PROCEEDINGS

The 4th ASEAN Environmental Engineering Conference

Editors
Istiarito
Henricus Priyosulistyo
Sunjoto

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Editors
Istiarto
Henricus Priyosulistyo
Sunjoto

Reviewers
Henricus Priyosulistyo
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Nakatsuji Takashi
Sunjoto
Marilou Dalida
Budi Santoso Wignyosukarto
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Website: http://tsipil.ugm.ac.id
E-mail: jurusan@tsipil.ugm.ac.id
Tel: +62-274-545675
Fax: +62-274-545676

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PREFACE

The Department of Civil and Environmental Engineering, Universitas Gadjah Mada, in collaboration with AUN/SEED-Net, is proudly organizing the 4th ASEAN Civil Engineering Conference (ACEC) and the 4th ASEAN Environmental Engineering Conference (AECC) in Yogyakarta on 22-23 November 2011 under the auspices of JICA. The joint conference provides forum for engineers and researchers in the region to collect and disseminate current issues in technology and researches in the field of civil and environmental engineering. The joint conference is part of a continuing series of regional conferences. Previous conferences were held in Thailand (1st ACEC, 2009) and The Philippines (1st AECC, 2009), Laos (2nd ACEC, 2010) and Indonesia (2nd AECC, 2009), and The Philippines (3rd ACEC and AECC, 2010).

More than eighty papers from twelve countries (Brunei Darussalam, Cambodia, Indonesia, Iran, Japan, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam) are presented in this joint conference. The papers are grouped in various topics, namely structural and material engineering, construction engineering and management, transportation engineering, geotechnical engineering, water resources engineering, disaster mitigation, green infrastructure, water quality and management, wastewater treatment, air quality management, climate change model, adaptation and mitigation, eco-hydraulics modeling. The papers are compiled in two volumes. This proceeding is the second volume containing papers topics related to environmental engineering to be presented in AECC whereas the first volume contains paper topics related to civil engineering to be presented in ACEC.

The organizing committee would like to extend its deepest gratitude to all participants who have contributed their papers and all parties involved throughout the conference without which this conference would not have been a success. The organizing committee wishes all participants a fruitful discussion during the conference and an enjoyable stay in Yogyakarta.

Yogyakarta, 22 November 2011

Dr. Istiarto
Chairperson of the Organizing Committee
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Wastewater Treatment Plant Design Software Development with Borland Delphi 7.0

F. S. Arumdhati and Nizam
Department of Civil and Environmental Engineering, Universitas Gadjah Mada, Yogyakarta, Indonesia

Abstract: Lack of standardized wastewater treatment facility, caused pollution by wastewater which did not managed properly into clean water resources. Wastewater treatment system design process is a complex process and full of meticulous detail, this makes the design process difficult and exhausting to be done. Software development is one of alternatives to make standardized wastewater treatment facility easy to be designed. The software is developed using wastewater treatment system design method from available literature, in this case literature composed by Metcalf & Eddy, Shun Dar Lin, and Sri Puji Saraswati is used. The method is chosen based on the clarity of the basic theory and the availability of input range suggested. Wastewater Treatment Plant unit process and unit operation that available is only for wastewater with degradable organic constituent. Design process involves 32 tables, 10 graphs, and 203 equations. The software is developed using Borland Delphi 7.0 and Microsoft Access. Software calibration is held by comparing the software output with the manual calculation result. Calibration process gives maximum error at 2.222 %, minimum error at 0 %, and average error at 0.079 %. The software is tested to 4 Bachelors and 7 students from Department of Civil and Environmental Engineering.

Keywords: wastewater treatment plant, software, development

1 INTRODUCTION

Water is one of the basic human needs. The reduced availability of clean water is clearly a problem that really needs to be considered for the sake of human survival. There are many things that cause the decrease in water availability. One of the causes of declining availability of water is polluted water sources due to lack of good management of wastewater.

Lack of clean water availability could occur due to declining quality of water resources due to pollution. Waste disposal that was not managed properly, clearly have direct negative impact on the environment. With such a situation, proper Wastewater Treatment Plant clearly becomes a necessity.

However, Wastewater Treatment Plant design has many considerations that must be fulfilled. Here are the steps for the design of Wastewater Treatment Plant (Saraswati, 2000);

a) Forecast the wastewater flowrates and constituent loading of the treatment system in the future.

b) Look for some treatment system alternatives that can possibly be used and some site alternatives.

c) Do the preliminary design for the most suitable alternative to be implemented. Preliminary design is conducted after the standard of wastewater effluent is determined.

Things to do in the preliminary design are as follow; solid balance analysis, hydraulic profile analysis, and determine the unit reactor dimension, pumping requirement etc. Calculation for unit reactor capacity and dimension is conducted after design criteria have been determined. The design criterias are determined from pilot plant and bench test, theoretical design criteria from the literature, or from the designer’s experiences.

d) Do the final design of the selected alternative, by: selecting the tools that will be used, piping and pumping design, instrumentation and control, electrical and mechanical, laboratory, maintenance tools, and operational manual.

Plant layout drafting, technical specification, and cost estimation calculation will complete the final task of Wastewater Treatment Plant design process.

Complex processes that involved in the design of wastewater treatment plant obviously require precision and accuracy in the design process, especially in unit reactor design process. This task makes the designer needs to work with so many design criteria, equations, and standards. Design tools such as computer software, obviously very helpful in this design process.
2 WASTEWATER TREATMENT SYSTEM AND DESIGN

2.1 Watertreatment Systems

Lin (2007), Metcalf & Eddy, Inc. (2003), and Saraswati (1996) are classifying wastewater treatment into three major categories: (1) primary (physical process) treatment, (2) secondary (biological process) treatment, and (3) tertiary (combination of physical, chemical, and biological process) or advanced treatment. Each category sometimes includes previous treatment device (preliminary), disinfection, and sludge management (treatment and disposal).

2.1.1 Preliminary Treatment Systems

Preliminary treatment systems are design to physically remove the larger suspended or floating material, and to remove the heavy inorganic solids and excessive amount of oil and grease. Preliminary treatment purpose is to protect pumping equipment and the subsequent treatment units. Examples of Preliminary treatment systems are screening, comminuting devices, grit chambers, flow equalization, and mixing & flocculation.

2.1.2 Primary Treatment Systems

The objective of primary treatment systems is to reduce the flow velocity of the wastewater sufficiently to permit suspended solids to settle. Thus, a primary treatment device may be called a settling tank (basin) or primary sedimentation tank (basin).

2.1.3 Secondary Treatment Systems

Secondary treatment is used to remove the soluble and colloidal organic matter which remains after primary treatment. Secondary treatment consists of application of a controlled natural process in which a very large number of microorganisms consume soluble and colloidal organic matter from wastewater in a relatively small container over a reasonable time. There are two types of secondary treatment; attached (film) growth such as trickling filter, and suspended growth such as activated sludge, ponds, and lagoons.

2.1.4 Advanced/Tertiary Treatment Systems

Advanced wastewater treatment is defined as the methods and processes that removed more contaminants from wastewater than the conventional treatment.

2.1.5 Disinfection

Disinfection refers to the partial destruction of disease-causing organism. Physical disinfectants that can be used are heat, light, and sound waves.

Disinfection with chlorine is example of disinfection process using chemical feeding, and tertiary ponds, also called polishing or maturation ponds, are relatively shallow ponds which use the sunlight as disinfectant.

2.1.6 Sludge Management

The solids and biosolids (formerly collectively called sludge) resulting from wastewater-treatment operations and processes are needed to be managed. The management of biosolids consists of their processing, reuse, and disposal.

Wastewater Treatment Plant unit processes and unit operations that available in the software are only for the wastewater treatment system with degradable organic constituent.

2.2 Design Consideration

Here are the design consideration for the unit process and unit operation that available in the software.

2.2.1 Wastewater characterization

Here are the wastewater characteristics that will be considered in the design process;

a) Discharge

Wastewater discharge is the main consideration for wastewater treatment plant design and in activated-sludge process wastewater discharge is affecting the number of aeration tank.

b) Temperature

Wastewater temperature affects on reaction rate, water specific weight, density, dynamic viscosity, kinematic viscosity, and also BOD removal efficiency in biological treatment process.

c) Hydrogen-Ion Concentration – pH

Nitrification is pH-sensitive and rates decline significantly at pH values below 6.8.

d) Alkalinity

Alkalinity in wastewater results from the presence of hydroxides [OH⁻], carbonates [CO₃²⁻], and bicarbonates [HCO₃⁻] of elements such as calcium, magnesium, sodium, potassium, and ammonia.

2.2.2 Wastewater Constituent

Wastewater constituent shows wastewater quality. Wastewater constituent which used in wastewater treatment plant design are BOD (total 5-d biochemical oxygen demand), sBOD (soluble 5-d biochemical oxygen demand), COD (total chemical oxygen demand), pCOD (particulate chemical oxygen demand), sCOD (soluble chemical oxygen demand), bpCOD (biodegradable particulate chemical oxygen demand), TKN (total Kjeldahl nitrogen), TSS (total...
suspended solid), VSS (volatile suspended solid), and nbVSS (non-biodegradable volatile suspended solid).

2.2.3 Environmental Condition
Here are the environmental condition that will be affect the wastewater treatment system;

a) Site Altitude
Atmospheric pressure is changing with elevation. Elevation is also affecting oxygen solubility correction factor for mechanical aerators with horizontal axis.

b) Air Temperature
Air temperature is affecting air density, dissolved-oxygen concentration in water, liquid temperature in suspended growth aerobic flow-through lagoon.

2.2.4 Aeration System
Aeration system will affect the power requirement or the airflow rate to fulfill the oxygen demand.

2.2.5 Bacterial Characteristic
Bacterial characteristic is provided as kinetic coefficient for the activated-sludge process.

3 DEVELOPMENT SEQUENCE

3.1 Literature Study
Software development starts with searching and collecting for wastewater treatment system design method in the available literature, in this case literature composed by Metcalf & Eddy, Shun Dar Lin, and Sri Puji Saraswati are used. The method is chosen based on the clarity of the basic theory and the availability of input range suggested.

3.2 Calculation Sequence
From the chosen methods, calculation sequence is made to understand the calculation flow.

3.3 Graph Interpretation into Equation or Table
Every graph that involve in the calculation process is interpreted into equation or table to simplify the graph interpretation in the software.

3.4 Manual Calculation
Manual calculation was conducted to verify the software calculation and understand the equation behavior without considering field conditions, and synchronization between unit process and unit operation. It is conducted for each calculation method, not only for each unit process and unit operation, so it is conducted for 27 calculation methods.

3.5 Software Design and Algorithm
The software is designed to be user friendly and easy to understand, and software algorithm is designed as easy as possible to be coded.

3.6 Database Making using Ms. Access
The database is made based on the graph interpretation using Microsoft Access.

3.7 Software Development Process using Borland Delphi 7.0
After the design and the algorithm are fix, the software is developed with Borland Delphi 7.0 and integrated with the database.

3.8 Software Calculation
Software calculation is conducted for each calculation method, not only for each unit process and unit operation, similar with manual calculation.

3.9 Calibration the Software Calculation with the Manual Calculation
Software calibration is held by comparing the software output with the manual calculation result. Calibration is done only to software output for user, not to every calculation step in the design process. This calibration is conducted for each calculation method, not only for each unit process and unit operation, so it is conducted for 27 calculation methods with 304 output items. If the software calculation is not satisfactory, then back to the software development step.

3.10 User Test
To find out how easy this software to used, the software is tested to 4 Bachelors and 7 students from Department of Civil and Environmental Engineering as user candidate for interface test.

4 COMPUTER PROGRAMMING

4.1 Borland Delphi
Delphi is a Windows application development software that published by Borland International. Delphi was developed from Pascal computer programming. On database handling, Delphi provides facilities that enable the software to interact with database like dBase, Paradox, Oracle, MySQL, and Ms. Access. (Pranata, 2003)

4.2 Database Programming
Microsoft Access is one example of Relational Database Management System (RDBMS) that is very famous in the PC environment. In this database
model, each table consists of rows/records and columns/fields, and any data therein can be connected with data in other table. (Kadir, 2009)

4.3 Software Specification

The software is named as ISYA WastePlant 1.0 – Wastewater Treatment Plant Design. Software development and calculation is using International Unit, and the number format is using international number format, period (.) for decimal symbol, and comma (,) for digit grouping symbol. The software capability is shown in the following table.

Table 1. Software capability

<table>
<thead>
<tr>
<th>Unit process and unit operation</th>
<th>Type</th>
<th>Design process</th>
<th>Sketching</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse Screen</td>
<td>Standard hydraulics calculation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>– Metcalf &amp; Eddie, Sri Puji</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Saraswati</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grit Chamber</td>
<td>Metcalf &amp; Eddie, Sri Puji</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Saraswati</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Metcalf &amp; Eddie</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Metcalf &amp; Eddie</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Metcalf &amp; Eddie</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Flow Equalization</td>
<td>Metcalf &amp; Eddie, Shun Dar Lin</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Mixing and Flocculation</td>
<td>Metcalf &amp; Eddie</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>U.S. EPA</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>U.S. Ten Standard</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Steel &amp; Me Ghee</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Peavy et al</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sedimentation</td>
<td>Metcalf &amp; Eddie</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>U.S. EPA</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>U.S. Ten Standard</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Steel &amp; Me Ghee</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Peavy et al</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Trickling Filter</td>
<td>National Research Council</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Shun Dar Lin</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Metcalf &amp; Eddie</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Activated-Sludge</td>
<td>Metcalf &amp; Eddie</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>CMAS (BOD removal only)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CMAS (BOD removal and nitrification)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SBR (BOD removal only)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SBR (BOD removal and nitrification)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Staged Reactor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ponds</td>
<td>Metcalf &amp; Eddie</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Areal Loading Rate Method</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Welner and Wilhelm Equation</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Shun Dar Lin</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Shun Dar Lin</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Lagoons</td>
<td>Metcalf &amp; Eddie</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td></td>
<td>Aerobic Flow Through With Partial Mixing Lagoons</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aerobic with Solids Recycle and Nominal Complete Mixing Lagoons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disinfection with Chlorine</td>
<td>Metcalf &amp; Eddie</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Tertiary Ponds</td>
<td>Shun Dar Lin</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

5 CALCULATION & ANALYSIS

5.1 Calculation Comparison

Software performance is shown by the error in calculation comparison between the manual calculation and software calculation. The calculation comparison is conducted for 27 calculation methods with 304 output items. In the following table, maximum and minimum error in every calculation method are shown.
Table 2. Error in the software calculation

<table>
<thead>
<tr>
<th>Unit process and unit operation</th>
<th>Type</th>
<th>Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Max</td>
</tr>
<tr>
<td>Coarse Screen</td>
<td>-</td>
<td>0.654</td>
</tr>
<tr>
<td>Grit Chamber</td>
<td>Rectangular horizontal-flow</td>
<td>0.032</td>
</tr>
<tr>
<td></td>
<td>Square horizontal-flow</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Aerated</td>
<td>0.000</td>
</tr>
<tr>
<td>Flow Equalization</td>
<td>-</td>
<td>0.000</td>
</tr>
<tr>
<td>Mixing and Flocculation</td>
<td>Mixing with Static In-Line Mixers</td>
<td>0.131</td>
</tr>
<tr>
<td></td>
<td>Mixing with Turbine and Propeller Mixers</td>
<td>0.053</td>
</tr>
<tr>
<td></td>
<td>Flocculation with Paddle Mixers</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>Flocculation with Turbine-Type and Propeller-Type Mixers</td>
<td>0.087</td>
</tr>
<tr>
<td></td>
<td>Flocculator-Clarifier</td>
<td>0.001</td>
</tr>
<tr>
<td>Sedimentation</td>
<td>-</td>
<td>0.010</td>
</tr>
<tr>
<td>Trickling Filter</td>
<td>National Research Council method</td>
<td>1.587</td>
</tr>
<tr>
<td></td>
<td>Shun Dar Lin method</td>
<td>0.893</td>
</tr>
<tr>
<td></td>
<td>Metcalf &amp; Eddie method</td>
<td>0.595</td>
</tr>
<tr>
<td>Activated Sludge</td>
<td>CMAS (BOD removal only)</td>
<td>0.129</td>
</tr>
<tr>
<td></td>
<td>CMAS (BOD removal and nitrification)</td>
<td>0.504</td>
</tr>
<tr>
<td></td>
<td>SBR (BOD removal only)</td>
<td>1.111</td>
</tr>
<tr>
<td></td>
<td>SBR (BOD removal and nitrification)</td>
<td>2.222</td>
</tr>
<tr>
<td></td>
<td>Staged Reactor</td>
<td>0.000</td>
</tr>
<tr>
<td>Ponds</td>
<td>Facultative ponds with areal loading rate method</td>
<td>0.791</td>
</tr>
<tr>
<td></td>
<td>Facultative ponds with Wehner and Wilhelm equation</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Aerobic ponds</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Anaerobic ponds</td>
<td>0.100</td>
</tr>
<tr>
<td>Lagoons</td>
<td>Aerobic Flow Through With Partial Mixing Lagoons</td>
<td>0.124</td>
</tr>
<tr>
<td></td>
<td>Aerobic with Solids Recycle and Nominal Complete Mixing Lagoons</td>
<td>0.062</td>
</tr>
<tr>
<td>Disinfection with Chlorine</td>
<td>-</td>
<td>0.000</td>
</tr>
<tr>
<td>Tertiary Ponds</td>
<td>-</td>
<td>0.654</td>
</tr>
</tbody>
</table>

5.2 Discussion

5.2.1 Calculation Method

Out of several methods that are available in several literatures, the method is chosen based on the clarity of the basic theory and the availability of input range suggestion. If the available methods are completing each other, that methods are combined. But, when there are any differences, in method or in calculation base, software will provide calculation option, so users will be able to choose which method or which calculation basic they prefer.

The accuracy and the effectiveness of the method are left to the authoritative references, the author did not conduct any research on the methods adopted in the software development.

5.2.2 Calculation Process

Calculation process to determined output is done in several ways;

a) Linier calculation process
Definition of linier calculation process is when the calculation process to get the output only involves the input and the available equation, whether calculated directly or needs several steps.

b) Calculation process involving database
For calculation process involving database, figure from the database is needed to be read in calculation process. Figure which needed to read the database is obtained from the input or from the previous calculation process.

c) Calculation process involving iteration process
Iteration process is being used to solve an implicit equation and a circular reference or to find an optimum condition. Simple iteration is enough to solve an implicit equation and a circular reference or to find an optimum condition independently, but in some unit processes several equations need to be solved in a series.
Table 3. Calculation process in the software

<table>
<thead>
<tr>
<th>Form</th>
<th>Linier calculation</th>
<th>Database reading</th>
<th>Iteration process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse Screen</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Grit Chamber - Rectangular horizontal-flow</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Grit Chamber - Square horizontal-flow</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Grit Chamber - Aerated</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Flow Equalization</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Mixing and Floculation</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Sedimentation - Met Calf &amp; Eddie</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sedimentation - U.S. EPA</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Sedimentation - U.S. Ten Standard</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sedimentation - Steel &amp; Mc Ghee</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Sedimentation - Peavy et al</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Trickling Filter - National Research Council</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Trickling Filter - Shun Dar Lin</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Trickling Filter - Met Calf &amp; Eddie</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Activated-Sludge - CMAS (BOD removal only)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Activated-Sludge - CMAS (BOD removal and nitrification)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Activated-Sludge - SBR (BOD removal only)</td>
<td>✓</td>
<td>✓</td>
<td>✓ (2)*</td>
</tr>
<tr>
<td>Activated-Sludge - SBR (BOD removal and nitrification)</td>
<td>✓</td>
<td>✓</td>
<td>✓ (3)*</td>
</tr>
<tr>
<td>Activated-Sludge - Staged Reactor</td>
<td>✓</td>
<td>✓</td>
<td>✓ (2,4)*</td>
</tr>
<tr>
<td>Ponds - Facultative ponds with areal loading rate method</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Ponds - Facultative ponds with Wehner and Wilhelm equation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Ponds - Aerobic ponds</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Ponds - Anaerobic ponds</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Lagoons</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Disinfection with Chlorine</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Tertiary Ponds</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

* The number of the iteration stages.

5.2.3 Error in Calculation

Maximum error is 2.222 % which occur in Staged Reactor Activated-Sludge 2nd Stage BOD Loading Rate, minimum error is 0 % which occurs in several points, and the average error is 0.079 %.

Calculation error/difference occurred because of rounding off of figure in every manual calculation steps, but in calculation process using software, the rounding off only being done at the output figures.

Linier calculation process and calculation process involving database has less error then iteration process, because iteration process has more calculation steps.

Minimum error occurred when the output result from linier calculation process. Maximum error in Staged Reactor Activated-Sludge 2nd Stage BOD Loading Rate occurred because this output is a result of linier calculation process, four stages iteration, and then two stages iteration. With relatively small error, this software has been verified to use.

5.2.4 Advantages and Limitations of the Software

Advantages of the Software;

a) Simplifies Wastewater Treatment Plant design process.
As shown in the manual calculation process, the Wastewater Treatment Plant design process involved many table and graph to be considered. By using the software, table interpolations and graph readings are done by the software, what the designer needs to do is to input the parameters that are needed in the calculation processes.

b) Accelerate Wastewater Treatment Plant design process.
Without table and graph interpretation, and the iteration process, Wastewater Treatment Plant design process using this software is definitely faster than manual calculation.

c) Increase the level of detail (meticulousness) and accuracy of Wastewater Treatment Plant design process.
Rounding the calculation result only at the output increased the meticulousness and accuracy of Wastewater Treatment Plant design process.
Limitations of the Software:

a) Variable notation using Greek letter is not available, so this kind of notation is converted into Latin letter.
   Example: \( \mu \) is converted into \( \text{Mu} \).

b) Variable notation using subscript is not available, so this kind of notation is written with similar font size in different row.
   Example: \( k_d \) is converted into \( k \cdot d \).

c) The output can't be saved as a project to be used in some other time.

d) Because the database of the software is using address to access, the software needs to be customized for distribution purpose.

e) Sketching process only produce proportional picture not scaled picture, because Delphi is only capable to draw in integer value.

5.3 User Recommendations

After users test that proceed to 4 Bachelors and 7 students from Department of Civil and Environmental Engineering, all participant state that this software is user friendly and satisfactory. Here are some recommendations from user for further development:

a) Basic theory is available in every unit process and unit operation form, so this software can be used not only for wastewater treatment plant design but also to learns about wastewater treatment plant design.

b) Provide hint for important component in the unit process and unit operation form, such as ‘default’ check box, to ease the software usage.

c) Software development with Indonesian Language, for easier usage.

6 CONCLUSIONS

a) The software simplifies Wastewater Treatment Plant design process by integrating the data base on the literature. It frees the designers from the whole table and empirical graph from the literatures and enables them to concentrate more on the selection and design of the unit processes.

b) The software accelerates Wastewater Treatment Plant design process by accelerating the manual table and graph interpretation, and the iteration process needed. Therefore, it is much faster than manual calculation.

c) The software increases the level of detail (meticulousness) and accuracy of Wastewater Treatment Plant design process by rounding the calculation result only at the output, when doing the manual calculation we tend to round the result in every step of the calculation.

ACKNOWLEDGMENTS

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REFERENCES


Study on The Application of AOD Bioassay; The Preliminary Study on Developing the Method of Determining the River Water Quality Status in Indonesia

Sri Puji Saraswati and Nizam
Department of Civil and Environmental Engineering, Universitas Gadjah Mada, Yogyakarta, Indonesia

Abstract: In order to have an efficient and optimal management of water resources, water quality should be estimated quantitatively in a measurable form, to allow an analytical expression relationship between water quality and external loadings and usages that affects water quality, such as nutrient loading, waste load allocation, intensity of water supply etc. River management often faced with the question of how the water management scenario can result in decrease or increase water quality. Water resources management should be directed not only in the concept of “one river, one plan, one management” that is oriented toward its utilization but also water resources management based on “ecohydraulic” which take into account environmental conservation (biotic & abiotic aspects). There are many methodological approaches used to have quantitative expression of water quality or the methods of determining the single index, status of water quality. One of them used in this research is by using the response of aquatic organism as indicator of water quality i. e Aquatic Organism Environmental Diagnostics (AOD), a bioassay method that was developed initially in Japan. AOD method was applied in some rivers in Yogyakarta during the rainy and dry season. The result shows that the method originally developed in Japan had to be adjusted and further developed according to tropical river condition, especially in Indonesia. As it is known that there is no single method of determining the status of other water quality that can be used universally/globally, it needs special adjustment to the physical, chemical and biological condition in the local environment. In this research AOD water quality variables are examined within the framework of the development of river habitat simulation methods based on ecohypdraulic.

Keywords: solid waste disposal, educopolis, recycle centre, global warming.

1 INTRODUCTION

In order to have an efficient and optimal management of water resources, water quality should be estimated quantitatively in a measurable form, to allow an analytical expression relationship between water quality and external loadings and usages that affects water quality, such as nutrient loading, waste load allocation, intensity of water supply etc. River management often faced with the question of how the water management scenario can result in decrease or increase water quality. Water resources management should be directed not only in the concept of “one river, one plan, one management” that is oriented toward its utilization but also water resources management based on “ecohydraulic” which take into account environmental conservation (biotic & abiotic aspects).

Parameters currently used to monitor river water quality is still limited to conventional multi parameters that measure physical (pH, EC, turbidity, etc.), chemical (BOD, nitrite, nitrate, etc.), and biological aspects (coliform, biodiversity index, etc.). While the level of quality of natural water resource is classified based on its utilization, such as industrial water, agricultural water, drinking water, etc., as is regulated in PP No 82/2001. Criteria and quality standard varies for each parameter, depend on the characteristics of each parameter. Results of water quality monitoring are published to the general public and used for planning, program development, and management of river water quality improvement and conservation for its optimal use.

Traditional approach in determining water quality status is by comparing measured water quality parameters with the standard. It is desirable to have a single index of water quality to simplify the monitoring as well as informing the public. Under this framework, there are many methods being developed based on habitat simulation. One of the methods is the aquatic organism environmental diagnostics (AOD). This approach use the response of aquatic organism as indicator of water quality by bioassay test. AOD was developed in Japan by Teiji Kariya (Kariya, T., et.al., 1987). The approach basically measure water toxicity to a target species. Conventional water toxicity test take a lot of time and resource, especially when the trace toxic material has a very small concentration. The AOD method is a quick test to measure the level of water toxicity without directly analyzing the toxic compound. In this research the method is being applied and adapted to measure water toxicity level at Opak and Gadjah Wong streams. Thirty sites had been selected for sampling purpose. As a comparison,
conventional water quality parameter measurement is also conducted concurrently to identify the water quality status based on existing standards. Opak and Gadjah Wong streams received domestic and industrial loads from the surrounding areas.

2 SITE CONDITION

Opak stream where the research was conducted is an upstream section of Opak river flowing pass the city of Yogyakarta to the Indian Ocean. Crossing Yogyakarta Province, there are three river basins, Serang River Basin, Progo RB, and Opak-Oyo RB, all flowing to the Indian Ocean. The catchment area of Serang and Opak-Oyo are within Yogyakarta Province, while part of Progo catchment area is in Central Java. The Opak river flow varies according to the season and the discharge from water springs in the upstream of the river. There are two AWL/Rs measuring Opak river discharge, at Karangsemut (downstream of the merger between Opak and Oyo rivers), and at Kretek (upstream of the merger). Records of discharge measurement at Karangsemut station indicated that the flow of the river varies from 3 to 40 m³/second. The daily discharge of Opak is around 2 – 11 m³/sec in dry season and 13 – 29 m³/sec in rainy season measured at Kretek AWLR (see table 2.) The stream in the study area is intensively used for irrigation. There are many weirs installed along the stream especially in the upper part down to the middle part. The watershed in the upstream is sparsely populated rural area and gradually changes to municipal urban area downstream. Catchment area of Opak River (main river to the estuary) is around 720.866 km². Opak is a meandering river, the main river is ± 70.12 km length, 110 – 170 m width. Catchment area of the Opak River (upstream of Opak River/Opak Hulu) is ± 348.79 km². The hydrological condition based on analysis of daily rainfall data from 1991-1998 (Saraswati, 2000) indicates that the rainy season started in November to April, while the dry season is from May to October. Arboretum of Opak stream is at Merapi’s slope; river flow is dependent on rainfall intensity. In dry season ground water seepage from the permeable soil along the river maintain the river flow. The data from Laboratory of Cartography, Faculty of Geography show that soil type in Opak watershed is regosol and kambisol from volcanic material and the physiographic of the watershed is volcanic slope, sand dunes and alluvial plain.

Table 1. Rainfall intensity (1992-1999) and average flow (1992-1999)

<table>
<thead>
<tr>
<th>Catchment Area</th>
<th>Rainfall in dry season (mm/month)</th>
<th>Rainfall in rainy season (mm/month)</th>
<th>Flow in dry season (m³/sec)</th>
<th>Flow in rainy season (m³/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G. Wong stream at Wonokromo Bantul</td>
<td>20 – 120</td>
<td>220 – 440</td>
<td>0.5 - 5.4</td>
<td>0.7 - 4.1</td>
</tr>
<tr>
<td>Opak river at Seloharjo Bantul</td>
<td>20 – 115</td>
<td>190 – 340</td>
<td>2 – 11</td>
<td>13 - 29</td>
</tr>
</tbody>
</table>


The study area is in Opak river (upstream to merging to the Gadjah Wong stream) with ± 41.72 km length, 4 – 28 m width and 0.0114 slope. Land use in the Opak catchment area is dominated by agriculture, the rest is village, rice field, non irrigated field, trees/forest, plantation, and dry field.

Gadjah Wong Stream where the research was conducted is a tributary of Opak-Oyo basin. All rivers are flowing to the south and discharge to the Indian Ocean. The river flow also depends on the season and the spring availability in the upstream. Rivers in the study area is intensively utilized for irrigation and municipal flushing using weirs installed in the river especially in the upper part down to the middle part. Land conversion to municipal areas in the north is very intensive. The Gadjah Wong Stream was for along time the favorite place for disposal of garbage/sewage/industrial waste of numerous residents and industries located along the stream. In fact this river was also noted for domestic usage as municipal water, irrigation and fishing culture. The length of Gadjah Wong Stream (opak river tributary) is ± 33.265 km in total with the average slope of 0.017, daily discharge fluctuates from 0.47 to 4.54 m³/sec (Dept PU, Proyek Pengembangan dan Pengelolaan Sumber Air, 2001) and river width varies between 2 to 14 m.

In addition to water pollution, most river in Yogyakarta experience rapid bottom degradation (Anonim, 1995/1996) due to extensive sand mining. Bottom degradation had caused many failure to river structures such as weirs, intakes, bridges, etc. Other problem related to the rivers in the region is flooding in some parts of Yogyakarta. River capacity in some region had been restricted due to urban pressure as well as natural phenomena such as depression. To prevent from flooding, some dikes and water gates have been constructed. Three tributaries of Opak (Winongo, Code, and Gadjah Wong) currently under PROKASIH program (clean river program) that has
been started since 1989 and being targeted to improve its water quality from industrial and domestic wastes. The availability of water quality data in a long time series is one of the reason in selecting this river for this study. The location where AOD and other multiparameter water quality parameter samples collected is shown in Figure 1.

![Map of Study Area](image)

Figure 1. Sampling Location in Gadjah Wong & Opak River.

3 RESEARCH METHOD

3.1 Sampling stations

Thirty study stations/sites of water sampling were established at accessible riffle areas above and below possible sources of pollution in Opak and Gadjah Wong river. Physical, Chemical conventional water quality parameters as well as AOD parameter determinations were made at each of sites in 2 periods of dry season and 1 period of rainy season for Gadjah Wong stream and 1 period dry & rainy season for Opak stream.

3.2 Water Quality Sampling & Laboratory Analysis

In this research, both the character of river water (the physical chemical of water quality such as Flow, pH, BOD₅, COD₅₅, etc) will be undertaken 3 times sampling every site at each season (rainy & dry season) for maximum, minimum and average value. The samples were analyzed for basic water quality parameters i.e. temperature, pH, Electric Conductivity, Dissolved Oxygen (DO), BOD₅, Turbidity and Chemical Oxygen Demand (COD₅₅) according to Indonesian National Standard (SNI, 2004) which mostly corresponded to the Standard Method of the American Public Health Association (APHA, 1998). A 1000 ml water were collected at each site along with three of 125 ml dark bottles for DO. To obtain the average values and to observe data variability, the sampling was conducted for three series of sampling day within each season. On site measurement was conducted for water and air temperature using a centigrade thermomenter, pH and Electric Conductivity HACH CO150. All 30 sites sampling were conducted from 7 am to 5 pm. To estimate the stream discharge, depth, width and surface current speed at 3 points were measured and recorded within each site during sampling day. DO is analyzed using yodometric method (azida modification) in accordance with SNI which is the adoption of Wrinkler method from the APHA Standard Method (APHA, 1998). Water turbidity is measured using Lamotte 2020, while COD is analyzed using titirmeric method with K2MnO4 standard solution. During laboratory analysis, the water samples are stored in the refrigerator at 4°C.

AOD test (Kariya et.al., 1987) was conducted by taking water samples. Each sample is 20 liter of water directly collected from the river. The main equipments for the AOD test are a rotary evaporator, cooler, and incubator. 1800 cc water sample filled into a glass flask immersed in the rotary evaporator. The flask is rotated at 60-80 rpm in a solution of 13% isopropil alcohol cooled down to a temperature between -15°C and -30°C. The water sample will gradually freeze inside the flask leaving the soluble material getting more concentrated. The fluid part of the water in the flask will gradually reduce and the concentration of the solution will increase. When the remaining fluid part in the flask is 180 cc, the solution in the water becomes 10 times more concentrated or 1000%. The freezing in the rotary evaporator is controlled to obtain a logarithmic incremental concentration of: 100%, 180%, 320%, 560%, 1000%, and 1800%. One hundred cc of each concentrated solution is poured in a separate petri dish. A bioassay test is conducted in each petri dish using fresh water fishes and shrimps. In the standard AOD method, the fresh water fishes used for the experiment are 2 months old Tanichthyes albonubes weighing around 50 mg each and average length of 15 mm, while the species of fresh water shrimp used is Paratya compressa improvisa with 14-15 mm body length and weigh 21-50 mg. Those two species of fish and shrimp are not common and difficult to find in Indonesia, therefore in the experiment Ciprinus caprio is used for the fresh water
fish and *Macrobrachium rosenbergii* is used for the shrimp. Seven fishes or 7 shrimps were put in each petri dish and kept at 20°C for fish and 25°C for shrimp. As a control a petri dish with destiled water is used. The number of fish/shrimp remain alive is observed and recorded after 0.5, 1, 2, 3, 6, 12, 25, and 48 hours. Dead fishes/shrimps are taken out from the petri dish. At the beginning and end of every experiment, pH and electric conductivity are measured and recorded. The number of living fishes/shrimps are plotted on a semi-logarithmic chart. Toxicity value 48hLC₅₀ is obtained by drawing a line at mortality rate of 50% until it passes the concentration axis (Saraswati S.P., 2005) with LC₅₀ AOD value ranging between 100% – 1800% or in a logarithmic scale between 0 – 5 unit. The higher the toxicity of the water, the lower the AOD value.

4 RESULTS & DISCUSSION

4.1 Physicochemicals Variables

The data collected from the experiments are analyzed using standard statistical analysis to test the validity and reliability of the data and to find outliers. In a data set with several water quality parameters, group of variables often correlate and interdependent. Several variables might represent a certain aspect of the water quality phenomenon in a certain combination. One of the suitable analytical tools to address this issue is multivariate statistical analysis such as the principal component analysis (PCA) (Pielou EC, 1984). PCA is used to simplify the structure of the water quality variables that have been collected that can be used to explain the condition of the river water quality. The method can also be used to indicate the dominant variables that can describe the water quality condition of the Gadjah Wong stream.

In early PCA analysis of each season in Gadjah Wong stream, the first two axis explained more than 85% and the first axis explained equal or more than 70% of environmental variables and COD, EC and Turbidity had significant positive on the axis. Negative loading was presented by DO at axis 2. Principal Component Analysis then was used to relate the site grouping to the three seasons of temporal changes of water quality/environmental variables. The first two principal component analysis accounted for 81.70% of the variances, with the 59.01 % explained variances by axis 1. The variables EC and turbidity has significant positive loading on the axis 1 while DO has significant negative loading. Significant loadings on axis 2 represented a positive gradient of increasing COD. Structure coefficient of variables measured for the first two components of the PCA was shown in table 1 (Saraswati S.P., 2009). Structure coefficients are the correlation between the origin variable and the principal component. In dry season 2002 site 6 in Gadjah Wong stream was no water therefore excluded from the analysis.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Axis 1</th>
<th>Axis 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC</td>
<td>0.57395</td>
<td>-0.159497</td>
</tr>
<tr>
<td>COD</td>
<td>0.294534</td>
<td>0.917903</td>
</tr>
<tr>
<td>DO</td>
<td>-0.569423</td>
<td>-0.010934</td>
</tr>
<tr>
<td>Turbidity</td>
<td>0.509498</td>
<td>-0.363173</td>
</tr>
</tbody>
</table>

Total variances explained 59.01% 22.69%

4.2 Single Water Quality Index

In general there are 2 groups of water quality index, 1) is the general water quality index and 2) is the specific water quality index. General water quality index has been extensively developed and used such as Ott WQI (water quality indexes) developed in the USA since 1959 (Ott W.R., 1978), Horton WQI in 1965 (Abbasi, 2001), NSFI (National Sanitation Federation Index) developed by Brown et.al. since 1970. NSFI method has been implemented in many countries in Asia and Europe including Indonesia (Samantray P., et.al., 2009, Wills M. and Irvin K.N., 1996, Hendrawan, D., 2005). Specific water quality index were developed for specific usage, such as fish and wildlife habitat index, public water supply index by O'Connor in 1971 using Delphi techniques by collecting expert opinion, Stoner index developed in 1978 for potable water and irrigation, Walksi and Parker in 1974 develop index for recreational water (swimming & fishing) and others (Ott W.R., 1978). There are many methodological approaches used to quantify water quality and determine the status of water quality. However, there is no composite water quality index (WQI) that is universally accepted. Many institutions develop and use different water quality index to represent river condition.

Another way to estimate and represent water quality is by using mathematical model such as DOₕₙ₅ method pioneered by Streeter & Phelps in 1925 (Thomann R.V., Mueller J.A., 1987), waste allocation method developed by Novotny V.(1996), biological response index such as saprobity index using certain species population as indicator, diversity index (such as Shannon-Wiener index) and scoring system (Biological Monitoring Working Party/BMWP Score, Belgian Biotic Index/BBI, and others) (Roosenberg, D.M.and Resh, V.M., 1993), using bioassay method, biomarker in ecotoxicology (Kaiser Jamil, 2001). According to Payne, A.I. (1986) and Dudgeon, D. (1999) the utility
of those indices has been widely used by local investigators for stream habitat/water quality assessment in Indonesian tropical streams, but its applicability is still doubted since some fauna present are typically different to temperate aquatic environments. Therefore it is desirable to establish a water quality index for tropical river quality, especially for Indonesian rivers.

AOD method is based on bioassay for river water conducted in the laboratory (Kariya et al., 1987). This method is relatively inexpensive compared to toxicity analysis and directly related to mortality of aquatic organisms. AOD diagnostics has been applied in many sites such as at Masuda irrigation channel at Natori river, Miragi Prefecture (Saraswati, SP., 2001), and can detect the water quality condition due to the impact from domestic/industrial waste. Water quality parameters measured from EC at the location was 0.18 – 0.36 uS/cm to EC 290 uS/cm (from concentration 1800%). As described earlier, PCA method can be used to indicate the dominant variables that can describe the water quality condition of the Gadjah Wong stream. Based on the statistical analysis, using PCA at Gadjah Wong river, it was found that the most dominant parameter to represent the water quality variability during the wet and dry seasons is the electric conductivity (EC). This parameter is used to relate with the PCA result.

4.3 Electric Conductivity and AOD as a Single Water Quality Indeks

Water quality during the dry season at Gadjah Wong stream has EC value between 160 – 470 uS/cm, poorer than during the wet season where the EC value is between 160 – 370 uS/cm. Opak stream EC values are between 166 – 290 uS/cm during the dry season and between 145 – 315 uS/cm during the wet season. Water quality condition at Opak river during the wet season can be represented by the AOD analysis using fish as the bioassay species. The logarithmic AOD_{fish} value was between 0 – 0.26 (concentration between 100% - 130%), lower than in AOD_{shrimp} during the dry season 0 – 1 (concentration between 100% - 290%) as shown in Figure 3. While the logarithmic scale of AOD_{shrimp} was around 1.4 (300% - 400%), and >1.5 in some samples.

![EC - AOD_{fish} Dry Season, Opak Stream](image)

![EC - AOD_{fish} Rainy Season, Opak Stream](image)

Figure 2. Water quality status (log scale LC50 AOD), at Opak stream during the dry (a) & wet (b) seasons.

During the dry season the stream water quality condition is relatively poor at Gadjah Wong stream with EC 160 – 470 uS/cm (class II based on water quality standard Yogyakarta Government Regulation, 2008). EC concentration variability can not be detected by AOD_{fish}. The toxicity of AOD_{fish} is between AOD 100% to 200%, or equivalent to AOD scale in 0 to 0.69. At that level of AOD concentration, the original water is already lethal for the fish species used as shown in Figure 3a. Water quality parameter variability at EC (160 – 470 uS/cm) can be detected by shrimp bioassay (Figure 3b).

The AOD_{shrimp} water quality values are correlated with EC values, the result is shown in Figure 4. There is a good correlation between the two parameters. Using data from the combined season the R^2 is 0.5251, while during the dry season only the R^2 is 0.7958. The variability of the river water quality and the correlation represent the seasonal variation that affect the stream water quality. During the dry season, the water quality become more steady.

Results from AOD experiment at Gadjah Wong and Opak streams using fish bioassay can detect water quality variation during the wet and dry seasons as can be seen in Figure 1.
Figure 3. Different response of fish (a) & shrimp (b) bioassay AOD during the dry season at Gadjah Wong stream.

Figure 4. Water quality condition AOD_{shrimp} during the dry and wet season at Gadjah Wong.

However, fish bioassay using *Ciprinus caprio* could not distinguish higher concentration of pollution, at EC > 160 uS/cm the water is already too toxic for the fish species to live. Observing this phenomena, the concentration condensation used in the standard AOD method had to be reviewed and adapted for water quality condition in polluted streams. It is proposed to use water dilution to lower the concentration of the toxic solution instead of increasing the concentration for the case of polluted water commonly found in rivers flowing through urban area. Using standard Kariya AOD protocol, AOD value of 100% (0 in logarithmic scale) means the water quality is very poor since the original water is already too toxic for fish to live. Higher level of AOD means the original concentration of toxic material is lower. 1800% AOD means the original concentration had been multiplied 18 times before it is lethal to the fish. In the proposed dilution method, the AOD toxicity index will be reversed.

Although the fish AOD can detect seasonal river water quality, it can not distinguished the water quality variability of highly polluted stream waters. Shrimp AOD can better detect the water quality variable at EC 160 – 470 uS/cm. The bio assay AOD procedure using fresh water shrimp *Macrobrachium rosenbergii* at lower concentration of pollution (EC < 160 uS/cm) has to be further evaluated. It is found in this research, that the shrimp AOD can be used to detect physical and chemical water quality level in the stream as is represented by the abundance of fish species in each sites as observed using PHABSIM/Physical Habitat Simulation (Saraswati S.P, 2005).

5 CONCLUSION

AOD test based on a modified Kariya method has been applied for water quality analysis in 30 sites at Gadjah Wong and Opak streams during dry and wet seasons. At all sampling points, conventional water quality parameter measurement were also conducted such as pH, EC, Turbidity, DO, and COD. The modification of the standard AOD test from Kariya is the species used for the experiment by using local fish species *Ciprinus caprio* instead of *Tanichthyes albonubes* and shrimp species *Macrobrachium rosenbergii* instead of *Paratya compressa impruviosa* that are easier to obtain. The other procedure follows the original procedure of Kariya.

From the AOD experiments at Gadjah Wong and Opak streams we can conclude that the AOD bioassay method can represent the variability of conventional multiparameter water quality such as pH, EC, BOD, etc. However, the method of increasing the
concentration of toxic solution is most suitable for very low concentration and not suitable for heavily polluted water such as the downstream part Opak and Gadjah Wong streams in Yogyakarta. The replacement of bioassay species has to be verified through laboratory scale test. The fish species was too sensitive to the existing water pollution concentration. The sensitivity of the bioassay has to be verified for lower pollution concentration, EC < 160 mg/l. There is a need to develop a bioassay procedure that is suitable for Indonesian streams, especially the heavy polluted water. The procedure developed should use local species that is sensitive enough and can be used as a single water quality index that can represent the river water quality.

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Department of Civil and Environmental Engineering
Universitas Gadjah Mada
Yogyakarta, Indonesia
website: http://tsipil.ugm.ac.id
e-mail: jurusan@tsipil.ugm.ac.id
tel: +62-274-545675
fax: +62-274-545676

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