Sally Septania Napitupulu (The Correlations between Building Heights and Wind Speed in Determining the Dimension of Windows in a High-rise Residential Building Façade)

by Library Referensi

Submission date: 20-May-2024 09:40AM (UTC+0700)
Submission ID: 2383603383
File name: ension_of_Windows_in_a_High-rise_Residential_Building_Facade.pdf (463.92K)
Word count: 4181
Character count: 21329

IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

The Correlations between Building Heights and Wind Speed in Determining the Dimension of Windows in a High-rise Residential Building Façade

To cite this article: S S Napitupulu *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **903** 012002

The Correlations between Building Heights and Wind Speed in Determining the Dimension of Windows in a High-rise Residential Building Façade

SS Napitupulu[1], G Hardiman[2], and RR Tobing[3]

[1]Doctoral Student of Architecture of Universitas Katolik Parahyangan
[2]Department of Architecture of Universitas Diponegoro
[3]Department of Architecture of Universitas Katolik Parahyangan

salnapitt.3@gmail.com

Abstract. Climate change due to architecture occurs as a result of technological developments that support the development of materials, electrical mechanics, structures, and building shapes that play a role in increasing emission levels in the air. One type of building in Indonesia that contributes to increasing emissions is the residential building known as *rumah susun*. This research employs the case study method, observing the *Rumah Susun* Jatinegara Barat, located in East Jakarta. The case study shows that the use of prototypes that are not environmentally friendly makes a building's performance worse. The use of precast, which resulted in monotonous window dimensions, is considered the main factor causing the failure of this *Rumah Susun* Jatinegara Barat to adapt to the surrounding environment. This problem occurred because the openings in the building façades had a monotonous dimension while the wind intensity that hit the building was increasing. The final result shows that the windows on the façades of the case study were not functioning except if all the openings in the residential unit are open. These results prove that the height of a building is an essential factor in planning high-rise flats, especially in Jakarta.

Keywords: climate change, passive ventilation, *rumah* susun, wind speed, window dimension

1. Introduction

Architecture is one of the main factors increasing emissions in the air and causing climate change [1][2]. This influence is inseparable from technological developments in the 19th century [3][4]. The benefits of technology providing convenience to humans make technology in architecture develop and spread rapidly. Technological advances also influence four architectural elements: materials, electrical mechanics, building structures, and building shapes. In practice, the four elements are divided into two groups, namely active and passive. Active technology belongs to the realm of materials and electrical mechanics, while passive technology can be found in the structure and shapes of the building [5][6].

The advancement of technology in Indonesia stems from the distribution of infrastructure, causing the urbanization rate to increase rapidly. This phenomenon makes large urban areas such as Jakarta become densely populated areas. In 1985, Jakarta was expanded to the borders, turning Jakarta into an overcapacity city [7]. The increasing amount of urbanization eventually transforms residential architecture in urban areas into vertical housings divided into two types, namely apartments and flats.

IOP Conf. Series: Earth and Environmental Science **903** (2021) 012002 doi:10.1088/1755-1315/903/1/012002

Apartments and flats have the same meaning: the arrangement of residential units to form a shared residence. However, if the arrangement is seen based on the four architectural elements, it can be seen that the materials, electrical mechanics, structure, and shape of an apartment building are easier to adjust because the construction cost is much higher than that of a flat. Therefore, when viewed through the relationship between climate change due to architecture and residential functions, flats have more complex problems.

Flat problems arise due to two factors, namely the planning system and the occupants' economic condition. Flat planning limits construction cost because, in contrast to apartments managed by private sectors, flats are managed by the state. This management division makes the procurement of flats focus on practical systems that aim to speed up construction time, namely the prototype system. Flat prototypes have the following characteristics: (1) the use of precast walls, (2) an asymmetrical building plan, (3) I-shaped dominant building mass configuration, (4) a monotonous window type, and (5) a unit area of 36 m^2 to 45 m^2 [8][9]. Prototypes are the leading cause of climate and architectural problems because prototype planning consists of human activities. The use of the prototype resulted in poor building performance, making the building unable to act as an intermediary between humans and nature.

The economic factor is one factor that can show the inability of a building to work correctly. Flat buildings have a low economic community target (MBR), so the ability of the building to act as an intermediary between nature (climate) and humans through windows on the building façade plays an essential role because not all flat residents can afford ventilation tools such as air conditioners (AC). However, since the flat prototypes are not environmentally friendly, the windows on the building façades cannot function optimally. This occurs because the dimensions of the windows are monotonous when the wind intensity (especially wind speed) that hits the building does not have a fixed intensity, making the use of mechanical technology inevitable. Based on GBCI data, windows on the façade play a 60% role in the successful performance of the building [10][11]. Therefore, the calculation of window dimensions on the building façade is essential to working optimally as an intermediary between nature and humans. In addition, flat buildings can become one with nature and contribute to suppressing the increasing temperature of the earth.

2. Methods

This research employs a case study method with the *rumah susun* Jatinegara Barat as the selected object in East Jakarta by focusing on the climate element of wind speed. The research object has limitations such as the character of the location, environmental conditions, and the existing conditions of the flat buildings. Some of the criteria include: (1) having a height of more than ten floors, (2) having poor window conditions, (3) being located in a river area, (4) having an I-shaped building mass, and (5) having a residential unit with a minimum area of 36 m^2, while the climate scope has been determined by the instability of motion and wind speed of urban areas if it was at the minimum altitude of 10 meters [12]. The study used a field survey to collect existing data, include room height, room area, and wall dimensions. The other data includes the thermal data of the room, namely wind speed, humidity, and room temperature. Values of humidity and room temperature units used as control variables validated the final results of the analysis. The two-field data were subsequently analyzed based on the three theories, namely by Terry S. Boutet, Givoni, and Olgyay, and technical standards in Indonesia, namely the Indonesian National Standard. With these research steps, the discussion in the paper includes understanding the theory of wind in architecture, *rumah susun* Jatinegara Barat as research objects, and field data analysis.

3. Results and Discussions

A basic understanding of the relationship between wind speed, flats, and windows is related to the intensity formed through the movement of natural elements, namely the sun and wind. The sun dominantly affects temperature through radiation transmitted by light, while wind dominantly affects humidity. In contrast to the two thermal units, wind speed intensity depends on the sun and gravity. The higher the temperature of a location, the faster the wind speed will be and the higher the location, the faster the wind speed will be with the more dynamics wind movement [13][14][15].

Wind in architecture has the role of cooling space—wind motion functions as a heat spreader that determines the direction of the speed of the room. In addition, wind in architecture also functions as a medium that helps release heat in the human body. Therefore, an understanding of the determinants of aperture dimensions with a focus on wind speed is inevitable.

3.1. Wind Speed and Window Openings in Theory

The structure, lay-out, orientation and shape of a building affect wind speed in architecture—the building's structure in determining the wind functions as a receiver and limiter of wind currents. The lay-out and orientation of the building affect the formation of a positive-negative field in the wind area. The terrain determines the spread of the winds. The positive field is in the area of the coming wind, while the negative field is on the reverse side [16].

The building part and the building height are two elements in the tire structure. The building consists of two parts, namely walls and windows. The wall has two functions: deflect and direct the wind, while the window acts as a barrier and the entrance to the room [17]. The height of the building affects the movement of the wind that will enter the space. On two-thirds of the lower part of the building, the wind will pass through the side and through the building structure three times as fast with the direction of the wind that enters the room coming from above. On the upper third of the building, the wind flows to the top of the building with the direction of the wind entering the room from below [18].

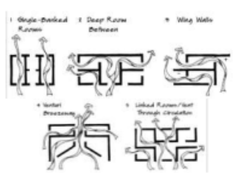

Figure 1. Walls as defenders of the wind

(source: Mark DeKay dan G.Z Brown. p: 229)

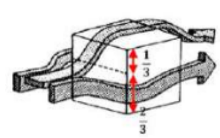

Figure 2. Illustration of wind movement against a building

(source: adaptasi dari *Terry S. Boutet*. p: 50)

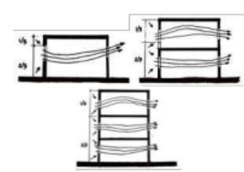

Figure 3. Illustration of wind movement into a building

(source: adaptasi dari *Terry S. Boutet*. p: 63)

The windows used in high-rise flat buildings are predominantly a projected sash window type. This type of window can open up to 100%. When the window is open at 100%, the direction of the incoming wind is the same as the direction of wind flowing outside the building; when the window is not open at 100%, the direction of the wind flow will follow the angle of the window opening. The determination of the size of the window or ventilation in theory is predominantly focused on finding the air rate, the inlet-outlet ratio, and the percentage of the wall area. This can be seen from several formulas or standards that are used globally or in Indonesia in particular.

In theory, there are at least two formulas based on the search for air velocity, inlet-outlet ratio, and the percentage of the wall area used in the calculation of window dimensions on the building façade, namely Terry S. Boutet's airflow rate search formula and B. Givoni's opening dimension formula, as follows[19][20][21]:

1. Terry S. Boutet : $Q = cfC_V Av$
   The search formula for Terry S. Boutet's airflow rate is focused on the search for air flow rate (Q), inlet area (Av), wind speed (V), and opening effectiveness (C_V) using the outlet-inlet ratio or C_V = 0.50 to 0.60 for winds perpendicular to the inlet or 0.25 to 0.35 for sloping winds with inlet, and conversion factors of 88.0 (cf).

2. B. Givoni : $\overline{V}_{(i)} = 0{,}45\,(1 - e^{-3{,}84x})V_{(o)}$

   The Givoni opening dimension search formula has a more complex calculation with a focus on airflow rate ($\overline{V}_{(i)}$), window to wall ratio (x), wind speed outside the building ($V_{(o)}$), and the basic natural logarithm = 2.72 (e).

Apart from these two formulas, there are also several standards or regulations governing openings in building façades in Indonesia, namely the Indonesian National Standard, as follows:
1. SNI 03-6572-2001: determination of the amount of ventilation based on the percentage of floor area and building class. A flat is a class-two building with a minimum opening size limit of 5% of the floor area of the room.

3.2. Rumah Susun Jatinegara Barat as the Research Object
Rumah susun buildings in Indonesia have at least some character and one of these is the window on the building's façade which has the same dimensions from the bottom to the top floor. The character of *rumah susun* is formed because *rumah susun* in Indonesia use a prototype system to speed up time and reduce cost of development. In addition, the type of windows of *rumah susun* predominantly has the same window shape, named projected sash window.

Figure 4. Projected sash window on bangunan *rumah susun* in Jakarta

Rumah susun Tambora (A), *rumah susun* KS Tubun (B), *rumah susun* Jatinegara Barat (C), *rumah susun* Pasar Rumput (D)

Rumah susun Jatinegara Barat have a characteristic location and environmental conditions that are common in high-rise flats in Jakarta, which are close to public transportation modes and located on a river bank. *Rumah susun* Jatinegara Barat is a 16-storey high and I-shaped mass building. 1st floor to 2nd floor are used as public areas and 3rd floor to 16th floor are used as residential areas with the building facing North and South following the river path.

Figure 5. Location map of *rumah susun* Jatinegara Barat

Figure 6. Conditions around *rumah susun* Jatinegara Barat

The building of *Rumah Susun* Jatinegara Barat has several existing conditions: (1) the maximum opening is 10°; (2) most of the occupants close their windows due to the wind; (3) some of the windows are damaged due to strong winds; (4) the windows are single windows with the projected sash type; and

(5) each of the residential units has a size of 5.4 m x 5.95 m, a room height of 3.15 m with a window size of 1.4 m x 0.84 m on the main façade located in the two main bedrooms of 2.2 m x 2.6 m.

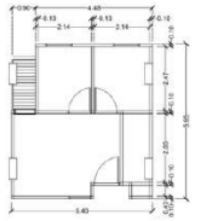

Figure 7. Residential unit floor plan of *rumah susun* Jatinegara Barat

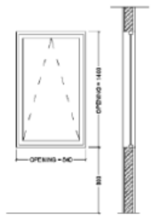

Figure 8. Windows detail on building façades

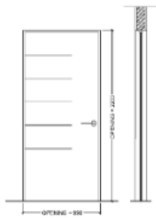

Figure 9. The main doors of the residential units

The configuration of the building mass of *rumah susun Jatinegara Barat* is I-shaped. It is forming a wind tunnel between the building towers. Field measurements carried out on 4th floor, 10th floor, and 15th floor with measurement times on 07.00 a.m. - 09.00 a.m., 11.00 a.m. - 01.00 p.m., and 03.00 p.m. - 05.00 p.m. show that the highest wind speed outside the building is 3.35 m/s (clear weather), 6.29 (strong wind), and 7.59 m/s (rain), as follows:

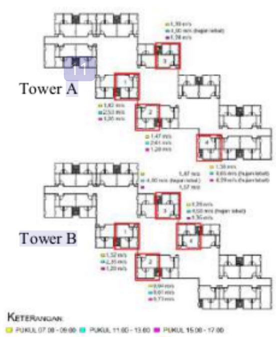

Figure 10. Wind measurement outside the building on the 4th floor

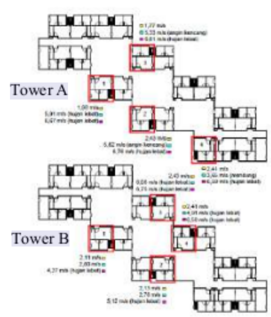

Figure 11. Wind measurement outside the building on the 10th floor

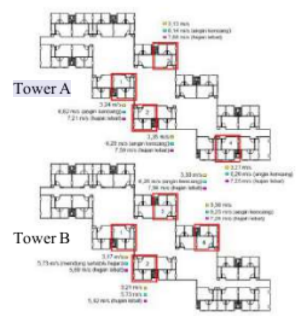

Figure 12. Wind measurement outside the building on the 15th floor

3.3. *The Relationship between Wind Speed and Windows on the Façades of Rumah Susun Jatinegara Barat*

Rumah susun Jatinegara Barat use a projected sash type with an opening area of 32,13 m^2 with a maximum angle of window opening is 10º. The openings located in residential units on the 3rd floor to the 16th floor. When there is and strong winds blow, none of the windows is used (closed), because the windows will fly with the wind and fall down if still used or opened.

IOP Conf. Series: Earth and Environmental Science **903** (2021) 012002 doi:10.1088/1755-1315/903/1/012002

Figure 13. Maximum angle of window - 10°

Figure 14. some of window opened when the weather is good.

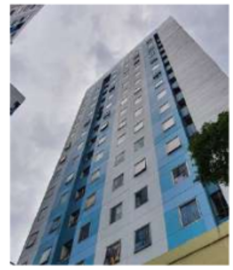

Figure 15. Window closed when rains and wind speed intensity is high

Based on the theory briefly described above, it is found that high-rise buildings that consider wind speed in their planning must pay attention to four aspects, namely: the structure of the building (the wall as a directional tool for the wind path in the room), building lay-out, orientation of the building which determines the wind entry area, and the height of the building which affects the direction of the outside wind into the building. From these four elements, it can be derived that there are two main problems in *rumah susun* Jatinegara Barat, namely: (1) the lay-out of the adjacent buildings and the formation a wind tunnel, thereby accelerating the speed of the wind entering the wind tunnel area, (2) the orientation of the building side by side with the river, so that the winds that follow the river flow hit the façade of the building directly, and (3) monotonous openings indicating the height of the building are not the focus of planning. Both of these problems can be seen clearly through the calculation of the average wind speed through the calculation of the formula carried out on the 15th floor measurement with the assumption that the measurement results have the largest number when compared to the other three heights, as follows:

Tabel 1. Calculation of Openings through Formulas

Theory	Formulas	Result	Standard Boundaries
Boutet	$Q = cf\,C_V Av$ $Q = 88.0{,}35.0{,}52182.7{,}493737$	$Q = 120{,}439\ CFM$ **(does not meet standards)**	Min: 255,62 CFM Max: 780,02 CFM
	$Q = cf\,C_V Av$ $Q = 88.0{,}35.0{,}52182.14{,}07033$	$Q = 226{,}239\ CFM$ **(does not meet standards)**	Min: 255,62 CFM Max: 780,02 CFM
	$Q = cf\,C_V Av$ $Q = 88.0{,}35.0{,}52182.16{,}97835$	$Q = 272{,}876\ CFM$ **(meet standards)**	Min: 255,62 CFM Max: 780,02 CFM
Givoni	$\overline{V}_{(i)} = 0{,}45\,(1 - e^{-3{,}84x})V_{(o)}$ $\overline{V}_{(i)} = 0{,}45\left(1 - 2{,}72^{-3{,}84^{2}/3}\right)3{,}35$	$\overline{V}_{(i)} = 1{,}388\ m/s$ **(does not meet standards)**	Min: 0,2 m/s Max: 0,6 m/s
	$\overline{V}_{(i)} = 0{,}45\,(1 - e^{-3{,}84x})V_{(o)}$ $\overline{V}_{(i)} = 0{,}45\left(1 - 2{,}72^{-3{,}84^{2}/3}\right)6{,}29$	$\overline{V}_{(i)} = 2{,}606\ m/s$ **(does not meet standards)**	Min: 0,2 m/s Max: 0,6 m/s
	$\overline{V}_{(i)} = 0{,}45\,(1 - e^{-3{,}84x})V_{(o)}$ $\overline{V}_{(i)} = 0{,}45\left(1 - 2{,}72^{-3{,}84^{2}/3}\right)7{,}59$	$\overline{V}_{(i)} = 3{,}145\ m/s$ **(does not meet standards)**	Min: 0,2 m/s Max: 0,6 m/s
SNI	5% x room size	Bedroom = 2,352 $m2$ Drying room = 1,760 $m2$ Main door = 2,178 $m2$ Total opening area = 6,29 $m2$ **(meet standards)**	$5\%\ x\ 32{,}13 = 1{,}60\ m2$

Based on the calculation results, the total number of openings in one residential unit has met the minimum size. However, based on the formula calculation, the amount of entry opening in the façade has not been functioning optimally because with only 10° openings based on the calculation of the room area and the inlet: outlet ratio, the wind is not sucked into the room (the result of Q dan $\overline{V}_{(i)}$ *does not meet the standard; Boutet's formula shows that at an environmental wind speed* *of 7,59 the window opening can function optimally, but in this context it will be considered that the window still does not work because the environmental wind speed is far above the maximum threshold for a comfortable environmental wind speed for humans, which is 3.1 m /s), except all windows and doors in the residential unit are wide open.*

3.4. Results

Based on the analysis carried out through theoretical studies of the relationship between high-level residential architecture and wind, case studies show that the determination of window dimensions on building façades can not only be seen through the area of space and the ratio of inlet: outlet openings in residential units, but must pay attention to the building's height as well. In addition, in theory, there is an affirmation that one of the elements influencing high-level architectural planning concerning the wind is the building's height. The functional shortcoming of windows on the façades *rumah susun* Jatinegara can also be seen from the temperature in the residential unit. The result of field measurements show that the average temperature of the residential unit is 30.75 ºC. These results do not comply with the comfortable standard of room temperature which is in the range of 21 ºC to 27 ºC.

4. Conclusion

Changes in the shape of dwelling have a positive impact in the form of additional green areas and a negative impact in the form of increased environmental emissions. *Rumah susun* as one of the vertical residences in Indonesia is one of the buildings that has a negative impact on the environment. This occurs due to the use of prototypes that are not based on the environment and make the building performance become worse. In theory, understanding the relationship between high-rise architecture and wind can be seen through four aspects, namely: building structure (walls), lay-out, orientation, and the building's height. However, in the case of *rumah susun* generally, the building's height is not the focus of planning. This deficiency is also seen in the formulas and standards for determining the dimensions of the openings which only focus on three aspects, namely: air velocity, inlet:outlet ratio, and room size. Through the analysis of case studies, it can be seen that these three elements are not sufficient to determine the dimensions of the windows on the façades of high-rise flats, especially in Jakarta.

5. References

[1] World Meteorological Organization. 2008. *Climate Change 2007: Synthesis Report*. Switzerland: The Intergovernmental Panel on Climate Change. p. 5.
[2] World Meteorological Organization. 2015. *Climate Change 2014: Synthesis Report*. Switzerland: The Intergovernmental Panel on Climate Change. p. 88.
[3] Hoppit, Julian. 2011. *The Nation, The State, and The First Industrial Revolution*. Journal of British Studies. p. 307-331.
[4] Anthony, Wringley. E. 2018. "*Reconsidering the Industrial Revolution: England and Wales"* dalam Journal of Interdisciplinary Volume 49 Nomor 1, p. 9-42.
[5] Frick, Heinz; Suskiyatno, FX. Bambang. 2007. *Dasar-dasar Arsitektur Ekologis: Konsep Pembangunan Berkelanjutan dan Ramah Lingkungan*. Yogyakarta: Kanisius. p. 151-161.
[6] Frick, Heinz; Ardiyanto, Antonius, Darmawan, AMS. 2008. *Ilmu Fisika* Bangunan. Yogyakarta: Kanisius. p. 87-95.
[7] Kusumawardhani, Ratu Arum. 2012. *Sejarah Perumahan di Jakarta*. Jakarta: Dinas Perumahan dan Gedung Pemda DKI Jakarta. p. 3-4, 94-95.
[8] Rukmana, Dadang dkk. 2019. *Jejak Langkah Hunian Layak Indonesia* Jakarta: Direktorat Jenderal Penyediaan Perumahan Kementerian Pekerjaan Umum dan Perumahan Rakyat. p. 72.
[9] Alfata, Muhammad Nur Fajri dkk. 2020. *Pedoman Desain Pasif Rumah Susun: Untuk Iklim Tropis Lembap di Indonesia*. Jakarta: Kementerian Pekerjaan Umum dan Perumahan Rakyat. p. 7-13.
[10] Green Building Council Indonesia. Vol.1 Building Envelope. Jakarta: The Goverment of the Province of Jakarta Capital Special Territory. p. 3.
[11] International Finance Corporation (IFC). 2011. *Jakarta Building Energy Efficiency Baseline and Saving Potential: Sensitivity Analysis*.

[12] Brown, G. Z. 1994. *Matahari, Angin, dan Cahaya*. Bandung: Intermatra. p. 26
[13] Wirjohamidjojo, Soerjadi; Swarinoto, Yunus. *Iklim Kawasan Indonesia: Dari Aspek Dinamik-Sinoptik*. Jakarta: Badan Meteorologi Klimatologi dan Geofisika. p. 45.
[14] Boutet, Terry. S. 1987. *Controlling Air Movement: A Manual for Architects and Builders.* United States: R.R Donnelley &Sons. p. 41-138.
[15] Szokolay, Steven. V. 2004. *Introduction to Architectural Science: The Basis of Sustainable Design*. Oxford: Architectural Press. p. 74.
[16] Lechner, Norbert. 2015. *Heating, Cooling, Lighting: Sustainable Methods for Architects.* New Jersey: John Wiley&Sons. p. 293-295.
[17] Dekay, Mark; Brown,G. Z. 2014. *Sund, Wind, and Light: Architectureal Design Strategies*. New Jersey: Wiley. p. 229.
[18] Boutet, Terry. S. 1987. *Controlling Air Movement: A Manual for Architects and Builders.* United States: R.R Donnelley &Sons. p. 63.
[19] Indonesia. *Standar Nasional Indonesia: SNI 03-7013-2004 tentang Tata Cara Perancangan Sistem Ventilasi dan Pengkondisian Udara Pada Bangunan Gedung*. p. 3.
[20] Boutet, Terry. S. 1987. *Controlling Air Movement: A Manual for Architects and Builders.* United States: R.R Donnelley &Sons. p. 22.
[21] Givoni, B. 1976. *Man, Climate, and Architecture*. London: Applied Science. p. 22.

Acknowledgments

I wish to thank Prof. Gagoek Hardiman and DR. Rumiati Tobing, for guiding, encouraging, and convincing me to always write and believe in my thoughts. I hope that this article will prove useful for readers and can become the basis for one of the existing sciences, both in the academic world and for its practitioners.

Sally Septania Napitupulu (The Correlations between Building Heights and Wind Speed in Determining the Dimension of Windows in a High-rise Residential Building Façade)

ORIGINALITY REPORT

13%	12%	9%	7%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.researchgate.net Internet Source	6%
2	www.mdpi.com Internet Source	2%
3	Submitted to Aston University Student Paper	1%
4	www.pocasi-volary.cz Internet Source	1%
5	R Afrizon, W S Dewi, L Dwiridal. "Analysis of physics parameters on aerophone musical instruments from Minangkabau as context meaningful learning", Journal of Physics: Conference Series, 2020 Publication	1%
6	Aida Fatimah, Abdu Fadli Assomadi, Arry Febrianto, Joni Hermana. "Efforts to Reduce Carbon Emissions from TPS3R and Rumah Kompos Facilities: Case Study in Surabaya",	1%

IOP Conference Series: Earth and Environmental Science, 2024
Publication

7	Submitted to California State University, Fresno Student Paper	<1 %
8	Submitted to Greenfield Community School Student Paper	<1 %
9	Tri Endangsih, Ikaputra. "Floating Houses Technology as Alternative Living on The Water", IOP Conference Series: Materials Science and Engineering, 2020 Publication	<1 %
10	www.readkong.com Internet Source	<1 %
11	www.hindawi.com Internet Source	<1 %
12	pdfcoffee.com Internet Source	<1 %
13	www.scribd.com Internet Source	<1 %
14	Submitted to University of Technology, Sydney Student Paper	<1 %

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		