Fuzzy Method to Determine the Feasibility of Domestic Water Quality

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***Abstract*—Water quality due to its direct correlation with human health becomes an important issue in fulfilling the needs of domestic water. The feasibility of water quality for the domestic needs must be in accordance with the standard as defined by the Regulation of Health Minister Number 416/PER/IX/1990. Domestic water refers to the water used to fulfil the needs of daily activities such as cooking, drinking, plant watering, or sanitary. The water quality can be observed from physical, chemical and biological parameters. These parameters must, at least, include odor, solved residue (TDS), turbidity, flavor, temperature, pH, and total Coliform. In this research, Fuzzy logic has been used to determine the water quality based on the physical, chemical and biological parameters. Not all parameters were tested with fuzzy method; there were a number of parameter tests must be carried out in the laboratory such as total total coliform, pH and TDS. Based on the sample taken, the water was seen transparent, little bit turbid, odorless, flavorless and at the average temperature of25℃. From the testing result using Fuzzy and the result of laboratory test, it can be concluded that the ground water in the region of Mungkid city on average is feasible to fulfil the domestic needs (daily needs of people nearby).**

***Index Terms*—waterquality, domestic water,fuzzy, turbidity, water colour.**

I. INTRODUCTION

Water quality is related to the content characteristics of the living creatures, substances, energy or other components in water. It is stated with some parameters; namely physical parameters (temperature, turbidity, dissolved density, and so on), chemical parameters (pH, dissolved oxygen, BOD, metal content, and so on) and biological parameter (the existence of plankton, bacteria and so on) [1].

The purpose of monitoring the water quality is to assess the feasibility of water resource for certain need such as to fulfil the domestic needs. Domestic water must fulfil the standards of quality in accordance with its allocation as stated in the Government Regulation of Indonesia Republic Number 20 of 1990.

Today, the volume of qualified water has been decreasingalong with the increase of the needs for domestic water and production activities in society [2]. In addition, the decline of water quality is related to the increase of population, topography, and land use [3].

The use of pipe for water distribution is one of factors determining the water quality for household needs. Water quality is something that must continually be concerned. As revealed by WHO, the unqualified water can be the cause of disease as well as the factor of mortality in children under 5 [4]. The quality of ground water is the measurement of feasibility for the needs of domestic or daily water. To keep the quality of water, the regular examination must be given in accordance with the provision of regulation. The parameter must be reviewed as stated in the Regulation of Health Minister No. 32 of 2017 on the Quality Standards of Environment Health and Water Health that cover turbidity, total dissolved solid substances, color, temperature, flavor and odor (Table 1). Meanwhile, the obligatory parameters for biology include Total Coliform and E-colli (Table 2).

TABLE.1 Physical Parameters in Quality Standard of Environment Health for Water Media [5]

No	Obligatory Parameter	Unit	Quality Standards
1.	Turbidity	NTU	25
2.	Color	TCU	50
3.	Dissolved Solid Substance	mg/l	1000
4.	Temperature	℃	Air temperature of ±3
5.	Flavor		Flavorless
6.	Odor		Odorless

TABLE.2 Parameter Biologi [5]

No	Obligatory Parameter	Unit	Quality Standard
1.	Parameter Coliform	CFU/100ml	50
2.	E.coli	CFU/100 ml	0

The quality standard as shown in Table 1 and Table 2 furthermore was used as a base in determining the feasibility of the condition of well water in the area of Kotamungkid.

When taking the sample, the condition of well water was so varied and the environment around the well was highly influential towards the water health. It can be proven from the result of the laboratory measurement towards the samples that have been taken as shown in Table 3. The result of the laboratory test showed the high rate of Total Dissolved Solids) was still in the allowed range but Total coliform in most of area of Kotamungkid exceeded the limit allowed.

In addition to the laboratory test, Fuzzy method was used to measure the parameters of temperature, color, and turbidity; further to be used as one of the ways to determine the feasibility of fresh water. The Fuzzy method is a method related to the uncertainty that has been the human nature [6]. The natural language of human would be changed into mathematical compilation [7].

II. METHOD

A. Research Area

Kota Mungkid is the capital of Magelang Regency as regulated in Government Regulation Number 21 of 1982. Kota Mungkid is located ± 15km from Magelang City, ± 30 km from Yogyakarta, and ±95 km from Semarang as shown in Figure 1. It is located in the altitude of 300-500 above the sea level with the rainfall on the average of 1645,5mmand average of air temperature of 26℃ . The average population density of this region is 23 citizens per km^2[8].

This research was conducted by taking the sample randomly in the wells of the citizens of Kota Mungkid, including some villages called Sawitan, Ngentak, Biyetan, Patran and Jangkungn. To determine the feasibility of domestic water, not all obligatory parameters in Regulation of Health Minister No. 32 of 2017 can be measured using the Fuzzy method. The parameters that could be observed physically included color, turbidity and temperature.

Figure 1. Kotamungkid Area

To observe the amount of coliform bacteria and Total Dissolved Substances in water, the laboratory test was conducted. In this research, the test on dissolved solids was conducted by referring to SNI (Indonesia National Standard) 06-6989.27-2005. Meanwhile, the amount of coliform bacteria was tested using IKM method /5.4.1.M/BLK-Y. The parameters of odor and flavor were tested by directly smelling and tasting by means of five senses. The result of the test on the sample of well water furthermore can be seen in Table 3.

TABLE.3 Result of Laboratory Test

Para-me-ter	Stan-dard	Testing Result				
		Nge-ntak Hamlet	Biye-tan Hamlet	Patran Hamlet	Jangkungan Hamlet	Sawi-tan Ham-let
TDS	1000 mg/l	315	307,5	261	250,5	349,5
Coli-form	50 MPN/ 100 ml	<1,8	240	>1600	920	>1600
Odor		Odor-less	Odor-less	Odor-less	Odor-less	Odor-less
Fla-vor		Flavor-less	Flavor-less	Flavor-less	Flavor-less	Flavor less

B. Water Quality

In Indonesia, the obligatory parameters that must be fulfilled to determine the water quality include those as shown in Table 1 and Table 2. However, in this research, to measure the feasibility of water quality, the parameters included the level of turbidity, temperature and color of water. Other parameters only could be observed through the laboratory test.

Turbidity is the optic characteristic of water that is determined based upon the amount of light absorbed by the substances in water commonly measured by means of Nephelometric Turbidity Unit (NTU) [1]. The suspended solid is highly correlated to the turbidity in which the more turbid suspended solid can make the value of its turbidity higher.

The water temperature is determined by the season, the height of sea level, the depth of water body, air circulation and cloud covering[1]. Commonly, temperature is stated with the unit of Celsius degree (℃) or Fahrenheit degree (°F). The increase of temperature can lead to the increase of metabolism rate and respiration of oxygen consumption and later increase the oxygen consumption. In addition, it can lead to the increase of the decomposition of organic substances by microbes.

The color of water in common is categorized into true colourand apparent colour. True color is influenced by the dissolved chemical substances; while the apparent color is the color that is influenced not only by dissolved chemical substances but also by the suspended substances. The color of waters is created by the organic and inorganic substances, existence of plankton, humus, metal ions (iron and manganese) and other elements. The oxidation of iron has made water reddish; while the oxidation of manganese has made water brownish or blackish. Carbonate Calcium coming from the calcic area has created green. On the other hand, the organic substances such as humus from organic substances can create brown.

C. Fuzzy Logic

The theory about the Fuzzy accumulation was firstly developed by Lotfi A. Zadehin 1965. Fuzzy logic has been used in any fields, such as for controlling system and in any artificial intelligence application [9].

Fuzzy logic is one of methods for analysis system that contains uncertainty. Decision making in fuzzy logic is done using an inference system. Fuzzy inference is the concept of using the fuzzy logic to map the output to fuzzy input. This mapping can be used as a reference for making decision about what the output will be. Membership functions, logical operations (mostly or/and), and IF-THEN rules are required for process fuzzy logic inference [10]. The main component of fuzzy inference system is depicted on Fig 2. Crisp input will be converted into fuzzy denomination, known as fuzzification. The result of the fuzzificationis used for rule evaluation. The output of rule evaluation in fuzzy must be translated into crisp value.

There are three types of fuzzy inference system: the linguistic models (Mamdany-type), the relational equation models, and Takagi-Sugeno-Kang models [11].

Figure 2. Fuzzy input and output of the Fuzzy Inference System [11]

In linguistic model both antecedent and consequence are

the fuzzy set,also known as the Max-Min method. In Mamdani inference method, the conseqent in the base of rule is calculated using t-norm ⋀ (minimum) andlogic connective "and", as expressed in the following equation 1.

$$\mu_R(x,y) = MIN\{\mu_A(x)\mu_B(x)\} \qquad (1)$$

After calculating the minimum value of each rule ($\mu_R(x,y)$), agregation needs for resulting composition operation of each rule. Graphical method is common for agregating the minimum value of each rule as depicted in Figure 2. The result of agregation is still in a crisp number. The output of the fuzzy should be changed into the crisp number through a process of defuzzification.

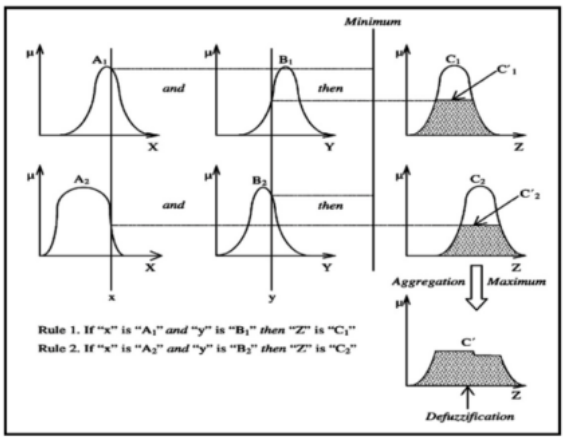


Figure 3. The Mamdani FIS [12]

There are several defuzzification methods i.e. maximum membership principle, centroid and weighted average method. The defuzzification technique often used is Centroid as given by equation 2 [13]. In this equation A is fuzzy set, x is universe of discourse and $\mu_A(x)$ is aggregated output membership function.

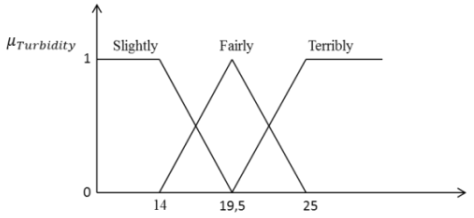
$$CoA = \frac{\int_i^n \mu_A(x)x\,dx}{\int_i^n \mu_A(x)dx} \qquad (2)$$

D. Fuzzy Inference System

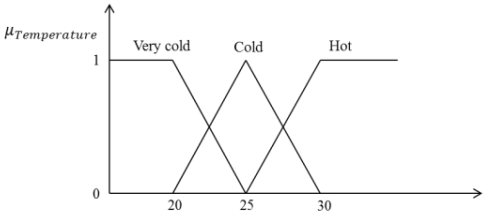
As shown in Figure 2, the making decision using Fuzzy method was conducted by making an inference system through 4 steps: fuzzification, fuzzy rule evaluation, aggregation and defuzzification[14].

The first step, fuzzification, refers to a process to change the crisp value into the membership function. The value of membership function is determined based on the limit of values of the parameters (temperature, color, and turbidity as listed in Regulation of Health Minister Number 416/PER/IX/1990. Membership function is a curve showing the map to the input spots into the values of its membership (membership function).

Membership function areshownin Figure 4 and 5. There are three input variables: turbidity, temperature and colour, while the feasibility is the output variable. The membership function of input and output is presented with the triangle and trapezium curve.



(a)



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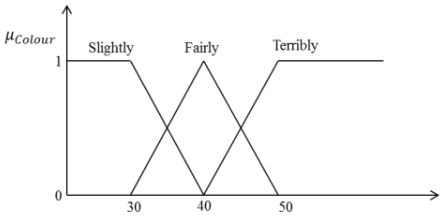

(c)

Figure 4. Fungsi Keanggotaan Proses Input, (a) Turbidity, (b) Temperature, (c) Color

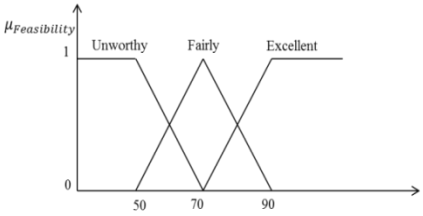

Figure 5. Fungsi Keanggotaan Proses Output (Feasibility)

Once the fuzzification process has been accomplished, it would be continued with rule evaluation that functions to evaluate the feasibility of domestic water. There are 6 rules used to evaluate:

[Rule 1]. If (Turbidity is slightly) and (Temperature is Very Cold) and (colour is slightly) then (Feasibility is fairly).

[Rule 2]. If (Turbidity is fairly) and (Temperature is Very Cold) and (colour is slightly) then (Feasibility is fairly).

[Rule 3]. If (Turbidity is terribly) and (Temperature is Cold) and (colour is fairly) then (Feasibility is unworthy).

[Rule 4]. If (Turbidity is fairly) and (Temperature is Cold) and (colour is fairly) then (Feasibility is fairly).

[Rule 5]. If (Turbidity is slightly) and (Temperature is Very Cold) and (colour is slightly) then (Feasibility is excellent) .

[Rule 6]. If (Turbidity is fairly) and (Temperature is Cold) and (colour is slightly) then (Feasibility is unworthy).

In the real test, those 6 rules were used concurrently by combining. The Fuzzy inferential system did the inferential operation in the rules and handled how the rules were

combined [12]. The consequence of each rule in the rule based system was measured using equation 1 in order to obtain the minimum value ($\mu_R(x,y)$) of each rule.

Hereafter, aggregation of minimum membership function needed for resulting composition of membership function. The aggregation can be described using ghrapical method as depicted in the last coloumbfigure 6.

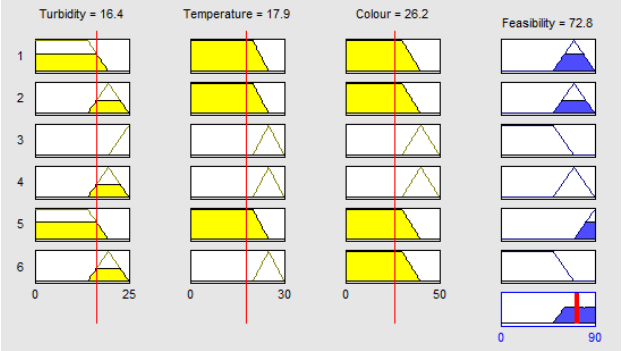

Figure 6. Ghrapical Method for Aggregation

III. RESULT AND DISCUSSION

This part presents the research result to determine the feasibility of domestic water in accordance with the sample of water from the well taken from a number of hamlets in Kotamungkid. The parameter that can be physically observed included turbidity, temperature, and color.

The observation was conducted by randomly giving an input in fuzzy system. The feasibility of domestic water was determined based upon the rules made and furthermore continued with validation of the results by the experts as shown in Table 4.

TABLE.4 Hasil Pengamatan

Turbidity	Temperature	Colour	Feasibility	Validation Expert
Slightly	very cold	fairly	excellent	valid
Slightly	very cold	slightly	excellent	valid
slightly	Cold	slightly	unworthy	valid
fairly	very cold	slightly	excellent	valid
slightly	Cold	slightly	unworthy	valid
fairly	very cold	slightly	fairly	valid
slightly	Cold	fairly	unworthy	valid
slightly	Hot	fairly	unworthy	valid
slightly	very cold	slightly	excellent	valid
fairly	very cold	fairly	excellent	valid

The feasibility of domestic water as shown in Table 4 highly determined by the perception of people doing an observation as turbidity, temperature and colourwere observed physically. The validation of experts played a very important role for this. The physical condition in field regarding the feasibility of domestic water was determined by the level of turbidity and color of water in which the more turbid and more colors can lead to the high level of infeasibility.

The feasibility of domestic water overall not simply was dependent upon the physical condition of water. Therefore, in this research, it was supported with the laboratory test as presented in Table 3. The laboratory test was used to determine the number of e-coli in water. The high number of bacteria e-coli is highly influenced by the cleanliness of well environment. This is indicated with the high number of e-coli in Patran, Jangkunganand SawitanHamlet that exceeded the standard value.

IV. CONCLUSION

Fuzzy method is quite effective to determine the feasibility of domestic water physically that is by observing the level of turbidity, color and temperature. The rule applied was highly dependent upon the related experts. Thus, the feasibility of domestic water overall would be dependent upon the laboratory test. Based on the result of the test using fuzzy method and laboratory test, the well water from samples taken in the area of Kotamungkid is feasible for the needs of sanitation and public bathing. For drinking, there must be a first processing as the content of e-colli is quite high andit is worried to bring a bad impact on health.

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