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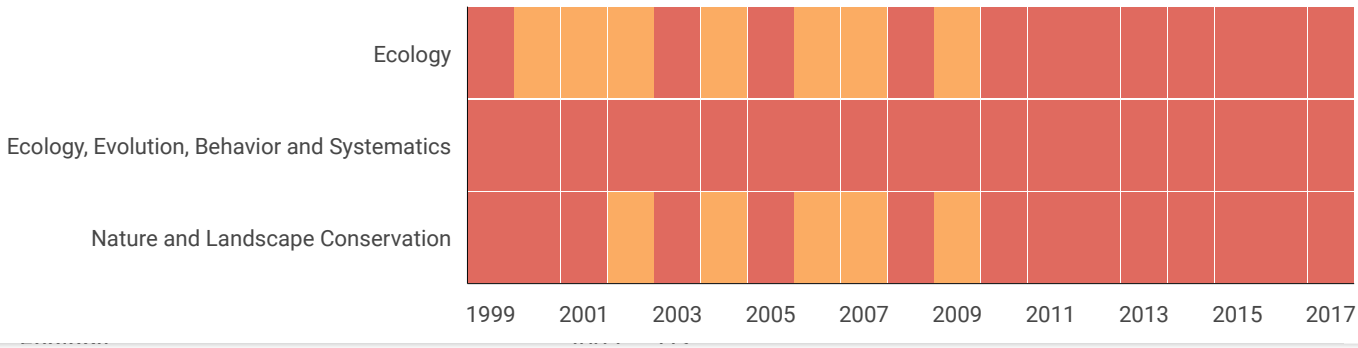

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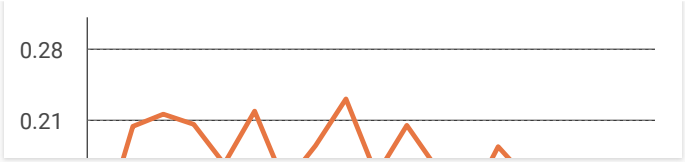

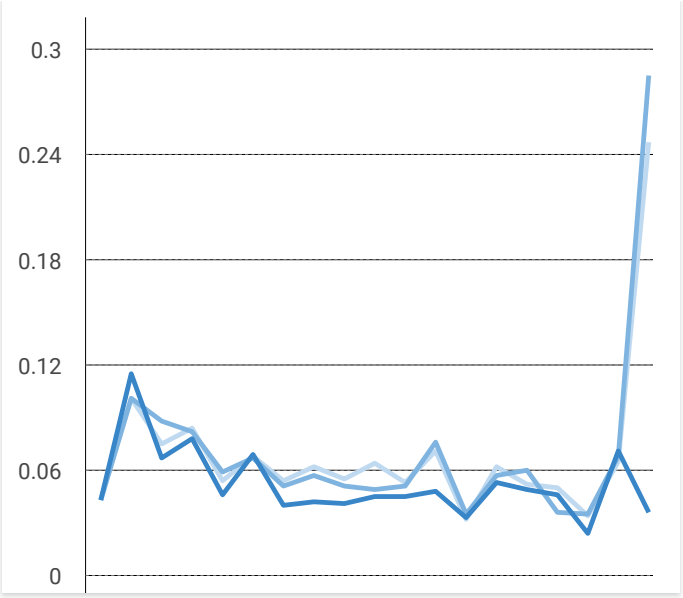

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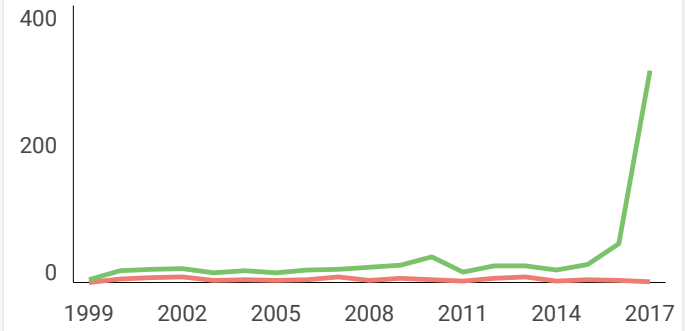

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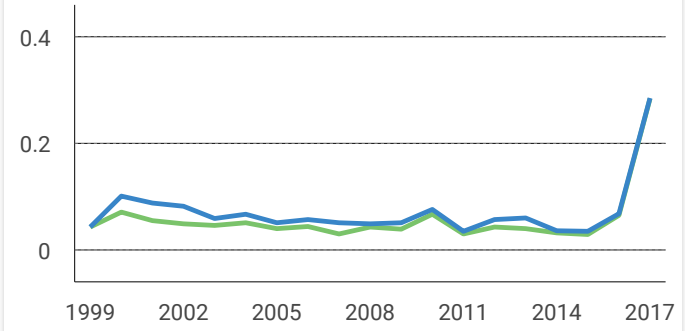

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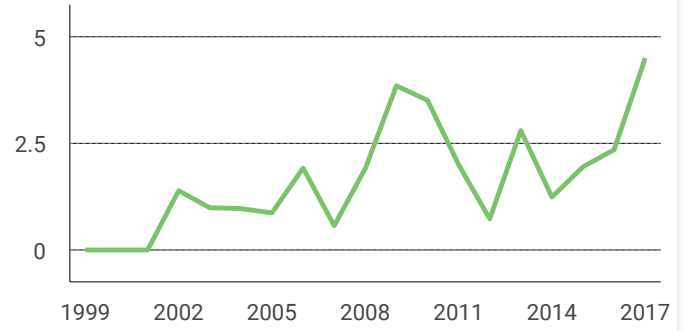

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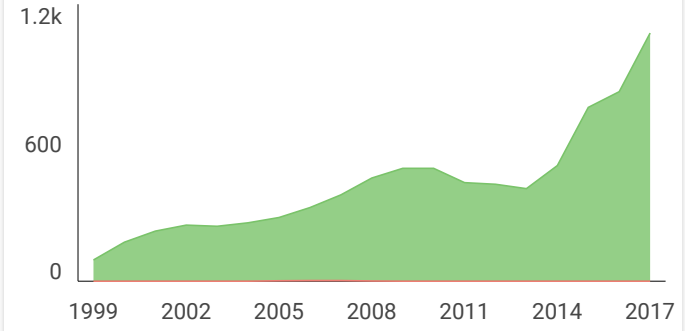

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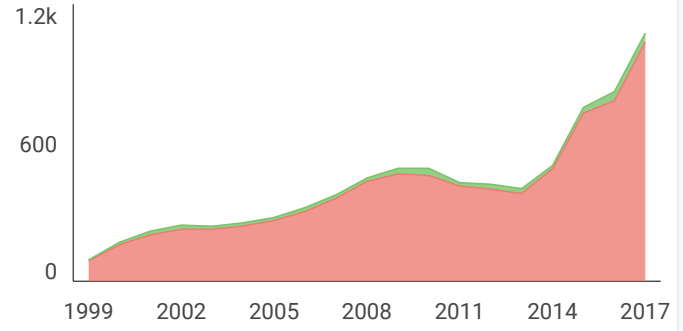

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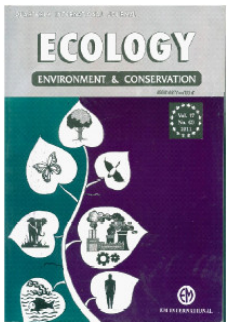

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Model multivariate adaptive regression spline on lead exposure found within the hair of Petrol station's workers in Gorontalo City, Indonesia

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ABSTRACT

MARS (*Multivariate Adaptive Regression Spline*) is one of the non-parametric regression models that employs modified recursive partitioning algorithm. This study applied MARS model in the data of Lead (Pb) exposure in the workers' hair at the petrol station in Gorontalo City, Indonesia. The study is intended to investigate the content of Lead in one's body. The results of the study reveal that the MARS model in the Lead exposure in the workers' hair at the petrol station in Gorontalo City consists of Y = 1.93593 - 0.219669 * BF8 - 0.0220152 * BF13. Based on that MARS model, there are only three variables out of 10 assumed to affect the Lead exposure in the workers' hair at the petrol station in Gorontalo City including the working time, disease symptoms, and age.

Key words: *Multivariate, Adaptive, Regression, Spline, Lead exposure, Hair.*

Introduction

Time series modelling is usually found in sufficiently stationary and linear data by application of Autoregressive Integrated Moving Average (ARIMA) method for prediction (Arsyad, 1999). This method is highly effective, and model that is highly suitable will be achieved when the two requirements above are met. If the data could not fulfil the assumption, then the obtained model would not be complete in describing the pattern of the system behaviour, hence, unsuitable for forecasting. Development of non-linear time series has been made through the introduction of several flexible methods in various applications, where Multivariate Adaptive Regression Splines (MARS) is one of them (Friedman, 1991). Fluctuated and non linear data and time series modelling to obtain the value of given period in the future was proposed through MARS approach, which was considered better than the stochastic model (Buja, Duffy, Hastie, Tibshirani, 2001).

One of the chemical elements that are dangerous to human health is the heavy metal. There are several heavy metals that are toxic and acts as a pollutant in the environment such as mercury (Hg), lead (Pb), Cadmium (Cd), and Cuprum (Cu). The lead that polluted the air can come from the burning residue of additive substance from the motor vehicles' fuel. The lead particles in the air can also come from other sources such as Allkil Pb factory and Pb-oxide, coal burning, etc (Sunu, 2001). The lead polluted air can enter the body through inhalation process. Most of the inhaled lead will enter the blood vessels in the lungs. Level of lead's absorption is heavily influenced by the size of the lead particle and the inhaled blood volume during the breathing process. The lead inhaled into the lungs will be absorbed and

chained with blood in the lungs to further be distributed to all tissues and organs. In tissues or organs, the inhaled lead will be accumulated within the bone. Regardless, to the small amount of inhaled lead, this metal can be hazardous. This was due to the lead compounds that are toxic to many functions of the body organs (Palar, 1994). The other mechanism for the lead to enter the human body is through oral or direct contact with the skin surface. About 40% of lead within the body which comes from inhalation process is absorbed into the respiratory system. About 5-10% of the lead compounds were absorbed into the gastrointestinal tract (Naria, 2005).

The danger of the inhaled motored-vehicles' emission has a long-term effect on human body. The emission that contained lead is found in vehicles that used leaded-fuels as anti-knock compounds. The lead element in the body can be deposited into the soft tissues (bone marrow, nerve systems, kidney, and liver) and hard tissues (bones, teeth, nails, and hair). The lead element within the soft tissues is toxic within that soft tissues itself (Ardiyanto, 2005), whereas the intrusion of a large quantity of lead into the human body could cause kidney failure (Soesanto, 1998). It can also cause cancer, problems in peripheral and central nervous system, digestion system, and reproduction system (Ardyanto, 2005). Also, in a pregnant woman, lead can penetrate the placenta and enter the blood circulation of the fetus. The lead will be disposed of with the breast milk after the baby was born (Palar, 1994).

There has been extensive research on the level of lead within the body. However, the focus of this investigation is on the petrol's station workers in Gorontalo regency. Therefore, a research to find out the level of lead accumulated within the petrol station workers' body is needed.

Lead Found in Hair

Hair is a solid structure which consists of solid keratin cells from made from epidermis follicles which shaped like a bulb that grows into the dermis layer. Normal and healthy hair looks shiny, elastic, and not easily broken, as well as absorbs water. Hair composition consists of 50.60% of carbon, 6.36% of hydrogen, 17.14% of nitrogen, 5.0% of Sulphur, and 20.80% of oxygen (Pusponegoro, Erdina H.D. 2002). Hair is also one of the skin adnexa that spread along the body except for the palm of the hands, soles of the feet, nails, and lips (Soepardiman, Lily. 2002). There are two generic types of hair in the human body, terminal hair, the pigmented hair that grows on the head, brow, eye lashes, and in the pubic regions, and vellus hair, the least pigmented hair that grows in almost all body parts. (Soepardiman, 2002).

In the human body, the lead will be disposed through the various mechanisms, including through hair. Considering that hair reflects more on the level of a heavy lead pollutant that has entered the body (Kamal, 2007). This is because hair contains a lot of structural proteins that composed of cysteine amino acid that contains disulphide bonds (- S - S -) and cysteine containing sulfhydryl groups (- SH) with the ability to bind the heavy metals that enter the human body. The level of tolerated lead in human hair is $12 \leq g/g$, in this level the toxin within the lead is not harmful (Palar, 1994).

Factors that influence the level of lead in human hair are the length of exposure, age, genetic, and nutrition, hence, hair can be used as an indicator for the level of lead pollution in human and animal (Ashraf *et al*. 1995).

Multivariate Adaptive Regression Spline

MARS is one of the non-parametric regression model which uses modified-recursive partitioning algorithm. The MARS modelling is preceded by three things below (Friedman & Silverman, 1989).

i. Base Function (BF) is a function defined from each region. A maximum number of recommended base functions (BF) are 2-4 times of the number of the predictor variable.
ii. Maximum interaction (MI) is a number of interaction that happens on the model. The number of maximum interaction (MI) are 1, 2, and 3, if the maximum interaction used is more than 3, then the CGV value will increase and the model used will be more complex. If the maximum interaction used is 1, it means there is no interaction among variables within the model. If the maximum interaction used is 2, then there is an interaction between two variables within the model. If the maximum interaction used is 3, it means that some interaction that happens within the model is mostly among three variables.
iii. Minimum observation (MO) is a number of minimum observations among knots. A number of maximum interactions (MI) are 0,1,2, and 3, beyond this figure, the CGV will increase.

Establishment of the value of the base function

(BF), maximum interaction (MI) and minimum observation will influence the MARS model that will be developed. The multivariate adaptive regression splines (MARS) can be written in the following formula

$$\hat{f}(x) = \beta_0 + \sum_{m=1}^{M} \beta_m \prod_{k=1}^{K_m} \left[S_{km} \cdot \left(x_{v(k,m)} - t_{km} \right)_+ \right]$$

Research Method

This study is an observational research with cross-sectional approach. This study is conducted on petrol stations' workers that work in seven petrol stations in Gorontalo city with a total number of 48 workers. The samples are taken between 07.00 – 11.00 am because that period is the peak time for vehicles to fill their petrol tanks in these stations. The testing of the hair samples is conducted in *Balai Pengawasan Mutu Perikanan* (fisheries quality control office, henceforth called as BPMP) of Gorontalo city.

The population in this study is all the workers of petrol stations in Gorontalo city. Samples are taken using purposive sampling method based on several criteria. The samples' criteria are as follow: (1) Age 20-40 years old; (2) Hair length minimum 5 cm; (3) Work tenure ≥ 2 years and (4) Volunteer to become respondents

Research Variables

The were three variables using of this research. These research Variables are: (1) Work Tenure. It is about the length of time where respondents, in their line of work have been exposed to lead. The longer the working tenure, the higher the risk to be exposed to lead. The objective criteria are short work tenure (≤ 2 years) and long work tenure (> 2 years); (2) Level of Lead (Pb). Number of lead accumulated in respondents' body. The tolerated lead exposure on human hair is ≤ 12 µg/g, hence, the toxicity is not severe (WHO, 1994). The objective criteria are normal, when the lead level is ≤ 12 µg/g and abnormal when the level of lead is > 12 µg/g and (3) Health problems on petrol stations' workers. Health concerns are often found in people who have been exposed to lead. The target of this study is the lead in the hair of petrol stations' workers in the area of Gorontalo city.

Primary data are obtained through an interview with additional observation sheet that contains the questions such as the identity of the respondents (name, age, and respondents' work history, medical history). The respondents' hair specimens are collected and tested on the level of lead in respondents' hair is conducted in the laboratory. Secondary data used in this study are data from BLHRD (Provincial Environment and Research Agency) of Gorontalo province, *Samsat* Office (Vehicle Registration office) of Gorontalo city, and *Badan Pusat Statistik* (statistical bureau) of Gorontalo Province.

Tool, Technique and Research Procedure

The method used in analysing the specimens in this study is Atomic Absorption Spectrophotometry (AAS). The samples are tested at BPMP laboratory of Gorontalo city.

i. Tools and equipment
- Hair scissor used to cut the respondents' hair
- Plastic bag
- Observation sheet
- Acetone and water
- beaker glass
- volumetric flask
- pipet
- mortar and pestle
- vial polyethylene
- PC computer
- Digital Scale
- *Kooling* Module (KMS) or water cooling system
- Atomic Absorption Spectrophotometry as tool of analysis
- Blower
- Petrol stations workers' hair
- Condensed Nitric Acid (HNO_3)
- Perchlorate Acid
- Aqua dest

ii. Hair specimen collection technique

Each respondent hair was taken 0.5 – 1 cm, then the hair is put into a labelled plastic bag. Respondents' data are also collected, such as the name, age, and work tenure.

i. Preparation Technique and AAS analysis

Prior to hair specimens' analysis, the specimens are washed with 100 mL of acetone and rinsed three times with water. After that, the hair is washed using the acetone to get rid of the fat and other contaminants that might interfere other elements in hair. The specimens then dried. The specimen then destroyed to obtain a homogenous result. The result is then put into a vial, each specimen is given a label.

Research Findings and Discussion

In Mars modeling process, there are three things to be considered: the base function (BS), maximum interaction (MI), and minimum observation (MO). The base function (BF) is a function defined from each region. The maximum number of recommended base function (BF) is 2-4 times of the number of the predictor variable (Friedman, 1991). The predictor variables that are suspected to influence the lead exposure are ten variables, hence, the number of base function that will be combined in the establishment of the model are 20, 30, and 40.

Maximum interaction (MI) is the number of interaction that happens on the model. The number of maximum interaction (MI) is 1, 2, and 3 (Friedman, 1991). If the maximum interaction used is more than 3, then the CGV value will increase and the model used will be more complex.

Minimum observation (MO) is number of minimum observation among knots. Number of maximum interaction (MI) is 0, 1, 2 and 3, beyond this figure, the CGV will increase.

The establishment of MARS model is conducted through trial and error for all combination of the BF, MI, and MO values that have been previously determined. The possible models based on those combinations are 36 models. From each of these modellings, GCV values will be produced and created predictor variables included into the model. The result is presented in Table 1 below.

Based on the table above, the smallest GCV values are found in model number 11, 23, and 35. Because these three models yield the same result, the model with the smallest MI and MO values are selected. Hence, the chosen model is model number 11, where the value of GVC is 0.08952 with the combination of BF=20, MI=3 and MO=2. The MARS model equation is

Y = 1.93593 - 0.219669 * BF8 - 0.0220152 * BF13

where,

BF6 = (×5 in (1));

BF8 = (×10 in (2)) * BF6;

BF13 = max (0, 39 - X_1) * BF8;

From this model, it is clear that out of ten variables that are assumed to have an influence on the model, only three variables that are proven to have an influence on lead exposure. Because the best model is a model with maximum two interactions, it is suspected that there are factors that are interacting with one another. This model consists of one intercept (base function master) and three base functions that consist two level-2 interactions.

To examine the variables that influence the lead exposure, interpretation of the MARS model is presented below. Interpretation of this MARS model is quite tricky because the base function in this model consists of not only one variable, but there is also the interaction between variables.

- BF8 = (X10 in (2)) * BF6, where BF6 = (X5 in (1)

It means that BF* coefficient will be meaningful if respondents were indicated to have some complaints and the length of work shift in petrol station was less than eight hours, then each unit increase in base function BF8 will decrease the lead exposure

Table 1. Trial and Error Result for All BF, MI, and MO Combinations

	BF	MI	MO	GCV
1	20	1	0	0.11958
2	20	1	1	0.11905
3	20	1	2	0.11888
4	20	1	3	0.11905
5	20	2	0	0.11518
6	20	2	1	0.09693
7	20	2	2	0.10564
8	20	2	3	0.09838
9	20	3	0	0.11553
10	20	3	1	0.10139
11	20	3	2	0.08952
12	20	3	3	0.09931
13	30	1	0	0.11933
14	30	1	1	0.11871
15	30	1	2	0.11856
16	30	1	3	0.11892
17	30	2	0	0.11518
18	30	2	1	0.09693
19	30	2	2	0.10564
20	30	2	3	0.09838
21	30	3	0	0.09838
22	30	3	1	0.10139
23	30	3	2	0.08952
24	30	3	3	0.09931
25	40	1	0	0.11933
26	40	1	1	0.11871
27	40	1	2	0.11856
28	40	1	3	0.11892
29	40	2	0	0.11518
30	40	2	1	0.09693
31	40	2	2	0.10564
32	40	2	3	0.09838
33	40	3	0	0.11553
34	40	3	1	0.10139
35	40	3	2	0.08952
36	40	3	3	0.09931

by 0.219669 percent.

• BF13 = max (0. 39 - X1) * BF8, where BF8 = (×10 in (2) * BF6 and BF6 = X5 in (1)

It means that coefficient BF8 =13 will be meaningful if the respondent's age were less than 39 years old and indicated health complaint and length of work shift in petrol station was less than 8 hours, then each unit increase in base function BF8 will decrease lead exposure by 0.0220152 percent.

Mars modelling in this study showed that there are interactions among predictor variables, which in turn influence the responds' variables as shown in the following table

Table 2 in general shows the significant interaction among variables in each base function. The three influential predictor variables indicate that each variable contributes to the responds' variable.

Level of variable's importance is the extent of predictor's variable contribution toward the MARS model. Level of predictor's variable importance in grouped function is calculated by the increase in GCV value. The increase of GVC value is due to the migrations of considered variables within the model. The importance level of predictor's variable is shown in the following table.

Table 2. Interaction in Base Function

BF	Interaction
8	Indicated to have health complaint and length of work shift in petrol station
13	Age indicated to have health complaint and length of work shift in petrol station

Table 3 shows that work tenure in petrol stations and health complaint indication have the biggest contribution by 100% in determining the lead exposure risk. The second contributed variable by 38.43% is the age of the respondents.

Tabel 3. Level of Predictor's Variable Importance

Variable	Level of Importance	GCV
Work tenure	100.00000	0.14486
Indicated health complaint	100.00000	0.14486
Age	38.43010	0.08373

Conclusion

Based on the findings and analysis discussed above, the following things are concluded in this study: MARS equation model obtained is:Y = 1.93593 - 0.219669 * BF8 - 0.0220152 * BF13. From this model it is obtained that out of 10 variables that are suspected to have an influence on the model, there are only three variables that have the influence on lead exposure namely, work tenure in a petrol station, health complaint indication, and age.

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