DOI: 10.1515/sspjce-2018-0017

Effects of changing retention time on efficiency of submerged MBR treating different types of grey water

Martina Rysulova, Joana America Castellar, Jordi Morato, Zuzana Vranayova, Daniela Kaposztasova

Technical University of Kosice, Slovakia
Faculty of Civil Engineering, Institute of Architectural Engineering
Polytechnic University of Catalonia
ESEIAAT, UNESCO Chair of Sustainability
e-mail: martina.rysulova@tuke.sk, zuzana.vranayova@tuke.sk

Abstract

It is known that grey water reused for non-potable purposes, provides a sustainable solution of water management by reduction of fresh water extraction and can contribute to water status improvement. Although reused grey water is not intended for potable use, the potential for certain contamination and pollution rate still exist and the treatment efficiency represents a key concern for grey water system utilization. Therefore, this paper explores and focuses on treatment efficiency of treatment technology specifically on submerged membrane bioreactor, what is considered as a successfully used technique of grey water treatment. The main aim was to evaluate the pollution removal in variously polluted grey water and consider a treatability of purposed technology, while changing the grey water retention time in bioreactor.

Key words: Grey water, retention time, MBR treatment

1 Introduction

Grey water has proven to be a useful substitute for fresh water in regards to non-potable purposes [1]. Grey water can be considered as a valuable source of water, however the reliability of the system is ensured by proper treatment of the water, to reduce the risks associated with water contamination to acceptable levels for the intended reuse application [2]. The level of grey water contamination and exact range of pollutants, is relatively difficult to specify, since the water quality is highly dependent on the user behavior. However, the hygienic safety and environmental tolerance represents most significant requirements for grey water system efficiency, hence water quality specification and control has to be undertaken.
Considering the origin of grey water and its great dependence on user living standards and habits, is hygienic safety associated with variable quality of water. Although there are variations in grey water quality, the analysis confirms that dark grey water - waste water

originating to kitchen and laundry, dispose with higher both physical and organic pollution compared to light grey water discharged from bathroom or non-separated grey water [3,4,5]. Generally grey water quality is covering different chemical, physical and microbiological contamination. The literature review shows some of the most common pollution parameters, those usually recognized features of grey water quality and their values are shown in Table 1.

Table 1: Concentration of general pollution parameters in grey water

	Parameter	Unit	Concentration		
			LGW	DGW	GW
CH/ PH	pH	(-)	5.0 – 8.6	6.3 – 10.0	6.1 - 8.4
	COD	(mg/l)	*42.9 – 8,000	26.0 – 1,600	*304 - *876
	BOD_5	(mg/l)	*14.9 – 200	48.0 – 756	41.0 – *261
	TSS	(mg/l)	*17.2– *54.0	*94.0 – *214	45.0 – 330
	Turbidity	(NTU)	*9.0 – 370	14.0 – 296	*70.0 – *119
	Temperature	(°C)	*17.0 – 38.0	*20.0 – *32.2	*20.0 – *37.4
N	N_{total}	(mg/l)	0.6 – 46.4	*4.5 – 60.0	*5.0 - 8.1
	P_{total}	(mg/l)	*0.1 – 2.20	0.06 – 57.0	*0.5 –11.0
M	Escherichia coli	(CFU/100 ml)	10^1 - 10^7	10^1 – 10^8	10^1 – 10^2
	Enterococci	(CFU/100 ml)	0	*10^1	10^1 – 10^5
	Coliform bacteria	(CFU/100 ml)	10^1 – 10^9	10^1 – 10^8	10^5 – 10^8
	Faecal coliforms	(CFU/100 ml)	10^1 – 10^6	10^1 – 10^4	10^2 – 10^6

Modified from [3,6,7,8,9] *Table is complemented by values measured during the research

The characteristics of GW (grey water) quality, including the pollution concentration of raw GW and the requirements for water quality according to intended reuse, underline the necessity of appropriate treatment technology settlement. According to proven experiences and prevailing utilization of MBR (membrane bioreactor) technologies treating GW, was purposed to test this system, according to specific conditions. The main aim of this paper was to analyze the efficiency of submerged MBR technology treating differently polluted GW, in accordance to changing retention time of water.

Measurement was applied at laboratory in the Center of excellence of integrated research, progressive materials, constructions and technologies at Technical University of Kosice, Faculty of Civil Engineering. The measurement begun 13.11.2017 and was finalized with the last sampling performed 10.01.2018. GW system and most of its segments are placed in presented laboratory.

2 Measurement methodology

Methodology applied in this paper (Figure 1) was based on experimental measurement consisting of water sampling. Samples were taken in 3 stages, according to changing retention time (direct, 12 hours, 20 hours). MBR treatment plant was operating with 3 types of GW: LGW (light grey water), DGW (dark grey water) and non-separated GW, when each type of

GW passed through all 3 sampling stages. Samples were then evaluated under accredited laboratory assessment.

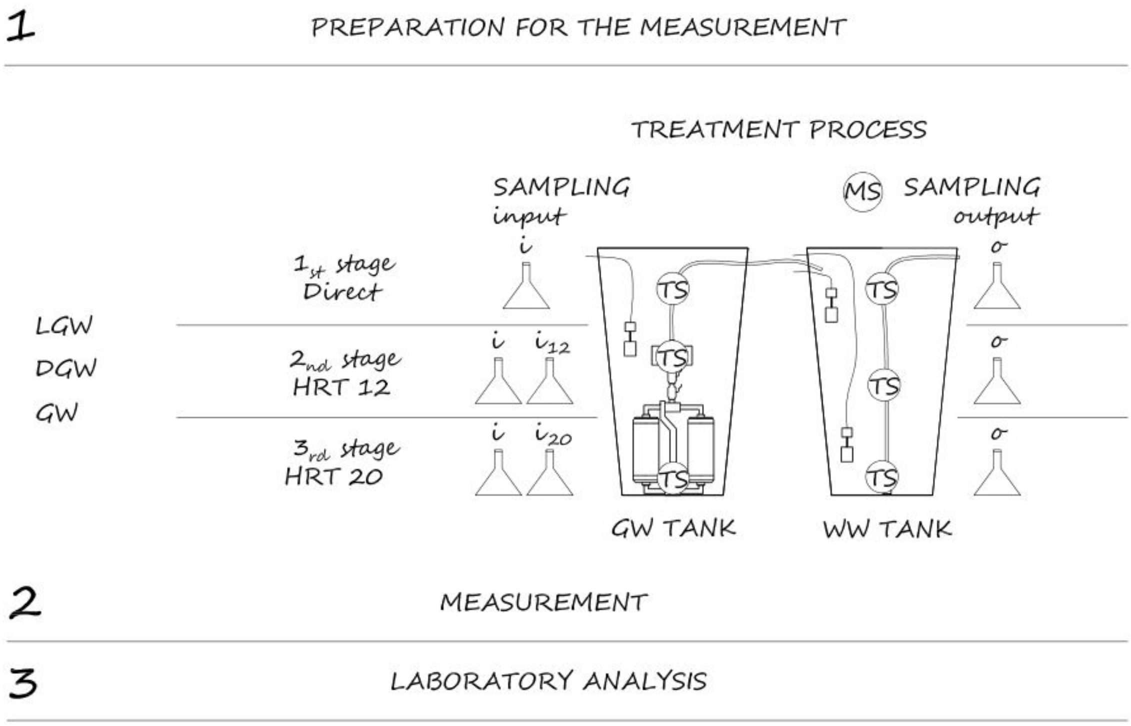

Figure 1: Measurement methodology

The different types of GW were collected according to sources used (Figure 2). In general, the sources can be divided into internal and external. Location of internal GW sources and MBR unit on the same floor level, eliminates the gravity water discharge from the devices in sanitary devices area. Therefore was necessary to design the pumping system that can lead GW into the treatment plant. To meet this requirement, was suggested to use a small, compact automatic lifting station, with maximum flow rate 149 L/min and maximum discharge height 8.5 meters [10]. Hence GW is firstly discharged by natural gravity flow directly into the lifting station with integrated tank of volume 9 L, then is GW pumping into the treatment plant. Since there are another sources directly connected with treatment plant, the pipelines leading from both sources (internal sources and external direct sources, are linked before the inlet to GW tank. After all cleaning processes is WW (white water) pumped for the further utilization back to sanitary devices area. The devices connected to WW supply are toilet, urinal and washing machine. Washing machine is the only device that can be supplied by both freshwater and WW, however during the measurement was considered just the connection to fresh water. Waste water discharged from toilet and urinal leads into the public sewer system.

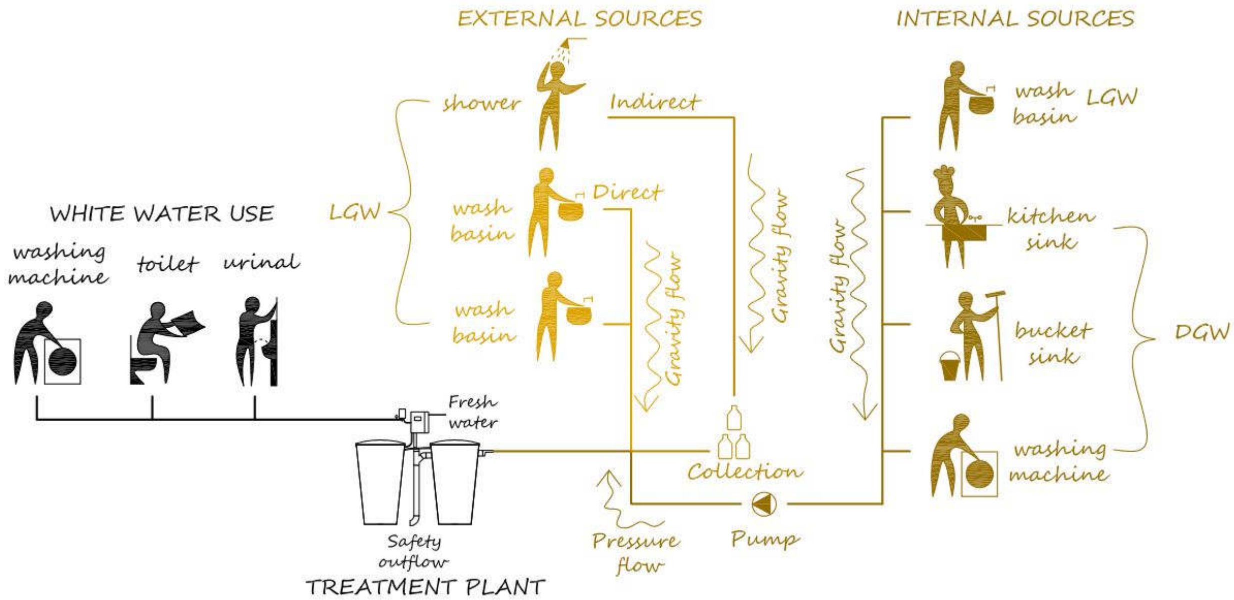

Figure 2: Grey water system scheme

3 Results

The results of water quality assessment are in regards to missing regulations and legislative framework dealing with GW technologies in Slovakia evaluated according to limited values for drinking water included in The Government Regulation Nr. 355/2007 Coll. and limit rates of waste water and special water pollution indicators in the Government Regulation No. 269/2010 Coll. According to the measurement methodology explanation above was MBR treatment plant operated with three types of grey water and under the changing retention time: direct, 12h and 20h. The comparison of water analysis results is given bellow.

3.1 pH

The title page must give the title of the paper, all authors with their affiliations and up to five keywords. The title page shall appear as the first page of this document. The body of the text must start after the key words. Results on Figure 3 show that there is no considerable difference between pH environment in each measurement phase and except one phase at DGW20, each analysis proved a basic pH of water. Most organic matter and bacteria are suited to a neutral or slightly basic pH environment, therefore an acidic pH can be considered as more suitable in their reduction. However, the increase of pH can have positive effect on TSS and COD removal [11,12], whereas this was not under the investigation intention. The main aim was to set up the treatment efficiency, what in regards to limitations, proved that the pH environment in all measurement phases is sufficient and in range of pH 6.5-8.5. Comparing the results with the BS 8525-1, setting up the limitations for grey water reuse and limited scope pH 5.5-9.5, are measured values as well acceptable for further use.

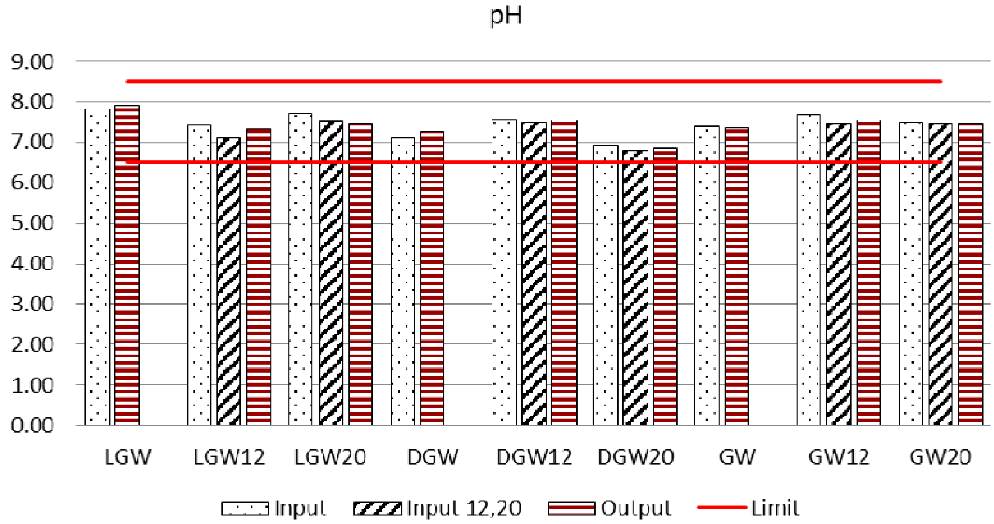

Figure 3: pH concentration in all types of GW

3.2 COD

From the results on Figure 4 can be seen an evident difference between COD concentration, therefore pollution rate measured in LGW and DGW or non-separated GW. It was expected that during the grey water retention in GWT (12, 20 hours) will the COD removal grow [13,14] however except the phase DGW12, was proven increase in each tested phase. Except one measurement phase LGW20 was all increased COD concentration subsequently reduced by membrane treatment, therefore proved certain pollution removal. Whereas the COD concentration in DGW and non-separated GW remains relatively high even after the treatment and the biological processes expected were not satisfied.

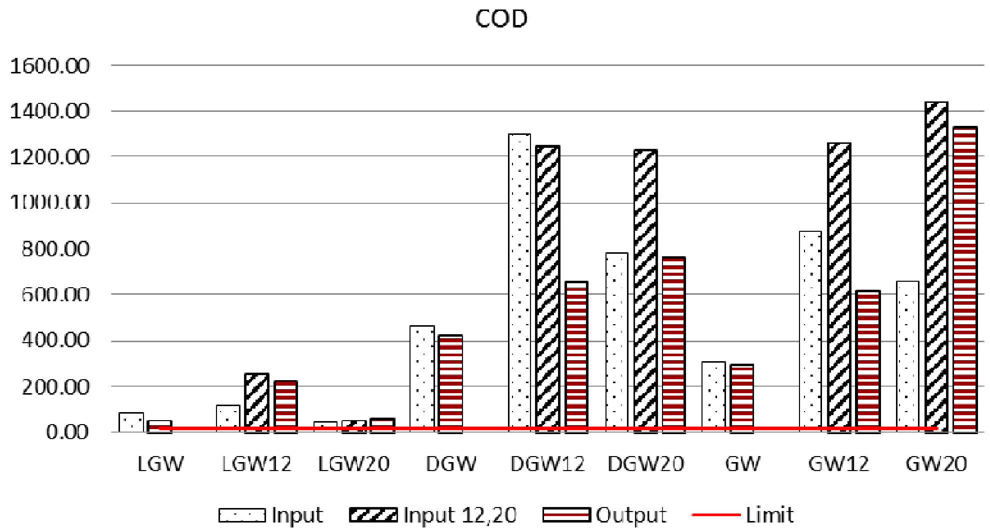

Figure 4: COD concentration in all types of GW

3.3 BOD_5

Results on Figure 5 proves lower concentration of BOD_5 in LGW than in DGW or non-separated GW as was expected. According changing retention time and as higher HRTs usually results in better removal performance and are applied for treatment that contains high BOD [15] was supposed that during the grey water retention in GWT (12, 20 hours) will appears a decrease in pollution concentration. Except the phase DGW12, was during the retention proven increase in each tested phase, however after treatment by membrane were except phase GW 20 all the concentration reduced. Measurement in phase GW20 recorded increase of BOD_5 even after membrane treatment. Whereas the BOD_5 concentration in DGW and non-separated GW remains relatively high even after the treatment and the biological processes were not satisfied. The legislative framework by BS 8525-1 and RD 1620/2007 don't specify the limitations for BOD_5 concentration. According to other guidance for white water utilization by WHO or Australian and Canada legislatives which settled the limit value ≤10.0 mg/l where values also not satisfactory.

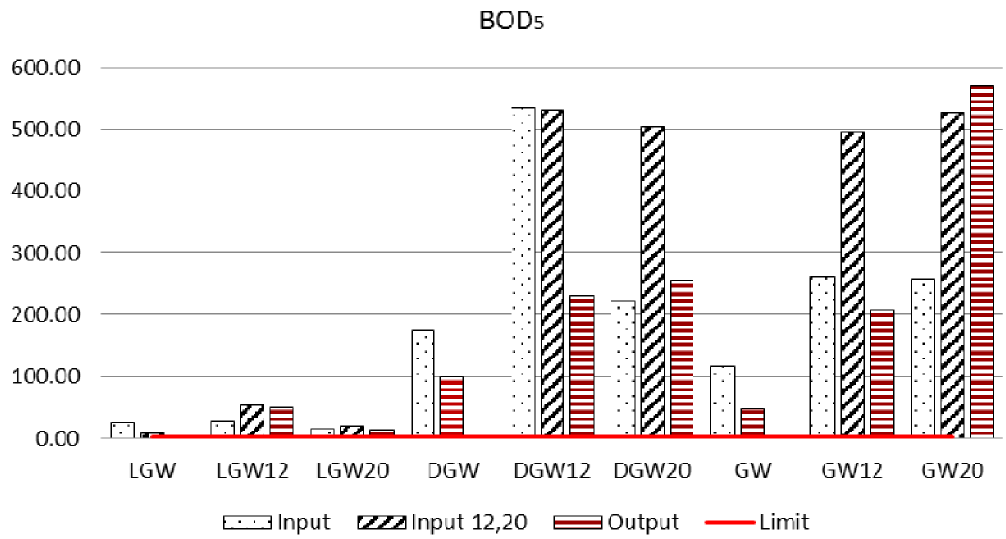

Figure 5: BOD_5 concentration in all types of GW

3.4 TSS

From the results on Figure 6 can be seen relatively positive treatment efficiency of TSS in all types of grey water, also the pollution concentration difference between LGW and DGW or non-separated GW. According to [16] was observed that lower HRT (8h) achieved higher TSS removal. In this case the can be stated that except two phases LGW12 and GW20 was during the retention TSS concertation reduced and further after treatment by membrane removed almost by 100%. Interesting value was measured at GW20, when TSS concentration during the retention raised twice it value. After treatment by membrane was this value reduced however not fulfilled the legislative limitation. The legislative framework by BS 8525-1 is not defining the limitation for TSS according to further purposes, however RD 1620/2007 specifies the limitations as 10 and 20 mg/l, what is similar to legislative limits according to Slovak government limitation compared, therefore the values that fulfilled this limit are also sufficient in regards to RD 1620/2007

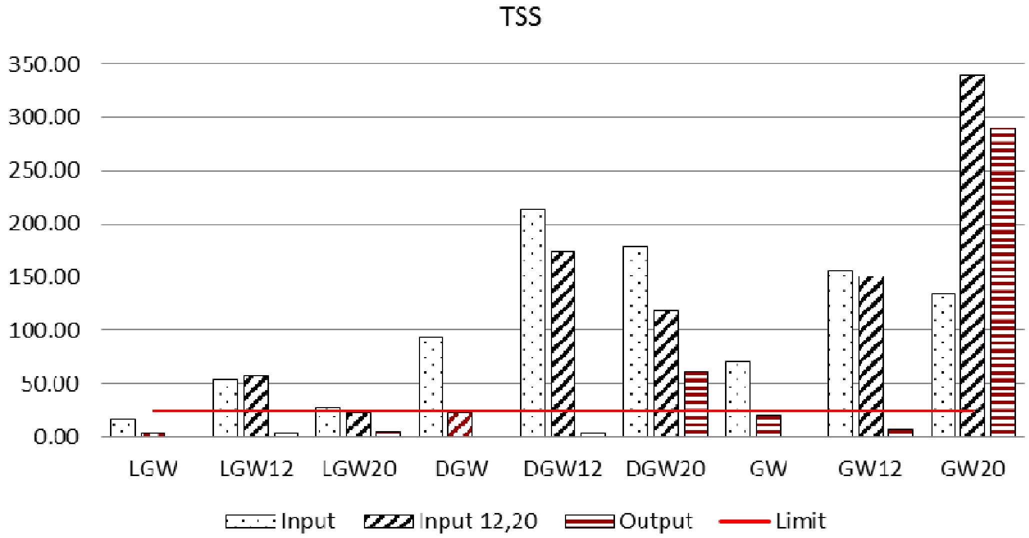

Figure 6: TSS concentration in all types of GW

3.5 Turbidity

The results on Figure 7 shows an evident difference between pollution of LGW and DGW or non-separated GW. On the figure can be seen a similar course of measured pollutants as it was in TSS. Even that the pollution removal is relatively positive and with high percentage, the legislative requirement according to Slovakia Government were not fulfilled. Comparing the results with BS 8525-1 which settled the limits to <10.00 NTU were satisfied the all the results except phases DGW20, GW and GW20, where the output values remains high even after treatment.

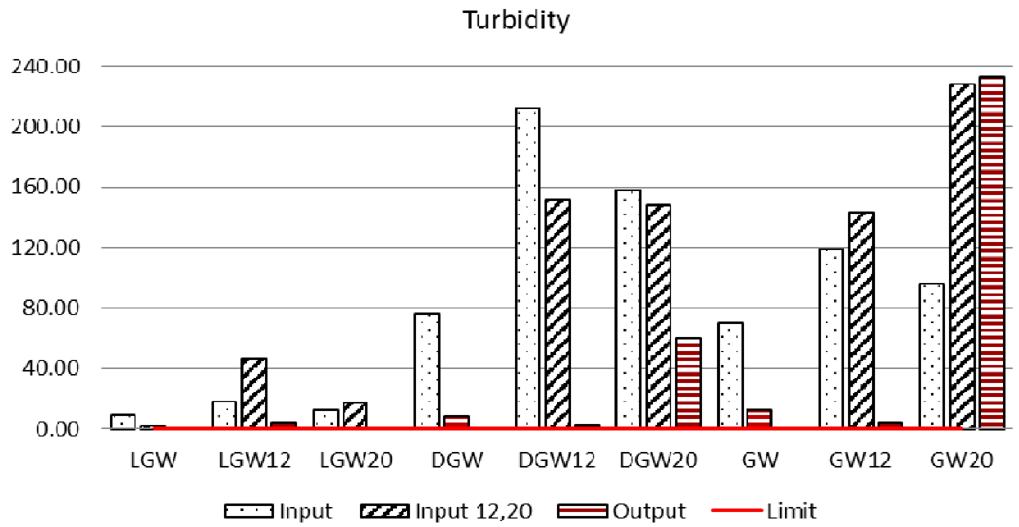

Figure 7: Turbidity concentration in all types of GW

4 Conclusion

An intention of this paper was to define the treatment efficiency of MBR treatment plant, in regards to changing retention time of GW in bioreactor. According to measured values was compiled a percentage score of average treatment efficiency divided by measurement phase and type of GW treated. In the events, when the value measured after treatment process increased was the treatment efficiency percentage determined as 0 value. The overall results are given in Table 2.

Table 2: Treatment efficiency of each measurement phase

	Types of grey water & Treatment efficiency		
Retention time	LGW	DGW	GW
Direct	45.80 %	44.01 %	29.67 %
12 hours	53.74 %	53.80 %	48.97 %
20 hours	33.51 %	30.23 %	3.53 %

Measurement results shows a relatively wide range of treatment efficiency, differing from only 3.53% measured in non-separated GW stored for 20 hours, till highest efficiency measured in DGW stored for 12 hours. Regarding the highest percentage of treatment efficiency reached in all three types of GW, appears 12 hours retention time as most effective operation setup for effective pollution removal, however the partial results have to be taken into account, where the pollution during retention usually increased.

The overall treatment efficiency reached according to type of treated GW (Figure 8), specifies LGW as most effectively treated, however with no particular difference with the efficiency reached by treating DGW. Treatment efficiency settled for non-separated GW, was proved relatively low, what was probably caused by high pollution levels that were not reduced by treatment.

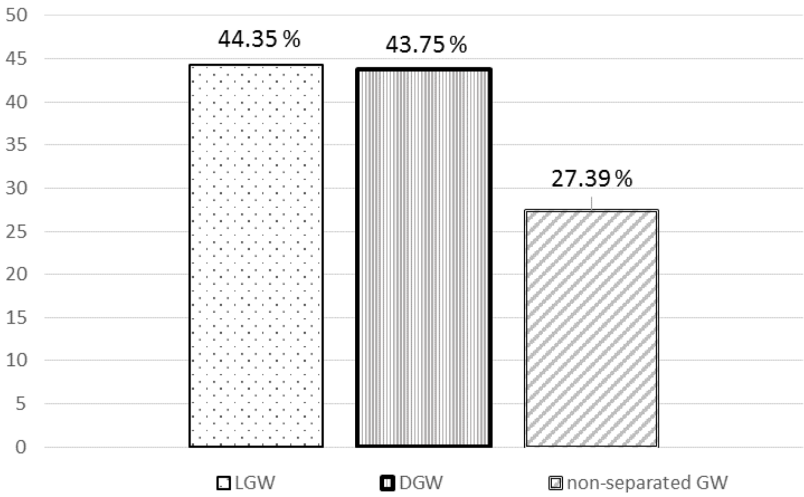

Figure 8: Treatment efficiency of individual GW type

Evaluation of MBR treatment system shows efficiency lower than 50%, what can be considered as unsatisfactory result. Recognizing all the impacts influenced the treatment system can be concluded that system was mostly operating only with membrane treatment, whereas improving the biological treatment performance can contribute to raise the overall treatment efficiency of MBR.

Acknowledgements

This paper was supported by projects VEGA n. 1/0202/15: Sustainable and Safe Water Management in Buildings of the 3rd Millennium; TATRABANKA Foundation n. 2015vs082 – Safe and sustainable use of water in building and Specialized Laboratories of East Slovak Water Association.

References

[1] Oh, Kai Siang et al. 2018. "A Review of Greywater Recycling Related Issues: Challenges and Future Prospects in Malaysia." Journal of Cleaner Production 171: 17–29. https://www.sciencedirect.com/science/article/pii/S0959652617322710 (February 7, 2018).

[2] Boddu, Veera M. et al. 2016. "Gray Water Recycle: Effect of Pretreatment Technologies on Low Pressure Reverse Osmosis Treatment." Journal of Environmental Chemical Engineering 4(4): 5. https://doi.org/10.1016/j.jece.2016.09.031.

[3] Eriksson, Eva, Karina Auffarth, Mogens Henze, and Anna Ledin. 2002. "Characteristics of Grey Wastewater." Urban Water 4(1): 85–104.

[4] Li, Fangyue, Knut Wichmann, and Ralf Otterpohl. 2009. "Review of the Technological Approaches for Grey Water Treatment and Reuses." Science of the Total Environment, The 407(11): 3439–49. http://dx.doi.org/10.1016/j.scitotenv.2009.02.004.

[5] Matos, Cristina, Ana Sampaio, and Isabel Bentes. 2007. Greywater Use in Irrigation : Characteristics , Advantages and Concerns.

[6] Burrows, W.D., Schmidt, M.O., Carnevale, R.M., Schaub, S.A., 1991. Nonpotable Reuse: Development of Health Criteria and Technologies for Shower Water Recycle. Water Sci. Technol. 24, 81 LP-88.

[7] Butler, D., Friedler, E., Gatt, K., 1995. Characterising the quantity and quality of domestic wastewater inflows. Water Sci. Technol. 31, 13–24. https://doi.org/10.1016/0273-1223(95)00318-H

[8] Casanova, L.M., Gerba, C.P., Karpiscak, M., 2001. Chemical and microbial characterization of household graywater. J. Environ. Sci. Heal. - Part A Toxic/Hazardous Subst. Environ. Eng. 36, 395–401. https://doi.org/10.1081/ESE-100103471

[9] Racek, J., 2016. Methodology of use greywater in the slected objects. Brno University of Tehcnology.

[10] Le Clech, Pierre, Bruce Jefferson, In Soung Chang, and Simon J. Judd. 2003. "Critical Flux Determination by the Flux-Step Method in a Submerged Membrane Bioreactor." Journal of Membrane Science 227(1–2): 81–93. https://www.sciencedirect.com/science/article/pii/S0376738803004241 (April 18, 2018).

[11] Ghanizadeh, G., Sarrafpour, R., 2001. The Effects of Temperature and PH on Settlability of Activated Sludge Flocs. Iran. J. Public Heath 30, 139–142.

[12] Dyan, M.O., Putra, G.P., Sumardiono, S., Djoko, T., 2015. The effect of pH and operation mode for COD removal of slaughterhouse wastewater with Anaerobic Batch Reactor. Waste Technol. 3, 7–13.

[13] Ebrahimi, A., Najafpour, G., Mohammadi, M., Babak, H., 2010. Biological treatment of whey in an UASFF bioreactor followed a three-stage RBC. Chem. Ind. Chem. Eng. Q. - CHEM IND CHEM ENG Q 16, 175–182. https://doi.org/10.2298/CICEQ100315025E

[14] Kuma, R., 2011. Study of Municipal Landfill Leachate : Recycling and Treatment Using UASBR with post treatment by Constructed Wetland Rajesh Kumar Taneja. Indian Institute of Technology Delhi.

[15] Isma, M.I.A., Idris, A., Omar, R., Razreena, A.R.P., 2014. Effects of SRT and HRT on Treatment Performance of MBR and Membrane Fouling 8, 488–492.

[16] Ahmad, M., Khan, Z., Jamal, S., Masoom, M., Aamir, E., 2013. Role of HRT in Biological Treatment of Combined Industrial and Municipal Wastewater. Int. J. Curr. Eng. Technol. 3, 766–774. https://doi.org/ISSN 2277 - 4106