ISSN : 2460-0849

UNIVERSITY OF BRAWIJAYA · UNIVERSITI MALAYA · UNIVERSITI SAINS MALAYSIA · UTHM

icwrdep

MALANG - INDONESIA

icwrdep 2015

THE 1ST YOUNG SCIENTIST INTERNATIONAL CONFERENCE OF WATER RESOURCES DEVELOPMENT AND ENVIRONMENTAL PROTECTION

5 - 7 June 2015

PROCEEDING

Environmental Engineering & Water Technology
Integrated Water Systems & Governance
Water Science & Engineering

WATER RESOURCES ENGINEERING DEPARTMENT
FACULTY OF ENGINEERING

Secretariat:
Water Resources Engineering Department
Faculty of Engineering, University of Brawijaya
Jalan MT. Haryono no. 167
Malang 65145 - East Java - Indonesia
Phone/ Fax. (0341) 562454
email: tsa_ub@ub.ac.id; wateresdev@ub.ac.id

Conference Website:
www.wateresdev.ub.ac.id

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FOREWORD

The 1st Young Scientist International Conference of Water Resources Development and Environmental Protection 2015 (ICWRDEP 2015) Water Resources Engineering Department, Faculty of Engineering, University of Brawijaya was conducted on 5 - 7 June 2015. The Conference was organized by Faculty of Engineering and collaborated with International University of Malaya (UM), Universiti Sains Malaysia (USM) and Universiti Tun Hussein Onn Malaysia (UTHM).

The participants of the Conference are about 60 participants come from more than 20 higher institutions, such as; Sepuluh Nopember Institute Of Technology, Surabaya (ITS), Bandung Institute of Technology (ITB), Bogor Agricultural University (IPB), The University of Lampung, Sriwijaya University, University of Muhammadiyah Malang (UMM), University of Brawijaya (UB), Padjajaran University, State University of Malang (UM), National Institute of Technology (ITENAS), Tidar university, State Polytechnic of Malang (Politeknik Negeri Malang), Mulawarman University, State Polytechnic of Padang (Politeknik Negeri Padang), Malang National Technology Institute (Institut Teknologi Nasional Malang), BBWS Mesuji Sekampung, Bengkulu University, Diponegoro University (UNDIP), Nusa Cendana University, Khairun University, Bantara University, University of Jember, State Polytechnic of Samarinda (Politeknik Negeri Samarinda), UM (University of Malaya), Universiti Sains Malaysia (USM) and Universiti Tun Hussein Onn Malaysia (UTHM), and others, which reflect the importance water resources engineering development and environmental protection.

The topics of conference are Environmental Engineering & Water Technology, Integrated Water System & Governance and Water Science & Engineering. The conference provide platform for researchers, engineers and academician to meet and share ideas, achievement as well as experiences through the presentation of papers and discussion. These events are important to promote and encourage the application of new concept of water resources development and techniques to practitioners as well as enhancing the knowledge of environmental protection with the current requirements of analysis, design and construction of any engineering concept.

As Head of Water Resources Engineering Department, we would like to express our deepest gratitude to the Rector University of Brawijaya, Keynote Speakers (Prof Satoru Oishi & Prof Tsuyoshi Imai from Japan, Assoc. Prof Faridah Othman and Prof Amir Hamzah from Malaysia), International Advisory Board members, organizing committee and also to all participants.

We would like to express our deepest gratitude to the Faculty of Engineering conducted such conference. This is the first International conference for the Department and we expect that this is will become 2nd annual activity for our Department.

Malang, 5 June 2015

Ir. Mohammad Sholichin, MT., Ph.D
Head of Water Resources Engineering Department
Faculty of Engineering University of Brawijaya

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Potential Greywater Quantification for Reuse in Newton Residence Apartment Bandung, Indonesia

Dyah Asri Handayani TAROEPRATJEKA[1]*, Yulianti PRATAMA[1], Devi Ayu PUTRIANTI[1]

[1] *Department of Environmental Engineering, Institut Teknologi Nasional (Itenas), Jl. Penghulu K.H. Hasan Mustafa 23 Bandung, Indonesia*
**Corresponding author's e-mail: dyahasri@itenas.ac.id*

ABSTRACT
Newton Residence Apartment is a 3-tower high-rise residential building located in Bandung, West Java, Indonesia. With the total number of 915 units and 47,472 m^2 building area, covering 5,349 m^2 of land, each tower consists of 22 to 36 floors. Total population of the building (including residents, employees, and visitors) is approximately 3, 245 people.
The objective of this study is to determine whether greywater generated in this building could contribute a significant amount of water to reuse, thus reducing the quantity of clean water pumped from the deep well as the main source.
Preliminary identification found that water generated from washbasin, floor drains from showers and faucets used for ablution, and air-conditioning (AC) condensate, as suitable sources as they fall into light greywater category. The result showed that the high-rise residential building has sufficient greywater quantity potential for reuse to cover all of the 69.72 m^3/day toilets and urinals flushing requirements. Greywater reuse could contribute up to 22% of the building's clean water quantity requirement, thus reducing the amount taken from the current source of deep well pumping, and save approximately Rp. 275,219,453.- per year of the current ground water tariff in Bandung.

KEYWORDS
Greywater reuse, AC-condensate recovery, quantification, high-rise residential buildings.

INTRODUCTION
The diminishing supplies of the earth's freshwater leave no other choices for humankind than to use it wisely. One of means of water conservation is through water reuse, which can be done through greywater reuse for toilet flushing and landscape irrigation in high-rise residential buildings. To measure out the possibility, a quantitative study was done in Newton Residence Apartment Bandung, Indonesia.

Greywater is a term used for wastewater discharges from residential buildings, excluding excreta and kitchen sinks. Discharges containing excreta, usually from toilets and urinals, are called blackwater. In order to maximize the potential quantity of greywater, the plumbing lines should be strictly separated from blackwater lines. Grey-water also requires separate treatment process before being reused for toilet flushing and fire-protection system.

Newton Residence Apartment is a 3-tower high-rise residential building located in Jalan Terusan Buah Batu no. 5 Bandung, West Java, Indonesia. As part of Newton The Hybrid Park, the apartment units are located in tower A and B, while tower C functions as a hotel. Each tower has its own basement and roof-top floor with 22 to 36 floors, sharing a podium up to the first four floors, and low rise apartment units in the 5th and 6th floor. There were four

types of unit in those towers: the one bedroom, 2-bedroom, 3-bedroom and studio, with total number of 915 units and building area of 47,472 m^2, covering 5,349 m^2 of land. Facilities in the building include a main lobby, offices, meeting rooms, prayer rooms (musholla), gym, spa, restaurants, mini market, and parking area. Total population of the building (including residents, employees, and visitors) is approximately 3, 245 people.

Figure 1. Artist's Depiction of *Newton The Hybrid Park* (Picture courtesy of Margahayu Land, 2014)

The objective of this study is to determine whether greywater generated in this building could contribute a significant amount of water to reuse, thus reducing the quantity of clean water that should be pumped from the main source, which is the deep well.
The scope of the study is to identify and quantify potential greywater generation from applicable sources for reuse – after subsequent treatments - for toilet flushing and landscape irrigation.

METHODS

In Newton Residence Apartment Bandung, potential sources of greywater were identified. Population numbers of the building was determined according to the area and functions of spaces in the building based on the building's plans and Neufert Architect's Data (Neufert, 2002). The population were comprised of the building's residents, employees, and visitors using plumbing facilities in the building.

The clean water quantity requirement for the building was first calculated by referring to SNI-03-7065-2005 Plumbing System Planning Procedures (Tata Cara Perencanaan Sistem Plambing) (Badan Standardisasi Nasional, 2005), according to the building's function and number of population. Another calculation of water use according to water-conserving plumbing fixture types then followed, with each plumbing fixtures' water use per minute, time duration and typical number of usage per day took into account to determine the specific number of water being generated by each type of plumbing fixtures.

After the clean water quantity has been determined, it was assumed that total wastewater discharge was 90% of clean water quantity, while the greywater's discharge was 80.65% of all wastewater discharge (Komala, Primasari, Kirana, & Sari, 2012). The quantity of greywater from AC condensate was determined by "Condensate Calculator" (Wilcut & Fry, 2010) due to limited study of AC condensate quantity in Indonesia. The Condensate Calculator put into account the outdoor and indoor temperatures and relative humidity, the AC's tonnage of system, percentage of outside air and produces the condensate's quantity in gallons per minute, gallons per hour, and gallons per day. The results are then compared to published literatures of greywater researches for discussions.

RESULTS AND DISCUSSIONS

The identification of potential sources of greywater in Newton Residence Bandung found water generated from washbasin, floor drains from showers and faucets used for ablution, and air-conditioning (AC) condensate, as the suitable sources as they fall into light greywater category. Figure 2 shows the categories and sources of greywater.

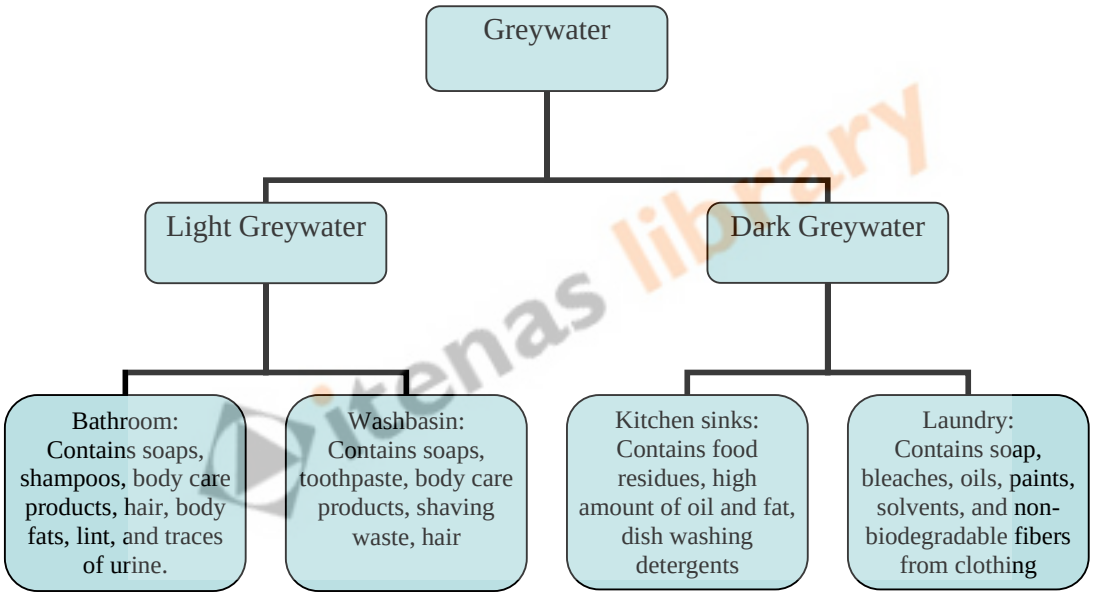

Figure 2. Greywater sources and their constituents (Morel & Diener, 2005), (Noah, 2002), (Queensland Government, 2008) as cited in (Ghaitidak & Yadav, 2013).

A study found that only buildings over approximately 9,280 m^2 typically yield enough AC condensate to justify the expense of condensate recovery for either cooling towers or landscape (Guz, 2005). Based on that, Newton Residence Apartment with its 47,472 m^2 building area was a suitable candidate for AC-condensate recovery.

The clean water calculation, based on the population of 3,245 people, yielded a requirement of 691.92 m^3/day. By comparison, clean water requirement calculation based on water-conserving plumbing fixtures gave the result of 157 m^3/day, since this method doesn't put into account the amount of water used for cooking, drinking, and other uses. The wastewater discharge calculated from water conserving plumbing fixtures was 141.30 m^3/day, comprised of 113.96 m^3/day greywater and 27.34 m^3/day blackwater.

By using the assumption of outside air temperature of 32°C (89F) and relative humidity of 95%, indoor temperature of 25° (77F) and 58% relative humidity, tonnage of system based on 1 PK AC of 2.85 kW (0.8134 ton) and 17% outside air, the AC Condensate Calculator generated 4.75 gallons per day (17.98 L) for a single split Air Conditioner. There were 1,786 units of single split ACs in the building, thus producing 32.11 m^3/day (5.89 GPM) of condensate.

To ensure the calculation generated by the AC Condensate Calculator produced realistic results, field data was also obtained by collecting AC condensate from an operating single split AC in one of Newton Residence office buildings. The AC produced 40 L of condensate per day (Putrianti, 2015).

In comparison, projects capturing air-conditioning condensate in San Antonio, USA, showed that 250 gallons (0. 946L) of condensate was generated each day by the downtown mall, and a central library produced 1GPM (0.06 L/s). Bahrain Airport Services in the Middle East uses 2.3 million gallons (8.7 million L) per year of condensate water for diverse purposes such as toilet flushing, washing, and landscape (Guz, 2005).

The result of potential greywater discharge quantity and percentage according to the sources in Newton Residence Apartments is shown in Table 1.

Table 1. Potential Greywater Discharge and Percentage in Newton Residence Apartments

Source	**Greywater Discharge (m^3/day)**	**Percentage (%)**
Floor Drains (Showers)	93.99	62.33
Air-conditioning condensate	36.85	24.43
Washbasins	19.72	13.08
Floor Drains (Ablution Faucets)	0.25	0.17
Total	150.81	100

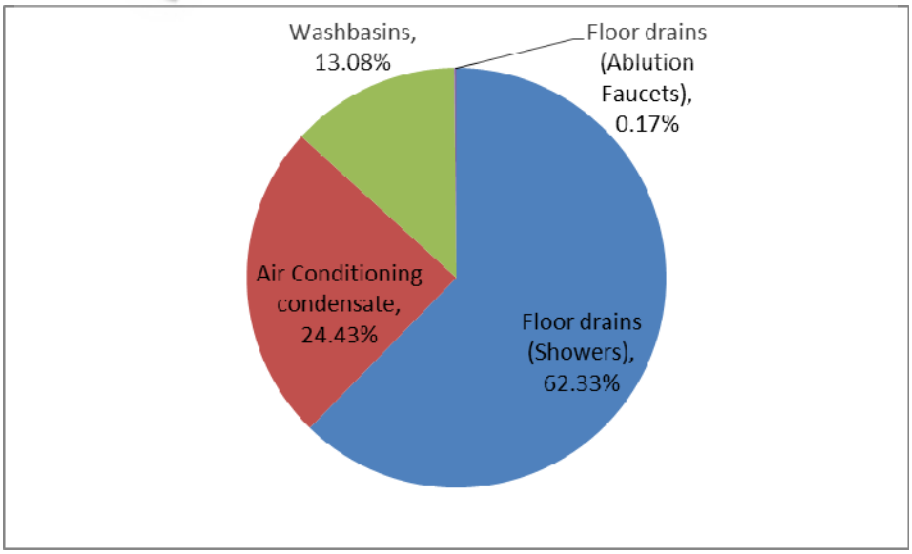

Figure 3. Distribution of Greywater Discharge Percentage

The largest source of greywater discharge, according to Table 1 and Figure 3, was the shower floor drain, with 62.33% of total greywater discharge. Air-conditioning condensate was at the second place, with 24.43% of total discharge. The condensate was followed respectively by washbasins and floor drains from ablution faucets with 13.08% and 0.17% of total discharge. For comparison, a study in cities of Irbid, Rusaifa, and Zarqa in Jordan showed that the biggest contributors of greywater in those semi-arid climate cities were from sink water (50-64%), followed by shower water (22%-33%), and laundry water (15-20%) (Jamrah & Ayyash, 2008). Sink water in that study were coming from limited activities such as hand washing, ablution, tooth brushing, and hair washing, more related to activities being at washbasin in this study, instead of kitchen sink.

These differences in greywater generation could be related to climate and customary differences. In Indonesia, due to the tropical climate, it is customary for each person to take showers twice a day. While in Jordan, with its semi-arid climate, people may not need to take showers as often as in Indonesia, and use the washbasin instead. In terms of water quality, air-conditioning condensate has favourable quality due the condensation process, where condensate-water is distilled, pure water when it forms on the condensate coils of an air handler. However, it can pick up bacterial contamination during formation and transport (Guz, 2005).

The greywater, after being collected and treated, will be used for toilets and urinals flushing and for landscape irrigation. The quantity will reduce after treatment, although the lost amount still cannot be determined due to limited study on the subject. One of the recommended greywater treatment that has proven its effectiveness and suitability for over 10 years in multi-story buildings, was through a series of funnel-shaped sedimentation tanks with sludge-removing devices, followed by a vertical-flow sand filter with reed bed, or a multiple-stage rotary biological contactor (RBC), or alternatively a trickling filter, coupled to a clearing tank to remove the biomass. The treated water is then disinfected by UV before it stored in the service water tank. Similar to stormwater systems, light also has a negative effect on greywater system and therefore, service tanks should be protected against daylight (Nolde, 1999).

Table 2. Calculation of Toilet and Urinal Water Flushing Quantity Requirements in Newton Residence

Population	Population Number			Toilet Flushing Water Requirements (L/person/day)		Total (L/day)
	Total	Men	Women	Men	Women	
Apartment residents	1.628		-		24	39.072
Hotel guests	910		-		24	21.840
Employee	257	129	128	12,4	14,4	3.442,8
Meeting Room visitors	362	181	181	12,4	14,4	4.850,8
Gym and Spa guests	40	20	20	4,8	9,6	288
Restaurant & Mini Market guests	48	24	24	4,8	4,8	230,4
Total Toilet and Urinal Water Flushing Quantity Requirement (Liter/day)						69.724
Total Toilet and Urinal Water Flushing Quantity Requirement (m^3/day)						69,72

Source : (Putrianti, 2015)

From calculation in Table 2, we could see that water quantity required for toilets and urinals flushing was 69.72 m^3/day, or 46.23% from potential greywater generation. The remaining greywater discharge could serve as an alternative water supply for the building's landscape irrigation, replacing the building's main water source, in this case, a deep well. The greywater reuse will provide up to 22% of the 691.92 m^3/day population-based clean water requirement. Greywater reuse will reduce the quantity of groundwater needed to be pumped out of the building's deep well. This will be more beneficial for the environment, and with the current ground water tariff of Rp. 5,000/m^3 in Bandung (Ramdani, 2014), greywater reuse in Newton Residences would save approximately Rp.754, 025. - per day or Rp. 275,219,453.- per year.

The treated greywater quality should be periodically compared to applicable standards for regulatory compliance. Currently, there are still no standard that specifically addresses greywater quality for reuse in Indonesia. Up until then, PP 82/2001 on Water Quality Management and Pollution Control (Pemerintah Republik Indonesia, 2001) could fill in, with greywater falling into water quality standard Class IV (least stringent), referring to its application for plants irrigation. The greywater system should also be tested once under several different conditions (e.g. faecal contamination, application of household chemicals) before operation. Following installation, a qualified inspection should be made, in which a full compliance to standard-installation regulation takes place. The operation of non-registered and untested greywater systems is connected to a potential hygienic risk to the user and the drinking water network (Nolde, 1999).

CONCLUSION

The identification and quantification of greywater generation in Newton Residence Apartments has showed that:

- The high-rise residential building has sufficient greywater quantity potential for reuse to cover all of the 69.72 m^3/day toilets and urinals flushing requirement, while the remaining discharge could further be used for landscape irrigation.
- Greywater reuse could contribute up to 22% of the building's clean water quantity requirement, thus reducing the amount taken from the current source of deep well pumping and save approximately Rp. 275,219,453.- per year of the current ground water tariff in Bandung.

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