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Fuzzy Logic Evaluation of Heavy Metal Pollution of Apa Dam Lake

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Abstract

Heavy metal pollution is among the biggest problems today. Conventional methods used to determine these impurities and upper and lower separation limit tables included in these methods. The results obtained by these statements are of equal importance when evaluating the whether near or far. Thus, each of the statements contained in quality parameter takes place in one of four classes. In this study, heavy metal pollution control of Apa Dam Lake, is used as an model index of water quality classification with classical methods as well as assessment made by fuzzy logic. During the study water samples were taken from detected five stations every month, and the resulting values (minimum, maximum, average); Al (0-0.251-0.018), Cu (3.972-21.165-9.84 µg/l), Zn (101-297-174 µg/l), Fe (121-955-463 µg/l), Cd (0 µg/l), Co (0-13-0.64 µg/l), Cr (0-25-1.708 µg/l), Pb (0-15-3.36 µg/l), Mn (40-685-240.53 µg/l) and Ni (0-58-28.46 µg/l) is presented in this form. In the interpretation of the results the fuzzy logic of the assessment method is used, considering average found values.

As a result, according to the account of fuzzy logic between measured parameters of Apa Dam Lake we can see that the homogeneity achieved and by calculation based on achieved an annual quality index of the output values, the quality index is 66% quality, 34% is a in very high quality class.

Keyword: Apa dam lake, heavy metal pollution, fuzzy logic assessment method

INTRODUCTION

The most important source of inorganic pollution in water is heavy metals. Heavy metals are passed to water resources by industrial waste or contaminated by acid rain, in the soil composition that heavy metals present and dissolution of soluble heavy metals in rivers, lakes and groundwater. Excessive heavy metals passes to water are diluted and partially create carbonate, sulfate, sulfur compounds in the form of water creating a solid base and they prospered in this region. Since adsorption capacity of sediment layer is limited, heavy metal concentrations in the water rises continuously. In our country, especially including Salt Lake that meets the needs of salt, since we don't take care of our environmental measures and adequate water basins and allow uncontrolled industrialization, concentrations of heavy metals are constantly being raised [1]. In this way, gradually increasing the concentration of heavy metals begins to move to the food chain and to the living things. Initially, they do not show any toxin effects but heavy metal accumulation effects the toxin in direct proportion to the mass of living things and causes unwanted diseases and death.

Apa Dam Lake is supplied by Çarşamba water. Çarşamba water is the most important river basin. There are not any major industry organizations around Apa Dam Lake, but there are intensive agricultural activities around the lake. Agricultural soils, plant nutrient uptake by plants and is depleted over time as a result of erosion. Thus; soil, which is the most important source of agricultural production; fertilization, pest control, cultivation, irrigation is attempted to make more efficient with agricultural operations. For the maintenance of fertility of the soil, nutrients removed by plants into the soil to fertilize emerges as one of the major issues [2]. Some ratio of heavy metals obtaıned by the result of fertilization, pass to the water. It was aimed to determine this ratio at Apa Dam Lake.

In the evaluation of water quality, pollution index method is used. But there are two unknowns in use of rubrics containing upper and lower limits of the traditional water quality assessment methods. The first of these, the traditional methods do not have certainty about the sketchy data and are giving rise to an approach. Because of the value of the measured parameters listed in the table limits, the distance or proximity are not taken into consideration. Secondly, every quality parameters are required to belong to one of four categories. In other words, all of the measured parameters should be gathered under a single category. If so appreciated, only a sampling of the presence of different quality grades in the area of the quality of the sampling area will lead to uncertainty in the definition of [3].

The purpose of this study, the determination of heavy metal pollution of Apa Dam Lake in 2010-2012, evaluating pollution as well as the classic classification based on fuzzy logic account.

MATERIALS AND METHODS

The study area, sampling and analysis

Ape Dam Lake, located within the boundaries of the Konya Çumra longitude between 37° 35' 97"North 32° 54' 54" East, is on the Çarşamba water, between Apasaraycık village and Apa town, 29.83 meters in height zoned earth-fill type, was built to avoid 90% irrigation 10% flood. Dam was opened for operating in 1963 [4]. Earth-fill type dam has body volume of 1.327.000 m³, which, in the normal water level, lake volume is 169 $hm^{3,}$ and lake area 12.60 km². Serves for irrigation to 97.015 hectares area (Figure 1).

The water samples which were taken to determine whether Heavy metal pollution of Apa Dam Lake is present, pollutants on sources from different depths and hydrodynamic properties selected were in consideration, in March 2010 and March 2012, between the two years were taken monthly from five measurement stations of the lake. In order to determine the heavy metals dissolution in water, the weight weighed specimens 0.45 µm pore diameter was filtered through Millipore filter paper. Filtered water samples were kept in the glass bottles cleaned with detergent, water, nitric acid, milli-Q water respectively and the bottles have been maintained in the refrigerator with 2% (v/v) concentrated nitric acid by acidification at 4 °C [5]. Heavy metals (Al, Cu, Zn, Fe, Cd, Co, Cr, Pb, Mn and Ni) readings were done by Hach Lange DR 2800 brand spectrophotometer by using appropriate kits.

Fuzzy logic inference system

Fuzzy logic is often includes the steps of a blur, blurred results and clarification (Figure-2). Blurring module; converts to blurred type by using the actual observed data, problem specifications determined in accordance with the shape of fuzzy membership functions. Fuzzy inference mechanism, evaluates the control rules stored in the fuzzy rule base. As a result of fuzzy reasoning, to achieve control movement of the membership functions which will be clarified later, one or more fuzzy outputs are obtained. Defuzzification is process of converting fuzzy outputs to numbers. Outputs of fuzzy systems are not possible for direct use in applications. In this case, fuzzy outputs must be clarified. Defuzzification is thought as the opposite to blurring process [6].

In this study; fuzzy logic model was used for detecting water quality according to heavy metal concentrations. Water Pollution Control Ordinance (2008) [7] were taken into consideration that distinguishes water into four classes according to the quality in the creation of the model. Classical classifications of the acceptable upper limit value of some heavy metals are presented in Table 1.

Figure 1. Geographic location of Apa Dam Lake and the sampling stations

Table 1. Heavy Metal Value of Water Quality Parameters [7] (WPCR, 2008)

Water Quality Parameters	Water Quality Classes			
	I	II	III	IV
Aluminium (Al) (mg/l)	0.3	0.3	1	>1
Copper (Cu) (µg/l)	≤20	50	200	>200
Zinc (Zn) (µg/l)	200	500	2000	>2000
Iron (Fe) (µg/l)	300	1000	5000	>5000
Cadmium (Cd) (µg/l)	3	5	10	>10
Cobalt (Co) (µg/l)	10	20	200	>200
Chromium (Cr) (µg/l)	≤20	50	200	>200
Lead (Pb) (µg/l)	10	20	50	>50
Manganese (Mn) (µg/l)	100	500	3000	>3000
Nickel (Ni) (µg/l)	≤20	50	200	>200

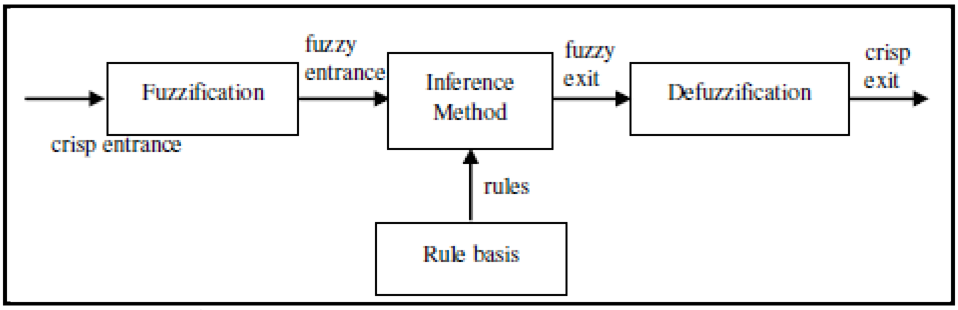

Figure 2. Fuzzy inference system [8].

Fuzzy model consists of six steps:

- (First step) Determination of the quality of heavy metals class by the measured value with a conventional classification and be collected in the four groups
- (Second step) In respect of Classical quality classifications the appointment of membership names of fuzzy models.
- (Third step) Creation of the triangular or trapezoidal membership functions related to the input and output values and determination of limit values.
- (Fourth step) Creation of the rule base using quality classes of the input values.
- (Fifth Step) Using of fuzzy logic algorithm by Mamdani approach and then determination of blurred output results of the groups with degrees of membership function parameters
- (Sixth step) Defuzzification for determining the quality index that results in four different fuzzy outputs ranging from 0 to 1 (Figure 2).

RESULTS

In order to determine heavy metal pollution of Apa Dam Lake, some heavy metal concentrations measured values were used at monthly intervals during two years at five different stations. According to the results of measurement stations received, the lowest and highest values are presented in Table 2.

As it is evident from Table 2, when stations are compared, it was found that heavy metal pollution is almost at equal level. It has been identified that samples collected from Station 1 have slightly higher values than others. Station that has the lowest pollution varies according to the type of heavy metal. For example, Station 1 in terms of Al, Cd, Cr and Ni; station 2 in terms of Zn, Pb and Fe; 5th station in terms of the Mn and Cu is determined to have the least pollution. Amounts of heavy metals in Apa Dam Lake in two year, considering conventional classification based on the quality of water for each class of heavy metals are presented in Figure 3. The membership functions of the fuzzy model and the corresponding classical class names are given in Table 3. The limit values of the membership functions that are adjacent to each other in the classic classification are determined based on the arithmetic mean of the limit values. With this approach, the classical classification of the limit values of fuzzy membership functions provided to remain in the model. In addition, measurements on the variable heavy metal were structured in triangular membership functions.

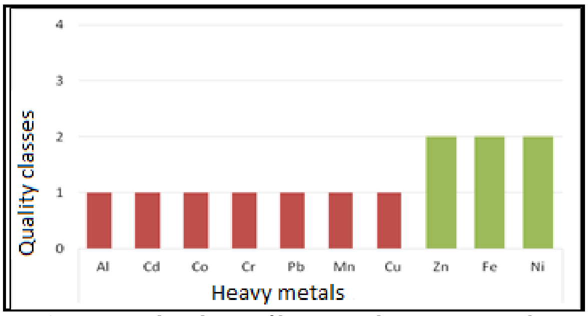

Figure 3. Quality classes of heavy metals in Apa Dam Lake

Table 3 Fuzzy model membership functions and provisions in the classic classification

Membership Function	Classical classification
High Quality	I
Good quality	II
Poor quality	III
Very poor quality	IV

Table 2. Minimum and maximum values of Heavy metals in stations.

	Station 1		Station 2		Station 3		Station 4		Station 5	
Heavy Metal	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**
Al mg/l	0	0016	0	0012	0	0015	0	0016	0	0018
Cu µg/l	4263	19172	4165	18136	4141	18176	4.2	21162	3972	21165
Zn µg/l	104	28 5	10 1	285	107	297	10 2	28 9	104	268
Fe µg/l	122	848	121	955	123	858	125	921	125	880
Cd µg/l	0	0	0	0	0	0	0	0	0	0
Co µg/l	0	11	0	7	0	5	0	10	0	13
Cr µg/l	0	17	0	14	0	12	0	11	0	25
Pb µg/l	0002	13	0001	11	0	14	0	13	0003	15
Mn µg/l	69	654	62	659	68	653	55	685	40	653
Ni µg/l	0	56	0	52	0	57	11	5 8	11	56

Membership functions of input variables and output results that have taken the limit values are presented in Tables 4 and 5. Process of observation results that were obtained in the stations are not out process range.

By using the limit values in Tables 4 and 5, every heavy metal obtained and output variables of each membership function charts are provided between Figure 4 and 13.

The base rule, by using heavy metal quality classes was set as follows:

IF (IF) **Cd** = Very High Quality or (or) **Co** = Very High Quality or (or) **Cr** = Very High Quality or (or) **Pb** = Very High Quality or (or) **Al** = Very High Quality or (or) **Mn** = Very High Quality or (or) Cu = Very High Quality (THEN) Output (Output) = Very Good Quality

IF (IF) **Zn** = Good Quality or (or) **Fe** =Good Quality or (or), **Ni** has good quality (THEN) Output (Output) = Good Quality

Lastly in the study, fuzzy quality results were calculated by taking average of the data obtained in the four different quality groups from the stations of Apa Dam Lake for two years and output results were clarified to find quality index of entire lake. Two-year average quality index of stations is presented in Figure 14.

Table 4. Membership functions of the input variables of the fuzzy model that have taken the limit values

Heavy metals	**Membership function**	**Limit values**		
		A	B	c
Aluminum (Al) (mg/l)	High Quality	<0	0	0.45
	Good quality	0.15	0.30	0.650
	Poor quality	0.45	0.650	1.5
	Very poor quality	0.650	1.5	>1.5
Copper (Cu) (µg/l)	High Quality	<0	0	35
	Good quality	10	35	125
	Poor quality	35	125	275
	Very poor quality	125	300	> 300
Zinc (Zn) (µg/l)	High Quality	<0	0	350
	Good quality	100	350	1250
	Poor quality	350	1250	2750
	Very poor quality	1250	3000	>3000
Iron (Fe) (µg/l)	High Quality	<0	0	650
	Good quality	150	650	3000
	Poor quality	650	3000	7000
	Very poor quality	3000	7500	>7500
Cadmium (Cd) (µg/l)	High Quality	<0	0	4
	Good quality	2	4	8
	Poor quality	4	8	12
	Very poor quality	8	15	>15
Cobalt (Co) (µg/l)	High Quality	<0	0	15
	Good quality	5	15	110
	Poor quality	15	110	275
	Very poor quality	110	300	>300
Chromium (total) (Cr) (µg/l)	High Quality	<0	0	35
	Good quality	10	35	125
	Poor quality	35	125	275
	Very poor quality	125	300	>300
Lead (Pb) (µg/l)	High Quality	<0	0	15
	Good quality	5	15	35
	Poor quality	15	35	65
	Very poor quality	35	75	>75
Manganese (Mn) (µg/l)	High Quality	<0	0	300
	Good quality	50	300	1750
	Poor quality	30	1750	4250
	Very poor quality	1750	4500	>4500
Nickel (Ni) (µg/l)	High Quality	<0	0	35
	Good quality	10	35	125
	Poor quality	35	125	275
	Very poor quality	125	300	>300

Table 5. Fuzzy membership function of the output variable of the model that have taken the limit values.

Output Variable	Membership Function	Parameters			
		a	b	c	d
Quality index trading range [0, 1]	**High Quality**	<b	0	0.125	0.375
	Good quality	0.125	0.375	0.625	-
	Poor quality	0.375	0.625	0.875	-
	Very poor quality	0.625	0.875	1	>c

(Meaning of numbers; I: High Quality II: Good Quality III: Poor Quality IV: Very Poor Quality)

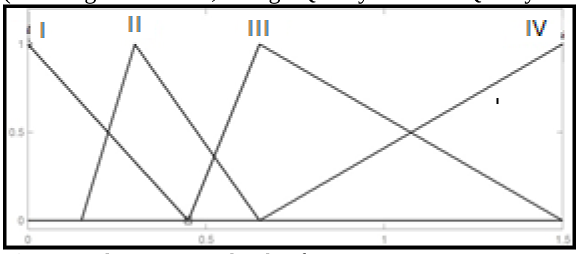

Figure 4. Aluminum membership function

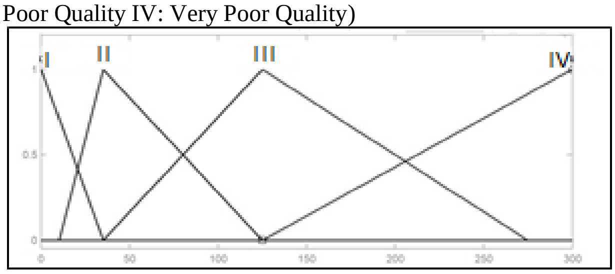

Figure 5. Copper membership function

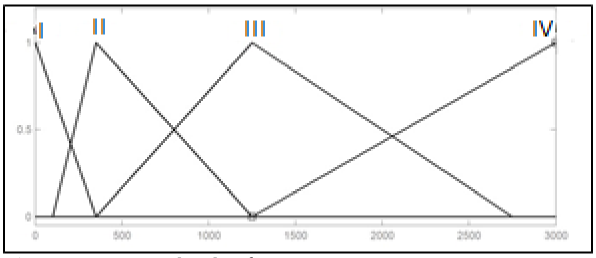

Figure 6. Zinc membership function

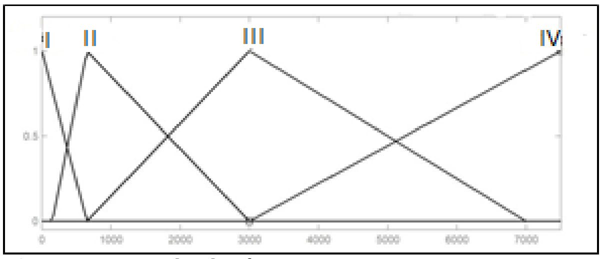

Figure 7. Iron membership function

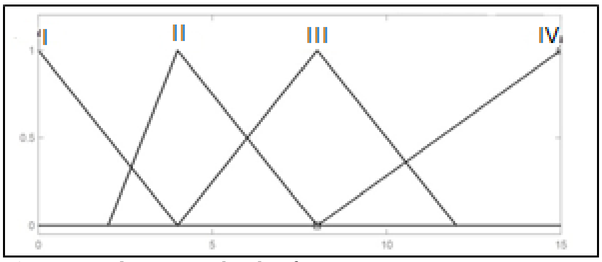

Figure 8. Cadmium membership function

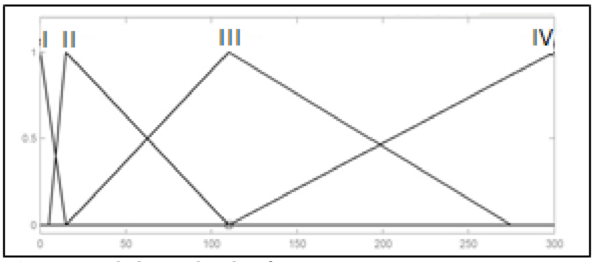

Figure 9. Cobalt membership function

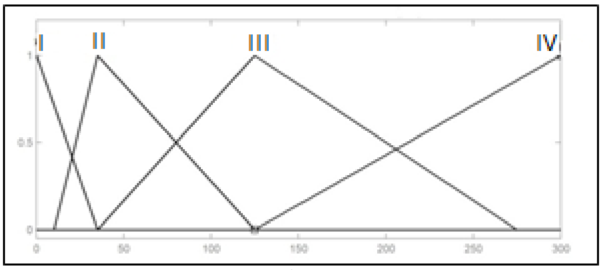

Figure 10. Chrome membership function

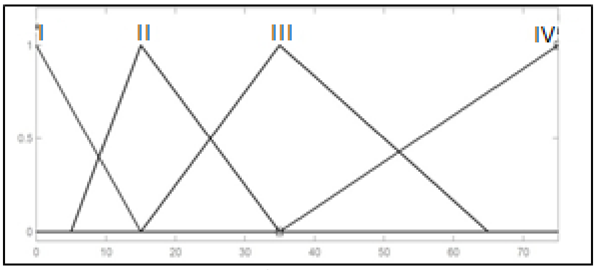

Figure 11. Lead membership function

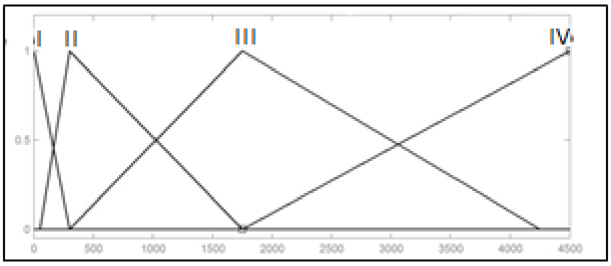

Figure 12. Manganese membership function

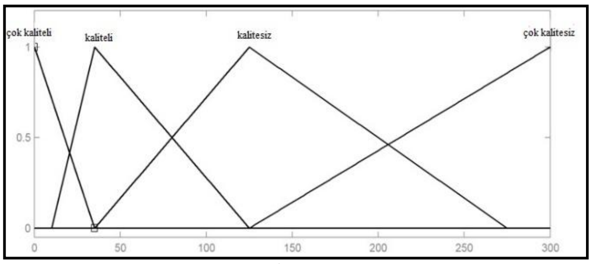

Figure 13. Nickel membership function

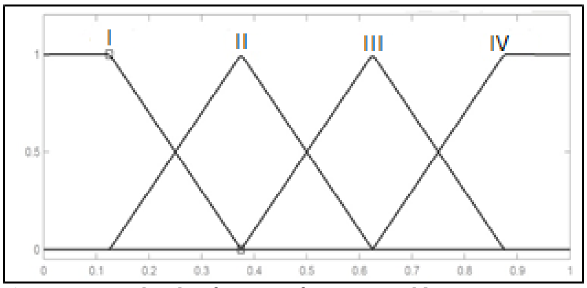

Figure 14. Membership function of output variables

DISCUSSION

Several studies have been made with heavy metals in Turkey. For example, In water sample from SDR (Sarıyar Dam Reservoir) the accumulation order of heavy metals was found as Pb>Cr>Cd>Hg in spring; Pb>Cr>Cd>Hg in summer; Pb>Cr>Cd>Hg in autumn and Pb>Cr>Cd>Hg in winter [9] . In this study, by using data from water pollution control regulations, fuzzy logic method is applied to make a decision. Fuzzy logic is one of the methods of artificial intelligence in the field of water engineering although it is not too much used, is becoming increasingly common, [10-11]. Fuzzy logic membership functions which characterize the fuzzy sets, or in other words, fuzzy numbers and transactions with fuzzy numbers, making the basis of fuzzy logic and fuzzy sets. Therefore, in order to understand what can be done with fuzzy logic and fuzzy sets, first you need to understand these processes [12]. In the work we have done, it was aimed to evaluate the proportions of heavy metals polluting water and evaluate these proportions from a different angle. With this method, a quality index was generated. The values in the classic classification must take part in only four quality classes. Traditional water quality regulations include quality classes determined by sharp sets and the boundaries between the different classes would be inherently difficult to understand [13]. However, the places in the quality classes may be clearly explained in the results of fuzzy inference. For example, average Ni in Apa Dam Lake is found 28 µg/l. According to these values, according to the Water Pollution Control Ordinance, Ni is in the II. class water quality. However, by evaluating the Ni by fuzzy logic, it is seen that 28% has very high quality and 72% good quality. In the same way if we look for Fe, it is averagely found 463 µg/l. According to these values, according to the Water Pollution Control Ordinance Fe is in the II. class water quality. However, by evaluating the Fe by fuzzy logic, it is seen that 21% has very high quality and 78.75% has good quality.

In the research, the triangular shape of membership functions with simple structure is the most used shape. With the use of this form it is very easy to comment where there is insufficient data and complicated function of many parameters. In triangular structure, the degrees of membership increases and decreases at a constant rate between 0 and 1. But in real environment the change in these type is very rare [14]. Triangular output is obtained by Mamdami mathematical model, is used in calculating fuzzy logic and this model was deemed appropriate. Because, Mamdami model is more intuitive and is more suitable for interpretation-based data entry. By monthly examination in Apa Dam Lake, it was determined that classical classification based on 7 parameters in terms of (Al, Cd, Co, Cr, Pb, Mn, Cu) in the first class, 3 parameters in terms of (Zn, Fe, Ni) in the 2nd class. When evaluated by fuzzy logic, value of one index of the quality parameters (two years quality index = 0.289) is reached (Figure 15). Furthermore, quality index of each station is determined and is presented in Figure 16. According to this index value, if it approaches to 0, it has very high quality, but when it approaches to 1, it has very poor quality. This method ensured the homogeneity between the measured parameters and by evaluating the resulting quality index of annual output value, we can see that 66% enters to the good quality, and 34% enters to the high quality class. This index value, explains easily that Apa Dam Lake has a good water quality.

Fuzzy logic methods have been applied to the lakes recently. It has been applied only in Eber Lake in Turkey. Eber Lake with physical and chemical water quality parameters by fuzzy logic evaluation and water quality classification studied in a study fuzzy inference system for water pollution assessment and classification are quite favorable results may be highlighted [3].

In addition, besides classical classification, more precise evaluation was made by fuzzy logic. According to the results of research, there is little pollution by heavy metals in Apa Dam Lake, determined by both classic classification and fuzzy logic.

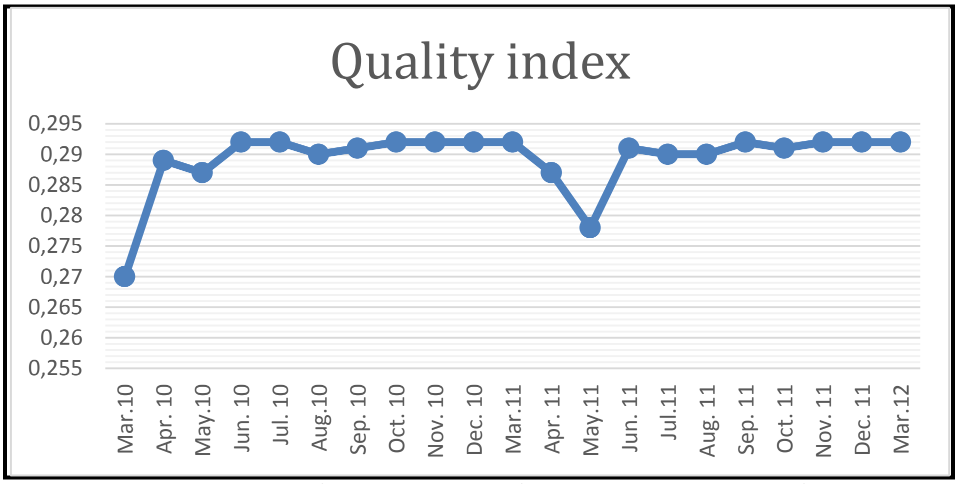

Figure 15. Monthly average of heavy metals derived from the results produced by the fuzzy model

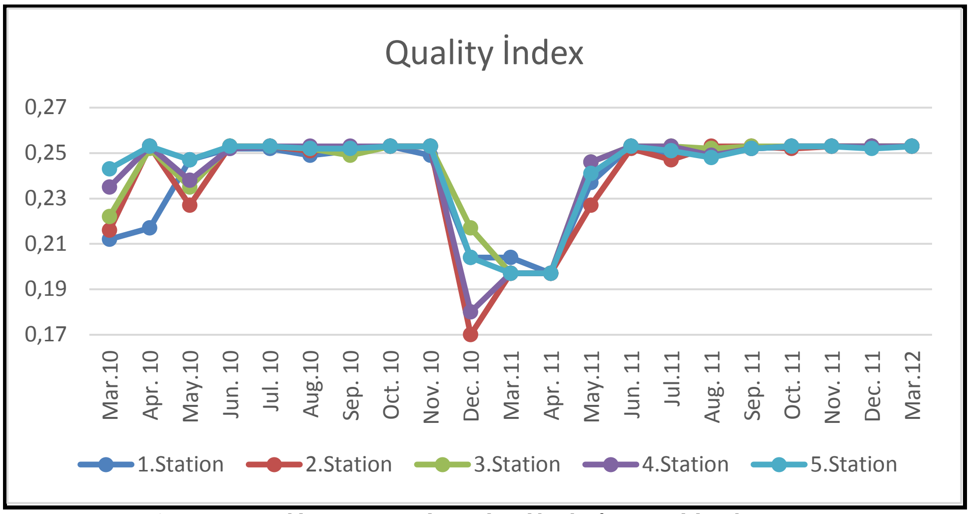

Figure 16. Monthly average results produced by the fuzzy model in the stations

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