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ANALYSIS OF DUSTFALL GENERATION FROM REGOSOL SOIL IN JAVA ISLAND, INDONESIA

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ABSTRACT

Dustfall is one of ambient air quality parameters according to PP 41/1999 about Air Pollution Control. Dustfall pollution in open field can be controlled effectively and efficiently if the influence of wind speed, soil moisture and land cover to dustfall generation are known. This research aims to obtain correlation between wind speed, soil moisture, and land cover factors on dustfall generation, to describe the influence of these factors on dustfall generation, and to analyze the physical properties of dustfall (dustfall particle's shape and size frequency distribution). The study was conducted with regosol soil samples from three different locations, i.e. Gunung Sindur Sub-District, Pelabuhan Ratu beach and Parangkusumo Sand Dunes. The instruments and materials used in the research were dustfall canister (AS 2011-1), filter paper (Whatman #41), wind blower, digital anemometer, digital moisture tester and universal oven. The measurement of dustfall generation was conducted in a laboratory scale using regosol soil from three locations as land cover. Analysis were also conducted on soil texture and physical characteristics of dustfall, i.e. shape and size frequency distribution. Based on the research results, wind speed known to be positively correlated with dustfall generation, while the soil moisture and land cover was negatively correlated with dustfall generation. The relationship between wind speed, soil moisture content, and the percent of land cover with dustfall concentration can be described with multiple polynomial equation. The size frequency distribution of dustfall particles from regosol soil in each sampling locations were dominated by particulate size of 10 - 100 μm.

Keywords: dustfall, multiple regression, particulate size, regosol

INTRODUCTION

Particulate in ambient air are form of aerosol which is defined as a simple form of solid particle or liquid that suspended in a gas [1]. The high concentration of dust in ambient air can be harmful to health, it causing health problem such as asthma and lungs irritation [2].

Dustfall is one of ambient air quality parameters according to Indonesian Government Regulation (PP 41/1999) about Air Pollution Control. High generation of dust into the ambient air is affected by four things: strong wind, dry soil, sparse vegetation, and saltating particles [3]. Therefore, the generation of dustfall is influenced by wind speed and direction, soil moisture, land cover, and type of soil. Generation of dustfall correlated negatively with soil moisture content and percentage of land cover and correlated positively with wind speed [4].

Regosol are one of soil type that classified by FAO (Food and Agriculture Organization), whereas in USDA (United State Department of Agriculture) taxonomy regosol can be classified as entisol or inceptisol. Regosol are a young soil that friable and eroded easily [5] [6]. It shows that regosol are type of soil which can be distributed easily by fluids (water and air).

The previous research by Yuwono *et al.* [7] and Amaliah *et al.* [4] described the relationship between generation of dustfall and wind speed, soil moisture content and land cover from ultisol, oxisol, andisol, and entisol soils in Java Island. Until now, there is no study that analyzing dustfall generation from regosol soil in Indonesia. Dustfall pollution in open field can be controlled effectively and efficiently if the influence of wind speed, soil moisture and land cover to dustfall generation are known. Air quality management strategy must consider the relative contribution of the natural and anthropogenic sources of air pollution [8].

The first objective of the research was to obtain correlation between wind speed, soil moisture, and land cover percentage factors on dustfall generation from regosol soil in three locations in Java. The second objective of the research was to describe the influence of these factors on dustfall generation from regosol soil in three locations in Java. The last objective of this research was to analyze the physical properties of dustfall (dustfall particle's shape and size frequency distribution) of regosol soil in three locations in Java.

MATERIALS AND METHODS

The study was conducted in Darmaga Sub-District, Bogor Municipality, Indonesia. Regosol soil samples were originated from three locations in Java, Indonesia, i.e. Gunung Sindur Sub-District (Bogor Municipality); Pelabuhan Ratu Beach (Sukabumi Municipality) and Parangkusumo Sand Dunes (Bantul Municipality). This study was carried out in February until May 2015.

The measurement of dustfall generation was conducted in a laboratory scale using regosol soil from three locations as land cover. Analysis were also conducted on soil texture and physical characteristics of dustfall, i.e. shape and size frequency distribution.

One day laboratory scale measurement includes three data collection. The first one was concentration of dustfall captured as much as 3 repetitions at the same time, with an average time about 8 hours. The second measurement was soil moisture content and wind speed, where data was captured 2 times (morning and afternoon). The third measurement was the percentage of land cover.

Soil texture analysis

Soil texture analysis was conducted using hydrometer method. Type of hydrometer used in this analysis was ASTM 151. This soil texture analysis would yield the percentage of clay, dust, and sand fraction from the soil. The analysis procedure was based on the steps set by the Centre of Agricultural Land Resources Research and Development [9].

Dustfall measurement

Tools and materials used for measuring the concentration of dustfall were dustfall canister, filter Whatman #41, OHAUS analytical balance, and oven. The requirements in measuring dustfall concentration set by Indonesian Standard namely SNI 13-4703-1998 about Determination of Dust Generation in the Air with Dustfall Catcher.

Analysis of correlation and regression

Referring to [4] and [10], after data were obtained, subsequent data analysis was continued to obtain the correlation between dustfall, wind speed, soil moisture content, and percentage of land cover using Pearson correlation technique and then followed by regression analysis. The analysis was performed with the help of software Minitab 14 for Windows. The P value of the calculation result using Minitab 14 for Windows was the value to make a decision. If the P value was less than a predetermined α (0.05), then there was a relationship between the variables, whereas if the value of P was greater than α, then there was no relationship between the variables. Regression analysis was a further analysis after getting the Pearson coefficient. Regression analysis can be used as a model to predict and check the accuracy of the data.

Measurement of size frequency distribution and shape of particulate

Analysis of particle size frequency distribution was performed by capturing dustfall on a transparent disc. The dust was attached passively on transparent disc to take the approach that the dust which caught on transparent disc was dustfall. Then, the disc with the attached dustfall was analyzed using a scanning electron microscope (SEM) to describe the morphology and particle size frequency distribution of dustfall from a different regosol soil type. Satsangi and Yadav (2014) stated that the SEM was an appropriate tool for analyzing the characteristics of particulate, especially for a single particle [11].

RESULTS AND DISCUSSIONS

Soil texture analysis

Results of soil texture measurements in the laboratory showed that the regosol soil picked up from Gunung Sindur Sub-District, Pelabuhan Ratu Beach, and Parangkusumo Sand Dunes were dominated by sand fraction as 88%, 98%, and 99%, respectively (grouping fraction based on USDA and FAO). The cumulative percentage of soil particle diameter is presented in Figure-1.

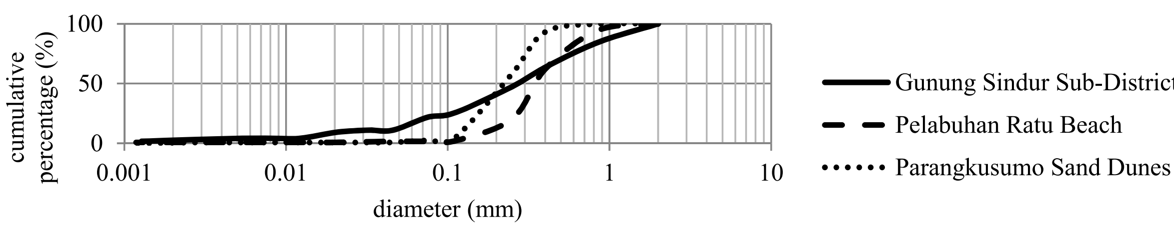

Figure-1. Cumulative percentage of soil particle diameter from three types of regosol soil.

The fraction of sand that dominates regosol land of Parangkusumo Sand Dunes was fine sand (diameter 0.1 - 0.25 mm), whereas the sand fraction Pelabuhan Ratu Beach was dominated by the medium sand fraction (diameter 0.25 - 0.5 mm). Regosol land of the Gunung Sindur Sub-District has soil texture fraction relatively uniform with the largest fraction was fine sand. The percentage fraction of soil particles on the three types of soil are presented in Table-1.

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Table-1. The percentage fraction of soil particles on the three types of regosol soil (grouping fraction based on USDA).

Fraction	Diameter (μm)	Particle fraction percentage		
		Gunung Sindur sub-district	Pelabuhan Ratu beach	Parangkusumo sand dunes
Clay	<2	4.00	0.80	0.46
Dust	2 - 50	8.00	0.85	0.64
Very fine sand	50 - 100	12.00	0.10	2.40
Fine sand	100 - 250	23.50	18.75	55.00
Sand	250 - 500	22.50	54.50	38.00
Coarse sand	500 - 1000	18.00	21.50	3.50
Very coarse sand	1000 - 2000	12.00	3.50	0.00

Laboratory analysis of dustfall generation from Regosol Soil

Dustfall generation laboratory measurement results with a variation of wind speed, soil moisture and land cover showed that regosol soil derived from Parangkusumo Sand Dunes having the greatest dustfall generation in comparison with the other two regosol soil sample. According to the soil texture fraction, regosol soil derived from Parangkusumo Sand Dunes has larger sand fraction and followed by regosol soil of Pelabuhan Ratu beach and regosol soil of Gunung Sindur Sub-District. It shows that, the bigger the sand fraction (larger particles) in a particular type of soil, the greater the generation of dust fall, while smaller particles will settle at a further distance. In the quiet atmosphere, a small-sized particulate matter (PM_{10} and $PM_{2.5}$) takes daily to yearly to settle and can cover a distance of over 1000 km, but can be washed by rain very quickly [12]. Dustfall generation data of regosol soil measured in laboratory is presented in Table-2.

Table-2. Dustfall generation of regosol soil measured in laboratory scale.

Sample location	**Wind speed** (km/h)	**Soil moisture content** (%)	**Land cover** (%)	**Dustfall** (ton/km^2.month)
Gunung Sindur sub-district	2.4 - 3.2	28.3 - 37.6	0 – 40	7.6 - 21.2
Pelabuhan Ratu beach	2.4 - 3.7	21.6 - 37.1	0 – 40	8.5 - 45.0
Parangkusumo sand dunes	2.4 - 3.7	22.6 - 37.8	0 – 40	11.0 - 65.1

Pearson correlation test using Minitab 14 indicates that the wind speed was positively correlated with the generation of dustfall, while the water content of soil and land cover was negatively correlated with the generation of dustfall (Table-3).

Table-3. Pearson correlation test using Minitab 14.

	Gunung Sindur sub-district	Pelabuhan Ratu beach	Parangkusumo sand dunes
Dustfall and wind speed			
Pearson coefficient	0.058	0.518	0.856
P-value	0.85	0.07	0
Dustfall and soil moisture content			
Pearson coefficient	-0.286	-0.094	-0.217
P-value	0.343	0.761	0.477
Dustfall and land cover			
Pearson coefficient	-0.787	-0.642	-0.406
P-value	0.001	0.018	0.169

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However, wind speed and soil moisture content does not show a clear correlation to the generation of dustfall at the regosol soil of Gunung Sindur Sub-District and Pelabuhan Ratu Beach as indicated by P-value greater than α (0.05). Unlike the regosol soil of Parangkusumo Sand dunes, wind speed was significantly correlated with the generation of dustfall (P-value = 0). The water content of the soil and land cover on regosol soil of Parangkusumo Sand Dunes not significantly correlated (P-value> 0.05).

The relationship between wind speed, soil moisture and land cover with dustfall generation can be described by a multiple polynomial equation. The multiple polynomial equation was a polynomial regression performed with one dependent variable and two or more independent variables. Multiple polynomial regression is often referred to as multivariate polynomial regression and was used to predict a value of which is affected by more than one contributes variables, these variables may be correlated and can be converted into a free variable that can be used for better estimate regression [13]. Two order of multiple polynomial equation with 3 independent variables and one dependent variable follows the pattern as in Equation 1.

$$a X_1^2 + b X_1 X_2 + c X_1 X_3 + d X_2^2 + e X_2 X_3 + f X_3^2 + g X_1 + h X_2 + i X_3 + j = Y \quad (1)$$

where,

X_1 = wind speed (km/h)
X_2 = soil moisture content (%)
X_3 = land cover (%)
Y = dustfall (ton/km^2.month)
a, d, f = quadratic effect parameters
b, c, e = interaction effect parameters
g, h, i = linear effect parameters
j = constant value

Constant values of “a” until “j” were obtained by trial and error using the add-in solver in MS. Excel 2007. Solver was run to find constants with the smallest RMSE value and the value of R-sq close to 1 between the models of polynomial equations and calculations in the laboratory. The process was run and produces constant values “a” until “j” as presented in Table-4.

Comparison of dustfall generation by measurement and by polynomial equations formed can be seen in Figure-2.

Table-4. Constant value used on multiple polynomial equation for three types of regosol soil.

	Gunung Sindur sub-district	**Pelabuhan Ratu beach**	**Parangkusumo sand dunes**
A	-1.E+01	3.E+01	7.E+00
B	2.E+00	-6.E-01	-8.E-01
C	-5.E+01	8.E+02	-7.E+02
D	-9.E-02	8.E-02	1.E-01
E	3.E+00	5.E+00	1.E+02
F	-2.E+01	-1.E+02	-1.E+03
G	1.E+00	-2.E+02	2.E+01
H	1.E+00	-2.E+00	-5.E+00
I	9.E+00	-2.E+03	-2.E+03
J	5.E+00	3.E+02	2.E+01
R-sq	0.86	0.95	0.99
RMSE	1.3	2.1	1.4

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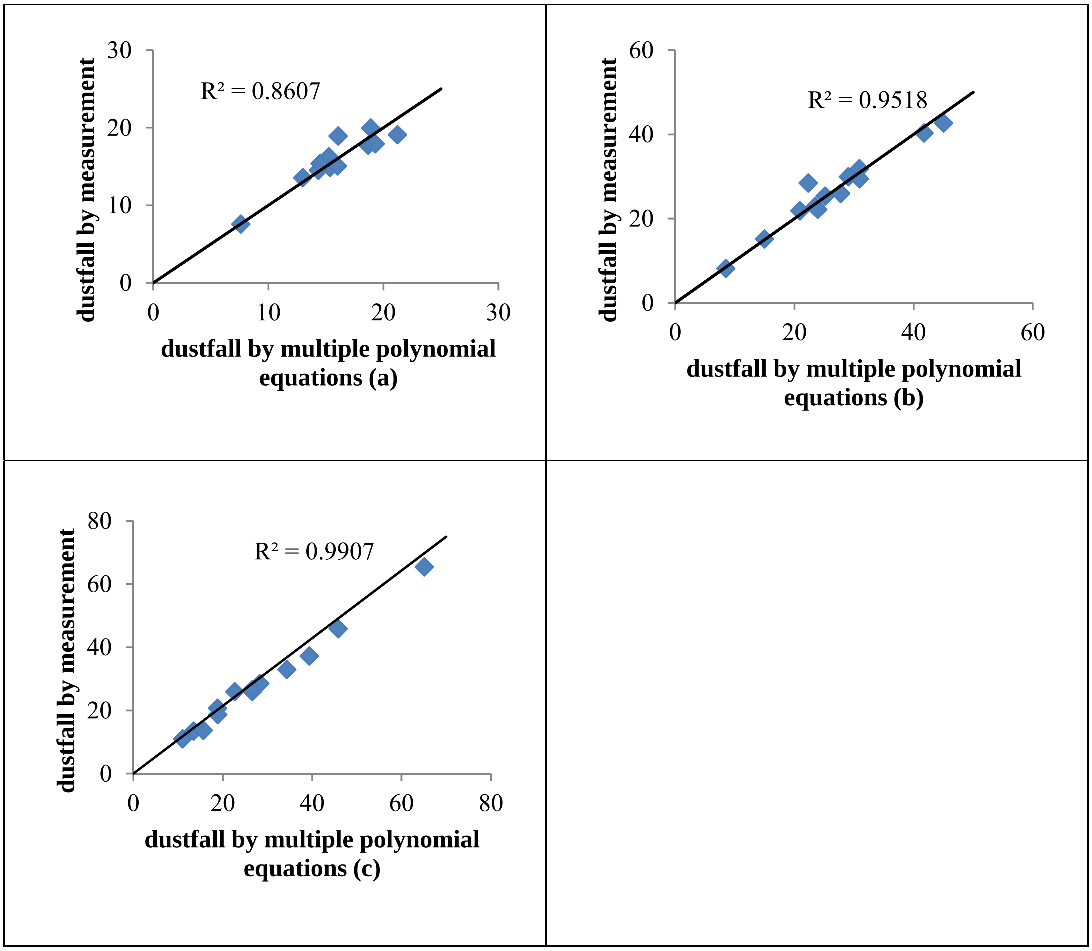
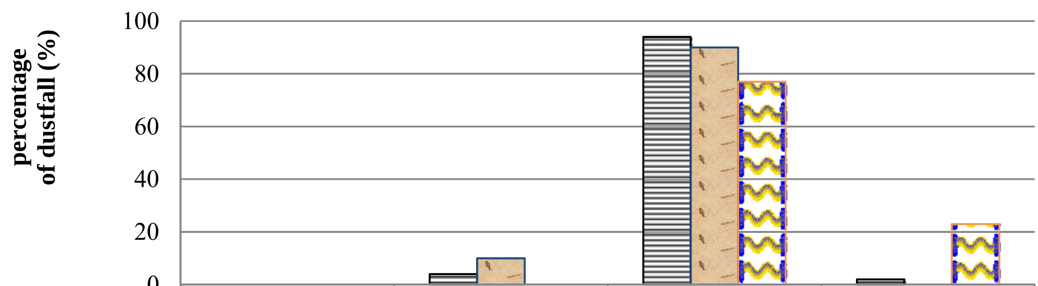


Figure-2. Comparison of dustfall by measurement and by multiple polynomial equations on regosol soil from Gunung Sindur sub-district (a); Pelabuhan Ratu beach (b); Parangkusumo sand dunes (c).

By using multiple polynomial equations such as equations 1 and constants as shown in Table-4, the relationship between wind speed, soil moisture content, the percent of land cover and dustfall generation can be described. The obtained R-sq of dustfall generation between measurement results and the dustfall generation on calculations using polynomial equation model on regosol soil in the Gunung Sindur Sub-District, Pelabuhan Ratu beach and Parangkusumo Sand Dunes, which respectively amounted to 0.86; 0.95 and 0.99. R-sq value of 0.86 means that 86% of the models used may explain the concentration of dustfall on the regosol soil in the Gunung Sindur Sub-District, as well as with R-sq 0.95 on regosol land in Pelabuhan Ratu Beach and R-sq 0.99 on regosol land in Parangkusumo Sand Dunes.

Analysis of size frequency distribution and shape of dustfall

Regosol soil of Gunung Sindur Sub-District, Pelabuhan Ratu Beach and Parangkusumo Sand Dunes are dominated by dustfall sized 10-100 µm and there was no dustfall sized at 0-2.5 µm. Size frequency distribution dustfall generation by regosol soil of the Gunung Sindur Sub-District, Pelabuhan Ratu beach and Parangkusumo Sand Dunes are presented in Figure-3.



dustfall size (μm)	0 - 2.5	2.5 - 10	10 - 100	100 - 500
Gunung Sindur Sub-District	0	4	94	2
Pelabuhan Ratu Beach	0	10	90	0
Parangkusumo Sand Dunes	0	0	77	23

dustfall size (μm)

Figure-3. Size frequency distribution on three types of regosol soil.

Based on the size frequency distribution, dustfall from Parangkusumo Sand Dunes sized 100-500 μm has more quantity than the other two regosol soil locations. This is caused by the soil-forming fraction Parangkusumo Sand Dunes dominated by coarse sand fraction (100-250 m) and medium sand (250-500 m).

Observations on dustfall shape of regosol soil derived from three different locations use a scanning electron microscope (SEM) produces relatively similar shape, especially on soils derived from Pelabuhan Ratu Beach and Parangkusumo Sand Dunes. Little difference was seen in the dustfall coming from Gunung Sindur Sub-District that looks stuck between the particles. This is because the regosol soil from the Gunung Sindur Sub-District have larger clay fraction than the other two locations. Centre of Research and Development of Soil and Agroclimate mentions that the clay fraction is the fraction that has the ability to bond, while the fraction of sand and dust is not [5]. The observation using the SEM can be seen in Figure-4.

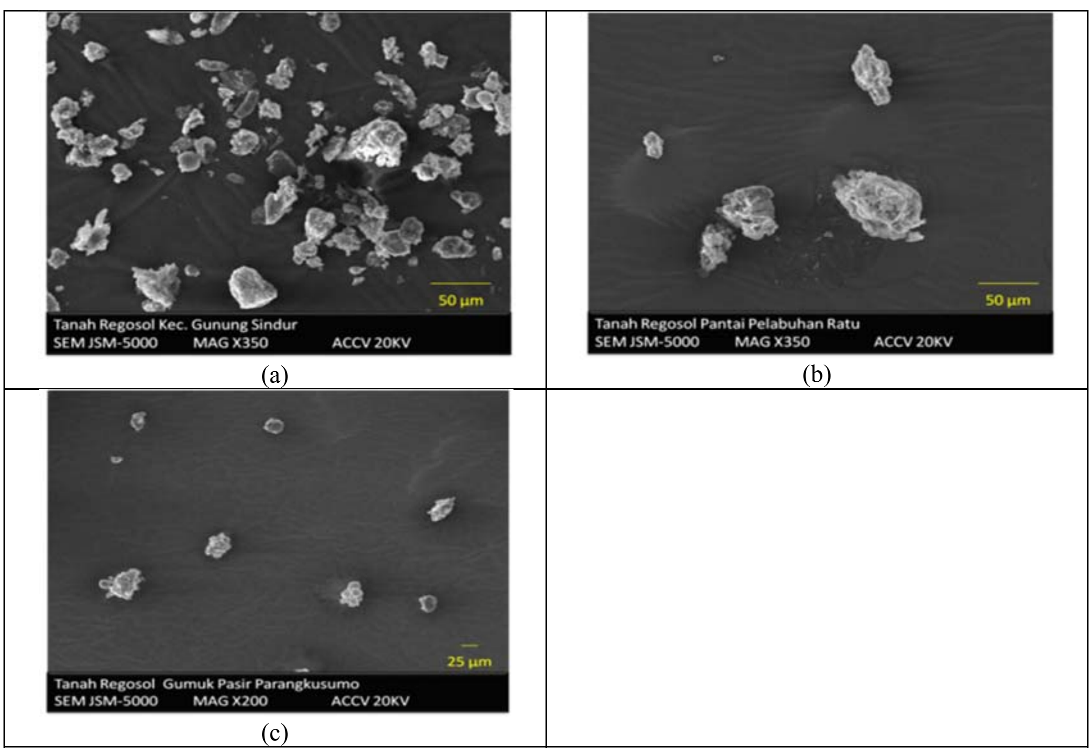


Figure-4. Shape of dustfall on regosol soil from Gunung Sindur sub-district (a); Pelabuhan Ratu beach (b); Parangkusumo sand dunes (c).

Size distribution, composition, and shape of dustfall in the air will affect the environment [14]. The size of the dustfall (which was larger than 2.5 μm and 10 μm) on the type of regosol soil of Parangkusumo Sand Dunes was allowed toxin to not bounded on the dustfall generation. Czier *et al.* (2011) mentions that $PM_{2.5}$ has a large surface area, toxin, including polycyclic aromatic hydrocarbons (PAHs) and heavy metals can be absorbed into the surface. Organs such as the lungs and heart, cells and DNA can be damaged by these toxins [15]. Masih *et al.* (2010) stated that the total PAH was absorbed into the PM_{10} [16].

CONCLUSIONS

Based on the research, there were three conclusions as follows:

a) The wind speed positively correlated with dustfall generation, while the soil moisture content and land cover was negatively correlated with dustfall generation.
b) The relationship between dustfall generation, wind speed, soil moisture content and land cover were described with multiple polynomial equations. R-sq value of dustfall from measurement result and calculations using polynomial equation model on regosol soil, in the Gunung Sindur Sub-District, Pelabuhan Ratu beach and Parangkusumo Sand Dunes were 0.86; 0.95 and 0.99, respectively.
c) The dustfall particle size frequency distribution of regosol soil from three different locations was dominated by the size of 10-100 μm, i.e. 94% on the regosol from Gunung Sindur District, 90% on the regosol from Pelabuhan Ratu Beach, and 77% on the regosol from Parangkusumo Sand Dunes.

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