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MANOVA Statistical Analysis of Inorganic Compounds in Groundwater Indonesia

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Abstract: *The present study was carried out to determination a levels of inorganic compounds contained in the ground water and Reverse Osmosis (RO) water filtration result. The data in groundwater samples was collected from Bekasi, Tangerang and Jakarta in Indonesia. A total of 30 samples were collected and analyzed for the determination of Cadmium (Cd), Chromium (Cr), Manganese (Mn) , Cyanide (CN) and Lead (Pb). The results of the study revealed that in groundwater, the average of Cd 0.0058 mg / l , Mn 1.5233 mg / l , Cr 0.0127 mg/l, Pb 0.0060 mg / l, and CN 0.0040 mg / l. The level of RO result were: Cd 0.0027 mg / l, Mn 0.1767 mg / l , Cr 0.0024 mg / l, Pb 0.0021 mg / l, and CN 0.0023 mg / l . It's mean that Cd and Mn in ground water were higher than the values recommended by PAK-EPA and WHO or the standard of Indonesian Ministry of Health. But after filtration Reverse Osmosis (RO) Mn and Cd levels decreased to levels below the standardized value. By comparing of mean in MANOVA and nonparametric MANOVA in α=5%, there are differences in average levels of inorganic substances Mn, Cr, Cd, Pb, and CN between before and after RO filtration.*
Keywords: *Inorganic Compounds, Ground Water, Reserve Osmosis, MANOVA*
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I. Introduction

Water is essential for human life. Functions of water in the body are cell life, chemical and metabolic reaction, transform of nutrients, body temperature regulation and elimination of waste [1]. Jakarta, Bekasi and Tangerang are a large region population in Indonesia. Water needs in these three areas is very high, but the local water company (PDAM) in Jakarta can only supply 39% of the population water needs. Most people use water refills. Some of them consume Reverse Osmosis (RO) water filtration result, but many low-income peoples directly consume groundwater for drinking.

Jakarta, Bekasi and Tangerang have many industries and densely populated residential. Increase in the number of septic tanks polluting the groundwater and can have serious health effects diseases such as hepatitis and dysentery. Inorganic compounds such as Chrome (Cr) reduces fatty acids and cholesterol and regulates sugar and insulin rates in the blood, but chronic exposure to high chromium levels causes lung cancer in human [2].

Groundwater for drinking has the potential to cause damage to liver, kidney, circulatory and nerve tissues and skin irritation from long-term exposures at levels above the Maximum Contaminant Level (MCL) [3]. Heavy metal toxicity like Lead (Pb), Cadmium (Cd), Manganese (Mn) are can result in damaged or reduced mental and central nervous function, cancer, lower energy levels, and damage to blood composition, lungs, kidneys, liver, and other vital organs [4]. Therefore, the study of inorganic compounds in the groundwater and water filtration Reverse Osmosis (RO) result was done.

There are some statistical methods for analysis the water quality, such as Multivariate Analysis of Variance (MANOVA) [5], [6]. Function of MANOVA is comparison of dependent variable means across multiple groups. It requires that the observations are independent, the response variables are multivariate normally distributed, and the covariance matrix of the dependent variables is homogeneous across groups. This research use MANOVA to compare inorganic compounds in the ground water and RO. The results of MANOVA can determine the effect of RO filtration in water quality, and the differentiation of quality water in groundwater and RO. When assumption of MANOVA, homogeneity variance or normal distribution, was violated, then it can use nonparametric MANOVA [7], [8].

II. Methodology

Sampling

For the present investigation, there were 30 groundwater samples collected from different localities of Bekasi, Tangerang and Jakarta in Indonesia. The time of data collecting was during the months of May to August 2013. The samples were in screw high density polyethylene bottles. The sample bottles were rinsed

twice with the sample water to avoid any impurity. It also labeled properly and immediately transferred to laboratory in Padjadjaran University in Bandung-Indonesia.

Determination Of Lead (Pb) And Cadmium (Cd)

Fifty ml of the test sample was inserted into beaker of 100 ml or 100 ml Erlenmeyer and add 5 ml of HNO_3 concentrated. It closed with watch glass then heated slowly until the residual volume of 15 ml - 20 ml. If destruction is not perfect (not clear), then added 5 ml of HNO_3 dense and closed with a watch glass and then heated again (do not boil). This process was done repeated until all dissolved metals, which looks sample of sediment color became somewhat white or test sample becomes clear. After the glass watch water was rinsed, put solute in the beaker. Then the test sample transferred into a 50 mL volumetric flask (filtered if necessary) and added demineralized water tera sign up right then homogenized. After the absorbance read at using AAS instrument [9], [10].

Determination Of Chrome (Cr)

Pipette a volume (V) of test sample and place in a 100 mL beaker, add 0.25 mL (5 drops) H_3PO_4, adjust to pH 2.0 ± 0.5 by addition 0.2 N sulfuric acid. Move the sample solution into 100.0 mL volumetric flask. For specify the calibration mark with demineralized water, add 2.0 mL of solution difenilkarbazida, shake and let stand 5 to 10 minutes; measuring absorbance at a wavelength of 530 nm or 540 nm; record the measurement results [11].

Determination Of Manganese (Mn)

Include 100 mL sample that has been whipped up into a homogeneous beaker, add 5 mL $HNMO_3$, and heat in an electric heater until the solution sample dry. Then added 50 mL of distilled water, put into a flask of 100 filter paper and matched mL through 100 mL with distilled water [12].

Determination Of Cyanide (CN)

Pipette 10 ml of standard solution of cyanide (± 1000 mg / l) to the Erlenmeyer (Duplo) and dilute with a solution of 0.04 M NaOH diluents by the volume of ± 100 ml which use a blank 0.04 M NaOH solution. After that, add 1 ml of indicator solution rodamina and do homogeneous process. Titar with standard-$AgNO_3$ solution until the color changes from clear yellow first red-brown, and chartreuse. Note that the volume of $AgNO_3$ standard solution worn on of Cianide (CN)[13].

III. Data Analysis

For analyze the research data, do the following steps:

1. Conduct descriptive analysis covers the average, standard deviation, minimum value and maximum value for Pb, Cd, Cr, Mn, and CN. [14]
2. MANOVA test using test Pillai's Trace, WilksLamda, Hotelling's Trace and Roy's Largest Root. The goal is to test whether there are differences in the average levels of inorganic compounds in groundwater samples and samples of RO filtration at α 5% [14]

The MANOVA assumption were the data is multivariate normal distribution and variance matrix is homogeny. The assumption tests used were Shapiro Wilk Normality test and Box's M [15]. If these assumptions were violated, it uses nonparametric MANOVA.

MANOVA with one factor have the model [14],

$$x_{ijk} = \mu_k + \tau_{ik} + \varepsilon_{ijk} \qquad (1)$$

Where,
x = the dependent variable
μ = the mean of x
τ = factor effect/treatment
ε = error
i = level of effect, i =1,2,…
j = the replication, j=1,2,…
k = number of dependent variable

The significant test uses the F and P value from the results of MANOVA table. Reject Ho if $F>F_{(df1,df2,\alpha)}$ or P value < α.

In this research the dependent variable was Mn, Cr, Cd, Pb, and CN. The factor was type of water, consist of 2 levels: ground water and water after RO filtration.

IV. Results And Discussion

The analysis in this study include descriptive analysis, test for normality, homogeneity testing, and Multivariate Analysis of Variance (MANOVA) for inorganic substances Mn, Cr, Cd, Pb, and CN in the ground water. Levels of these substances were divided into two groups based on water samples, i.e. the samples of raw water (control) or ground water and the results of filtration water by Reserve Osmosis (RO).

TABLE 1. Characteristics of Chromium (Cr)

Samples	Mean	Standard Deviation	Min	Max
• Ground Water	0,0127	0,0051	0,0030	0,0180
• RO water filtration	0,0024	0,0030	-0,0060	0,0090

From the Table 1, it can be seen that the average levels of substance Chromium (Cr) after in RO filtration was lower than in ground water. It was 0.0127 mg/l in ground water and 0.0024 mg/l in RO. Cr levels in the Ground water and RO filtration results still eligible of the values recommended by PAK-EPA and WHO [16] or the standard of Indonesian Ministry of Health 0.05 mg /l.

TABLE 2. Characteristics of Manganese (Mn)

Samples	Mean	Standard Deviation	Min	Max
• Ground Water	1,5233	0,4717	1,000	3,500
• RO water filtration	0,1767	0,1194	0,000	0,300

The average levels of substance Manganese (Mn) RO filtration results lower than in groundwater (see Table 2). Mn levels in the ground water still higher than the values recommended by PAK-EPA and WHO or the standard of Indonesian Ministry of Health 0,5 mg/l. It was perform that quality of Mn in ground water was poor. Otherwise, RO water filtration results still eligible of the values recommend.

TABLE 3. Characteristics of Cadmium (Cd)

Samples	Mean	Standard Deviation	Min	Max
• Ground Water	0,0058	0,0007	0,0050	0,0070
• RO water filtration	0,0027	0,0012	0,0010	0,0050

Such as Mn, the average level of Cadmium (Cd) in RO filtration was lower than in groundwater (see Table 3). Cd levels in the ground water still higher than the values recommended by PAK-EPA and WHO or the standard of Indonesian Ministry of Health 0.003 mg/l, but in RO water filtration was still eligible.

TABLE 4. Characteristics of Lead (Pb)

Samples	Mean	Standard Deviation	Min	Max
• Ground Water	0,0060	0,0030	0,0040	0,0090
• RO water filtration	0,0021	0,0009	0,0010	0,0030

Lead (Pb) in ground water was 0.0060 mg/l and in RO filtration was 0.0021 mg/l (see Table 4). Average of Pb in RO filtration was lower than in groundwater. But all of them still eligible of the values recommended by PAK-EPA and WHO or the standard of Indonesian Ministry of Health 0.01 mg /l. As well as for Cyanide (CN), the average in RO filtration was lower than in groundwater. But all of them still eligible of 0.007 mg /l (see Table 5).

TABLE 5. Characteristics of Cyanide (CN).

Samples	Mean	Standard Deviation	Min	Max
• Ground Water	0,0040	0,0008	0,0030	0,0050
• RO water filtration	0,0023	0,0008	0,0010	0,0040

Multivariate Normality Test

Before conduct the MANOVA analysis, it performed the multivariate normal assumption. The hypothesis used is as follows:

H_0: The data follow a normal distribution multivariate distribution.

H_1: The data do not follow the distribution of a multivariate normal distribution.

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Shapiro-Wilk normality test
data:  Z
W = 0.8345, p-value = 1.095e-06
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FIGURE 1. Output of Multivariate Normality Test

It was use Shapiro Wilk test in R. From the results, it can be seen that Pvalue is 0.07247 (see Figure 1). It was less than $\alpha = 5\%$, so the data content of Mn, Cr, Cb, Pb, and CN were not follow a multivariate normal distribution. So the MANOVA assumption was violated.

Multivariate Homogeny Test

The second assumption of MANOVA analysis is homogeneity of variant of covariance matrix. This study use Box's M to test the homogeneity. Hypotheses used are:

H_0: variance covariance matrix homogeneous

H_1: variance covariance matrix is not homogeneous

TABLE 6. Box's M Test

Box's M	P value
7,344	0,000

The test results by SPSS are presented in Table 6. The conclusion is reject Ho or variance covariance matrix is not homogeneous. So, the MANOVA assumption was violated. This is indicated by the value P value = 0.000 which less than $\alpha = 5\%$.

Manova

MANOVA test was done through test Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root. The hypothesis used is

H_0: There is no difference in the average levels of inorganic substances Mn, Cr, Cd, Pb, and CN

H_1: There are differences in average levels of inorganic substances Mn, Cr, Cd, Pb, and CN

Decision making is the reject Ho if the P value less than α. The test results showed that the value of P value on all testing is less than $\alpha = 5\%$. So the conclusion is that Ho rejected or there are differences in average levels of inorganic substances Mn, Cr, Cd, Pb, and CN between before and after RO filtration.

TABLE 7. MANOVA Test

Effect		Value	F	df 1	df 2	P value
Intercept	Pillai's Trace	0,999	8065	5,000	54,000	0,000
	Wilks' Lambda	0,001	8065	5,000	54,000	0,000
	Hotelling's Trace	746,753	8065	5,000	54,000	0,000
	Roy's Largest Root	746,753	8065	5,000	54,000	0,000
Treatment	Pillai's Trace	0,938	164	5,000	54,000	0,000
	Wilks' Lambda	0,062	164	5,000	54,000	0,000
	Hotelling's Trace	15,169	164	5,000	54,000	0,000
	Roy's Largest Root	15,169	164	5,000	54,000	0,000

Nonparametric MANOVA

In the MANOVA analysis discussed above, it can be seen that the assumption of normal distribution and homogeneity were not met. Therefore, a comparison analysis was done using a nonparametric MANOVA. Output analysis is presented in Table 8. These results indicate that the value of P value less than 0.001 $\alpha = 5\%$. So the conclusion is that Ho rejected or there are differences in average levels of inorganic substances Mn, Cr, Cd, Pb, and CN between before and after RO filtration. It was also performs that RO filtration can be use to get a better water quality in Bekasi, Tangerang, and Jakarta, Indonesia.

TABLE 8. Nonparametric MANOVA Test

Source	df	SS	MS	F	P value
Water	1	6,6388	6,6388	67,512	0,001
Residual	58	5,7034	0,0983		
Total	59	12,3422			

V. Conclusion

From the results of laboratory tests indicate that the groundwater in the area of Bekasi, Tangerang and Jakarta (Indonesia) levels of manganese (Mn) and Cadmium (Cd) above are standardized by the PAK- EPA, WHO or the Indonesian Ministry of Health. But after filtration Reverse Osmosis (RO) Mn and Cd levels decreased to levels below the standardized by PAK- EPA, WHO and Indonesia Ministry of Health. Generally, all the inorganic compounds in ground water and RO filtration were difference. The average in RO was less than in ground water. It was supported by MANOVA analysis. In α=5%, it conclude that there are differences in average levels of inorganic substances Mn, Cr, Cd, Pb, and CN between before (ground water) and after RO filtration.

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