The distribution of paraquat and carbosulfan residues in Indonesia

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Abstract. The paraquat (Par) and carbosulfan (Carb) residue are thought to have contaminated soil, water, and plant in eight provinces of Indonesia as study sites i.e. Riau, Lampung, West Java, Central Java, East Java, South Sulawesi, West Sulawesi, and South Kalimantan. The objective of this study was to get information related the use and effects of Par and Carb. The soil samples were collected with a stainless-steel spoon. Water samples were taken using a grab sampler. Harvest panicles manually, only from upright and unlodged plants (rice). Analysis of samples were used HPLC, while for Carb residue analysis was used GC. The limit of detection of Par residue in soil were at the range of 0.0479 to 0.0597 µg g⁻¹. Par and Carb residues are not found in water and plants (below the detection limit). The total Par and Carb residue in soil were in the range of 0.1525 to 14.4366 mg kg⁻¹ and 0.0582 to 0.3072 mg kg⁻¹, respectively or below the tolerance limit. Par residue distributed to all study locations, while Carb residue found in Java, Sulawesi and Kalimantan Islands. The results of this study indicate that Par and Carb residues in water, soil and plants are still safe.

1. Introduction

Many losses that occur in the agricultural sector are caused by the presence of weeds. One alternative in controlling weeds is to use herbicides [1]. The commonly used herbicide is paraquat dichloride (1,1'-dimethyl-4,4'-bipyridinium dichloride). Paraquat dichloride was registered in the United States in 1964 for use as a contact herbicide to control or suppress a broad spectrum of emerged weeds. Paraquat dichloride (1,1'-dimethyl-4,4'-bipyridinium dichloride) is a nonselective contact herbicide, desiccant, defoliant, and plant growth regulator primarily used on field crops and fruit and nut crops.

Over use of pesticides and not complying with standards can leave a residue that has a negative impact on humans, biota and the environment [2]. Wibawa [3] reported that herbicide extensively applied not only to control weeds target but can also leave a residue in soil that is harmful to ecology. Furthermore, over use and mis use of Par and Carb on oil palm plantations, vegetable and food crops causing damage to the environment (soil, water and air) and non-targeted organisms.

In Indonesia, Par is herbicides that designated as limited used pesticides according to Ministry of Agriculture Decree No. 39/Permentan/SR.330/7/2015. However, Par is a broad-spectrum herbicide that widely used by farmers to control broadleaf, narrow, and grass weeds in plantation, food and vegetable crops. According to Alhuda and Nugroho [4] that the combination of amethrin and Par with dose of 1 kg ha⁻¹ respectively is effective for controlling weeds in corn plants. Furthermore, Par has the ability to improve soil (no tillage) chemical properties, increase the percentage of weed control and reduce weed dry weight and increase the yield and yield components of soybean crops [5]. Perkasa et al. [6] showed that herbicide Par effectively suppressed total dry weight of weeds at 4, 6, and 8 weeks after planting of...
soybean plant on the tidal swamp. The results of the study by [7] that Par dichloride herbicide with a dose of 414 to 966 g ha\(^{-1}\) was able to suppress the growth of total cassava weeds until 8 weeks after application.

Par transformation in the soil can occur by several mechanisms including photodegradation, chemical degradation, and microbial metabolism. Photodecomposition reactions occur in the surface few centimeters of soil [8]. In culture extract, biodegradation of Par is rapid, disappearing within 2 to 3 weeks [9]. There are several groups of microorganisms (bacteria, fungi, actinomyces, and yeast) that degrade Par as a nitrogen source [9, 10]. Par, a polar organic compound, is very rapidly adsorbed on clay and soil organic matter [11]. Par was not mutagenic, as judged by noninterference with DNA metabolism, and had no reverse mutation-inducing capability [12]. Par had little or no teratogenicity to mammals [13]. Generally, Par residues declined to around 50% at the end of the studies, which was about 10 to 20 years.

Carb [2,3-dihydro-2,2-dimethylbenzofuran-7-yl (dibutylaminothio) methylcarbamate] is one of insecticide of Carbamate group is liquid, toxic. Meanwhile, Carb is an insecticide that widely used by farmers in Indonesia to control caterpillars, thrips, aphids, mites, on vegetable crops, food, and plantation. Carb is a contact and systemic pesticide that has high toxicity to the environment and plant. According to Sumiati and Yulianto [14] that Carb is used in citrus plants to control Asian Citrus Psyllid (Diaphorina citri). The Carb residue in the citrus is < 0.005 ppm. Furthermore, the results research of Trisnaningsih [15] showed that the treatment of insecticides of Carb 200 g L\(^{-1}\) at concentrations of 0.25 to 3.00 ml L\(^{-1}\) did not cause a resurgence on brown planthopper. The objective of this study was to get the information the use and effects of Par and Carb.

2. Materials and methods
Analysis activities were carried out at the laboratory of the Indonesian Agricultural Environment Research Institute (IAERI) in Pati, Central Java, Indonesia.

2.1. Samples collection
A total of 161 samples (soil, water and plant) was collected from April to July 2018 from 8 locations/provinces (Riau, Lampung, West Java, Central Java, East Java, South Sulawesi, West Sulawesi, and South Kalimantan) reflecting different land-based activities in Indonesia (figure. 1). The list of samples, analyzed in 2018 and distribution of sample locations showed in Table 1. All the samples (soil, water and plant) were put on soil sample plastic bag, water sample plastic bottle respectively, and then put on iced box immediately, and transported to the laboratory in Pati, Central Java, packed in dry ice. Water samples were taken using a grab water sampler with cleaned plastic bottle (500 ml). The 500 ml plastic bottles were rinsed twice with samples then carefully filled just to overflowing, without passing air bubbles through sample or trapping air bubbles in sealed bottles. Preparation of these bottles included washing with detergent, rinsing with tap water and ultrapure water. All samples were filtered through 0.45 µm fiber glass filters to remove sand and debris after returning to the laboratory and extracted immediately.

The agricultural soil samples (0 to 20 cm) were collected with a stainless-steel spoon. All the samples were immediately transferred to the laboratory and kept at –20 °C in the refrigerator. The samples were freeze-dried, homogenized and passed through a 63 µm sieve. All the equipment used for sample collection, transportation, and preparation, were free from Par and Carb contamination. Harvest panicles manually (120 days after planting), only from upright and unlodged plants (rice).

2.2. Analysis of par in soil and plant
Analysis of Par in soil followed the following method: To 20±0.002 g of samples (soil or plant) in 250 ml Erlenmeyer was added 150 ml of 0.1 M potassium hydroxide (KOH), shake it with a shaker for 16 hours. Heat for 1 minute above the heating plate. After hot Erlenmeyer was lifted and cooled. Centrifuge for 10 minutes at 4,000 rpm. The centrifuge was then filtered. A clear supernatant was accommodated in a 300 ml volume flask. The precipitate from the centrifuge was washed with 0.01 ml HCl of 25 ml.
Centrifuge for 10 minutes the supernatant combines with the supernatant before in a 300 ml round flask. Concentrate with rotary evaporator to a volume of 5 ml under vacuum at a temperature of 60°C. Set the pH to 1.8 to 2.0 and transfer it in the centrifuge tube. Centrifuge for 10 minutes at 2,500 rpm. The extract was flowed to the cation exchange column. Rinse with HCl 0.01 M as much as 2 x 55 ml. Re-attach with rotary evaporator to a volume of 5 ml in a vacuum with a temperature of 60°C to become 10 ml with methanol (70%), prior to analysis using the HPLC. The detection limit for this method was 0.0151 µg g⁻¹ (soil) and 0.0180 µg g⁻¹ (plant) respectively [16-18].

**Table 1.** List of samples analyzed in 2018 and distribution of sample locations.

| Locations       | Commodities          | N | Soil | Water | Plant |
|-----------------|----------------------|---|------|-------|-------|
| Riau            | palm oil             | 12 | 6/-  | 6/-   | -     |
| Lampung         | rice, corn, palm oil | 28 | 6/6  | 4/5   | 3/4   |
| West Java       | rice, corn, chili    | 19 | -/9  | -/8   | -/2   |
| Central Java    | rice, corn, chili    | 19 | 6/9  | 2/2   | -     |
| East Java       | rice, corn, chili    | 20 | 6/9  | 2/3   | -     |
| South Sulawesi  | rice, corn, chili    | 24 | 6/9  | 4/5   | -     |
| West Sulawesi   | cocoa                | 12 | 9/-  | 3/-   | -     |
| South Kalimantan| rice, corn           | 27 | 6/6  | 6/3   | 3/3   |
| **Sum***        | **161**              |   | 45/48| 27/26 | 6/9   |

*Par/Carb

**Figure 1.** Map showing sampling locations (n = number of samples; S = Soil, W = Water, P = Plant).

2.3. Analysis of par in water

100 ml of water sample was extracted using 100 ml of n-hexane in a separating funnel. Add 150 ml of 0.1 M Potassium hydroxide (KOH), shake with a shaker for 16 hours. Heat for 1 minute above the heating plate. After hot Erlenmeyer was lifted and cooled. Centrifuge for 10 minutes at 4,000 rpm. The centrifuge was then filtered. A clear supernatant was accommodated in a 300 ml volume flask. The
precipitate from the centrifuge was washed with 0.01 ml HCl of 25 ml. Centrifuge for 10 minutes the supernatant combines with the supernatant before in a 300 ml round flask. Concentrate with rotary evaporator to a volume of 5 ml under vacuum at a temperature of 60°C. Set the pH to 1.8 to 2.0 and transfer it in the centrifuge tube. Centrifuge for 10 minutes at 2,500 rpm. The extract was flowed to the cation exchange column. Rinse with HCl 0.01 M as much as 2 x 55 ml. Reattach with rotary evaporator until the volume of 1 ml under vacuum with a temperature of 60°C and add up to 10 ml with methanol (70%), prior to analysis using the HPLC. The detection limit for this method was 0.0545 µg L\(^{-1}\) [19].

2.4. Analysis of carb in soil and plant
Analysis of Carb in soil and plant followed the method: Weigh 20±0.002 g of the sample (soil or plant), put into centrifuge tubes. Add 40 ml of high purity acetone, then shake with centrifuge for 30 minutes. Then filtered using filter paper. Transfer the liquid to a 300 ml heart pumpkin. Repeat the above steps 2 (two) times. Glue the liquid using a vacuum system adhesive at a temperature of <35°C and a speed of 25 rpm, until the volume is ± 30 ml then transfer it to a 500 ml separating funnel. Add 100 ml of 10% NaCl solution to the separating funnel. Add 50 ml of high purity n-hexane, shake for 20 minutes using a shaker. Let stand until it forms 2 layers, namely the n-hexane and water layers. Cover the water layer in a 250 ml separating funnel, leave the n-hexane layer. Add 50 ml of n-hexane to the separating funnel containing a layer of water, shake for 20 minutes using a shaker. Let stand until it forms 2 layers, namely the n-hexane and water layers. Discard the water layer, combine the n-hexane layer with n-hexane. Add 100 ml of distilled water and shake it. Let stand until 2 layers were formed and remove the water layer. Perform this step 2 (two) times. Enter gradually 100 ml of n-hexane elution solution: diethylether (85: 15), flow with a flow rate of 20 drops minute\(^{-1}\). Glue the elution using a vacuum system adhesive at a temperature of <35°C with a speed of 25 rpm to volume + 1 ml. Transfer it to a 10 ml test tube. Rinse the pumpkin with n-hexane, then the rinse results were put in the test tube above (do it 2 times). Concentrate the volume into 2 ml with a stream of nitrogen gas [20, 21].

2.5. Derivatization for carb analysis
Prepare a 6% v/v FDNB stock solution by piping 6 ml of FDNB dissolved in 94 ml of acetone p.a. The stock solution of 0.5 N KOH by weighing KOH was 28.05 g KOH and dissolved in 400 ml of distilled water in a 500 ml backer glass, then stirred using a magnetic stirrer. After dissolving, adjust the volume to 500 ml with distilled water. 5% Borax stock solution by weighing 25 g of borax and dissolving it in 450 ml of distilled water, then stirring using a magnetic stirrer. After dissolving, set the volume up to 500 ml. And the stock mixture of n-hexane and petroleum ether with a ratio of 45: 3 (v/v) as needed. After the stock solution was prepared, derivatization can be started by dissolving the concentrated extract from the 10 ml test tube put in a 300 ml round flask, rinse the test tube with 20 ml of acetone if the sample was stored in the same flask. Steam the solvent in the flask by evaporating it to ± 1 ml, then add 100 ml of distilled water, 1 ml of FDNB 6%, and 2 ml of KOH 0.5 N, then shake with a mechanical shaker (Shaker) for 20 minutes. After that, add 10 ml of 5% borax then extract was heated in a water bath at 80 °C for 20 minutes. When finished chill in a tub that has been filled with cooling water. After chilling, transfer the extract solution from the pumpkin to the separating funnel, then add 10 ml of the n-Hexane mixture and Petroleum ether and shake with a mechanical shaker for 3 minutes. After finishing shaking, lift the separating funnel and place the iron greeting and let it stand until a clear separation appears. The n-hexane and petroleum ether mixture fraction were at the top, while the water fraction was below. Dispose of the water fraction until the boundary mark and fraction of n-hexane and petroleum ether are filtered with filter paper + anhydrous sodium sulfate as much as one spoon (± 2 g) and stored in a 10 ml test tube and ready for injection in GC. The detection limit for this method was 0.0633 µg g\(^{-1}\) (soil) and 0.0782 µg g\(^{-1}\) (plant) [22-24].

2.6. Analysis of carb in water
100 ml of water is put in a 500 ml separating funnel. Add 100 ml of 10% NaCl solution to the separating funnel. Add 50 ml of high purity n-hexane, shake for 20 minutes using a shaker. Let stand until it forms
2 layers, namely the n-hexane and water layers. Cover the water layer in a 250 ml separating funnel, leave the n-hexane layer. Add 50 ml of n-hexane to the separating funnel containing a layer of water, shake for 20 minutes using a shaker. Let stand until it forms 2 layers, namely the n-hexane and water layers. Discard the water layer, combine the n-hexane layer with n-hexane. Add 100 ml of distilled water and shake it. Let stand until 2 layers are formed and remove the water layer. Perform this step 2 (two) times. Enter gradually 100 ml of n-hexane elution solution: diethylether (85:15), flow with a flow rate of 20 drops minute\(^{-1}\). Glue the elution using a vacuum system adhesive at a temperature of <35 °C with a speed of 25 rpm to volume + 1 ml. Transfer it to a 10 ml test tube. Rinse the pumpkin with n-hexane, then the rinse results are put in the test tube above (do it 2 times). Concentrate the volume into 2 ml with a stream of nitrogen gas [20, 21].

2.7. Derivatization of carb in water
Prepare a 6% v/v FDNB stock solution by piping 6 ml of FDNB dissolved in 94 ml of acetone p.a. The stock solution of 0.5 N KOH by weighing KOH was 28.05 g KOH and dissolved in 400 ml of distilled water in a 500 ml backer glass, then stirred using a magnetic stirrer. After dissolving, adjust the volume to 500 ml with distilled water. 5% Borax stock solution by weighing 25 g of borax and dissolving it in 450 ml of distilled water, then stirring using a magnetic stirrer. After dissolving, set the volume up to 500 ml. And the stock mixture of n-hexane and petroleum ether with a ratio of 45: 3 (v/v) is 200 ml / as needed. After the stock solution is prepared, derivatization can be started by dissolving the concentrated extract from the 10 ml test tube put in a 300 ml round flask, rinse the test tube with 20 ml of acetone if the sample is stored in the same flask. Steam the solvent in the flask by evaporated it to ± 1 ml, then add 100 ml of distilled water, 1 ml of FDNB 6%, and 2 ml of KOH 0.5 N, then shake with a mechanical shaker (Shaker) for 20 minutes. After that, added 10 ml of 5% borax then extract is heated in a water bath at 80°C for 20 minutes. When finished chill in a tub that has been filled with cooling water. After chilling, transfer the extract solution from the pumpkin to the separating funnel, then add 10 ml of the n-Hexane mixture and Petroleum ether and shake with a mechanical shaker for 3 minutes. After finishing shaking, lift the separating funnel and place it in stand until a clear separation appears. The n-hexane and petroleum ether mixture fraction was at the top, while the water fraction is below. Dispose of the water fraction until the boundary mark and fraction of n-hexane and petroleum ether are filtered with one spoon filter + sodium sulfate paper (± 2 g) and stored in a 10 ml test tube and ready for injection in GC. The detection limit for this method was 0.0569 µg L\(^{-1}\) [22].

2.8. Calculation of par and carb levels
Inject 5 µL of the sample solution into HPLC for Par and 1 µL into the GC for Carb. Determine the levels of each Par and Carb in the test sample based on the area of the chromatogram results by plotting to compare with the area of the standard curve.

2.9. HPLC method for the determination of par
The Par residue was analyzed with a HPLC (Agilent 1260) with a diode array detector equipped C18 column (4.6 mm×150 mm, (5 um), agilent). The column temperature was 35°C. Mobile phase is methanol (70%) at a flow rate of 0.5 mL min\(^{-1}\). Volume samples were 5 µL. The concentrations of Par were determined by comparing the peak height of the samples and the calibration curves of the standards. The correlation coefficient of calibration curves of Par were all greater than 0.998. Peak identification was conducted by the accurate retention time of each standard (±1%) and also confirmed by HPLC [25].

2.10. GC method for the determination of Carb
Gas chromatography used in 2014 Shimadzu type with SPL-1 injector, FPD detector, Rtx-1 capillary column (dimethyl polysiloxane, 30 m x 0.25 mm id), AOC-20i auto sampler, 250 °C injector temperature, 230°C column, and 250°C detector, inject volume is 1 µL.
3. Results and Discussion

The concentration of Par and Carb pesticides in soil, water and plant from several provinces of Indonesia in 2018 was analysed. The results of the validation/verification method by AOAC 2005, US-EPA 1987, AOAC 1990, Baros 1995, Directorate of Plant Protection 2006, US-EPA 2013 [16-18, 21, 22, 25] are in the range of KAN (National Accreditation Committee) requirement. The method detection limit and recovery of the analysed Par pesticide residues by spike Par standards for 7 times were 3 times standard deviation of 0.0151 µg g⁻¹ (in soil), 0.0545 µg mL⁻¹ (in water) and 91.20 to 98.71% (in soil), 81.93 to 93.33% (in water), respectively. The method detection limit and recovery of the analysed Carb pesticide residues by spike Carb standards for 7 times were 3 times standard deviation of 0.0633 µg g⁻¹ (in soil), 0.0569 µg mL⁻¹ (in water) and 80.34 to 97.54% (in soil), 82.44 to 96.65% (in water), respectively. Figure 2 showed that the amount of residue detected in soil samples> water> plants.

![Figure 2](image-url)

**Figure 2.** Number of residues in soil, water and, plant were detected.

3.1. Par residue

Par was detected in soil in several provinces of Indonesia (table 2). Residue level of Par was predominant in soil samples, with the highest concentration being 14,4366 mg kg⁻¹ in South Kalimantan province (Tanah Laut Regency, Batu Ampar District, Tajau Pecah Village), but the concentration is still below of previous studies (tolerance limit) from the European Commission [26] of 15 mg kg⁻¹ (figure 3). Par residue is commonly found in soil because Par is a polar organic compound, which is very quickly absorbed in clays and soil organic matter [11, 27]. Jaya [28] reported that in Batu Ampar district (Tanah Laut Regency, South Kalimantan Regency) have found the concentration of Par residues in soil although the concentration found was low compared to the present study of 0.204 ± 0.0038 mg kg⁻¹. The low concentration is due to the determination using UV-Vis spectrophotometer where the sensitivity level was lower than HPLC. In surveys of a large number of Korean orchards which had received Par over a period of 26 years up to 1996/97, the highest Par concentration in topsoil was 35 mg kg⁻¹ with a mean of 7.5 mg kg⁻¹ [29]. Par cannot rapidly degrade in the environment and was adsorbed in clay lattices that require urgent environmental remediation [42].

Par residue is not found in surface water or below the detection limit (0.0569 µg g⁻¹) (table 2) (figure 3). The same thing happened as reported by Ismail [30] that of the 14 water sampling points from drainage channels in Kerian rice fields, Par residues were detected in only a few water samples at level ranging 0.6 to 6.9 µg L⁻¹. Verissimo [31] reported that Par residues were found in surface water of a stream that crosses a rural area of intensive agricultural production in the mountainous region of Rio de
Janeiro, with the concentration residue of average 0.075 \( \mu g \) \( L^{-1} \) and maximum 0.279 \( \mu g \) \( L^{-1} \). The occurrence of Par residues in water (drainage channels) seems to absorb colloidal soil particles and the fact that the soil in the planting area tested is mostly clay. The detected residual level is very low and does not cause toxicological concerns. Cheah [32] reported that the herbicide, Par, accidently applied to surface water, was rapidly adsorbed into the sediment. On the other hand, low Par concentration in water bodies are commonly observed during drought periods, which can be justified by the absence of surface runoff causes by rainfall [33]. Par concentration levels in surface water are referred to the World Health Organization (WHO) acceptable daily intake (ADI) and the Environment Protection Agency (EPA) reference dose (RfD) of 0.0045 mg kg\(^{-1}\) d\(^{-1}\), or equivalent to 90 \( \mu g \) \( L^{-1} \) with consumption of 3 L d\(^{-1}\) from drinking water [34].

Table 2. Concentration of Par and Carb in soil, water, and plant from several provinces of Indonesia.

| Provinces    | Residues detected | Concentration | Par | Carb |
|--------------|-------------------|---------------|-----|------|
|              | \( n \)            | Soil          | Water | Plant |
| Riau         | 12                | 6             | 6     | 8.4366 | < LoD |
| Lampung      | 28                | 12            | 9     | 7     | 1.4062 | < LoD |
| West Java    | 19                | 9             | 8     | 2     | -      | < LoD |
| Central Java | 19                | 15            | 4     | -     | -      | < LoD |
| East Java    | 20                | 15            | 5     | -     | 1.1210 | < LoD |
| South Sulawesi | 24              | 19            | 9     | -     | 3.8000 | < LoD |
| West Sulawesi | 12               | 9             | 3     | -     | 0.7579 | < LoD |
| South Kalimantan | 27            | 12            | 9     | 6     | 14.3487 | < LoD |

\( n \) = number of samples; \( S \) = Soil, \( W \) = Water, \( P \) = Plant.

![Figure 3. Par residue soil, water, and plant from several provinces of Indonesia.](image)

Par residue also is not found in plants (rice) (Table 2) (Figure 3). Lima [35] reported that Par found in different type of rice in Brazil (Parboiled, Agulhinha rice, Brown rice, Japanese Rice, Arboreal Rice) with concentration range of 0.20 to 1.42 mg kg\(^{-1}\). Five samples showed values above the maximum permitted limit (0.5 mg kg\(^{-1}\)). No deleterious effects were noted on any of the crops grown (maize,
wheat, soybean and bermudagrass), and Par residues were not detected (<0.05 mg kg\(^{-1}\)) in any of the harvested grain [29]. Bromilow [29] reported that the use of Par in conservation tillage systems, which can control erosion in marginal areas as well as bringing other benefits. Par has also been found widespread use in orchards and plantation crops, either to control weeds or to manipulate the ground so as to minimize competition with the crop.

3.2. Carb residue

Carb residues were found in East Java, South Sulawesi and South Kalimantan, while in water and plants, Carb residues are not found (Table 2) (Figure 4). The higher concentration of Carb in soil of 0.3072 mg L\(^{-1}\) in South Kalimantan province. From a study (under laboratory condition in black, red and alluvial soils following application @ 5 and 10 mg kg\(^{-1}\)) by Merlinkamala [36] reported that Carb residues progressively declined with time and reached below detectable level (<0.01 mg kg\(^{-1}\)) within 75 days in red and alluvial soil and 90 days in black soil.

![Figure 4. Carb residues in soil, water, and plant from several provinces of Indonesia.](image)

In nature, Carb will be flown and soaked through the soil. While the soil has important natural constituents, humic compounds and soil ions. Humic acid and calcium ions are organic materials that are found in many waters. Humic compounds play a role in chemical reactions which cause these compounds to be colloidal which have a high adsorption capacity and are able to interact with Carb [37]. This causes Carb in water not to be found or detected.

Varca [38] reported that in rice leaves, Carb residue lasted till 7 DAS. In another study by Kabir [39] reported that in the brinjal sample containing Carb residue were analyzed using the GC-MS QP2010. Carb residue was detected in the sample up to 7 days after spray (DAS) and the quantities were over maximum residue limits (MRL) of 0.2 mg kg\(^{-1}\). At 4 DAS, it was 0.104 ppm, which was below the MRL. Kamala and Kennedy [40], also reported that Carb residues was detected in brinjal fruits both at the first and third harvest were well below the maximum permissible residue limit (MRL) of 0.1 \(\mu\)g g\(^{-1}\) at the recommended dose of 250 g a.i. ha\(^{-1}\) and hence the carbamate chemical, Carb is well recommended for managing the brinjal pest without any harm to the environment. From a study by Trevisan [41], it was revealed that the residue level of Carb in citrus decreased rapidly and being not found in samples after 7 DAS.
4. Conclusions
Par residue found in the soil and distributed in Riau, Lampung, East Java, South Sulawesi, West Sulawesi and South Kalimantan. Similar to Par, Carb residues found in the soil, but only distributed in the areas of East Java, South Sulawesi and South Kalimantan. Residues of Par and Carb found in the soil in several provinces in Indonesia, but their concentrations are still below tolerance limits. Par residue is mostly found in soil in the provinces of Riau, Lampung, East Java, South Sulawesi, West Sulawesi and South Kalimantan. Par and Carb residues were not found in surface water and plants (rice). The results showed that the Par and Carb residues in water, soil and plants at concentrations were still safe for the environment. However, further research is needed to determine the bioaccumulation of Par and Carb which has an effect on human health.

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