Evaluation of the effectiveness of wastewater treatment plant for super-intensive shrimp farms (A case study on Punaga Village, Takalar)

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Abstract. Wastewater becomes a problem if it is not appropriately treated. Shrimp farms are one of the examples of an industry that produces wastewater. Super Intensive farms usually have a high concentration of wastewater pollution and above the threshold required. Therefore, this study aims to evaluate wastewater changes from super-intensive farms to wastewater treatment plants (WWTP) and evaluate the effectiveness of WWTP to treat the wastewater. The study was done through laboratory texting (ex-situ) and field (in-situ). This type of research uses the descriptive method, describing the characteristics that systematically determined. This study uses purposive sampling method and integrated sampling for six weeks in the Wastewater Treatment Plant (WWTP) unit and raw water from the reservoir of a super-intensive pond. Research has been conducted from May to June 2016. The result found that the effluent of wastewater from super-intensive farms tends to increase or contaminated with pollutants such as waste metabolites, un-eaten nutrient waste by fish, and waste detritus. Based on optimum standards of environmental sanitation by the Ministry of Health in 2011, it shows that the effectiveness is more likely to decrease the pollutant (already efficient: 60% < x = 80%). The effectiveness of TSS parameter is efficient enough by 63.4%, TN 60.0%, Phosphate (PO₄) 59.21%, 64.07% BOD. Nevertheless, the effectiveness of TOM parameter based on the optimum standards allowed by the Ministry of Environment 51 2004 is 15.45%, which is inefficient (x = <20%); the parameter of pH is 3.67% and DO 17.01%. Both parameters of pH and DO are more likely to increase or quite efficient. According to KEP28 / MEN / 2004 regarding Shrimp Effluent Quality standards and the results bioassay test, there were 100% of Survival Rate (SR), and it was in good condition for the medium term for 96 hours (4 days).

1. Introduction
Super intensive oriented shrimp pond culture has a future cultivation system characterized by the volume of small culture containers, high stocking densities, high productivity, minimal waste load, and top product competitiveness [1]. The eco culture system combines a super-intensive technology pond with an enlargement unit, a water quality treatment unit, and a continuous wastewater treatment unit. The system uses the principles of physical and biological treatment in the Wastewater Treatment Plant (WWTP). On the average, wastewater treatment plant and disposal system for shrimp ponds in Indonesia, currently, implement wastewater disposal by utilizing only a disposal reservoir with a deposition system without the application of physical and biological principles [2,3].
The type of waste produced in aquaculture is material residues of shrimp faces and urine. The waste is derived from the decomposition processes of organic material; feed that is not consumed by shrimp; dead plankton populations that contain high nutrients such as nitrogen compounds, (proteins, amino acid, urea), carbohydrates, vitamins, and fats resulting from excretion of shrimp from shrimp metabolism [4].

In commercial aquaculture, there are 30% of total nutrients from shrimp's feed that is retained into the body of aquatic animals. The remaining 70% is not consumed and excreted to produce waste [1]. Feeding on intensive and semi-intensive aquaculture contributes to an increase of organic matter and significant nutrients to the coastal water environment [5]. Too many nutrients in coastal waters lead to eutrophication. Besides, it also causes ecological changes in plankton, a high level of sedimentation, and a change in productivity and benthic community structure. In general, the waste that comes from the rest of the cultivation activities is rich in nutrients. So, if the quantity of feeding is too high, it will trigger an increase in the excretion of cultured animals to produce metabolic waste. The metabolic process can produce inorganic nitrogen compounds and unstable toxic water in the water.

The wastewater disposal derived from super-intensive shrimp ponds tends to contain a high concentration of pollutants that are still above the required threshold [1]. With the existence of previous research, the function of wastewater treatment plant (WWTP) super-intensive shrimp ponds are expected to reduce or increase the burden of super-intensive pond waste. As a result, the quality and quantity are within the required range. Therefore, based on the description from this background, the writer is interested in conducting research entitled "Effectiveness of Super Intensive Shrimp Pond Wastewater Treatment Plant (WWTP) in Punaga Village, Takalar Regency".

2. Methodology

2.1. Time and location
Water quality sampling began in May-June 2016. This type of research uses descriptive methods, describing characteristics that have been determined systematically. The technique of determining the point and taking with purposive sampling and integrated sampling methods has been conducted for six weeks. Monitoring wastewater from the super-intensive pond is once a week, to be exact every Tuesday (at 08.00-11.00 am). Monitoring is done after the disposal of super-intensive pond sludge/mud at the collector drain/pond gathering point before giving artificial feed/pellets.

2.2. Literature study
A literature study is conducted to collect supporting theories through scientific journals, theses, prior research, and textbooks that are relevant to research. The related research should relate to the characteristics of super-intensive pond waste in the field of fisheries, the level of efficiency of the use of WWTPs, and raw water reservoirs as environmental regulation required by the relevant governmental provisions.

2.3. Field measurement (in-situ) and laboratory analysis (ex-situ) research
Field research (in-situ) is observational research by directly observing research sites at the BPPBAP Super Intensive Pond WWTP site in Punaga Village, Mangarabombang District, Takalar District, determining sampling points and taking samples, and analyzed in the laboratory (ex-situ) water samples based on variables predetermined research.

2.3.1. Research instrument.
Complementary equipment for water sampling in the field (in-situ) in general, namely Cool Box, ATK Equipment, Camera, Bottles/Containers, measures 1000 ml of water quality sampling on a laboratory scale, size 9 ml for bacterial sample bottles, and 125 ml for BOD bottles.
2.3.2. Retrieval of research data.

- **Sample Container Preparation Techniques**
  All sample containers must be thoroughly cleaned in the laboratory before sampling to avoid sample contamination in the field. The number of containers prepared must always be more than needed for quality assurance, quality control, and reserves.

- **Sampling Method**
  The method of taking a sample with a combined place (integrated sample), namely a joint sample, is considered separately from several areas with the same volume is representative of the sample. Pond sludge production or water used is carried out twice a day during the cultivation process before the feed/pellet is given. The amount of feed is 100 m3 of the total WWTP volume of 6,988 m3 at the height of 10 cm from the pond 2.0 m with an area of ponds 1,000 m2 of 3 super intensive farm plots that operate. Schedule of water sampling is carried out once a week or every Tuesday in ± 5 hours, starting from 08.00 WITA until 11.00 WITA. At first, the wastewater is collected in the pond's central drain or pond sludge pool. After that, it will come out in the collector drain or sewer collection channel leading to the super-intensive pond's sewage treatment plant (WWTP). The research sample is taken at the final discharge/effluent of each treatment installation, such as a monitoring sample pool. Water samples are taken three times as replicates, or each volume was 1 L/1000 mL for approximately six observations of a weekly nature to prevent error data testing results.

- **Sampling Technique**
  In general, water sampling techniques refer to section 59-the standard method of water and wastewater sampling (BSNI-979-786-012-4: 2008) taken from several points in one location at different times, with the same volume. The following is a technique for taking samples of super-intensive shrimp pond wastewater for water quality testing.
  - Prepare a water sampling device following ex-situ and in-situ measurements.
  - First, take a rinse tool/bottle with water samples to be made, 3 (three) times.
  - For ex-situ (laboratory) measurements, a sample of water is taken by the purpose of the analysis (while closing the bottle before rising on the surface to avoid oxygen contamination). Then, it mixes in a temporary container (1 Liter sampling bottle), then homogeneous;
  - Put it in each container that suits the designation analysis;
  - For in-situ (field) measurements, do tests immediately for parameters of temperature, salinity, pH, and dissolved oxygen (DO) that can change quickly and cannot be preserved;
  - a special notebook for in-situ measurements is a tool used to test parameter in the field;
  - Sampling for testing parameters in the laboratory was carried out preservation stored in a cool box.

2.4. Biological/bioassay test

Medium-term bioassay or bioassay exposure time (LC50-96 hours), e.g. the ability of test animal organisms to kill lethal concentrations of 50% of organisms exposed for 96 hours or 4 days according to [6] the American Standard Methods for the Examination of Water and Wastewater Public Health Association (APHA).
Table 1. Biological/bioassay analysis methodology in situ.

| Bio-indicator Types | Number of Commodities | Analysis Methodology | Location |
|---------------------|-----------------------|----------------------|----------|
|                     | Clean Reservoir | Wastewater Reservoir | Instrument | Material |
| Shrimp              | 30           | 30                   | DO-Meter, Thermometer, pH | Wastewater (test) and raw water (control) samples |
| Tilapia Fish        | 30           | 30                   | pH Solution, Refractometer, | In-Situ |
| Mullet Fish         | 30           | 30                   | 1 Set of Aerator, Aquarium |

\[
\% \text{ Survival Rate (SR)} = \frac{A_{first} - A_{end}}{A_{first}} \times 100\% \tag{1}
\]

Where,
- Survival Rate (SR) = Animal Survival Test (%)
- \(A_{first}\) = Number of Preliminary Test Animals
- \(A_{end}\) = Number of Final Test Animal

2.4.1. Evaluating the effectiveness of WWTP performance ex-situ research. Evaluating the effectiveness of WWTP by calculating [7,8] the level of success achieved from a building's ability to reduce wastewater contaminant, so that it can approach the standard criteria allowed.

\[
\% \text{ Efficiency of WWTP} = \frac{(A-B)}{A} \times 100\% \tag{2}
\]

Where,
- \(A\) = Level of Influent parameter (inlet)
- \(B\) = Level of Effluent parameter (outlet)

The optimum standard of environmental sanitation in accordance with the WWTP technical guidelines by the Indonesian Ministry of Health in 2011 [9] and Metcalf & Eddy [8] states that the level of WWTP efficiency is classified as follows:
- Very efficient : \(x > 80\%\)
- Efficient : \(60\% < x \leq 80\%\)
- Efficient enough : \(40\% < x \leq 60\%\)
- Less efficient : \(20\% < x \leq 40\%\)
- Inefficient : \(x \leq 20\%\).

2.4.2. Evaluate the Bioassay / Bioassay test in-situ. Wastewater quality on test animals exposed for 96 hours/4 days that have been contaminated by the toxicity of aquaculture. Wastewater concentration through biological tests/bioassay tests using aquatic test animals, with reference to government regulations Decree of the Minister of Maritime Affairs and Fisheries Number: KEP.28/MEN/2004 concerning Quality Standards for Shrimp Pond Effluents [10] and the attachment No.3 KepmenLH 51 Year 2004 concerning Quality Standards for Sea Water Quality for Sea Biota [11].
3. Results and discussions

3.1. Performance of Super Intensive Pond Water Treatment Plant (WWTP)

Table 2 shows recapitulation of data for all types of critical parameters such as supporting settings, additional parameters for the field (in-situ), and laboratory (ex-situ) super intensive pond wastewater quality.

Based on Table 2, the average of laboratory analysis results (ex-situ) and field (in-situ) in the period May-June 2016 is the analysis results from the measurement at the control points of water reservoirs are relatively low such as temperature, pH, and DO parameters. Thus, the analysis results of salinity, TSS, TN, PO₄, BOD, TOM, and the total of bacteria are relatively high. The result also shows the tendency of an increase of pattern at the influent point in the sedimentation pond.

Based on the environmental quality standard of the water, the results of field measurements (in-situ) are the temperature conditions and the changes in the thermometer was 29.05°C at the influent point and 29.46°C at the effluent point of WWTP. Thus, in general, the average temperature produced is still at optimum temperature in the environment ranging from 27°C to 32°C [12, 13]. The results of salinity analysis at the influent and effluent points of WWTP were 39.34‰ and 38.80‰, respectively. It proves that the salinity result is still at the optimum level of concentration. As a result, the biota living in the seawater ecosystem is still able to adjust. The survival of marine biota is because of the osmotic pressure from the environment with optimum salinity ranging from 30‰ - 50‰. It is also classified based on the level of salinity of the type of saltwater [14].

Table 2. Results of measurements of in-situ and ex-situ super intensive ponds for the period May-June 2016

| Parameters       | Raw Water of TSI | Influent of WWTP | Effluent of WWTP | Threshold | Test Location |
|------------------|------------------|------------------|------------------|-----------|---------------|
| Temperature - (oC) | 29.36            | 29.05            | 29.46            | (27 oC - 32 oC) | In-situ       |
| Salinity - (%o)  | 37.24            | 39.34            | 38.80            | (30‰ - 50‰) | In-situ       |
| pH               | 8.82             | 8.40             | 8.72             | 6.0-9.0   | In-situ       |
| DO - (mg/L)      | 6.86             | 5.27             | 6.35             | >5        | In-situ       |
| TSS - (mg/L)     | 23.3             | 145              | 53.1             | <200      | Ex-situ       |
| TN - (mg/L)      | 0.15             | 4.9              | 1.97             | <4.0      | Ex-situ       |
| Phosphate (PO₄) - (mg/L) | 0.25             | 4.50             | 1.84             | <0.5      | Ex-situ       |
| BOD - (mg/L)     | 4.92             | 19.54            | 7.02             | <45       | Ex-situ       |
| TOM - (mg/L)     | 49.63            | 68.02            | 57.52            | <50       | Ex-situ       |
| Total Bacteria - (CFU/mL) | 10³              | 10⁴              | 10⁴              | <108      | Ex-situ       |

Meanwhile, the pH of super-intensive pond wastewater was 8.40 units of pH at the influent point, and the effluent was 8.72 pH units. This condition of pH in the effluent point of WWTP super intensive pond is still suitable for aquatic biota that is tolerant of the pH in the range between 6.5-8.5 [15, 16]. The average pH resulting in the water was > 7 pH means that the condition of the water was more likely alkaline [17]. The dissolved oxygen (DO) parameter at the influent point was 5.27 mg/l, and at the effluent point, it contained 6.35 mg/l. An increase of dissolved oxygen indicates that the process of mechanical aeration system performance in the wastewater treatment continuously has a positive impact on the ecosystem environment, mainly marine biota.
Based on the results analyzed in the laboratory at the effluent point in the biocontrol pond, the Total Suspended Solid (TSS) parameter is 53.1 mg/l, followed by Total Organic Matter (TOM) is 57.52 mg/l. While Bio-Chemical Oxygen Demand (BOD) is 7.02 mg/l, Total Nitrogen (TN) and Total Phosphate (TP) is 1.97 mg/l and 1.84 mg/l, respectively. Also, the total bacteria is 104 CFU/mL.

Based on the analysis from in-situ and ex-situ evaluation, it is shown that the results are still below the quality standards of the optimum normal of an environment. Those parameters are temperature, salinity, pH, dissolved oxygen (DO), Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), Total Nitrogen (TN), Total Bacteria, are still within the tolerable limit. Besides, for the parameter phosphate (PO₄) and total organic matter (TOM), it is always above the quality standard. However, the results obtained are not too far from the value of the size limit that is tolerated by environmental regulations.

### 3.2. Performance effectiveness of key parameters of super-intensive pond water treatment plant

Assessment of WWTP efficiency levels on the physical ability of WWTP in treating wastewater is shown in the following table 3. The evaluation is based on optimum environmental sanitation standards according to WWTP technical guidelines set out by the Indonesian Ministry of Health in 2011 for parameters (TSS, TOM, BOD, TN, Phosphate) and optimum standards allowed by the Ministry of Environment No. 51 of 2004 (DO, pH). The effectiveness of the performance of the critical parameter in the Super Intensive Pond Wastewater Treatment Unit and figure 1 about recapitulation of the effectiveness of the essential parameters at the influent and effluent points of the WWTP based on the characteristics of the super-intensive pond wastewater.

**Table 3.** The effectiveness of the performance of critical parameters in the super intensive pond wastewater treatment plant.

| Parameters          | Effectiveness of WWTP (%) | Influent of WWTP | Effluent of WWTP | Raw Water of TSI | Optimum Efficiency Standards for WWTP (%) | Level of WWTP Efficiency |
|---------------------|---------------------------|------------------|------------------|------------------|------------------------------------------|--------------------------|
| pH                  | 3.67                      | 8.40             | 8.72             | 8.82             | (x<20)                                    | Efficient enough         |
| DO-mg/l             | 17.01                     | 5.27             | 6.35             | 6.86             | (x<10)                                    | Efficient                |
| TSS-mg/l            | 63.4                      | 145              | 53.1             | 23.3             | 60 < x = 80                              | Efficient                |
| TN-mg/l             | 60                        | 4.9              | 2                | 0.15             | 60 < x = 80                              | Efficient                |
| Phosphate (PO₄)-mg/l| 59.21                     | 4.50             | 1.84             | 0.25             | 40 < x = 60                              | Efficient                |
| BOD-mg/l            | 64.07                     | 19.54            | 7.02             | 4.92             | 60 < x = 80 x = 80                       | Efficient                |
| TOM-mg/l            | 15.45                     | 68.02            | 57.52            | 49.63            | < 20                                      | Inefficient              |

Based on table 3, the performance improvement of key parameters in the Super Intensive Pond Wastewater Treatment plant (WWTP) for the period May-June 2016 is ± >60%. It means that the percentage of efficiency in terms of the production process of the WWTP building to the process of super-intensive pond wastewater is efficient [8]. Based on the evaluation [9], the average parameters that effectively treat super-intensive wastewater is total suspended solids (TSS), Total Nitrogen (TN), Phosphate (PO₄), and oxygen demand biochemistry (BOD). The parameters are in the range of 60% <x = 80%, which is efficient. On the other hand, Total Organic Material (TOM) is not efficient (x<20) in reducing organic matter such as carbon (C), hydrogen (H), and oxygen (O). Nitrogen (N) has been fermented through the process of waste mineralization. Inefficient for TOM parameters is because of the internal factors such as electricity disturbance and oxygen content in the water. Oxygen content in the water can decrease the rate of decomposition of organic matter aerobically because it requires oxygen supply continuously. Therefore, mechanical aerators do not balance. Only 1-2 HP shows it to the presence of water quantity and the amount of organic matter. As for the pH, parameters is 3.67% and DO 17.01% (x => 10%), tend to be an efficient enough to improve the concentration of
super-intensive pond wastewater quality under the optimum standards allowed by the Ministry of Environment No.51 of 2004.

Based on figure 1, the effectiveness of the vital parameter's performance at the influent point in the sedimentation pond is relatively high. It indicates to decrease the concentration at the end of effluent in the biocontrol pond. The high value of the effectiveness of WWTP buildings’ performance is an indication of the quality improvement in the water. The efficiency of WWTP to reduce the BOD parameter is 64.7%. It is the same as 12.52 mg/L levels of organic matter needed by aerobic bacteria in transforming the labile organic compounds into stable organic compounds through the process of respiration [19]. Followed by the highest levels, the efficiency of WWTP of Total Suspended Solids (TSS) is 63.4%. It is the same as 91.9 mg/L of total suspended solids, both suspended organic matter (phytoplankton and zooplankton, bacteria, and particles of organic matter) and suspended inorganic materials (sand refined) and sludge dissolved in super-intensive pond waste [20]. Then, the Total Nitrogen (TN) efficiency is 60% or 2.9 mg/L of total nitrogen, coming from concentrations of feed levels that are not consumed. The wastewater is rich in protein, acids amino, urea, and excretion formed. Then the levels of Phosphate (PO₄) are 59.21% or 2.66 mg/L, which is formed by phosphorus levels such as organic phosphates contained in super-intensive pond wastewater. It is an essential nutrient in the growth of aquatic animals and plants that affect the level of productivity of a marine [17]. Meanwhile, the effectiveness value of the total organic matter (TOM) parameter is 15.45% or as much as 10.5 mg/L of entire organic matter including carbon (C), hydrogen (H), Oxygen (O) and Nitrogen (N) from the composition plant and animal tissue.

![Figure 1](image-url)

*Figure 1.* Recapitulation of the effectiveness of the performance of critical parameters at the influent and effluent points of WWTPs based on the characteristics of super-intensive pond wastewater.

For the parameters of pH and dissolved oxygen (DO) are inversely proportional to the previous settings. The parameters tend to increase to the effluent point of WWTP super intensive ponds or fluctuating depending on changes in natural water conditions. For example, there is a change in the effectiveness of pH parameter, which is 3.67% or 0.32 pH units, while the efficacy of dissolved oxygen (DO) levels is 17.01%.

It is permissible to the changes in pH level <0.2 pH unit while the optimum conditions allowed for dissolved oxygen (DO) level is >10% [11]. The statement has fulfilled the levels of dissolved oxygen when adding oxygen from WWTP mechanical equipment or diffusion from the atmosphere. Whereas for pH parameters, it is still above 0.1 pH units, the pH change that is allowed from the limit tolerated by the Decree of the State Minister of the Environment.
Therefore, based on the evaluation results of the effectiveness of super-intensive pond WWTP performance, it can be concluded that the smaller the concentration of wastewater and pollution load from the effluent point, the higher the percentage rate of effectiveness of the test results and the more efficient the physical unit’s ability to super-intensive pond waste treatment vice versa.

3.3. Super intensive pond wastewater effluent bioassay

Based on Table 4, the results of total Bioassay Test Animal survival rate (SR) is 100% survival rate of test animal is still able to withstand the toxic concentration contained in the final effluent of super-intensive wastewater pond with the exposure for 96 hours (4 days) in the medium. There are 90 test animals used as biological indicators are declared to be still in good condition. It indicates that the quality of wastewater for super-intensive shrimp ponds is relatively good condition and is safe to be discharged into water bodies (coastal and marine areas). It is also moderately effective in reducing organic matter and high nutrients from aquaculture disposal activities.

| Commodity          | Weight (gr/tail) | Number of fish/shrimps | Exposure Time (hours) | Survival Rate (SR) |
|--------------------|------------------|-------------------------|-----------------------|--------------------|
| Mullet Fish        | 1.695            | 30                      | 24 48 72 96           | 90% of 100%        |
| Tilapia Fish       | 9.68             | 30                      | 24 48 72 96           | 90% of 100%        |
| Vaname Shrimps     | 2.28             | 30                      | 24 48 72 96           | 90% of 100%        |
| Total Bioassay Test Animals |          |                         | 90% of 100%            |

The categories of organism types with low food chain characteristics cultivated in biocontrol ponds function as a biofilter and aquatic adsorbent. The biocontrol can filter and absorb wastewater from the super-intensive pond with high concentration to be low in toxic content. The organism types as bioindicators are tilapia, milkfish, baronang fish, seaweed, and drought. As a result, the water is free of poisonous substances that can potentially damage the marine biota ecosystem if there is no special treatment before turning to the water body.

4. Conclusions

1. Based on the excellent standard of environmental sanitation under the WWTP technical guidelines by the Ministry of Health of 2011, the percentage of effectiveness tends to decrease the concentration or efficient enough to reduce the pollutant (60%<x=80%). For TSS parameters is 63.4%; TN is 60%; Phosphate (PO₄) is 59.21%; BOD is 64.07%. only TOM parameter is inefficient (x = <20%), which is 15.45%. Meanwhile, the evaluation of pH parameter based on the optimum standard allowed by the Ministry of Environment No.51 of 2004 is 3.67% (x = <20%) and DO 17.01% (x => 10%). It indicates that it tends to increase the level of pH and DO but be efficient enough to improve concentration pond intensive wastewater quality.

2. Based on the results of laboratory analysis (ex-situ), the average key parameters of the study are under the Decree of the Ministry of Environment and the Ministry of Maritime Affairs and Fisheries Number: KEP28 / MEN / 2004 concerning Quality Standards for Shrimp Pond Effluents. However, for the parameters PO₄ and TOM is still above the required environmental quality standards, assuming, in general, the wastewater is safe and feasible to dispose of water (coastal and marine).

3. Survival rate (SR) of test animals through bioassay tests shows that there are 100% of the right conditions of the animal tested for the medium term for 96 hours (4 days). According to the Standard Methods for the Examination of Water and Wastewater, according to the American Public Health Association (APHA), 1976, it is safe to be discharged into water bodies (coastal and marine areas) and should be recirculated as raw water for cultivation activities.
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