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The early detection of glyphosate-based herbicides exposure in the palm plantation of Banyuasin district, Indonesia

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ABSTRACT

Glyphosate (*N*-(phosphonomethyl)glycine) has been used in plantation areas as an herbicide and continuously increased use over the past decade. However, the excesses use of glyphosate potentially formed the residues which accumulate in agricultural products and become pollution for the environment. The presence of glyphosate in the environment threat not only biological elements but also the community which impacts death. This research aimed to trace the active ingredient of glyphosate in the plantation area of PT X in Banyuasin District-Indonesia. The samples were water, ambient air, and soil taken in the plantation area. In the water body, the highest residue of glyphosate was found in the main drain (0,02 µg/L), followed by a collection drain (<0,005 µg/L), and consumed water (<0,005 µg/L). The water pH differentiated the contained glyphosate which correlated to how the glyphosate dissolved in the water. In the soil sample, the highest glyphosate was found in the plantation which has never harvested (immature plant) showing 0,09 mg/kg of glyphosate. The most possible reason was that in those area has lower palm trees (1-3 meters) and mostly dominated by weeds. In the ambient air, the concentration of glyphosate was 125,50 µg/m^3 and still under the threshold value regulated by the government of the Republic of Indonesia. The low concentration of glyphosate in the air was because most of the glyphosate applied in the plantation area was in the liquid phase which sprays directly to the weeds. The possible mist formed during the spraying was down to the soil or water. In conclusion, the contamination of glyphosate in the plantation area of PT. X in Banyuasin District, Indonesia was under the threshold value of environmental quality standard.

Key words : *Herbicide, Glyphosate, Environmental Pollution*

Introduction

The uses of pesticides in agricultural and plantation areas areannually increasing, especially in developing countries (Maggi *et al.,* 2019) such as Indonesia (Sriyani and Salam, 2008; Jatsiyah and Hermanto,

2020). The type of pesticide widely used in agricultural and plantation areas is herbicide (European Commission, 2002; 2017; Herlander *et al.,* 2012; FOEE, 2013; Maggi *et al.,* 2019; Karasali *et al.,* 2019; ATDSR, 2020). The use of herbicides contributed to the increasing in agricultural productivity and save the production cost because of using a few workers to maintain the plantation (Herlander *et al.,* 2012; Steinmann *et al.,* 2012; FOEE, 2013). The use of herbicides with large doses formed the herbicide residues which can accumulate in agricultural products, sediment in the environment, pollute the surface and groundwater. The way of contamination can be through a one-waysource from the direct herbicide applied location or through runoff or leaching where the pesticide is used. The herbicide can accumulate on the surface of water sources such as lakes, rivers, or ponds, and it can dissolve and be integrated into groundwater reserves such as reservoirs (Cerdeira and Duke, 2006; 2010; Tang *et al.,* 2015; Avigliano and Schenone, 2015; Helander *et al.,* 2018; ATDSR, 2020).

One of the most active ingredients of herbicides used in plantation and agricultural area is glyphosate (N- (phosphonomethyl) glycine). (Locke *et al.,* 2008; FOEE, 2013; Mamy *et al.,* 2016; Myers *et al.,* 2016; Wilson *et al.,* 2018; Faria *et al.,* 2018; Barnett and Gibson, 2020; ATDSR, 2020). Glyphosate is a weak organic acid which is easily soluble in water due to its polar properties, but insoluble in non-polar solvents such as acetone, ethanol and benzene. (Mamy *et al.,* 2016; Faria *et al.,* 2018; ATDSR, 2020). Glyphosate is a non-selective, systemic and post-growth herbicide which is widely used in agricultural land (Cerdeira and Duke, 2006; Maggi et al., 2019; Karasali *et al.,* 2019; Gillezeau *et al.,* 2019).

The palm oil plantation is reported using a high amount of glyphosate to eliminate the weeds (FOEE, 2013; Jatsiyah and Hermanto, 2020). Glyphosate as an active herbicide has a broad spectrum in controlling annual weeds, especially deep-rooted weeds. In terms of eradication ability, glyphosate is relatively slow, but spraying glyphosate can easily translocate to other parts of the plant, resulting in high effectivity in eliminating weeds. Glyphosate is absorbed by plants through the leaves (cuticles), then spread to all parts of the plant. Glyphosate herbicide translocation in the plant body generally through the simplas generating the accumulation occured under the tissue of young leaves and meristem tissue. In addition, some of the plants pass the glyphosate through the translocation of the apoplast (FOEE, 2013; Gillezeau *et al.,* 2019; ATDSR, 2020; Jatsiyah and Hermanto, 2020).

The mechanism of glyphosate to kill weeds is by inhibiting the activity of EPSP enzyme (5-enolpyruvyshikimat-3-phosphate) synthase. The enzyme EPSP is produced by shiikat – 3 – phosphate or phospoenolpyruvate through shikimat acid pathway. The enzyme EPSP plays the role in the biosynthesis of the amino acids tryptophan, phenylalanine, and tyrosine. The presence of glyphosate inhibits biosynthetic activity and results in the depletion of amino acids required for protein synthesis in the synthesis pathway for growth. The symptoms of chlorosis on young leaves and growing points are followed by necrosis that occurs on days 4 - 7 after the application of the herbicide glyphosate (this type of grass has high susceptibility). The other species which has less susceptible has the necroses on the day of 10 to 20 after the application of glyphosate. The pieces of evidence of inhibition were shown by the formation of purplish-red color on the leaves or shoot defects (FOEE, 2013; EFSA, 2015; 2017; Faria *et al.,* 2018; ATDSR, 2020). The negative impact on public health risks, especially for the worker who is exposed to these active ingredients can be acute, sub-chronic, chronic, and systemic. Health risk effects include irritation of the airways, skin, and mucous membranes, stomach, pain, nausea, vomiting, shock, dyspnea, or in the worst case generating respiratory failure (WHO, 2004; De Roos *et al.,* 2005; Qiao, 2012; Avigliano and Schenone, 2015; Myers *et al.,* 2016; Van Bruggen *et al.,* 2018; Zang *et al.,* 2019; ATDSR, 2020). In addition, the exposure of glyphosate in the environment become an alien substance which can pollutant the environment (Qiao, 2012; FOEE, 2013; ATDSR, 2020).

This study aims to trace the exposure of glyphosate in the palm plantation. The result is important as the early prevention of environmental pollution especially in Banyuasin district and becomes the information for the plantation to maintain the future use of herbicide.

Materials and Methods

This research is a quantitative study with a cross-sectional design. All the collected data were measured in February 2020 in PT X Karang Agung,

Musi Banyuasin District which has a specific land area of 4.294 Ha. The samples were obtained from water bodies, ambient air, and soil in the plantation area. The calculation of glyphosate concentration in water was carried out using chromatography gas (APHA, 2005). Furthermore, US-EPA and NIOSH 5003 methods were applied to measure the amount of glyphosate in soil and air, respectively.

Results and Discussion

Glyphosate detected in water

There was three main sampling points the first one was the main drain, collection drain, and drinking water consumed by the local community. The results of water sampling analysis were shown in Table 1.

The results showed that the highest glyphosate concentration was found in the main drain at 0.02 µg / L in the palm plantation area, while the glyphosate concentration in both collection drain and consumption water was found to be <0.005 µg / L. The water pH differentiated the contained glyphosate in which the pH of main drain, collection drain, and drinking waterwere 7.7, 8.13, and 4.6, respectively. The pH of water correlated to how the glyphosate dissolved in the waterin which the solubility of glyphosate was 620 g/L in the neutral pH (7).

The future analysis confirmed that the mechanism of glyphosate contaminate water was through direct contamination from glyphosate sprays during the application, runoff or leachate pathways from the excesses using of glyphosate, and the residue formed in the main drain. This condition causes glyphosate to enter the water sources with sediment. This statement was supported by Cerdeira and Duke (2010).

Glyphosate detected in soil

There were three sampling points conducted which was the soil from immature plant, mature plant, and Main Road. Table 1 showed that all the soil sample was generally categorized as acid soil with pH < 6,5. The highest glyphosate was found in the soil sampled from immature soil followed by mature plant, and main road. The high concentration of glyphosate in immature plant was because of the intensity of applying the glyphosate in immature plant. The immature plant was relatively low plant (1-3 meters) and the area was dominated by weeds. The applying frequency was high in the area of immature plant since the people said it as the infestation area and applying the high intensity of glyphosate was believed as the way to prevent the crop failure.

Glyphosate is easily absorbed into the soil and sediments which could be not degraded over the years, except at soil surface. The loss of glyphosate

Table 1. The result of analysis of glyphosate in water, soil, and air in the PT X

The result of glyphosate measurement in watersamples (n=3)						
Parameter	Unit	Main Drain	Collection Drain	Drinking Water	Environmental threshold	LOD
pH		7,7	8,13	4,6	7	
Temperature	^{O}C	26	29,6	26	± 3^{O}C	-
Glyphosate Conc.	mg/L	0,02	<0,005	<0,005	0,03	0,005
The result of glyphosate measurement in soil samples (n=3)						
Parameter	Unit	Immature plant	Mature plant	Main Road	Environmental threshold	LOD
pH H_2O	-	5,55	5,97	5,05	-	-
pH KCL	-	5,05	6,8	4,86	-	-
Glyphosate Conc.	mg/kg	0,09	0,07	<0,005	0,5	0,005
The result of glyphosate measurement in ambient air samples (n=6)						
Parameter	Unit	Time	Average Value	Threshold Value	LOD	
Glyphosate Conc.	µg/m^3	25 minutes	125,50	500	0,125	

due to photodecomposition is about 50% within three weeks where glyphosate is very persistent in the soil, relatively stable under normal pressure and pH (FOEE, 2013; ATDSR, 2020). The exposure of glyphosate in the environment does not directly cause health problems for humans, but the presence of glyphosate in the soil through the application of spraying, being spilled and dumped intentionally in plantation areas or being carried away by rainwater will cause the glyphosate to be retained and remain in the soil through the adsorption process. The presence of glyphosate in soil contaminate the groundwater which was consumed by the community in the plantation area.

Glyphosate detected in ambient air

The concentration of glyphosate in the air was measured using a personal air sampler for 25 minutes which was placed 30 cm around the breathing area. Table1showed that all the six (6) samples measured, the average glyphosate concentration in the air was 125.50 µg/$m^3$and it was still below the threshold value of 500 µg/m^3 (ACGIH, 2015). This is because the glyphosate used in the studied area is in the form of a 20% solution and diluted with water before being sprayed. The composition of glyphosate solution applied in PT. X consisted of 100 mL of glyphosate solution which was mixed with 15 liters of water. The high content of water in the glyphosate sprayers formed the mist which were easier to fall to the ground than inhaled by the worker.

Conclusion

The early detection of glyphosate in the studied area confirmed that all the sample taken in water, soil and air had the glyphosate concentration below the environmental quality threshold. Glyphosate was a non-selective, systemic and post-growth herbicide which was widely used in agricultural land. The activities in agriculture and plantations include spraying applications of glyphosate and other pesticide active ingredients can become the environmental pollution if the applying the glyphosate did not conduct in the a specific amount of concentration. Furthermore, the comprehensive study needed to be done to calculate the effective concentration of glyphosate to eliminate the weeds in the plantation area.

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