Grouper : Jurnal Ilmiah Perikanan
Vol. 16 No. 2 (2025) pp. 471-481
pISSN: 2086-8480 | eISSN: 2716-2702
Journal Homepage: https://grouper.unisla.ac.id/index.php/grouper

Endosulfan Analysis of Berau Delta Pond Soil

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Submitted: 07 July 2025 Revised: 19 August 2025 Accepted: 28 September 2025

Keywords:
Aquaculture;
Berau;
Endosulfan

ABSTRACT

The aquaculture areas of Berau Regency are traditionally managed through a polyculture system involving tiger shrimp (*Penaeus monodon*) and milkfish (*Chanos chanos*) in the Berau Delta. Aquaculture practitioners commonly apply insecticides and herbicide at the start of the rearing period or post-harvest to control weeds along pond embankments and surrounding areas. These practices have contributed to endosulfan accumulation in pond soils over time and affect aquaculture productivity. Assessing endosulfan levels in soil is critical and may inform level of level of accumulation of the harmfull sibstance overtime. This study aimed to inform soil characteristics across different pond age categories, hypothesizing that soil quality declines with increasing cultivation duration. The research was conducted within the operational aquaculture cycle, sampling soils from three ponds representing construction periods of 1990–2000, 2000–2010, and 2010–2020. Laboratory analysis revealed that pond soils in the Berau Delta did not contain detectable levels of endosulfan, with all samples showing concentrations below the limit of quantification (LoQ) of 0.040 mg/kg.

INTRODUCTION

The aquaculture area in Berau Regency is concentrated in Pegat Batumbuk Village, Derawan Island Subdistrict, applying traditional pond patterns that rely on large plots averaging more than 10 hectares. With unstable shrimp production, a polyculture system of tiger shrimp and milkfish is commonly used. Although it is costly for the owner to operate, chemical treatments are practiced, but farmers face declining production from season to season.

Aquaculture production declined dramatically between 2000 and 2010, especially in 2005, when aquaculture productivity was only half of total productivity (PKSPL, et al., 2023). After the year 2000, ponds had to be rejuvenated and maintained as their quality declined due to cultivation processes that did not pay attention to the environment. Dissolved materials, microclimate, and human behavior can easily affect the dynamics of the conditions (Riki Saputra, Restu, and Ayu Pratiwi 2017). The success rate of aquaculture is influenced by the conditions in which aquatic organisms live, such as pond water quality and sediment soil (Weda and Restu 2025). Contrary to terrestrial conditions, aquatic conditions are more unstable (H et al. 2022).

The results of the traceability census of shrimp production in Pegat Batumbuk in 2022 showed that 87% of farmers used Thiodan insecticide. In the pond culture cycle, the volume reached 214,485 milliliters, both at the beginning of rearing and after harvest. Thiodan insecticide and gramoxone herbicide kill shrimp pests and predators in the courtyard (field plot in the center of the pond) and at the edge of the pond embankment (Rijal, 2021). In cultivation operations, fertilizers and appetite enhancing supplements are used for cultivated commodities (Sondeng and Nuryadi 2023). The majority of farmers use dolomite lime to neutralize soil pH. (Trisnawati, Beja, and Jeksen 2022) and using lodan, ursal, linex and king milkfish as growth supplements for shrimp and milkfish seedlings (Melanie, Zilfira, and Akbar 2023). Until now, many brands of endosulfan active ingredients are available but the ones that are widely found and circulated in the market are Thiodan, Indodan 25 EC, and Akodan 35 EC. These are used to kill pests early in the cultivation cycle. Akodan is also used to poison fish in rivers as well as killing crop pests.

Recent facts reveal that environmental quality continues to decline, causing a decrease in production yields and the rampant use of disinfectant chemicals, herbicides, pesticides, insecticides, and inorganic fertilizers. Several factors cause the decline in the quality of aquaculture areas, one of which is pollution that enters the environment, especially the active ingredient endosulfan which produces residues (Rachmansyah et al. 2017). Some fishery exports were rejected because they were suspected of containing pesticide residues that exceeded the safe limit for consumption (Suwoyo 2015). In addition, uncontrolled use has increased plant resistance to pests and diseases, mortality of living things and natural enemies and accumulation of harmful chemicals in the soil (Damanik 2024).

Organophosphates, carbamates, pyrethroids and organochlorines are common insecticide residues found in soil, water and foodstuffs (Dzulfiqar 2024). Organochlorine residues (lindan, aldrin, dieldrin, heptachlor, DDT, and endrin) are some of the insecticides that are still found in soil, water, and some agricultural and fishery commodities despite being banned (Theresia et al. 2023). Farmers commonly use the insecticide Endosulfan to control fry predators in ponds. Endosulfan is a type of insecticide that is long-lasting and toxic in the environment (Nalle 2022). Its residues have the potential to accumulate in soil, degrade soil quality, contaminate water sources, and cause biomagnification (Andriani 2021).

Soil quality is critical to shrimp aquaculture productivity (Farkan et al. 2017). Much evidence shows that substance exchange between soil and water and pond bottom conditions greatly affect water quality, although water quality management is considered one of the most important factors in shrimp farming (Quyen et al. 2020). These conditions indicate the influence of endosulfan accumulation and pond age on the productivity of aquaculture. One of the parameters of endosulfan content and pond age that may affect pond productivity is soil characteristics. Pond bottom soil aids in the decomposition and exchange of nutrients present in sediments and in the water column (Hidayanto 2004). Therefore, to meet the data needs in order to analyze the soil characteristics of the effect of the active ingredient endosulfan at several periods of pond construction on pond productivity, soil samples were analyzed that decreased in quality as the cultivation period increased.

METHOD

The research was conducted in March 2024. Data were collected at the Berau Delta traditional pond location in Kampung Pegat Batumbuk, Berau Regency. Water sample analysis was conducted at the Laboratory of the Agricultural Environmental Instrument Standard Testing Center, Jakarta.

This study was designed to determine the content of the active ingredient endosulfan in pond soil in the operational cycle of aquaculture. The main focus is on ponds that represent the criteria for the use of endosulfan active ingredients in the period of pond development 1990 - 2000, 2000 - 2010, and 2010 - 2020.

The overall condition of the ponds is uniform and therefore represented by only a few samples from the land clearing period. The ponds are located in a cluster of pond landscapes as demonstration plots of the “shrimp carbon aquaculture” (SECURE) program which implements mangrove ecosystem restoration initiatives to increase traditional pond production by reducing the cultivation area to 20% of the pond area (Sigalingging, Bulan, and Suryana 2023).

Table 1. Determination of location based on the period of pond construction

No.	Sample Code	Year Development Period	Description
1.	Sample 1	1990 - 2000	Community pond
2.	Sample 2	2000 – 2010	Pilot pond
3.	Sample 3	2010 - 2020	Community pond

Source: Primary data after processing, 2024

Site selection was based on the following considerations: (1) organochlorine compounds in water originate from residues in soil from previous applications; (2) ponds in the Berau Delta are homogeneous with more than 10 hectares per plot; (3) The active ingredient endosulfan from insecticides, pesticides, and herbicides is significantly used directly in ponds and inputs from the agricultural subsector that drain into surrounding waters, (4) Thiodan is used by most farmers before the aquaculture cycle begins, and (5) this area is one of the pilot pond plots for the development of the SECURE program that implements mangrove restoration strategies to support sustainable aquaculture productivity.

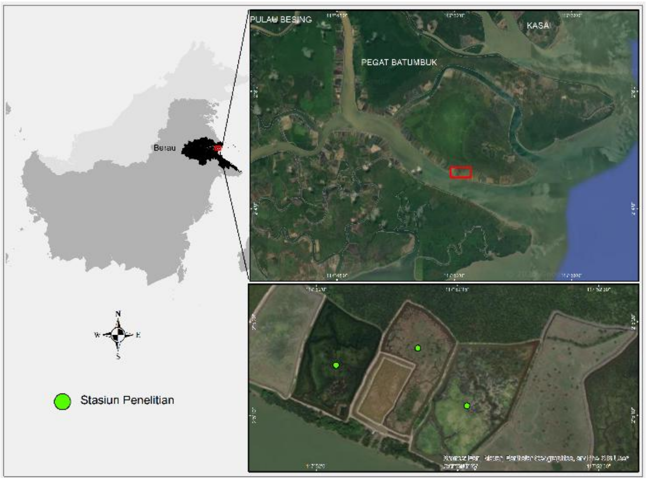

Figure 1. Research location
Source: Data analysis (2024)

Soil sampling at the pond site was carried out using a portable scoop. Starting with determining the center point in a representative area or that represents the characteristics of the sampling area, followed by measuring the distance between points using a roll meter as far as five meters in the direction of four opposite directions in a composite manner. Surface soil samples were collected for analytical purposes as much as 500 grams at a depth of 10 cm, where residues in subsurface soil indicate the depth of endosulfan penetration. The soil samples were then mixed from the five points in a basin container and put into a sample bag. From the soil mixture that was considered homogeneous, samples were taken for analysis. The soil samples were labeled and stored in a coll box with a low temperature of ±15 ^{0}C for later analysis in the laboratory.

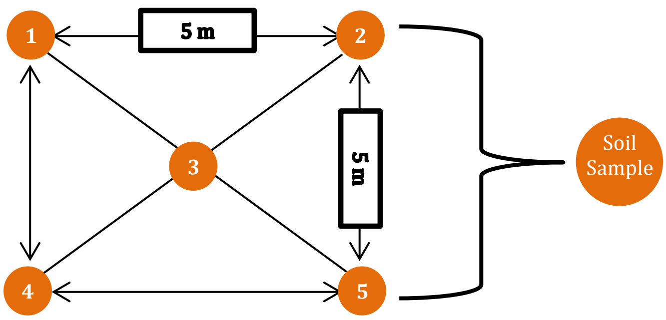

Figure 2. Sketch of composite soil sampling technique
Source: Data analysis (2024)

Before the soil sample is put into the sample bag, note that the organic matter attached to the soil must be removed to make the analysis easier (Mariffatun, Harsanti, and Jatmiko 2004).

RESULT AND DISCUSSION

Endosulfan is a non-systemic organochlorine insecticide that is widely used in the agricultural sector, especially in developing countries such as Indonesia (Taufik and Setiadi 2015). Endosulfan is harmful to insects, fish, mammals and other aquatic animals. Endosulfan is absorbed by the body through digestive, respiratory, and skin tissues. Over the years, residual endosulfan can remain in the soil, damaging the microbial composition of the soil and disrupting aquatic ecosystems. In addition, they have the ability to escape from the soil through erosion of the soil surface, which allows them to spread to neighboring areas (Andina 2015).

The active ingredients of organochlorine compounds can persist for a long time in soil, water, animal tissues, and plants. They are also not easily broken down by enzymes, microorganisms, or ultraviolet light. In soil, Endosulfan accumulates due to its long-lasting nature (Rachmansyah et al. 2017). Although certain microorganisms can biodegrade, this process is not always rapid, so residual endosulfan may persist for a long time (Taufik and Setiadi 2015). Compounds with these properties are classified as good in terms of function, but are not environmentally friendly (Suryono, Rochaddi, and Irwani 2016).

In aquaculture, the active ingredient endosulfan has been proven to control various types of pests and intruders. However, the use of this active ingredient can have negative impacts on aquaculture organisms, such as reducing survival, increasing residue content in sediment and water, and increasing recurrence and resistance to intruders, which is harmful to food safety (Nalle 2022). This can lead to ecological imbalances, which can reduce production (Taufik and Setiadi 2015). Residual endosulfan can spread over the soil surface through erosion, river water flow, sea, and wind gusts depending on the environmental conditions and chemical properties of endosulfan. The time required to complete this process varies (Nalle 2022). If endosulfan and other pollutants are used in amounts that exceed the recommended dose, it will negatively affect the ecosystem and change the population and types of species. A reduction in the number of species in an ecosystem will lead to ecosystem instability and population explosion of certain species as there are no natural predators for them (Damanik 2024).

Endosulfan residue test results of pond soil showed that the soil from each pond plot did not contain the active ingredient endosulfan. The test results also showed that none of the samples exceeded the limit of detection (LoQ) of 0.040 mg/kg. This indicates that the soil does not contain endosulfan pollutants. However, because this study only identified residues of organochlorine active ingredients, it cannot be said to be safe against residual pollutants because there may still be other chemical compounds or residues contained in the soil.

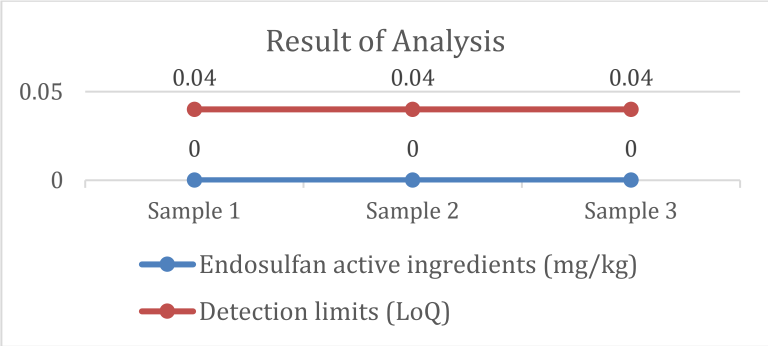

Figure 3. Test results for endosulfan active ingredient in pond soil samples
Source: Test result report BPSI-LINGTAN (2024)

The results show that endosulfan residues are lower than the detection limit due to the temporary use method of the material. This means that the substance did not settle in the soil as it was discharged directly into open water after use. Technically, the undetectable endosulfan residues in soil sediments may be due to routine farming cycle procedures, including draining or rinsing the ponds, turning or hoeing the soil, and soaking and washing the pond bottom to volatilize, dissolve and remove endosulfan residues adsorbed in the soil.

Endosulfan is often used in ponds, but more often on watered land so as to reduce the possibility of residues. Its low concentration can markedly affect the growth of snails and interfere with their body functions. In addition, pollutants, including endosulfan, can affect feeding behavior, absorption, digestion, assimilation, excretion and hormonal changes. All of these have a direct or indirect impact on the products consumed (Karim and Latuconsina 2022). Several factors can affect the level of endosulfan in pond soil and cause endosulfan residues to be absent. The decomposition of toxic chemical compound residues after use through microbial processes, chemical reactions, or sunlight is known as residual toxic chemical compound degradation. This process can degrade through various means, such as leaching, volatilization, weathering, enzymatic degradation, and translocation (Putri et al., 2014). The flow of water from rivers, seas, and wind can carry chemical compounds from the land surface to other places. The duration of the degradation process depends on the chemical properties and environmental conditions (Manuaba, 2009).

Formulation and application of chemical compounds, weather conditions, soil physics and chemistry, and watershed conditions affect the infiltration of agrochemical solutions into waters (Sugrani et al. 2023). On the other hand, dispersal in nature includes dilution, physical, chemical, and biological degradation; dispersal by biotic and abiotic matter; transfer into the food chain; sediment transfer; evaporation, decomposition; influence of currents and turbulence; and metabolic products to the water as a result of the death of polluted biota (Supriady Syam 2024).

Endosulfan can be biologically degraded by microorganisms in soil, for example by a consortium of bacteria that can degrade about 90% of endosulfan within 20 days in each soil layer. Within 30 days, the bacterial consortium can eliminate 95% of endosulfan in the topsoil, 96% in the middlesoil, and 99% in the subsoil. The order of degradation rate from the fastest to the longest was subsoil, midsoil, and topsoil (Pipit, 2021). Microorganisms that live in riverbeds or ponds can reduce the levels of endosulfan that have dissolved in water (Dorthi Ester Junita Daeli and Natalia Krisitiani Lase 2025). These conditions allow for reduced concentrations of endosulfan remaining in the environment, so its residues may not be detected in soil testing.

The stability of endosulfan can be affected by components such as soil pH and moisture. The half-life of endosulfan can be extended under certain conditions, such as low pH. However, in unfavorable situations, it can be rapidly degraded (Nalle 2022). Agricultural fields often have conditions that favor endosulfan accumulation, such as proper soil moisture and pH suitable for adsorption of these compounds. In contrast, farm systems that have a constant flow of water have the ability to wash most of the endosulfan residues into the water, thereby reducing the accumulation of endosulfan in the soil (Jannah, Nurdin, and Putri 2024). Absorption and leaching are the two main transport processes associated with soils and sediments in the transport and removal of environmental contaminants, as they (1) provide surfaces for absorption, (2) serve as buffer systems, and (3) serve as leaching agents (Sufriady Syam 2022).

In addition to the effects of endosulfan application, hydrodynamics and river flow quality affect the distribution and degradation of endosulfan residues in coastal areas. In pond hydrological systems, water is often moving and flowing, which allows leaching of chemical solutions from the soil surface into the water. Much of the active endosulfan will dissolve and be carried with the water to its disposal site. This can help maintain the balance of the aquatic ecosystem and reduce the accumulation of residues in the soil (Jannah et al. 2024).

In case of light erosion, the water current will erode the part of the soil that contains chemical residues. Leaching is more effective with larger volumes of water flow (Sufriady Syam 2025). The extent to which dissolved chemicals can be washed out is also influenced by geological structure. Water currents help microorganisms break down endosulfan in addition to physically washing the residue away. This washing process reduces the likelihood of residues collecting at any given point. Most aquatic species are no longer threatened by this harmful compound and will improve environmental safety for animals living in the vicinity.

Material transport is an important part of the presence of pollutants including organochlorines in the environment. Most are deposited and cause concentration differences in surface waters and sediments (Syam, S., 2022). Since organochlorines are generally insoluble in water, chemical compounds adsorbed by soil particles are carried into surface runoff in the form of soil suspensions. Runoff water flowing over the land surface produces organochlorine compounds in river water from the erosion of the soil surface layer. As a result, organochlorines are carried into receiving water bodies and contaminate aquatic ecosystems, including fish (Jannah et al. 2024).

During their growth, organisms absorb nutrients from the soil, so soil products must contain the same agrochemicals. This condition will have a negative impact because these products are consumed by humans and living things. As a result, even in very low concentrations, these products will accumulate in the body and harm the health of the living beings that consume them.

CONCLUSION

Residues of the active ingredient endosulfan were not found in Delta Berau Pond soil. The results of endosulfan residue testing at all sampling locations did not exceed the limit of quantification (LoQ) of 0.040 mg/kg. However, further research is needed to determine if endosulfan active ingredient residues are found in other media. This may be because the pond bottom is frequently washed and soaked, so the residues are not absorbed in the soil. However, because this study only identified residues of organochlorine active ingredients, it cannot be said to be safe from pollutant residues because there may still be other chemical compounds or residues contained in the soil.

ACKNOWLEDGEMENT

Thanks to Yayasan Konservasi Alam Nusantara, LPPM and LPM Muhammadiyah Berau University for their support and cooperation in organizing the tridharma of higher education.

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