Water saving plan by water reuse in the hotel building

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Abstract: - What is grey water and how we can use it? There are lots of proven and operating grey water systems in the world. Slovakia is in this regard quiet lagging country, where system doesn't have this position, neither instance of application. Due to approach the topic of reuse systems, this article describes grey water system reuse and its brief characteristic. The main aim of this article is to characterize the grey water system, its design and water treatment on the case study by pointing out its saving potential. Therefore this study confirms, that system of alternative recycled water use, can save particular source of potable water, where the water is unnecessarily wasted and used where drinking water quality is no needed. In parallel to water savings, grey water system can bring financial savings, which are relevant especially for users at decision-making processes. It is obviously that system have advantages and disadvantages, but if we are sustainable thinking, we have to refer about every drop of water we can save, and we can consider that grey water system is the way we can reach it.

Key-Words: - water demand, water production, saving potential, system design, grey water, white water

1 Introduction

The reuse of waste water represents common part of building water cycle in most countries [2, ,11,13,16],. We can say that for Slovakia is using of recycled water entirely new concept. For end users are in particular the best known terms like using rainwater, or in case of sufficient groundwater sources using water from the well. But it is important point to the fact, that there exist another alternative source of water supply, which is daily available during our routine using of water in buildings.

The main topic of this article is to describe, how we can treat with this source of water, and demonstrate its potential utilization, which means saving particular source of potable water and in parallel to water savings, bring financial savings.

2 Description of Grey Water System

Grey water system can be described as system which is oriented on capturing waste water before its discharging from building. If we want to apply this system, the waste water has to be separated on grey water and black water.

There are a lot of descriptions, what grey water means, for example according to British Standard, we can consider grey water as domestic wastewater excluding faecal matter and urine [1]. This characteristic specifies using waste water from sanitary appliances, which are not expected high rate of water pollution. Usually that are sinks, baths and showers, also can include washing machines, but with sufficient cleaning process, which ensure the required quality of water for its further use.

The significant part of the system is to provide the appropriate treatment system for grey water, which depends on the types of contaminants, removed [2] and required quality of white water that returns back to building.

3 Case study of Grey Water System application - Option I.

3.1 Designing the system

At this stage it is important to define grey water system parts for proposed building. Determine what we can consider as grey water production and white water demand. Depending on this specification and according to chosen types of sanitary we can estimate amount of water pollution and according to target utilization estimated the require water quality, which will be reuse in building water cycle.

3.2 Building characteristics

As an example we used the hotel building. The building has four floors; on the first floor we can

find reception, fitness, restaurant, kitchen and technical room (Fig.1).

Fig. 1 South - East view of the Hotel

The rest floors are approximately identical, with only one difference on the second floor, where hotel rooms ale placed instead of conference rooms. Hotel provides accommodation for 128 people.

3.3 Grey water system in hotel building

Due to ensure the natural water system in building, with minimal use of additional energy the self-gravity grey water discharge system from sanitary was designed [6,15]. Therefore the technical room, where is placed wastewater treatment plant and storage tanks for grey and treated grey water usually called - white water, are placed on the first floor, the water was collected only from the second to fourth floor (Fig.2).

Fig. 2 The 1st and typical floor with grey water use

Sanitary appliances which will produce grey water are sinks, kitchen sinks, showers and baths. Cleaned white water will be used for toilets and urinal flushing, cleaning and from May to September also for irrigation.

3.4 Amount of water in the system

During calculation it is important to establish daily production of grey water and daily demand of white water and the comparison has to fulfill following condition:

$$Q_{prod} \geq Q_{24} \quad (1)$$

Q_{prod} - volume of produced grey water per day (l/day)
Q_{24} - volume of white water demand per day (l/day)

When this condition is fulfilled, we can consider that system has potential for grey water use.

Following calculation was transferred according to calculation [3].

Daily production of grey water

Determination of daily production of grey water per day, was based on a number of sanitary appliances which produce grey water. We selected 139 appliances (Table 1) [7].

Table 1 Amount of sanitary produced grey water

Sanitary appliances	Sanitary amount	Grey water production q_{prod} (l/day)
Shower	52	90
Bath	7	150
Kitchen sink	3	5
Sink	77	-

$$Q_{prod,i} = \sum_{i=1}^{m} (q_{prod,i} \cdot n_{mj,i}) \quad (2)$$

$$Q_{prod} = (q_{prod,shower} \cdot n_{bed} + q_{prod,bath} \cdot n_{bed} + q_{prod,sink} + q_{prod,kitchen,sink} \cdot n_{person}) \quad (2)$$

Q_{prod} - volume of produced grey water per day (l/day)
$q_{prod,i}$ - grey water production per unit or day (l/day)
$n_{mj,i}$ - amount of the same measuring units

If the production per unit or day is missing, as it is in this case, it can be determined according to this relation:

$$q_{prod,\ sink} = q_c \cdot n_c \quad (3)$$

q_c - grey water production for relevant activity (l)
n_c - amount of the same units performing within one day

$$q_{prod,\ sink} = 3.((2 .128) + (2.8) + (2.12) + (2.120) \quad (3)$$
$$q_{prod,\ sink} = 1\ 608 \text{ l/day}$$

(3)

$$Q_{prod} = (90.112+150.16+1\ 608 +5.12) \quad (2)$$
$$Q_{prod} = 14\ 148 \text{ l/day} \quad (2)$$

According to calculation is hotels grey water production 14 148 l/day.

Daily demand of white water

Daily demand of white water is created by 86 sanitary appliances and water demand for cleaning and irrigation (Table 2, 3).

Table 2 Amount of sanitary utilizing white water

Sanitary appliances	Sanitary amount	Flushing volume q_0 (l)
Toilet	80	6
Urinal	6	4

Table 3 White water demand for cleaning and irrigation

Type of water demand	Exploited area A (m^2)	White water demand q (l/m^2)
Cleaning	2 086,7	0,1
Irrigation	1 230,6	1

$Q_{24}= (q_{wc}. n_{person} + q_{pis}. n_{person}+ q_{clean}. n_{clean} + q_{irr}. A_{irr})$ (4)

Q_{24} - volume of white water demand per day (l/day)
$q_{n,i}$ - white water demand per unit or day (l/day)
$n_{mj,i}$ - amount of the same measuring units
A_{irr} - irrigated area (m^2)

Water demand for flushing toilets and urinals is determined by following relation:

$q_{wc}= q_0. p= 6. 4,42 = 26,52$ l (5)
$q_p= q_0. p = 4. 3 = 12$ l (5)

q_0 - flushing volume (l)
p - number of uses

$Q_{24}= (26,52. 195 + 12. 65+ 0,1. 2\ 086,7 + 1. 1\ 230,6)$ (4)
$Q_{24}= 7\ 390,67$ l/day (4)

Daily amount of required white water for purposed building at maximum occupancy and in months when we consider irrigation 7 390,67 l/day.

During months when irrigation is unnecessary, is the amount of white water demand 6 160,07 l/day.

3.5 Potential of grey water reuse

According to calculated values, we can estimate the potential of grey water system for this building (Fig. 3 and 4).

$Q_{prod} \geq Q_{24}$ (1)
14 148 $\geq$ 7 391 l/day include irrigation (1)
14 148 $\geq$ 6 160 l/day without irrigation (1)

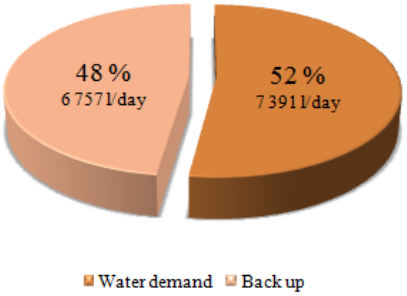

Fig. 3 White water demand including irrigation

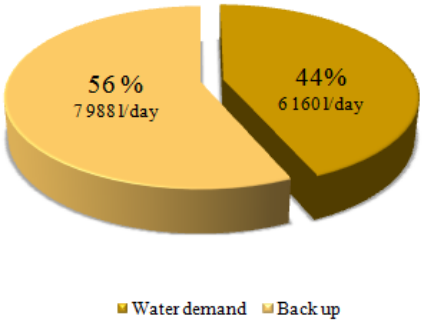

Fig. 4 White water demand without irrigation

This specific case proves that condition is fulfilled and the production of grey water covers the daily requirement of white water. Grey water production also creates the substantial amount of back up, which can supply building during unexpected water demands. In possibility of no utilization for back up, water can be safety discharged from building by waste water drainage.

3.6 Amount of water in system according to real conditions

The calculation was provided with 100 percent hotel occupation, what we can consider as a rare event. For example how can the water production and white water demand look like, we can mentioned the comparison of real occupancy of hotel in Liptovsky Mikulas during 2014th year (Table 4 and 5)(Fig 8).

Table 4 Annual grey water production

Month	Days	Grey water production Fully hotel occupancy		Hotels occupancy [%]	Grey water production [l/month]
		Daily [l/day]	Monthly [l/month]		
January	31	14 148	438 588	22,6	99 121
February	28		396 144	96,1	380 694
March	31		438 588	45,12	197 891
April	30		424 440	13,42	56 960
May	31		438 588	17,97	78 814
June	30		424 440	35,02	148 639
July	31		438 588	77,88	341 572
August	31		438 588	83,33	365 475
September	30		424 440	26,75	113 538
October	31		438 588	15,58	68 332
November	30		424 440	8,4	35 653
December	31		438 588	18,73	82 148

Table 5 Annual white water demand

Month	Days	White water demand Fully hotel occupancy		Hotels occupancy [%]	White water demand [l/month]
		Daily [l/day]	Monthly [l/month]		
January	31	6 160	190 960	22,6	43 157
February	28		172 480	96,1	165 753
March	31		190 960	45,12	86 161
April	30		184 800	13,42	24 800
May	31	7 391	229 121	17,97	41 173
June	30		221 730	35,02	77 650
July	31		229 121	77,88	178 439
August	31		229 121	83,33	190 927
September	30		221 730	26,75	59 313
October	31	6 160	190 960	15,58	29 752
November	30		184 800	8,4	15 523
December	31		190 960	18,73	35 767

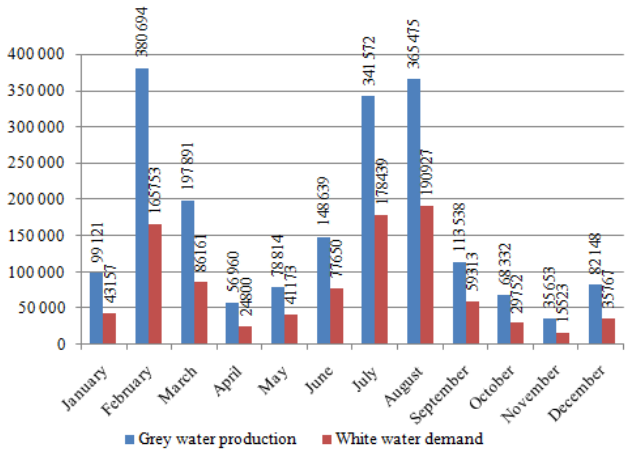

Fig. 8 Comparison of the grey water production and white water demand according to hotels occupancy

4 Case study of Grey Water System application - Option II.

4.1 Building characteristics

As the second option of grey water system application we use the same building, but including also the first floor. We can consider that the technical room with all of the equipments included in grey water system is placed in the underground floor. That means we can extend the grey water system of 58 sanitary equipments.

4.2 Amount of water in system

Daily production of grey water

Adding the first floor to grey water system extended the daily production of 38 sanitary appliances (Table 6)

Table 6 Amount of sanitary produced grey water

Sanitary appliances	Sanitary amount	Grey water production q_{prod} (l/day)
Shower	52+17	90
Bath	7	150
Kitchen sink	3	5
Sink	77+21	-

$$Q_{prod,i} = \sum_{i=1}^{m} (q_{prod,i} \cdot n_{mj,i}) \quad (2)$$

$$Q_{prod} = (q_{prod,shower} \cdot n_{bed} + q_{prod,bath} \cdot n_{bed} + q_{prod,sink} + q_{prod,kitchen,sink} \cdot n_{person}) \quad (2)$$

Q_{prod} - volume of produced grey water per day (l/day)
$q_{prod,i}$ - grey water production per unit or day (l/day)
$n_{mj,i}$ - amount of the same measuring units

If the production per unit or day is missing, as it is in this case, it can be determined according to this relation:

$q_{prod,\ sink} = q_c \,.\, n_c$ (3)

q_c - grey water production for relevant activity (l)
n_c - amount of the same units performing within one day

$q_{prod,\ sink} = 3.((2.128)+(2.8) + (2.12) + (2 .120) + (3. 150)+(2.100))$ (3)
$q_{prod,\ sink} = 2\ 258$ l/day (3)

$Q_{prod} = (90.112+50.100 +150.16+2\ 258+5.12)$ (2)
$Q_{prod} = 19\ 798$ l/day (2)

According to calculation is hotels grey water production 19 798 l/day.

Daily demand of white water
Daily demand of white water was extended of 20 sanitary appliances (Table 7 and 8).

Table 7 Amount of sanitary utilizing white water

Sanitary appliances	Sanitary amount	Flushing volume q_0 (l)
Toilet	80+13	6
Urinal	6+4	4

Table 8 White water demand for cleaning and irrigation

Type of water demand	Exploited area A (m^2)	White water demand q (l/m^2)
Cleaning	2 086,7 + 1 385,7	0,1
Irrigation	1 230,6	1

$Q_{24} = (q_{wc}.\ n_{person} + q_{pis}.\ n_{person} + q_{clean}.\ n_{clean} + q_{irr}.\ A_{irr})$ (4)

Q_{24} - volume of white water demand per day (l/day)
$q_{n,i}$ - white water demand per unit or day (l/day)
$n_{mj,i}$ - amount of the same measuring units
A_{irr} - irrigated area (m^2)

Water demand for flushing toilets and urinals is determined by following relation:

$q_{wc} = q_0.\ p = 6.\ 4{,}42 = 26{,}52$ l (5)

$q_{wc} = q_0.\ p = 6.\ 4 = 24$ l (5)
$q_p = q_0.\ p = 4.\ 3 = 12$ l (5)

q_0 - flushing volume (l)
p - number of uses

$Q_{24} = (26{,}52.\ 195 + 24.\ 120 + 12.\ 195 + 0{,}1.\ 2\ 086{,}7 + 1.\ 1\ 230{,}6)$ (4)
$Q_{24} = 11\ 969$ l/day (4)

Daily amount of required white water for purposed building at maximum occupancy and in months when we consider irrigation 11 969 l/day.

During months when irrigation is unnecessary, is the amount of white water demand 10 739 l/day.

4.3 Potential of grey water reuse

According to calculated values, we can estimate the potential of grey water system for the whole building (Fig. 9 and 10).

$Q_{prod} \geq Q_{24}$ (1)
19 798 ≥ 11 969 l/day include irrigation (1)
19 798 ≥ 10 739 l/day without irrigation (1)

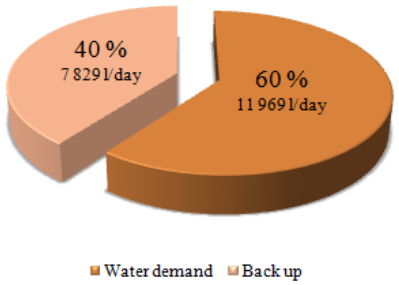

Fig. 9 White water demand including irrigation

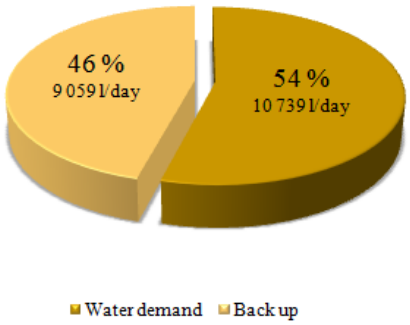

Fig. 10 White water demand without irrigation

The case study also proved that condition is fulfilled and the production of grey water covers the daily requirement of white water. Grey water production also creates the substantial amount of back up, which can supply building during unexpected water demands. In possibility of no

utilization for back up, water can be safety discharged from building by waste water drainage.

4.4 Amount of water in system according to real conditions

The calculation was provided with 100 percent hotel occupation, what we can consider as a rare event. For example how can the water production and white water demand look like, we can mentioned the comparison of real occupancy of hotel in Liptovsky Mikulas during 2014th year (Table 9 and 10).

Table 9 Annual grey water production

Month	Days	Grey water production Fully hotel occupancy		Hotels occupancy [%]	Grey water production [l/month]
		Daily [l/day]	Monthly [l/month]		
January	31	19 798	613 738	22,6	138 705
February	28		554 344	96,1	532 725
March	31		613 738	45,12	276 919
April	30		593 940	13,42	79 707
May	31		613 738	17,97	110 289
June	30		593 940	35,02	207 998
July	31		613 738	77,88	477 979
August	31		613 738	83,33	511 428
September	30		593 940	26,75	158 879
October	31		613 738	15,58	95 620
November	30		593 940	8,4	49 891
December	31		613 738	18,73	114 953

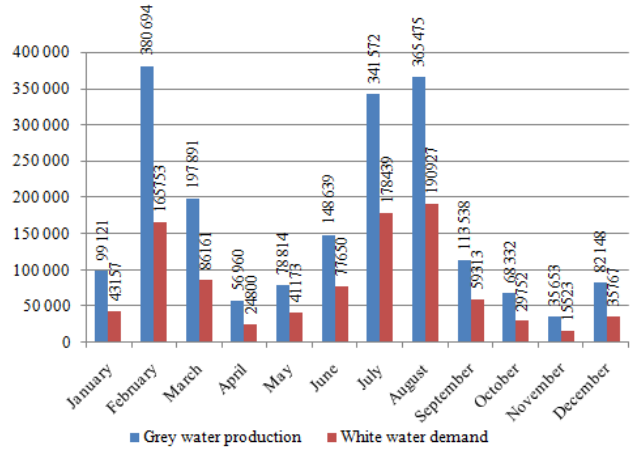

Fig. 11 Comparison of the grey water production and white water demand according to hotels occupancy

Table 10 Annual white water demand

Month	Days	White water demand Fully hotel occupancy		Hotels occupancy [%]	White water demand [l/month]
		Daily [l/day]	Monthly [l/month]		
January	31	10 739	332 909	22,6	75 237
February	28		300 692	96,1	288 965
March	31		332 909	45,12	150 209
April	30		322 170	13,42	43 235
May	31	11 969	371 039	17,97	66 676
June	30		359 070	35,02	125 746
July	31		371 039	77,88	288 965
August	31		371 039	83,33	309 187
September	30		359 070	26,75	96 051
October	31	10 739	332 909	15,58	51 867
November	30		322 170	8,4	27 062
December	31		332 909	18,73	62 354

5 Comparison with used grey water systems

5.1 Average water consumption in 2-3 star hotels

It is clear that the daily water consumption is specific for each hotel, because the water consumption is affected by several factors (provided services, number of beds, occupancy, users' behavior). But according to some studies and grey water system application, we can say that for 2-3 star hotels is recorded water use 160 l/day per guest, of which is 52 l/day the amount of grey water discharge. Potential grey water quantities are in this case 1,65 m^3/day and for month it reach 49,5 l/month [9].

5.2 Measured water consumption in 3 star hotel in Spain

According to measured values of water in this hotel the amount of water consumption was 145 l/day per guest, from which 36 l/day was amount of grey water and this source was used for toilet flushing [5]. The grey water was used just for toilets flushing which represents amount 5,2 m^3/day saved potable water. Monthly grey water demand is in this case 156 l/month [10].

5.3 Comparison

If we compare the referred values of grey water consumption (Fig.12), we can see, that calculated method could be oversized, what is usual event, because for instance the designing of grey water system for hotel is calculated for maximal utilization of sanitary appliances and maximal occupancy of hotel, which is in most hotels unique situation. Therefore is normally that real condition and system operation will prove the lower usage. However the oversizing could be useful in occasions, where the amount of produced water will be unexpectedly high and also in high white water demand [12].

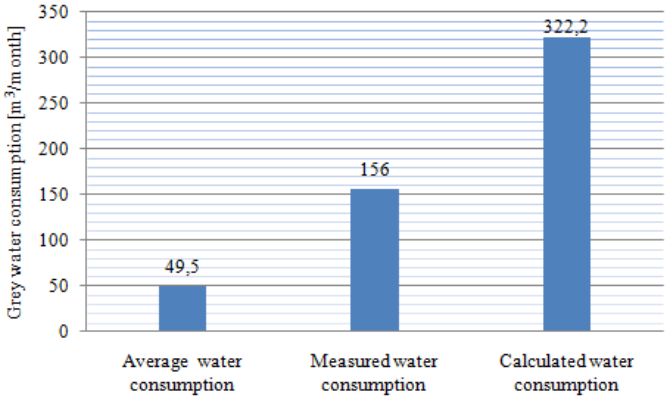

Fig. 12 Comparison of the grey water consumption

6 Discussion

We can consider that these examples of grey water application prove that system has some saving potential especially for potable water.

1st option proves that if we are considering with the occupancy of hotel above, our annual saves will values 948 m^3 of potable water. It is understood that with water savings, we save some sort of financial sources. For this specific case it represent 1 035 € savings per year, with actual price for water supply 1, 0922 €/m^3 [4] in Liptov region, which is famous Slovak region for summer and winter holiday. According to actual price for water discharging to public sewer in this region - 1, 3282 €/m^3 [4,8] the savings reach 1 259,10 € per year. Overall savings on water supply and discharging water will be 2 294,5 €.

2nd option also proved that system have saving potential, specifically 1 586 m^3 of potable water, what represent financial savings 1 732 € per year for water supply and 2 107 € per year for sewage discharging. Overall savings on water supply and sewer discharging for this case study will be 3 693 € per year.

7 Conclusion

The modern decentralized water infrastructure can include site-collected rainwater, grey water, storm water, and black water systems. The main goal is to point out a need for standardization to protect the public and to ensure that reliable systems are designed, installed and maintained. It is necessary to define regulation and set standards for designing hybrid systems for example according to foreign national standards and performed experiments in Slovak conditions. From this example of grey water application we can consider, that system is efficient in terms of saving potable water. It is clear that the changing of hotel occupation will have impact on the water and financial savings. The target of this article was to introduce the grey water system and pointed out that with this system we can save certain amount of potable water, which is used for purpose where it is with its quality unnecessarily wasted.

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