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Research Article

Chemical disinfectants detoxify wastewater containing various organic substances

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ABSTRACT

The use of disinfectants is intensive and widespread during the pandemic. Disinfectants are mixed with various organic wastewater substances, and also resuspend from the soil surface during the rainy season, which are eventually discharged into river waters. This study aimed to assess the potential of alcohol in detoxifying wastes containing organic substances so as to secure their disposal into water bodies. Preparation of organic substance solutions, aquatic test biota, and measurement of substance concentration parameters, as well as substance toxicity to biota, were all carried out using international standard laboratory protocols. In addition, real wastewater containing various organic substances was also investigated. It was revealed that the toxicity rating of organic substances to microbes was in line with their toxicity rating to zebrafish aquatic biota indicator. The toxicity rating of organic substances to microbes was expressed in the ratio of biological to chemical oxygen demand. The acute lethal concentration of half the number of zebrafish was a rating of the toxicity of organic substances to aquatic biota. Both of these toxicity measures were closely related to the solubility properties of substances in organic matter, which were expressed as octanol-water partition coefficient values. A very important finding was the potential of alcohol to detoxify wastewater containing mixed organic substances to secure its discharge into water bodies. This supports the continued use of alcohol disinfectants as a health protocol in daily life.

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INTRODUCTION

The use of disinfectants is indefinite and without limitations on environmental health conditions. Disinfectants in various forms have been formed to eliminate disease-causing microbes. Sunlight is one of the physical disinfectants that have formed naturally, which we know existed before human life on earth. The development of human life and disease problems has broadened and deepened knowledge to produce various disinfectants, both physical and chemical forms. Responding to the problem of the COVID-19 pandemic, chemical disinfectants have become one of the health protocols for everyone around the world. Various formulations of chemical disinfectants are available and used. Of particular concern are glycerol [1], isopropyl alcohol [2], and ethanol [3]. The use of disinfectants is predicted

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to continue even after the pandemic ends. The consequence is the enrichment of organic matter in wastewater, both from personal hygiene and existing wastewater production [4] and treatment processes [5].

Meanwhile, the wastewater generated in daily life also contains various types of organic substances. More attention to organic substances in daily wastewater is the content of oxalic acid, acetic acid, lactose, sucrose, glucose, and formaldehyde. Oxalic acid is a cleaning agent for laundry and household appliances from stains on metal [6]. Acetic acid is one of the common fermented food products in addition to many organic substances sourced from foodstuffs, which are generally lactose, sucrose and glucose [7]. Often foods contain naturally occurring formaldehyde, which is intentionally added as a preservative even though its use must be limited [8]. All existing organic matter content and new enrichment in wastewater becomes an urgency for its treatment [9] discharge into water bodies [10], as well as evaluation of existing wastewater plans [11].

Therefore, this research was carried out with a new approach in the form of alcohol disinfectant as a detoxification of organic wastewater. The first objective was to obtain a rating of the toxicity of organic substances to microbes and to freshwater indicator biota. The second objective was to determine the potential of alcohol-type disinfectants to secure waste disposal into freshwater bodies.

MATERIALS AND METHODS

The following organic substances were of pro-analytical quality for laboratories, i.e., lactose, sucrose, glucose, oxalic acid, acetic acid, formaldehyde, glycerol, isopropyl acid, and ethanol. The first six organic substances were solution materials as a simulation of organic wastewater. The next three organic substances were alcohol disinfectants. Each organic matter solution was measured for biological oxygen demand (BOD) and chemical oxygen demand (COD) content based on [12, 13]. and prepared in various concentrations of 10 mg/L, 100 mg/L, and 1,000 mg/L.

The aim was to rank the BOD/COD ratio as a measure of the level of toxicity of organic substances to microbes. Each organic substance was also measured in terms of octanol water partition (Pow) based on [14] to assess the lipophilic properties of the substance. Each substance parameter was measured in three replications, thus, the data obtained were nine measurements of the concentration of each organic substance. The result of which was the average.

Furthermore, each organic substance underwent an acute toxicity test for 96 h on the indicator biota of zebrafish *Brachydanio rerio* to secure the discharge of effluent into freshwater bodies. Probit statistical analysis was used to determine the lethal concentration of the substance on biota [15].

The mixture of organic substances in simulated wastewater was proportional to the volume and its toxicity against *B. rerio* was calculated using the following equations:

$$\boldsymbol{M = \sum_{i=1}^{n} TUi} \quad (1)$$

Where *TUi* was equal to the sum of the toxicity units of each substance [16]. The toxicity unit (*TU*) was the reciprocal of the lethal concentration of the substance to 50% of the test biota (*LC-50*).

$$\boldsymbol{TU = \left(\frac{1}{LC-50}\right)} \quad (2)$$

The Equation 2 was derived from researchers [16–19] and has been used by other researchers [20].

The mixed effect can be evaluated according to the values of *M* and *Mo* under the following arrangements:

$$\boldsymbol{Mo = \left(\frac{M}{maxTUi}\right)} \quad (3)$$

The mixed effect assessment was stated as follows:

$M < 1$:	Synergistic
$M = 1$:	Simple additive
$M = Mo$:	Independent
$M > Mo$:	Antagonism
$Mo > M > 1$:	Partial additive

The mixture of organic substances simulating wastewater that has synergistic toxicity properties then undergoes the addition of an alcohol disinfectant. In this mixture of wastewater and disinfectant, BOD and COD measurements were carried out as well as a 96 h acute toxicity test for *B. rerio*. This mixture is to assess the antagonistic toxicity properties, which indicates the potential of alcohol as detoxification of organic wastewater.

Wastewater samples in the field which actually contain various organic substances are taken from the residential landscape of domestic activities and where the wastewater is discharged into rivers [21, 22]. Real wastewater samples were tested to assess their suitability with the simulation results of the organic matter mixture. The selected wastewater samples were those containing BOD and COD of less than 1,000 mg/L in accordance with the limits of the concentration of the tested organic substances.

RESULTS

The results of the measurement of the parameters of organic substances in the wastewater simulation group were presented in Table 1. Specifically, the BOD/COD ratio was simply the calculation of the results of the two parameters, and the *TU* was calculated using Equation 2.

Based on the TU results in Table 1, a mixture of all wastewater organic substances in equal volume proportions yields M < 1 (Equations 1 and Equation 3). This means that any mixture of organic substances has the potential for a syner-

Table 1. Organic matter parameters and toxicity to *B. rerio*

Organic matter solution	BOD (mg/L)	COD (mg/L)	BOD/COD	Pow	LC-50-96 h-*B. rerio* (mg/L)	TU of substance
Lactose	7.7–750.7	8.3–962.0	0.8–0.9	0.7–0.8	851	0.0012
Sucrose	5.7–495.3	7.3–954.0	0.5–0.8	0.7–1.4	685	0.0015
Glucose	4.2–452.0	6.3–899.0	0.4–0.7	0.7–1.1	372	0.0027
Oxalic acid	0.8–114.7	7.7–796.0	0.1–0.3	1.1–2.3	42	0.0238
Acetic acid	1.7–158.7	6.7–792.0	0.2–0.4	0.7–1.6	30	0.0333
Formaldehyde	0.8–98.7	5.3–123.0	0.1–0.2	0.7–4.5	24	0.0417

Table 2. Lethal concentration of mixed organic matter by addition of alcohol to *B. rerio*

A mixture of substances in equal volume proportions	BOD (mg/L)	COD (mg/L)	BOD /COD	LC-50-96 h- B. rerio (mg/L)	Toxicity properties of the mixture
Sucrose+Acetic acid+Glycerol	11.8–814.7	15.3–1,051.0	0.8–0.8	205	Antagonistic due to Glycerol
Acetic acid+Formaldehyde+Isopropyl alcohol	0.8–52.9	1.4–98.8a	0.5–0.6	191	Antagonistic due to Isopropyl alcohol
Oxalic acid+Formaldehyde+Ethanol	0.7–83.5	2.0–299.0	0.3–0.4	59	Antagonistic due to Ethanol

Table 3. Toxicity of real wastewater contains a variety of organic substances

Samples	BOD (mg/L)	COD (mg/L)	BOD/COD	LC-50-96 h- *B. rerio* for real wastewater
Household wastewater	108.0	200.0	0.54	188
Laundry and textile washing wastewater	446.0	960.0	0.46	78

gistic effect, which increases its toxicity to *B. rerio*. Therefore, the results of this experiment deliberately divided the toxicity of organic substances at the LC-50 limit of 100 mg/L. In this case, the low toxicity was LC-50 >100 mg/L, and the high toxicity was LC-50 < 100 mg/L, for both microbes and *B. rerio*.

With the LC-50 limit, further experiments were carried out for mixtures of low and high toxicity organic substances, and mixtures of high toxicity organic substances with the addition of alcohol disinfectant. In the settings, glycerol was added to the mixture of sucrose (LC-50 > 100 mg/L) and acetic acid (LC-50 < 100 mg/L), all of which were in the same volume proportion. Likewise, for mixing organic substances that have an LC-50 < 100 mg/L with the addition of isopropyl alcohol and ethanol. The results of the measurement of BOD, COD, and toxicity parameters of the mixture were presented in Table 2.

Table 2 showed the addition of alcohol to wastewater containing a mixture of organic substances produces an antagonistic effect that reduces its toxicity to *B. rerio*. Therefore, these disinfectants are capable of detoxifying organic matter, which protects the life of biota in water bodies.

The results of the real wastewater toxicity study were presented in Table 3. The Pow parameter of the real wastewater was of course not measured. This was because the content of organic substances was not specific apart from being a mixture of various organic substances. The LC-50-96 h results against *B. rerio* were for real wastewater that has been enriched with alcohol disinfectant during the pandemic.

DISCUSSION

The results of the study of single organic substances Table 1 shows the BOD/COD ratio in the range of easily biodegradable (more than 0.5) and non-biodegradable, or toxic to microbes (less than 0.5). As the results of previous studies [23], the range of the BOD/COD ratio was closely related to the Pow range, where biodegradable organic substances have a Pow smaller than the Pow of non-biodegradable substances. The Pow results show that biodegradable organic substances were hydrophilic, whereas non-biodegradable organic substances were lipophilic, which easily accumulates into the biomass of biota. Thus, the lipophilic nature of the organic substance explains its toxicity to microbes.

Similarly, the results of LC-50-96 h-*B. rerio* for non-biodegradable organic substances showed less than biodegradable organic substances. This indicates that non-biodegradable organic substances become more toxic to *B. rerio*.

Again, the toxicity of organic substances to *B. rerio* is due to the lipophilic nature of organic substances, which easily accumulate into *B. rerio*.

The association of Pow with the toxicity of organic substances to microbes and *B. rerio* has been in line with and confirms the results of previous studies by other researchers [24–26]. All of them use different organic substances from each other, thus strengthening the correlation between Pow, accumulative properties of substances, and toxicity of substances to biota.

The aforementioned results of the laboratory studies can be applied to respond to the use of disinfectants that enrich the quality of wastewater and even to runoff during the rainy season. Especially for wastewater containing BOD and COD of not more than 1,000mg/L, people need not worry too much about the effects of discharging disinfectant-rich wastewater into fresh water bodies as previously designed and practiced. This was evidenced by the results of research for real wastewater in Table 3, which shows a fairly high ratio of BOD/COD and LC-50-96 h. Both were considered biodegradable and less toxic to aquatic biota. During this three-year pandemic, there have been no reports of damage to water quality and aquatic biota with the exception of microbes.

However, careful attention needs to be paid to wastewater that has a BOD and COD concentration of more than 1,000 mg/L, such as leachate from the degradation of solid waste in landfills. In this condition, other detoxification methods are needed that are able to reduce BOD and COD below 1,000 mg/L, such as wetland treatment involving a variety of plants [27]. Plants are resistant to alcohol disinfectants [28].

CONCLUSIONS

The first objective of this study has been achieved by showing that the toxicity rating of organic substances to microbes is the same as their toxicity rating to zebrafish. The second but more important objective is the toxicity of alcohol disinfectants to microbes but has the potential to reduce the toxicity of organic mixtures to zebrafish. This is a representation of the potential ability of alcohol disinfectants to detoxify organic wastewater that is safely discharged into water bodies. Therefore, the use of alcohol as a microbial disinfection does not worsen the chemical quality of the environment and its effect on macro biota.

The limitation of this research was the mixture of organic substances based on the same volume proportion. The concentration of each organic substance was a maximum of 1,000 mg/L. Therefore, further research is needed regarding the proportion of the mixture of organic substances, which optimally reduces its toxicity to zebrafish. In addition, the concentration of organic matter should be increased to more than 1,000 mg/L.

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DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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