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Water Reuse Possibilities at Students Dormitories

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1. Introduction

Water reuse possibilities are included in green universities strategies and different options are under consideration at some universities around the European Union countries. Vilnius Gediminas Technical University Senate approved Green University conception on 2015.01.29 including water reuse options in buildings renovation programme. Integrated reviews on possible water reuse systems include sustainable, technological, economic (Friedler & Hadari 2006) and social approaches (Al-Jayyousi 2003, Ilemobade et al. 2013). Reused water qualitative and quantitative analysis were carried out by academic researchers from different countries worldwide (Angelakis & Durham 2006, Burkhard & Deletic 2000). Water reuse technology must be carried out following the principles of sustainable development which, in recent years, has been referred globally in the universities (Jóźwiakowski et al. 2015). One of the intensive points of water use are students dormitories situated nearly all universities.

Water demand in domestic activities for bath and/or shower usually ranges between 56 and 100 L/d per capita comprising 38% of the total daily water demand. Nearly all used water is transformed into wastewater, which can be generalised into two different categories: grey-water: all domestic wastewater except toilets, comprising 60-70% of the domestic water demand; black-water from WC equipped toilets, comprising nearly 30% of the domestic water demand. Some measurements showed that since domestic grey-water quantity is greater than its possible reuse for toilet flushing, it is feasible to reuse only the less polluted

grey-water quantities originating from baths and/or showers and thus reduce treatment needs and possible adverse effects. Therefore, there is a need to evaluate easier-in-use measures for the estimation of water quantities, qualities indicators and estimations which will indicate sustainable development (Hiroaki 2008). in an appropriate practical way and which will be easy to understand both for the end users (students) and for the academic society (Krozer & Hophmayer-Tokich 2010).

Usually research has been dedicated on the development and improvement of different treatment and reuse methods (Li et al. 2012, Li et al. 2010, Lin et al. 2005) whereas the quantitative measurements of grey-water reuse have been only theoretically evaluated (Bixio et al. 2011). The main aim of this article is to perform a quantitative analysis of practically balanced grey-water reuse systems, since unless proven possible, grey-water reuse practice will not become in use. The analysis was carried out on students dormitories, where the students who attend "Water sources technologies" course were measuring their own use of water needs for different activities. The article focuses on multi-storey students dormitories buildings, which are typical to universities occupied urban areas where the water reuse potential is most significant on a sustainable development scale (Friedler & Hadari 2006).

2. Methods

All students from Environmental Engineering Faculty of Vilnius Gediminas Technical University (Lithuania) (attending "Water sources technologies" course on third study year in spring semester) were instructed about measurements of domestic water use. Totally 148 students were divided to working teams till 10 persons in each group and all members were measured theirs water use for showers, WC flushing, cooking, washing, cleaning and other related activities. All measurements were estimated hourly, daily and monthly following obtained litres per capita numbers. All students were living in 16 floors students dormitories situated near the university campus. Students rooms were equipped with shower, WC, hand washing basin and kitchen facilities with usual water taps without water saving devices. All roommates were involved in water quantities measurements on used water flow. Male and female working teams were involved in measuring their water use separately with possi-

bilities to evaluate water needs following gender indicator. Some working team members were absolute "leaders" in water use quantities and theirs explanations were related with high load of sport exercise or beauty treatment.

Open presentations on measurements progress were carried out weekly (ones per week) mostly related to knowledge exchange and corrections on obtained mistakes. All working teams were advised to estimate statistically approved maximum, minimum and average water use quantities. Some comparison techniques were in use when evaluating different demand for water use following related activities (study time – schedule, sport, beauty treatment etc.). Finally after last discussions by the end of May we obtained finished reports on water use and possible water reuse balances on hourly, daily and monthly water quantities. Some similarities in water use for showering and WC flushing were obtained in measurements and nearly all working teams agreed on possible grey-water reuse from shower to WC. All possible water reuse balances were carefully estimated and samples taken from shower water to quantitative analyse using laboratory equipment related to analysing of Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and suspended materials (SM), turbidity. Grey-water from shower was standing still for one, two and 3 days, imitating possible storage for reuse and all changes in water quality changes were recorded and compared.

3. Results and Discussion

The average water use during the measurement was 48 L per one student per day for shower, where 31 L were used to flush the toilets, which represents reuse possibilities on the order of 64%, in accordance with other published percentages. These values include in total daily consumption per one student equal to average of 100L. The average total water use through toilet flushing was 10 m3/d (in case if all students will stay at the dormitory). From these data an average storage time of 54 h was calculated for shower water; approximately similar storage time (48 h) has also been recommended for untreated grey-water (Orona 2014).

Table 1 presents the evaluation of the water reuse quantities, i.e. the average, minimum and maximum amounts of the estimated meas-

urements, from the first to the last days, taking into account the evaluation criteria from seven working teams and the numbers assigned to those criteria by the authors.

Table 1. Statistically evaluated water use per one student
Tabela 1. Statystyczne zużycie wody na jednego studenta

Team Nr.	average, shower L/day	min shower L/day	max shower L/day	average, WC L/day	min WC L/day	max WC L/day
1	46	18	90	32	20	50
2	41	25	74	45	32	70
3	47	18	90	35	20	45
4	40	12	144	22	6	63
5	42	25	57	36	27	45
6	26	11	93	12	6	18
7	48	11	144	31	6	70

Average distribution of weekly measured water use was evaluated for ten different weeks and generalized in Figure 1, presented below.

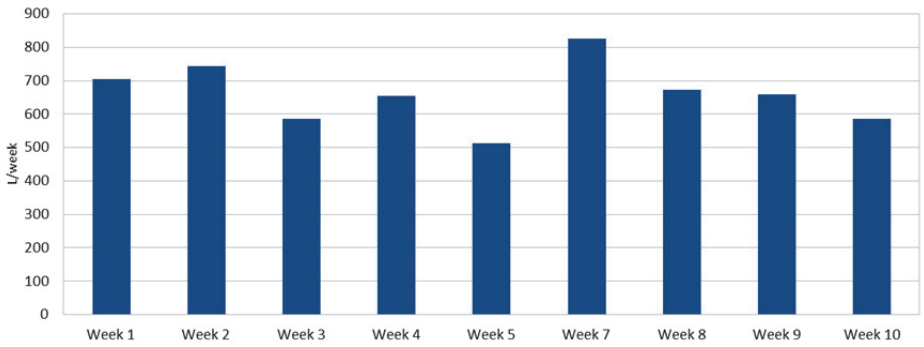

Fig. 1. Evaluation of weekly provided measurements
Rys. 1. Ocena tygodniowych pomiarów

The analyses indicate that among the students water use under evaluation the difference was estimated approximately equal till 60% as the most significant between weekly water use. Average water use per

one week was evaluated following different needs including: shower, WC, personal hygiene, cooking, laundry. Total percentage of different water use is presented in Figure 2 with shower and WC related water qualities.

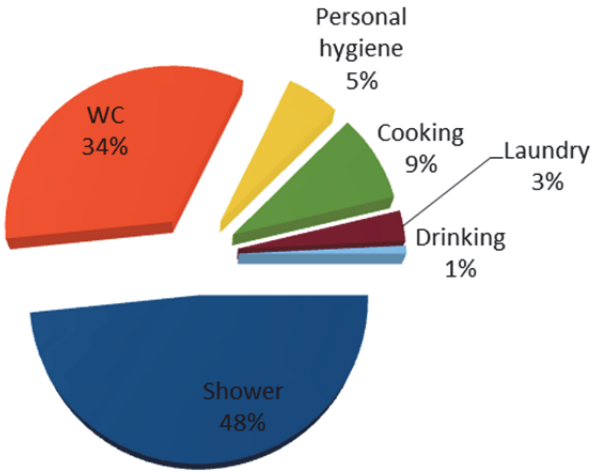

Fig. 2. Total percentage of different water use
Rys. 2. Przeznaczenie wody

Following all measurements, estimations and general evaluation grey-water from showers quantity is sufficient to the water quantity of the flushing WC. All grey-water from showers can be collected to the storage reservoir and conveyed from there gravitationally through a separate pipeline to the WC flush systems in each floor. Some shortage of grey-water from showers in the storage reservoir is filled up by conventional water supply through a one-way valve, and any excess is discharged through the wastewater collector of the dormitory.

Different water use quantities per one student per day are presented following all days of the week in Figure 3 and evaluated following biggest differences between minimum and maximum daily use was approximately 40%.

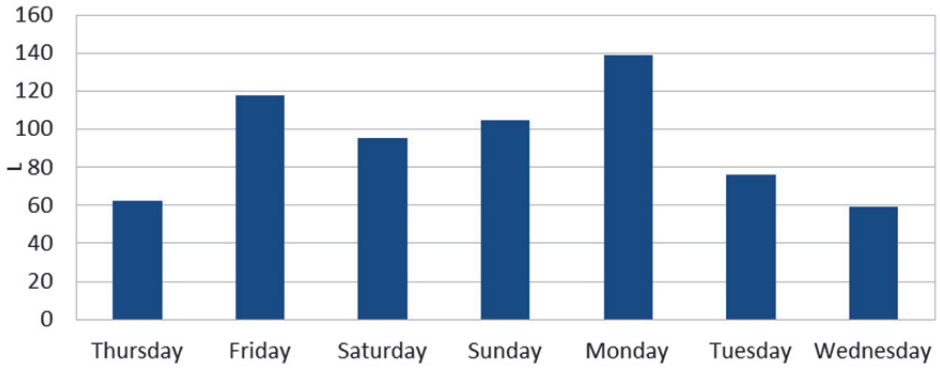

Fig. 3. Daily water use per one student on different days per one week
Rys. 3. Dzienne zużycie wody na jednego studenta w poszczególne dni tygodnia

Visual coverage of WC flushing water quantities with shower grey-water can be seen from Figure 4, where in first columns minimum monthly quantities (Litres per month per one student) are presented, with average amounts in the middle columns and maximum used in the last columns.

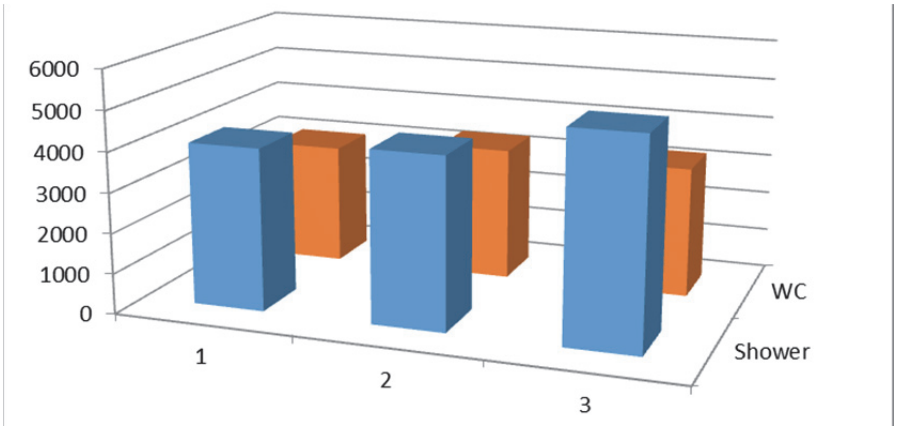

Fig. 4. Monthly water use per one student following: 1 – minimum, 2 – average and 3 – maximum estimated quantities
Rys. 4. Miesięcznie zużycie wody na jednego studenta: 1 – minimalne, 2 –średnie, 3 – maksymalne oszacowane ilości

From the Figure 4 total amount of reused grey-water from all showers can be equal to 1200 m^3 per month in case if all students are living at the dormitory. Reused water amount will interacts with energy savings (Lazarova 2012) on water pumps running water all day long to 16 floors students' dormitory.

Finally qualitative measurements were carried out at the University laboratory and additional results obtained from different storage time for grey-water from showers. Statistically estimated results are presented in Table 2 following sampling from freshly obtained grey-water from showers, water standing still in the reservoir for 1, 2 and 3 days at room temperature.

Table 2. Grey-water quality indicators following different retention time
Tabela 2. Wskaźniki jakości szarej wody po różnym czasie retencji

Indicators / Retention	BOD_7 mg O_2/L	COD mg/L	SM mg/L	Turbidity NTU
1 day	159	235.6	57	71.4
2 days	162	251.2	72	71.6
3 days	103	243.3	51	73.2
Freshly obtained	113	184.2	70	74.3
Reference (Eriksson et al. 2002)	109	263	40-60	69

Obtained qualitative indicators were compared with reference from Eriksson and coauthors article published on 2002 and some similarities were found in all measured and estimated results. Some changes in water quality after 1, 2 and 3 days storage were insignificant for possible use in WC flushing system. Collected grey-water can be used without additional treatment in WC flush reservoirs with usual domestic disinfectants (Pidou et al. 2008, Donner 2010).

4. Conclusions

The unique advantage of grey-water reuse is the possibility of water collection at the place where the wastewater is generated. If such systems are properly operated and maintained, it is possible to reduce quantities of wastewater related to the environment pollution and that may

contribute to the saved water resources (Schäfer & Beder 2006). Additionally, it is necessary to provide proper educational activities that should improve the potential water users' knowledge of which technologies of domestic water reuse are recommended and how a related system should be operated and maintained to ensure sustainable development of Green Universities.

On the basis of water use analysis it was found that the most advanced technologies among those used in different countries are systems with grey-water obtained from showers reuse and reliable constructed WC flushing systems at students dormitories.

With a highest predominance of obtained from shower grey-water it is the system with water reuse for WC flushing that was indicated as the most effective solution for students dormitories; but taking into account the investments (economic criteria), the possibility of application of that technology on any different place (university buildings) should be evaluated with additional measurements.

It was found that the most appropriate was the technology involving the grey-water reuse of used for showers water. The qualitative analysis demonstrated that the application of that technology is in accordance with the principles of sustainable development, due to obtained grey-water quality, sufficient water retention stability and high reliability of acceptable quality.

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Możliwości ponownego wykorzystania wody w akademikach

Streszczenie

Głównym celem niniejszego badania było oszacowanie, w jakim stopniu ponowne wykorzystanie szarej wody może przyczynić się do zaoszczędzenia wody dostarczanej do akademików. Badanie zostało przeprowadzone z udziałem studentów trzeciego roku Wileńskiego Uniwersytetu Technicznego im. Giedymina (Litwa). Ilość ponownie wykorzystanej wody mierzono w następujący sposób: dziennie (L/d) przez 24 godziny, tygodniowo L przez 7 dni i miesięcznie przez 30 dni. Ilość wody obliczono i oszacowano za pomocą charakterystyki technicznej zamontowanych kranów.

Ponowne wykorzystanie wody jest jedną z kluczowych strategii systemu Zielonego Uniwersytetu na Litwie. Może ono pomóc uświadomić, że w studenckich akademikach potrzebne jest wprowadzenie energooszczędnego sprzętu, opartego na idei zrównoważonego rozwoju. Obecnie, możliwość ponowne go wykorzystania wody i energii jest określana tylko na podstawie funkcjonalności materiałowej lub analizy kosztów. Nie są brane pod uwagę środowiskowe, gospodarcze i społeczne aspekty zrównoważoności. W niniejszym badaniu, oceny możliwości ponownego wykorzystania wody i jej zaoszczędzenia dokonano za pomocą zintegrowanej metody oceny dostępnych możliwości. W celach porównawczych w badaniu odniesiono do przykładów z Unii Europejskiej.

Słowa kluczowe:
ponowne wykorzystanie wody, zapotrzebowanie na wodę,
zaopatrzenie w wodę, Zielony Uniwersytet

Keywords:
water reuse, water demand, water supply, Green University