatment plant is remote controlling the treatment by experts and educated workers. Which means measuring the pollution of the filters, checking if the filling of the filters was changed and measuring the pH and temperature. Based on these, the water treatment plant would provide filtering to the final consumers.

REFERENCES

1. Mallik, A., & Arefin, M. A. (2018). Clean water: Design of an efficient and feasible water treatment plant for rural South-Bengal. Journal of Mechanical Engineering Research and Developments, 41(1), 156–167. https://doi.org/10.7508/jmerd.2018.01.019
2. Martynov, S. et al. (2020). Modern trends at natural and wastewater treatment plants reconstruction. IOP Conference Series: Materials Science and Engineering, 907(1), 0–8. https://doi.org/10.1088/1757-899X/907/1/012083
3. Momba, M. et al. (2009). Survey of disinfection efficiency of small drinking water treatment plants: Challenges facing small water treatment plants in South Africa. Water SA, 35(4), 485–494. https://doi.org/10.4314/wsa.v35i4.76795
4. Liao, X., et al. (2015). Bacterial community change through drinking water treatment processes. International Journal of Environmental Science and Technology, 12(6), 1867–1874. https://doi.org/10.1007/S13762-014-0540-0/FIGURES/7

5. Poitelon, J. B. et al. (2010). Variations of bacterial 16S rDNA phylotypes prior to and after chlorination for drinking water production from two surface water treatment plants. Journal of Industrial Microbiology and Biotechnology, 37(2), 117–128. https://doi.org/10.1007/s10295-009-0653-5
6. Rao, S. M. (2007). Reverse osmosis. Resonance 2007 12:5, 12(5), 37–40. https://doi.org/10.1007/S12045-007-0048-8
7. Pinto, A. J. et al. (2012). Bacterial community structure in the drinking water microbiome is governed by filtration processes. Environmental Science and Technology, 46(16), 8851–8859. https://doi.org/10.1021/ES302042T/SUPPL_FILE/ES302042T_SI_001.PDF
8. Tang, H. L., & Xie, Y. F. (2016). Biologically active carbon filtration for haloacetic acid removal from swimming pool water. Science of The Total Environment, 541, 58–64. https://doi.org/10.1016/J.SCITOTENV.2015.09.059
9. Nagakura, Y., et al. (2015). Modern Electrical Technology for Water Treatment Plants. 45(4), 110–121.
10. Sutherland, K. (2008). Water filtration: Bulk water filtration techniques. Filtration & Separation, 45(10), 17–19. https://doi.org/10.1016/S0015-1882(08)70496-8
11. Nicolae, A. et al. (2019). Identifying data dependencies as first step to obtain a proactive Historian: Test scenario in the water industry 4.0. Water (Switzerland), 11(6). https://doi.org/10.3390/w11061144
12. Fewtrell, L. et al. (1997). Microbiological quality of bottled water. Water Science and Technology, 35(11–12), 47–53. https://doi.org/10.2166/WST.1997.0708
13. Deflorio-Barker, S. et al. (2016). Water recreation and illness severity. Journal of Water and Health, 14(5), 713–726. https://doi.org/10.2166/WH.2016.002
14. Piferi, C. et al. (2021). Intensity comparison between UV lamps and plasma emission for air purification studies. AIP Advances, 11(8), 085209. https://doi.org/10.1063/5.0057033
15. Kahdim, A. S. et al. (2003). Modeling of reverse osmosis systems. Desalination, 158(1–3), 323–329. https://doi.org/10.1016/S0011-9164(03)00471-5
16. Sun, M. et al. (2021). Electrified Membranes for Water Treatment Applications. ACS ES&T Engineering, 1(4), 725–752. https://doi.org/10.1021/ACSESTENGG.1C00015
17. Bouchard, C., Beauchamp, N., Abi-Zeid, I., Lamontagne, L., Desrosiers, J., & Rodriguez, M. (2010). Multicriteria decision analysis for the selection of a small drinking water treatment system. Journal of Water Supply: Research and Technology-Aqua, 59(4), 230–242. https://doi.org/10.2166/AQUA.2010.071
18. Arendze, S., & Sibiya, M. (2014). Filter backwash water treatment options. Journal of Water Reuse and Desalination, 4(2), 85–91. https://doi.org/10.2166/WRD.2013.131
19. Rietveld, L., Van Der Helm, A., Van Schagen, K., Van Der Aa, R., & Van Dijk, H. (2008). Integrated simulation of drinking water treatment. Journal of Water Supply: Research and Technology-Aqua, 57(3), 133–141. https://doi.org/10.2166/AQUA.2008.098
20. T. Eisenberg, E. Middlebrooks, Reverse osmosis treatment of drinking water, (1986), 1–271, doi:10.1016/B978-0-250-40617-3.50004-4

ACKNOWLEDGEMENT
This study was supported by CZU Faculty of Engineering *IGA 2022 – 31130 30103 1312*

Corresponding author:
Ing. David Guth, Department of Mechanical Engineering, Faculty of Engineering, Czech University of Life Sciences Prague, Kamýcká 129, Praha 6, Prague, 16500, Czech Republic, phone: +420 224 383 181, e-mail: guthd@tf.czu.cz