A statistical model for remediation plan of endosulfan-contaminated lowland rice fields with agricultural waste

E S Harsanti, A N Ardiwinata, I Zulaehah and A Hidayah

Indonesia Agricultural Environment Research Institute, Pati, Indonesia

E-mail: esharsanti@gmail.com

Abstract. Persistent Organic Pollutants (POPs) compounds are still found in agricultural land in Indonesia. One of them is α-endosulfan which is a potent insecticide in the green revolution era. Remediation of agricultural contaminated land is needed to be a sustainable benefit. The purpose of the research is to develop a statistical model of sustainable remediation with agricultural waste in α-endosulfan-contaminated lowland rice fields. The study was conducted from June 2015 to May 2016 with experimental methods in the screenhouse. The experiment used a completely randomized design (CRD) with seven treatments of combinations of biochar-compost manure, and three replications. The results showed different equation models in the first planting season and the second planting season. The model illustrates that α-endosulfan contamination 0.16 mg g⁻¹ can be reduced to be below MRL by adding biochar-compost ratio 1:4. The availability of organic matter and total bacteria in the soil can reduce α-endosulfan residues. Both factors should be managed by increasing their availability in the soil. In the second season, organic C content in the soil did not significantly affect α-endosulfan residues that had been below MRL. The statistical model of α-endosulfan contaminated-land remediation can be used to plan the remediation of a pesticide-contaminated land, especially endosulfan.

1. Introduction

National food needs always increase along with the increasing number of Indonesia’s population each year, which had reached 240 million in 2010 [1]. Fulfilling the national food needs for the Indonesian population with a growth rate of 1.5% each year is faced with a decrease in the environmental quality, biodiversity, and soil and water resources due to contamination by pollutants [2]. The use of pesticides, including insecticides, experienced a sharp increase in the period 1979 to 1996. Although in 1989 it declined with the initiation of agro-ecology based agricultural management recommendations in 1994 but pesticides use in Indonesia is always increasing until present. The use of several insecticides has been banned, especially organochlorine include endosulfan based on the Minister of Agriculture Regulation No. 43 of 2019.

The organochlorine group is categorized as persistent organic pollutants (POPs) compounds that are toxic and persistent, one of which is endosulfan. Endosulfan use is widely spread in the world such as EU, India, Indonesia, Australia, Canada, Mexico, US (38 states), Central America, Brazil, and China [3]. Endosulfan is one of the persistent organic pollutants (POPs) compounds that are still found in agricultural land in Indonesia. One of them is α-endosulfan which is a potent insecticide and is liked by farmers in the era of the green revolution. α-Endosulfan is persistent, bio-accumulative, and very toxic. According to Harsanti et al. [2], 18.1% of Jombang’s paddy field area is contaminated with
endosulfan to levels that exceed the MRLs concerning soil remediation guidelines, with levels recorded in the range 0.0032 to 0.2196 mg kg\(^{-1}\). In the National Implementation Plan, endosulfan is a POPs compound so that monitoring of its presence and reduction efforts must be carried out so as not to pollute the environment according to the provisions of the Stockholm Convention [4]. Endosulfan residue in environment can cause bio-concentration. According to Rahmawati et al. [5], the concentration in catfish cultivated around agricultural land in the upstream Citarum watershed was detected 17 times higher than the residual endosulfan concentration in 2010 and had the highest residue compared to other organochlorines. According to Indratin et al. [6], detection of endosulfan in the blood of farmers in three vegetable lands (Brebes, Pati, and Magelang) that have exceeded acceptable daily intake (ADI) values. Endosulfan exposure can lead to diabetes mellitus type II [7].

As an effort to increase food production through intensification, extensification, rehabilitation and diversification programs, which intensification is the implementation of agricultural technology innovation [8]. One of the technologies used to strengthen agricultural productivity is the use of agrochemicals including pesticides. However, this technological approach causes unsustainable agricultural management. Insecticide residues in the environment that are carried away at harvest can impact on the competitiveness of products in the free market. Remediation of agricultural land contaminated by pesticide residue is needed to be a sustainable benefit. A synergistic positive effect of compost and biochar mixtures on soil organic-matter content, nutrients levels, and water-storage capacity of a sandy soil under field conditions was observed [9]. Application of biochar in the soil at a dose of 2.5\% and 5\% of the soil weight was able to reduce soil loss due to erosion by 50\% and 64\%, but for advanced soils, the 5\% dose was effective for improving physicochemical and reduce soil loss [10]. According to Harsanti et al [11], enrichment of activated charcoal with consortia microbes is more effective in reducing the residual levels of insecticides than activated charcoal without microbial enrichment. Biochar has been reported to enhance pesticide degradation by microorganisms in soil. Lehman et al. [12] state that biochar contains high levels of amorphous carbon and dissolved organic matter so it can be a source of carbon for the growth of microorganisms so that they can increase microbial activity. Biochar as an amendment was an effective method in remediating pesticide residues in the soil that depend on the type of raw material, pyrolysis temperature, and application rate [13].

Sustainable remediation based on local resources is the improvement of paddy soil by combining biological, physical and chemical remediation, while remediation in previous studies is generally still partial. Some biochar researches have been reported, but how to plan the remediation can be success not yet studies. A remediation model should be developed for planning the agriculture land remediation. The purpose of this study is to develop a statistical model of sustainable remediation with agricultural waste in \(\alpha\)-endosulfan-contaminated lowland rice fields.

## 2. Materials and methods

The study was conducted in June 2015 to May 2016 with experimental methods in the screen house at Jakenan experiment station, Central Java, Indonesia. The experiment used a randomized complete design with seven treatments of combinations of biochar and compost manure, and three replications. The bulk soil sample was taken from the rice fields of Plandi Village, Sub District Jombang, Jombang District. The location of the soil sampling was located at the coordinates 112°14'05"-112°15'15" E and 7°32'15"-7°34'30" S with an altitude of about 45 to 50 m above sea level. Laboratory analysis was carried out at the Laboratory of Indonesian Agricultural Environment Research Institute (IAERI).

The cultivation of rice in pots in the screen house experiment was carried out by referring to the dosage from Integrated Cropping Calendar to optimize production following the carrying capacity of local, economical resources through proper management of nutrients and plants by using available nutrient sources efficiently including organic fertilizers and inorganic fertilizers. Based on a previous study, soil samples taken were soil contaminated with endosulfan. The soil sample was dried, pounded, and sieved with a 2 mm sieve. Soil samples were put into each pot of 13 kg absolute dry weight.
The source of indigenous organic material used is agricultural waste in the form of manure from chicken manure or cow manure and biochar from corn cobs available in the study area. The biochar-compost formulation is 25% to 50% or with a ratio of 1: 4 and 2: 4 based on dry weight [14], and the dosage is twice as high as 100% (1:1). The dose of manure given is 2 t ha⁻¹ which refers to the dose from the integrated cropping calendar. The water used to irrigate the plants is water-free contaminant and it is carried out somewhat stagnant in a measured manner. The experiment was arranged using a completely randomized design (CRD) with 7 treatments and 3 replications. The treatment of notation can be written as follows:

A0: Contaminated Soil without remediation
A1: Soil contaminated-remediation-1 (corncob biochar: compost of chicken manure, ratio 1 : 4)
A2: Soil contaminated-remediation-2 (corncob biochar: compost of chicken manure, ratio 2 : 4)
A3: Soil contaminated-remediation-3 (corncob biochar: compost of chicken manure, ratio 4 : 4)
A4: Soil contaminated-3-remediation (corncob biochar: cow manure compost, ratio 1 : 4)
A5: Soil contaminated-remediation-5 (corncob biochar: cow manure compost, ratio 2 : 4)
A6: Soil contaminated-remediation-6 (corncob biochar: cow manure compost, ratio 4 : 4)

Amendment material in the form of a biochar-compost (organic fertilizer) formulation is applied during land preparation by immersing it like a farmer’s practice. Provision of biochar compost repairer is carried out every planting (3 planting seasons). Experiments were carried out for 3 growing seasons with a rice-paddy-mustard / rice cropping pattern. Residue sampling was carried out on soil, leaching water, and plant products. Soil and water samples were sampled 3 times per season to see the dynamics and to obtain time-series data.

Each pot filled with soil samples contaminated with endosulfan was given a soil repairer according to the treatment formulation and incubated for one week. Soil conditions are maintained in submerged conditions. Two rice seedlings of Ciherang variety are transplanted from the nursery after 15 days of planting. Fertilizer N, P, K are given according to the dosage of the integrated cropping calendar, namely 138 kg N, 27 kg P₂O₅, 60 kg K₂O per hectare. N fertilizer is given in three stages, namely 1/3 dose of N given before planting, 1/3 dose of N at the stage of active tillers, and 1/3 dose of N at the panicle initiation stage. Fertilizer P is given once before planting, fertilizer K is given in two stages, namely ½ dose of K before planting, and ½ dose of K in the panicle initiation stage.

The collection of experimental data on the model of remediation in the observed greenhouse scale includes (1) endosulfan residue content in the soil (depth 0 to 20 cm) (2) residual content of endosulfan in products at harvest using technical guidelines for a sampling of pesticide residues [8], and (3) endosulfan residue in water Analysis of endosulfan residues in soil and plants was carried out using Shimadzu gas chromatography (GC) equipped with an ECD-electron capture detector, with standard methods of extraction by SNI 06-6991.1-2004 and [15], while the residual endosulfan in water according to SNI 06-6990.1-2004. Other observations were made on environmental conditions including: air temperature, soil temperature, soil pH, and simulation rainfall to describe the field conditions during the planting season in the rainy season (WS).

The observations made included (1) endosulfan residue before the initial application of remediation material and then 2 times per season, namely 7 days after application, panicle initiation stage at harvest time; Observations were made at 2 times the growing season (paddy-paddy). (2) Regular observations of soil temperature, air temperature, soil pH during the study, (3) Observation of the total microbial population at harvest in each growing season, (4) Soil sampling for soil chemical observations: pH (method electrodes), total N (Kjeldahl method), P₂O₅ extracted HCl 25%, K₂O extracted HCl 25%, cation exchange capacity / CEC (1N NH₄OAc immersion method), organic C (Walkley-Black method), base saturation, cations interchangeable, Aluminum saturation, (5) The best quality of the biochar-compost formulation is indicated by the variable pH-H₂O, C-organic (ashes), total N (Kjeldahl), levels of P₂O₅ and K₂O (HNO₃ and HClO₄) [14]; and (6) Observation of the role of biochar was carried out in the treatment with the best yields at harvest per season.
The description stage for the remediation model used multivariate statistical analysis. The multivariate statistical analysis method was used because the problems in this study have complex, non-linear, dynamic characteristics, and many related variables.

The model of the relationship between the concentration of endosulfan residues in the soil and soil variables was analysed using simple linear regression analysis, multiple regression, and correlation test. According to [16]), the linear regression equation is mathematically described as follows: 

\[ Yi = a + \beta Xi + ei \] 

or 

\[ Yi = \beta_0 + \beta_1X_1 + \beta_2X_2 + \ldots + \beta_iX_i + ei \]

where \( Yi \) = the concentration of endosulfan residues; \( Xi \) = certain soil variable (e.g. \( X_1 \) = soil pH, \( X_2 \) = soil temperature at plant roots, \( X_3 \) = soil organic C content, \( X_4 \) = total bacterial population in soil, \( X_5 \) = total fungal population in soil); \( a \) or \( \beta_0 \) = intercept; \( \beta \) = gradient; and \( ei \) = the effect of the error spreading freely following the normal distribution \( (0, \sigma^2) \). Variables of endosulfan residue concentration, soil pH, soil temperature, organic C, total bacterial population and total fungal population were observed and measured at the mature stage of plant growth (before harvest) of all treatments and replications in the experimental unit (n = 21).

The data obtained from each observed variable were analysed using multiple regression using statistical programs. The closeness of the relationship between the endosulfan residue concentration and certain soil variables is indicated by the r value (correlation coefficient). High r-value with real regression can be used to consider the management of paddy soil contaminated with pesticide residues in the strategy of remediation and improvement of crop and soil quality. All data were analysed by SPSS program.

The model simulation stage is carried out to find out that the variables in the simulation model built can predict contamination conditions (dependent variable) which are influenced by several variables. Validation is done by calculating the significance test value on several influential main variables [16].

3. Results and discussion

The effect of remediation in the first season, at 17 days after application, the highest reduction in \( \alpha \)-endosulfan concentration occurred in the combination treatment of corn cob biochar: cow manure with a ratio of 1:4 (A4) followed by a combination treatment of corn cobs biochar: chicken manure with a ratio of 1:4 (A1). Decreased \( \alpha \)-endosulfan concentration in the soil at 17 days after application and tended to increase at the primordial stage of rice flower, but decreased again before the first rice harvest and at 95 days decreased in all treatments.

The concentration of \( \alpha \)-endosulfan in rice soil at the season I is relatively lower than 10 ppb. The \( \alpha \)-endosulfan residue until below maximum residue limit (MRL= 0.0085 mg kg\(^{-1}\)). Endosulfan sulfate metabolites increased before the harvests of the season I and II. However, biochar-compost remediation can relatively suppress endosulfan sulfate metabolites 1.8 to 67.3%, in the season I and 49.7% to 67.7% in season II with the largest percentage decrease in the combination of biochar-compost cow manure. The residual endosulfan sulfate after remediation was lower than without remediation.

3.1. Remediation model of agricultural sustainability

The preparation of a simple remediation model begins with a correlation test for each independent variable on the dependent variable. The independent variables tested included \( C_1 \) = soil pH; \( C_2 \) = Soil temperature; \( C_3 \) = C soil organic at plant roots; \( C_4 \) = total bacterial population \( (10^5 \text{ CFU g}^{-1} \text{ soil}) \); \( C_5 \) = Total fungi population \( (10^4 \text{ CFU g}^{-1} \text{ soil}) \). The five variables indicate a correlation to the dependent variable, namely the concentration of endosulfan in the soil.

Multivariate test of five variables with the dependent variable (soil endosulfan residue). The multiple regression equation models at the season I as follows:
Ŷ = 0.787 - 0.0274X₁ - 0.00817X₂ - 0.369X₃ - 0.00199X₄ - 0.00311X₅  \hspace{1cm} (1)

Where
Ŷ : α-endosulfan residue in paddy soil  
X₁: soil pH 
X₂: soil temperature 
X₃: C organic soil in roots 
X₄: total bacterial population \(10^5\) CFU g⁻¹ soil 
X₅: total fungi population \(10^4\) CFU g⁻¹ soil 

Table 1. Significance test of the multiple regression equation on season I- II.

| Predictor      | Coefficient | Standard deviation | T-count  | Probability | R²  |
|----------------|-------------|--------------------|----------|-------------|-----|
| Constanta      | 0.787300    | 0.305800           | 2.57     | 0.021       |    |
| Soil pH        | -0.027370   | 0.038900           | -0.70    | 0.493       |    |
| Soil temperature | -0.008165   | 0.004377           | -1.87    | 0.082       |    |
| C organic      | -0.368600   | 0.156400           | -2.36    | 0.032       | 0.675|
| Bacteria total | -0.001989   | 0.000813           | -2.45    | 0.027       |    |
| Fungi total    | -0.003112   | 0.002136           | -1.46    | 0.166       |    |
| Constanta      | -0.000100   | 0.064130           | -0.00    | 0.999       |    |
| Soil pH        | 0.008695    | 0.006256           | 1.39     | 0.185       |    |
| Soil temperature | -0.001522   | 0.001332           | -1.14    | 0.271       |    |
| C organic      | 0.010630    | 0.015930           | 0.67     | 0.515       | 0.596|
| Bacteria total | -0.000375   | 0.000137           | -2.72    | 0.016       |    |
| Fungi total    | 0.000051    | 0.000069           | 0.74     | 0.472       |    |

Source: Results of statistical analysis with SPSS

The results showed different equation models in the first and second seasons. The first model in equation (1) with the number of observations (n=21) showed \(R^2 = 0.675\), \(R = 0.821\), and \(F = 6.219\). The model illustrates that α-endosulfan contamination conditions around 0.16 mg g⁻¹ can be reduced by α-endosulfan residues to below MRL by adding biochar-compost ratio 1:4. The availability of organic matter and total bacteria in the soil can reduce α-endosulfan residues. Both factors should be managed by increasing their availability in the soil.

The remediation model of endosulfan contaminated rice field by utilizing agricultural waste in season II is as follows:

\[ \hat{Y} = -0.0001 + 0.00869X₁ - 0.00152X₂ + 0.0106X₃ - 0.0003X₄ - 0.00052X₅ \] \hspace{1cm} (2)

Where
\(\hat{Y}\) : α-endosulfan residue in paddy soil 
X₁: soil pH 
X₂: soil temperature 
X₃: C organic soil in roots 
X₄: total bacterial population \(10^5\) CFU g⁻¹ soil 
X₅: total fungi population \(10^4\) CFU g⁻¹ soil

In the second season is showed in equation (2), with \(R^2 = 0.596\), \(R = 0.77\) and \(F = 4.12\) value. The above equation showed variable availability of organic C in the soil and the total bacterial population in the soil significantly determines the residual content of endosulfan in the soil with the probability value being \(P = 0.032\) and \(P = 0.027\), respectively. In season II the remediation model is largely determined by the presence of a total bacterial population with a value of \(P = 0.016\). This is due to the
presence of endosulfan in season II that has shown a decrease. Organic C content in the soil did not significantly affect α-endosulfan residues that had been below MRL.

3.2. Model Simulation
The expected endosulfan residue in the soil is <MRL (0.0085 mg kg⁻¹), so to simulate how the presence of α-endosulfan residue is safe for the environment, several soil variables must be managed to condition the remediation target. Some of the soil parameters are soil pH, soil temperature, C-organic, bacterial population, and fungal population in the soil. Based on the multivariate statistical test in the first model (season I), it is known that the variables that have a significant effect are organic C and total bacterial population, so the other variables (soil temperature, pH, and total fungus) are assumed to be fixed with an average value of n = 21, namely pH = 6.13; ground temperature 26.30 °C; total fungi = 3.83 x 10⁴ CFU g⁻¹ soil. Based on the multiple regression model in the first equation, to get a residue below the BMR (0.0085 mg kg⁻¹), the X₃ (organic C) variable must be increased from 0.88% to 0.92% or X₃ ≥ 0.92%, and X₄ (total soil bacterial population) should be increased from 19.5 x 10⁵ to 23 x 10⁵ CFU g⁻¹ soil or X₄ ≥ 23 x 10⁵ CFU g⁻¹ soil.

3.3. Model Validation
The validation of the remediation statistical model of wetland contaminated with endosulfan was tested with the assumption of HEIL GAUSS. Based on the validation test, the season I model obtained provisions including 1) Homoscedasticity (homoscedasticity), 2) Existence, 3) Independence, 4) Linearity, and 5) Normality [17]. Homoscedasticity criteria are accepted which is shown there is no clear pattern, scatterplot (randomly). The remediation statistical model of endosulfan-contaminated lowland soil has accepted the criteria with a mean value close to 0 (-5.1 x 10⁻¹⁵) and a relatively small standard deviation value (0.86). Independent criteria are not accepted which is indicated by the Durbin Watson value of 2.7 (if the durbin value is between -2 to +2 it means that the independence assumption is met) (table 2).

### Table 2. Model Summary

| Model | R   | R²   | Adjusted R² | Std Error of the Estimate | Durbin Watson |
|-------|-----|------|-------------|---------------------------|--------------|
| 1     | 0.821 <sup>a)</sup> | 0.675 | 0.566       | 0.2075                    | 2.713        |

Note: a) Predictor: constanta, populasi of fungi, soil temperature, bacteria population, soil pH, C-soil organic; b) Dependent variabel: endosulfan residue

The un-acceptance of the independent criteria is due to the relatively small number of n samples, namely n = 21. The number of n required is n ≥ k x 10 and according to multivariate statistics the minimum k value is 5 (5, 9, 10, 15, 20, 25, 30) so that the minimum n required is 50[17]. However, with a value of R² = 0.675, this result is accepted. The linearity assumption test is met the significance value of 0.003 from the ANOVA test (overall F test) if the results are significant (p < 0.05) then the model is linear). The normality assumption is accepted if the data spread around the diagonal line and follows the direction of the diagonal line [18]. The normality test of the remediation statistical model is accepted. In season II, all five validation tests meet the criteria.

3.4. Discussion
The increase of endosulfan sulfate at maturity growth stages in both seasons is due to the soil condition, namely flooded (anaerobic) at the beginning of growth to the filling phase, and unflooded (aerobic) before harvesting time. The results of this study support the opinion of [19] which states that inundation conditions reduce the formation of endosulfan sulfate and increase the rate of degradation. Endosulfan by oxidation can break down into endosulfan sulfate and hydrolysis will become endosulfan diol [20]. Therefore, the endosulfan sulfate residue can be relatively low under stagnant conditions.
Remediation can suppress the increase in endosulfan sulfate caused by the role of biochar-compost adsorption on contaminants. Contaminants in the soil are absorbed into the clay soil, compost surface, and biochar surface. The contaminants that escape from the biochar surface traps will enter the biochar pores and are used by microbes as a food source. This mechanism is related to the characteristics of corncob biochar which has an Iodine absorption capacity of 452 mg g$^{-1}$ with a maximum adsorption capacity of 8.7 mg g$^{-1}$ at a biochar dose of 0.1 gram. Activation of biochar into activated charcoal affects the pore structure and surface of the functional groups so that the functional groups play a high role in reactivity in biochar [21]. Qian et al. [22] states that the absorption of contaminants is due to ion exchange by functional groups on the surface or called ion bridges. The loss of contaminants in the environment is influenced by uptake of clay soil surfaces, presence of organic matter (absorption ability), carbon organic coefficient (Koc), and Kow [9]. Soil microbial biomass increases in humus when brought closer to biochar [23].

The use of multivariate statistical analysis methods in this study has advantages and disadvantages. The superiority of the multivariate statistical analysis method in this study is that it can describe the real conditions of endosulfan pollution in very complex lowland soils to be simpler, it can predict the effect between variables and the relationship between variables. The weakness of the multivariate statistical analysis method for this study is that it cannot intervene in model that is built like the system dynamics model [18, 24]. The model was based on data from screen house experiments under controlled conditions [25]. However, these weaknesses can be overcome by trying to observe the parameters of environmental elements that affect natural conditions, including air temperature, soil temperature, simulating rain with rainfall based on natural conditions when testing rice in rice fields during the rainy season.

Based on the multiple regression equation, the decrease in endosulfan residue in the soil was only significantly affected by the increase in the availability of organic C in the soil and the total bacterial population in the soil. It means, to reduce endosulfan residues, these two main factors must be managed by increasing their availability in the soil. Application of 2 ton ha$^{-1}$ combination of biochar and compost manure was able to reduce endosulfan residues below the MRL. Increasing the organic C in soil and soil bacterial population can be done by increasing soil amendment dose by more than 2 t ha$^{-1}$ so that the residual endosulfan concentration in the soil is lower than the MRL. The combination of biochar and compost 2 t ha$^{-1}$ manure was able to increase organic C in soil 0.67% to 0.89%. Soils with high organic matter content can also absorb high pesticides [26], and high organic matter is used as an energy source for pesticide degrading bacteria in the soil [27, 28].

Based on the testing of the model with considering the influence factors of the remediation process, it is evident that the remediation of polluted paddy soil by utilizing agricultural waste is largely determined by the presence of organic C and microbial populations, especially bacteria which can accelerate the degradation process to 21 days faster than without remediation. The remediation model can use to plan a remediation of insecticide contaminant especially endosulfan in lowland rice. The remediation can improve the number of rice products and the quality of the environment (land, water, agricultural products) which has implications for the quality of human health and protect environmental sustainability.

Moreover, by the statistical model our cognitive map of the causal structure of the system is much simplified in comparison to the complexity of the system so that the conclusions are not based on the dynamics of everything that exists but based on the basis of multiple correlation-regressions. This has a direct consequence of limited rationality, namely, the many limitations of attention, memory, information processing capabilities, and time limiting decision making [25].

4. Conclusions
A statistical model of sustainable remediation with agricultural waste in α-endosulfan-contaminated lowland rice fields can be developed for the planning of agricultural land remediation. Two main factors must be managed by increasing their availability in the soil are organic carbon and microbial
population, especially bacteria which can accelerate the degradation endosulfan process to 21 days faster than without remediation in paddy field.

The multiple regression equation model at season I is

\[ \hat{Y} = 0.787 - 0.0274X_1 - 0.00817X_2 - 0.369X_3 - 0.00199X_4 - 0.00311X_5 \]

with \( R^2 = 0.675, R = 0.821, F = 6.219 \) value. Whereas at season II is

\[ \hat{Y} = -0.0001 + 0.00869X_1 - 0.00152X_2 + 0.0106X_3 - 0.0003X_4 - 0.000052X_5 \]

with \( R^2 = 0.596, R = 0.77, F = 4.12 \) value.

The model for remediation of soil contaminated with endosulfan residue by utilizing agricultural waste that is built is still very limited in variables and the number of samples so that research related to the development of a remediation statistical model needs to increase the influence factor and the number of samples.

Acknowledgements

We would like to thank the Indonesian Agency for Agricultural Research and Development (IAARD) for its financial support and the Indonesian Agriculture Environment Research Institute (IAERI) for its support on additional data and facilities. We also thank the technicians (Slamet Riyanto, and Uhwatul Muanisah).

References

[1] UNFPA 2010 *The 2010-2035 Indonesia population projection*. UNFPA-Indonesian Government [https://indonesia.unfpa.org/sites/default/files/pubpdf/Policy_brief_on_The_201_\%E2%80%93_2035_Indonesian_Population_Projection.pdf](https://indonesia.unfpa.org/sites/default/files/pubpdf/Policy_brief_on_The_201_\%E2%80%93_2035_Indonesian_Population_Projection.pdf) (Accessed September 2020)

[2] Harsanti E S, Kusnoputran H, Suparmoko M, Ardiwinata A N 2018 Preliminary study of environmental risk from endosulfan usage during the Green Revolution: Case study in central paddy area of Jombang District East Java Indonesia In: Adi & Achwan (Eds) *Competition and Cooperation in Social and Political Sciences* (London: Taylor & Francis Group) p 256-266

[3] Weber J, Halsall C J, Muir D, Teixeira C, Small J, Solomon K, Hermanson M, Hung H and Bidleman T 2010 Endosulfan, a global pesticide: A review of its fate in the environment and occurrence in the Arctic *Science of the Total Environment* 408: 2966-2984

[4] National Implementation Planning (NIP) 2014 *Review and update rencana implementasi nasional untuk Konvensi Stockholm tentang polutan organik persisten (POPs) di Indonesia* (in Bahasa) (Jakarta: Republik Indonesia)

[5] Rahmawati S, Margana G, Yoneda M, Oginawati K 2013 Organochlorine pesticide residue in catfish (*Clarias sp.*) collected from local fish cultivation at Citarum watershed, West Java Province, Indonesia, *Procedia Environmental Sciences* 17: 3–10

[6] Indratin, Poniman, A. *Ichwan and A N Ardiwinata 2008 Seminar dan Dialog Nasional Sumberdaya Lahan Pertanian hal 113* (in Bahasa) Buku III Informasi Sumber Daya Air, Ilklin, dan Lingkungan (Bogor, 18-20 November 2008)

[7] Agency for Toxic Substances and Disease Registry (ATSDR) 2013 *Draft toxicological profile for endosulfan Public Health Service Agency for Toxic Substances and Disease Registry (ATSDR)* (US: Department of Health and Human Services)

[8] Ardiwinata A N, Jatmiko S Y and Harsanti E S 2007 *Pencemaran bahan agrokimia di lahan pertanian dan teknologi pengendaliannya* p 88-129 *In: Fagi AM, Pasandaran E, and Kurnia U* (Eds) *Pengelolaan Lingkungan Pertanian Menuju Mekanisme Pembangunan Bersih* (in Bahasa) (Jakarta: Balai Penelitian Lingkungan Pertanian)

[9] Megharaj M, Ramakrishnan B, Venkateswarlu K, Sethunathan N, Naidu R 2011 *Bioremediation approaches for organic pollutants: A critical perspective*. *Environment International* 37: 1362-1375

[10] Shih-Hao Jien and Chien-Sheng Wang 2013 *Effect of biochar on soil properties and erosion potential in highly weathered soil* *Catena* 110: 225-233
[11] Harsanti, E S, Ardiwinata A N, Mulyadi and Wihardjaka A 2013 Peran aktif arang dalam mitigasi residu pestisida pada komoditas tanaman strategis (in Bahasa) Jurnal Sumberdaya Lahan 7(2): 57-65
[12] Lehmann J, Rillig M C, Thies J, Masiello C A, Hockaday W C and Crowley D 2011 Biochar effects on soil biota – a review. Soil Biol. Biochem. 43: 1812–1836
[13] Yang Ding, Yunguo Liu, Shaobo Liu, Huang X, Zhongwu Li, Xiaofei Tan and Lu Zhou 2017 J. Pedosphere 27: 645-661
[14] General Directorate of Food Crops 2006 Methods of Pesticide Residues Tests in Agricultural Products (Indonesia Agricultural Ministry) p 116-118
[15] Mattjik A A, Sumertajaya M 2000 Perancangan Percobaan dengan Aplikasi SAS dan MINITAB (in Bahasa) (Bogor: IPB Press) p 344
[16] David G. Kleinbaum, Lawrence L Kupper and Hal Morgenstern 1982 Epidemiologic Research: Principle and Quantitative Methods (New York: Van Norstrand Reinhold)
[17] Roberto A, Canales-Flores, and Francisco Prieto-Gorcia 2016 Activation methods of carboneous materials obtained from agriculture waste Chemistry and Biodiversity 13: 261-268
[18] Qian T, Zhang X, Hu J and Jiang H 2013 Effect of environmental conditions on the release of phosphorus from biochar. Chemosphere. xxx xxx-xxx. http://dx.doi.org/10.1016/j.chemosphere.2013.07.041
[19] Taylor M D, Klaine S J, Carvalho F P, Barcelo D and Everaarts J 2003 Pesticide residues in coastal tropical ecosystems: distribution, fate and effects London, Taylor and Francis
[20] Thangadurai P and Suresh S 2014 Biodegradation of endosulfan by soil bacterial cultures International Biodeterioration and Biodegradation 94: 38-47