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Research Article

Contamination of *E.coli* Bacteria in Spamdus Genjahan Water Distribution Network from Karst Groundwater Source

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ABSTRACT

Karst groundwater is raw water used by Spamdus Genjahan to fulfill domestic water needs. Considering the vulnerability of karst groundwater to pollution and its distribution process, the research aimed to describe the suitability of water in the network as well as the spatial distribution of *E.coli* and the relationship between distance and it's concentration. The concentration of E.coli was tested from water samples taken from 20 outlets as representatives of the close, medium and farthest distances from the source. The feasibility of water is carried out by comparing the results of laboratory tests with the water quality threshold value for clean water and domestic purposes. Spatial distribution was analyzed through spatial analysis using Geographic Information Systems, while the relationship between distance and E.coli concentration was carried out using the scatterplot method in GIS. The results showed that the concentration of *E.coli* in most of the samples was above the allowable threshold for sanitation hygiene purposes. Meanwhile, the distance from the outlet to the source did not show a strong correlation with the level of *E.coli* concentration. However, there are weak indications that lead to an increase in concentration with the *E.coli*.

Keywords : karst groundwater, clean water, higiene sanitation water, *E.coli*

INTRODUCTION

Karst groundwater in general has characteristics that are susceptible to pollution (Budiyanto, 2018, Budiyanto et al., 2020; Nanou & Zagana, 2018; Chen et al., 2021). The karst landscape where this research was carried out is naturally capable of escaping water quickly, as well as having a low ability to protect its groundwater against contamination. The nature of the porosity of karst rocks that easily pass water can trigger the movement of pollutants quickly (de Waele, 2017; Alili et al., 2018; Golob et al., 2019). The speed of dispersion of pollutants is increasingly magnified by the increasing rainfall in the Gunungsewu karst area (Cahyadi & Prabowo, 2017). The low filtration ability of the soil and rock resulted in the concentration of the amount of pollutants not being reduced much in the groundwater source (Zhao et al., 2021). This groundwater is then used by residents through spring discharge (Harjito, 2014; Widyastuti et al., 2019) or pumping.

E. coli is a pollutant that is commonly found, especially in water sources in the Gunungsewu karst area, both in surface water and subsurface water (Widyastuti et al., 2019). *E. coli* bacteria are a type of biological pollutant that can live in water bodies (Bambang et al., 2014; Reinhart & Rifani, 2021). Bacteria can thrive in stagnant water bodies or in tissues (Irshabdillah

& Widyastuti, 2020; Reinhart & Rifani, 2021). Studies from Khakim & Masduqi, (2017) showed the development of *E. coli* bacteria in drinking water networks. Water that will be used as clean water or drinking water must be free from the existence of these bacteria. The threshold for the existence of these bacteria in water based on Ministry of Health (2017) is 0 per 100 ml sample. This shows that the quality of water for drinking purposes must be seriously considered. Pal (2014) explained that existence of *E. coli* bacteria in drinking water can cause serious to fatal effects on human health such as gastrointestinal disorders, diarhea and fever. Further, Rock & Rivera (2014) described the existence of specific types (strains) of this *E. coli* bacteria, namely *E. coli* types: Enterotoxigenic, Enteropathogenic, Enterohemorragic, and Enteroinvasive. Based on this description and considering the pattern of water distribution from Spamdus Genjahan which is mostly above ground level, it is necessary to study the concentration of *E. coli* bacteria in the water.

Spamdus Genjahan is a drinking water system for residents in the Gunungsewu karst area that utilizes karst groundwater. This drinking water network system was built for the community, especially during the dry season. Spamdus Genjahan supports the water needs of residents in five hamlets which are included in two villages namely Genjahan village, Kapanewon Pojong and Karangmojo village Kapanewon Karangmojo, Gunungkidul Regency. This system is managed independently by local residents with a simple method. Water is not treated before entering the distribution network. Karst groundwater is lifted using a pump and stored in one main reservoir. The water is then directly distributed through pipelines to resident house. This condition allows for water quality problems, namely contamination of coli bacteria in the Spamdus Genjahan drinking water system (Budiyanto et al., 2021).

Based on the conditions described above, the problem that arises is about the feasibility of water produced by Spamdus Genjahan in accordance with clean water standards and the potential distribution of *E. coli* in tissues, especially the relationship between distance and concentration.. The aims of this study were to: (1) explore information related to the quality of Spamdus Genjahan drinking water, especially the *E. coli* bacteria pollutant, (2) find out the distribution pattern of *E. coli* bacteria in the distribution network system based on the distance of the outlet.

METHODS

Study Area

The study areas include three formations, namely the Wonosari formation (Tmwi), the Oyo formation (Tmo), the Semilir formation (Tmse), and the Alluvial Formation (Qa). Topographically, the north side is higher than the south side which forms an alluvial plain area. The Semilir Formation consists of volcanism material such as weathered volcanic ash. The Oyo Formation is a transition from a volcanic area to a karst area. The rocks in this formation are mixed from volcanic and karst origins. The alluvial area has the thickest soil layer at this location. The land is generally black and a small part is red on the north side. The Wonosari Formation is a karst area formed from carbonate rocks with the main elements Ca and Mg. The dissolving process in carbonate rocks forms the morphology of this region. Surface water is rare because most of the water enters the underground river system through fissures and fractures in the rock. The research was held on Spamdus Genjahan drinking water network in the Ledok Wonosari area. The research area has karst characteristics as Figure 1.

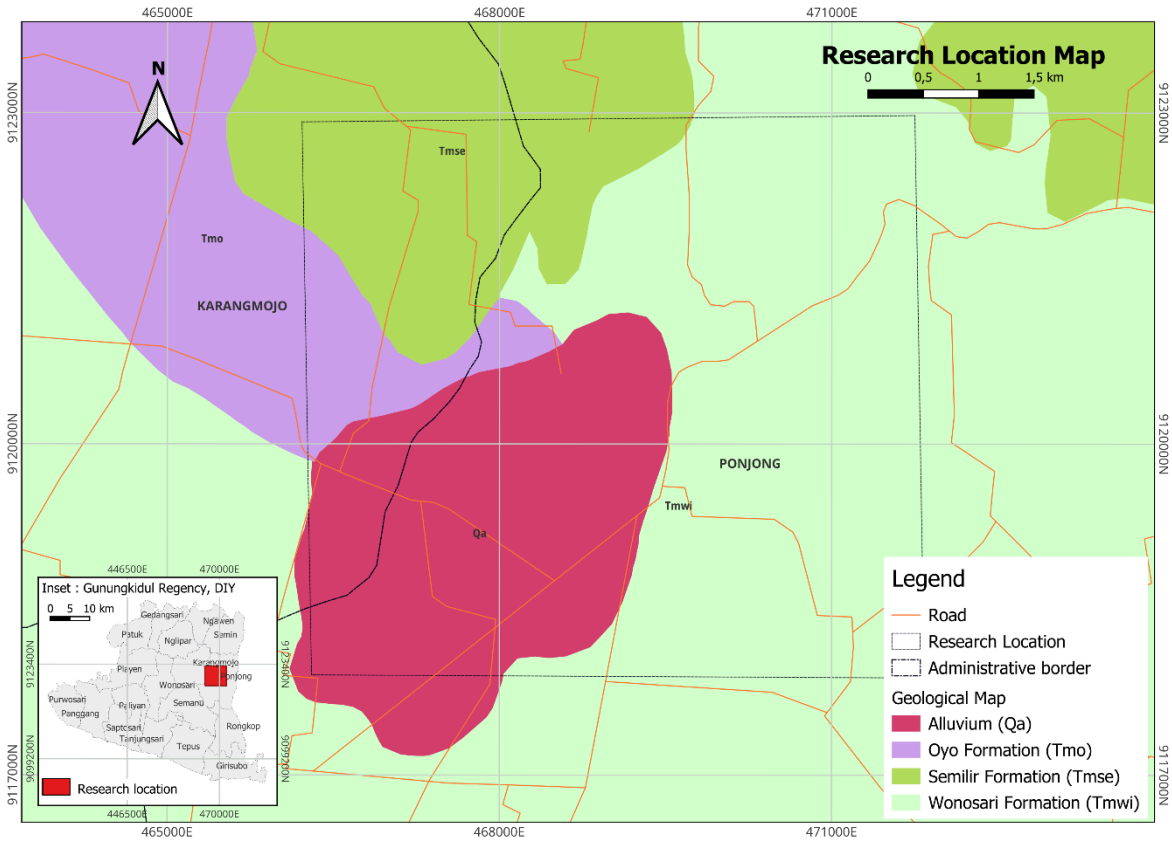

Figure 1. Study Area

This study measured the concentration of *E. coli* bacteria in water sources and their network systems, as well as measured the effect of distribution network distance on the E. coli concentration. The research was carried out through the following stages :

Survey and network mapping of groundwater distribution Spamdus Genjahan

This stage was carried out using a geographic information system. This stage is intended to produce an up-to-date map of the water distribution network, location points for water sources that function as intakes, and customer location points which are outlets of the network, as well as the distance from each outlet to the source. The survey was conducted through terrestrial means based on Google image data. The coordinates of the location of people's homes and water sources are identified using GPS and recorded on the table. Network observation is done by measuring the network directly and recording the size of the pipes on the network. The measurement process is accompanied by the manager of Spamdus Genjahan.

Sampling

The population in the research is the water in the Spamdus Genjahan distribution network and the distance from each outlet point to the source. The samples taken consisted of water at the source and at the outlet with close, medium and farthest distances. Each of these outlet point classifications was taken as many as 6 to 7 samples purposively by considering their spatial distribution. One sample is taken from a water source point. The sample water was taken using a coliform sample bottle in accordance with the directions from the BBTKLPP water laboratory of the DIY Province, which was planned as a sample testing institution in this study. The sample bottle is first sterilized and put in a closed box. Fully taken in conditions not exposed to sunlight. The sample delivery process is carried out no more than 2 hours to the laboratory in a closed state and maintained temperature.

Sample Testing

Sample testing was carried out in the BBTKLPP water laboratory of the DIY Province. The parameters tested were *E.coli* content parameters. The sample is sent to the laboratory in less than 24 hours in a sample vial that is protected from exposure to time and placed in a box. Testing of samples carried out by the BBTKLPP Laboratory of DIY Province.

Analysis

The analysis was carried out on water quality data released by the BBTKLPP water laboratory, Ministry of Health, DIY Province. The analysis is intended to answer the aims of this study, namely the concentration of *E. coli* bacteria in the Spamdus Genjahan drinking water distribution system and the effect of the length of the distribution network from the source on the concentration of the E. coli bacteria.

The analysis to answer the first research question is to summarize the data from the laboratory analysis into a table of *E. coli* concentrations at each sample point. The table is compared with the table of clean water quality standards and applicable drinking water quality standards. Analysis to answer the second research question is through spatial analysis using geographic information systems. The method used is a scatterplot between the distance variable and the E.coli concentration value. This method is intended to determine the relationship between distribution distances and bacterial concentrations.

RESULTS

The water used in the Genjahan Spamdus network is karstic groundwater. This research succeeded in mapping the entire network and outlet points along with the location of the water intake sources. Water is pumped and distributed to resident houses using a pipe network. Water is distributed in the network by gravity. The distance from source of each sampel can be seen in Table 1. Before being distributed, water is collected in the main reservoir and then channeled into a two-inch main pipe. These pipes channel water from the main tub to several main distribution locations. Network extensions are carried out using one-inch and three-fourth-inch pipelines. The distribution of water from the network to the customer is carried out with half-inch pipes. The measurement results using the Geographic Information System are known to be the distance of each sample outlet. Table 1 shows that the nearest water user outlet point is at a distance of 75 meters and the farthest is at a distance of about 1500 meters from the main reservoir.

Table 1. Distance of each sample outlet from source

No	Sample	Distance (m)
1	Main tub	0
2	K1.1	207.6
3	K1.2	396.7
4	K1.3	388.4
5	K1.4	417.1
6	K1.5	75.2
7	K1.6	589.1
8	K2.1	516.8
9	K2.2	544.5
10	K2.3	744.7
11	K2.4	658.7
12	K2.5	982.3
13	K2.6	811.8
14	K2.7	577.0
15	K3.1	862.9
16	K3.2	1591.8
17	K3.3	986.0
18	K3.4	1355.4
19	K3.5	798.4
20	K3.6	1439.8

Figure 2 shows the water distribution pipeline network, water user outlets (blue dots), and *E.coli* measurement sample points (red dots). Figure 2 illustrates the distribution of outlets from the Spamdus Genjahan network. The location of the reservoir is at the blue box point. The location is the highest point as a water distribution center. Water is spread gravitationally to the entire outlet point. Two pipes measuring 2 inches are installed parallel to the north - south and have a fairly steep slope. The height difference between the beginning of the pipe and the end of the pipe reaches about 50 meters with a distance of approximately 200 meters. This condition provides a good gravitational effect for water distribution to user locations.

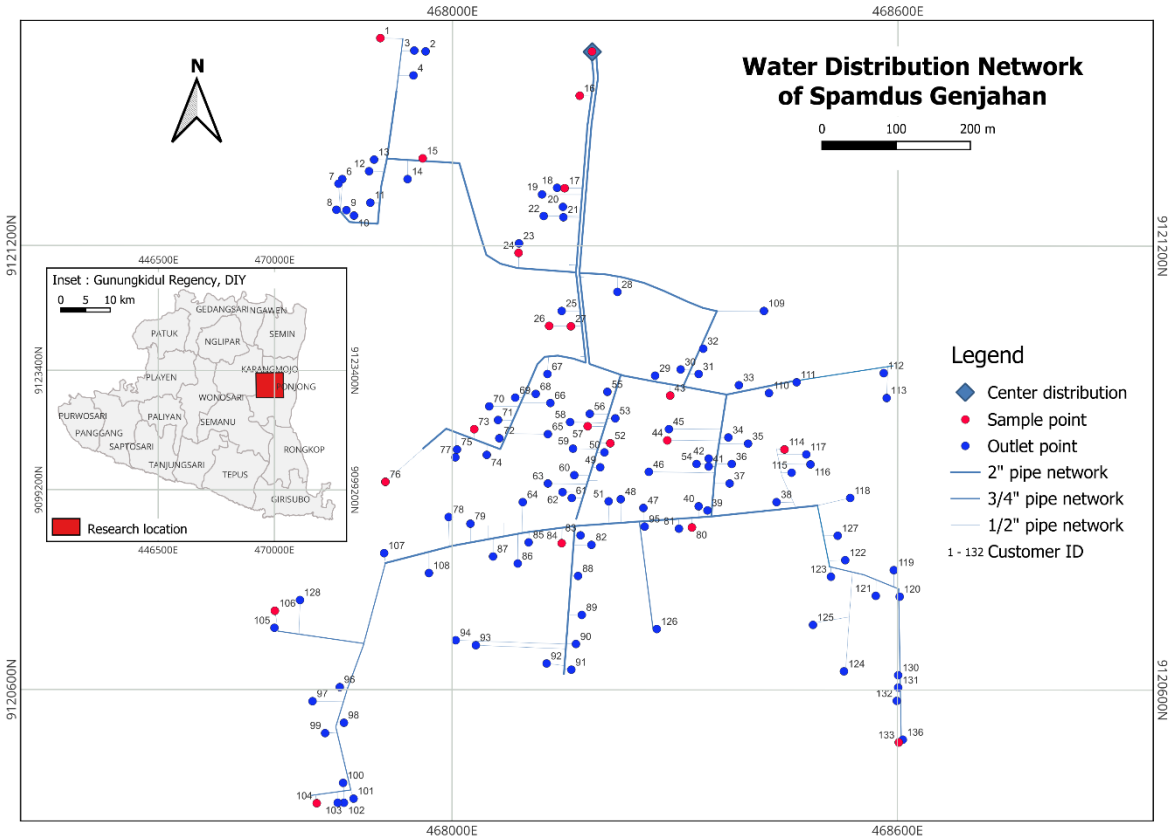

Figure 2. Water Distribution Network Map of Spamdus Genjahan

The largest pipelines are indicated by the thickest blue line leading north – south. This network has a high elevation gradient up to the first cross. The slope gradient gets smaller from that first cross to the end of the tissue. Distribution is continued using dividing pipes of smaller sizes. In the figure is indicated by a thinner blue colored line. Furthermore, water will be channeled to each outlet using a 1/2-inch pipe. The round point is the location of water outlets or customers of the Spamdus Genjahan network. The red round dot is the outlet point sampled in this study. The densest distribution of outlets is in the middle of this distribution network system, and less and less often in tune with the longer distances.

The E.coli bacteria concentration at each sample location was known from the test results at BBTKLPP Yogyakarta on July 7, 2022. The *E.coli* concentration shows in Table 2.

Table 2. Concentration of *E.coli* in the sample

No	Sample	Concentration (CFU/100ml)
1	Main tub	5
2	K1.1	TNTC
3	K1.2	0
4	K1.3	15
5	K1.4	5
6	K1.5	2
7	K1.6	1
8	K2.1	62
9	K2.2	0
10	K2.3	0
11	K2.4	0
12	K2.5	88
13	K2.6	2
14	K2.7	7
15	K3.1	1
16	K3.2	31
17	K3.3	0
18	K3.4	36
19	K3.5	TNTC
20	K3.6	0

The concentration of *E.coli* in the main bath has a concentration of 5 CFU/100 ml. This condition indicates that there is contamination of *E. coli* bacteria in the main reservoir. The reservoir is a closed building that holds pumped karst groundwater. The cause of the existence of *E.coli* pollutants is possible from groundwater karst or leaks contained in this main tub building. Furthermore, the test results show that there are two outlet points with very high concentrations, namely in sample K1.1. and K3.5. The test result sheet states the concentration with the code TNTC (too many to count) which means a very high concentration in the testing process. The value of high contamination concentration was shown in five samples, namely K1.3, K2.1, K2.5, K3.2, and K3.6. Concentrations reach double-digit values between 15 – 88 CFU/100 ml. There are six sample points that show *E.coli* concentration values between 0 to 10 CFU/100 ml, namely at points K1.4, K1.5, K1.6, K2.6, K2.7, and K3.1. Samples with an E.coli concentration value of 0 CFU/100 ml were found at six sample outlet points, namely K1.2, K2.2., K2.3, K2.3, K3.3., and K3.6.

The existence of *E.coli* in water determines the suitability of the water to be used as drinking water or clean water for sanitation purposes. Based on the Regulation of the Minister of Health of the Republic of Indonesia number 32 of 2017 the threshold for the concentration of *E.coli* in clean water for sanitation hygiene purposes is 0 CFU/100 ml. Based on this setting, most of the water coming from the Spamdus Genjahan network is above the threshold. The range of *E.coli* concentration values from each sample point showed different conditions. The results of the analysis show that only six samples out of twenty test samples show conditions that meet the threshold requirements.

The scatterplot analysis between outlet distance and *E.coli* concentration showed a not strong correlation, but there was a tendency for an increase in *E.coli* concentration with *increasing distance.* The calculation using this scatterplot removes three sample outlet points, namely the main body point and K1.1, and K3.5 which have very extreme values. The R2 value resulting from the correlation between distance and *E.coli* concentration at seventeen sample points only shows 6.90%. This value indicates the low correlation between distance and E.coli concentration from each sample outlet. However, the trend line of the scatterplot shows a line that goes up from the bottom left to the top right. This indicates that there is a tendency to increase the concentration of *E.coli* in line with the increase in outlet distance. The scatterplot can be seen in Figure 3.

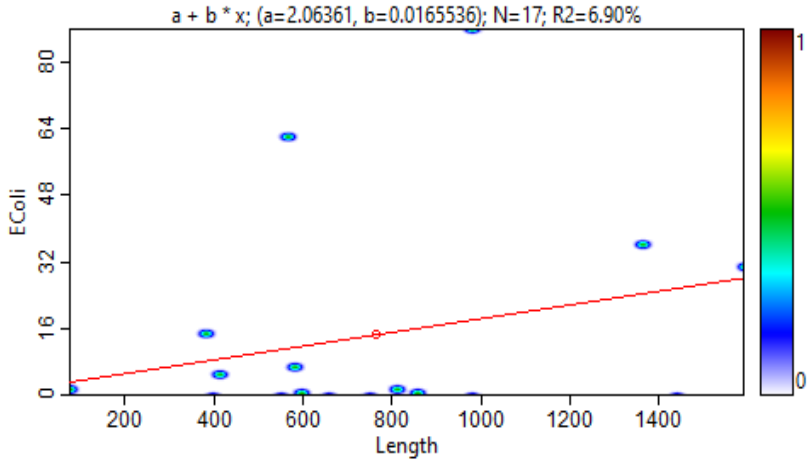

Figure 3. The relationship between distance and concentration of *E. coli*

Figure 3 shows the weak relationship between water distribution distance and *E. Coli* concentration levels. However, there is a weak tendency that the concentration level of *E. Coli* may increase the further the distribution distance of the water is, which may be caused by environmental factors.

DISCUSSION

Spamdus Genjahan utilizes karst groundwater karst as raw water. Water is pumped, stored in the main tank and then distributed to residents who use water. The distribution process is not preceded by water treatment to reduce the concentration of pollutants such as *E.coli*. The existence of *E.coli* in the main tank indicates a leak of contaminants in the groundwater system or in the tank. The existence of *E.coli* contaminants in drinking water sourced from karst groundwater is in line with previous studies from Irshabdillah & Widyastuti (2020) and Reinhart & and Rifani (2021). The findings of this study are also in line with Matthies et al. (2016) which found *E.coli* concentrations in raw water from the Gunungsewu karst groundwater river system.

The concentration of *E.coli* from each sample showed different conditions. Most of the samples showed the existence of E.coli bacteria with concentrations exceeding the threshold of the Regulation of the Minister of Health of the Republic of Indonesia No. 32 of 2017. The threshold is intended for sanitary hygiene purposes, which includes bathing, washing, and other purposes related to individual health. Based on the results of the study, it was found that there were only six samples that met the requirements. The test results indicate that the water from Spamdus Genjahan needs to be processed in order to meet the standard threshold for clean water or drinking water. The need for a water treatment process is in line with findings Matthies et al. (2016) and Yogafanny et al. (2014) which showed that the Gunungsewu karst groundwater needs to be treated before being used. The processing process exemplified by the two references is through filtration. In addition to this, Sengupta & Saha (2013) stated that the process of disinfection of *E.coli* bacteria through the use of biofilters, photocatalysis, chlorine administration, and the use of bacteriophages.

The calculation results show a weak relationship between distance and the concentration of *E.coli* at each sample outlet. This condition is slightly different from Khakim & Masduqi (2017) which stated the strength of the distance factor to increase the concentration of *E.coli*. Based on the reference search, it is known that this difference is caused by a large difference in the network. The Genjahan Spamdus Network is a small water distribution network with the furthest distance of only about 1500 meters. However, there was a tendency to increase the concentration of *E.coli* in the calculation results of this study. The increase occurred mainly in outlets that used open pipelines and were placed above ground level with a long distance. Increased concentrations also occur in pipelines that pass near waste dumps or livestock sheds. The trend line in the calculation results indicates an increase in the concentration.

The weak correlation between distance and concentration implies the existence of other factors as the cause of the existence of *E.coli* contamination in the sample. It is very possible that environmental factors need to be watched out for as triggers for the existence of E.coli. The high concentration of *E.coli* in some sample locations may have come from leaks or exposure to contamination originating from the sample environment. Based on observations, it is known that many pipelines are above ground level. Exposure to E.coli contamination is very likely to occur through seepage or contact during the process of utilizing water at the outlet faucet. This condition is in line with the conclusion from Sari et al. (2019) which stated that it is very possible for septic tank seepage to pollute the water distribution network

CONCLUSION

Based on the results and discussion in this study, it can be concluded that: (1) Most of the water from the outlets of Spamdus Genjahan water users does not meet the requirements for the water eligibility threshold for sanitation hygiene water needs. Pre-processing is required before being used to remove *E.coli* contamination. (2) The distance of the outlet to the source does not have a strong relationship in increasing the concentration of *E.coli* at the outlet of Spamdus Genjahan water users.

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DECLARATIONS

Conflict of Interest

We declare no conflict of interest, financial or otherwise.

Ethical Approval

On behalf of all authors, the corresponding author states that the paper satisfies Ethical Standards conditions, no human participants, or animals are involved in the research.

Informed Consent

On behalf of all authors, the corresponding author states that no human participants are involved in the research and, therefore, informed consent is not required by them.

DATA AVAILABILITY

Data used to support the findings of this study are available from the corresponding author upon request.

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