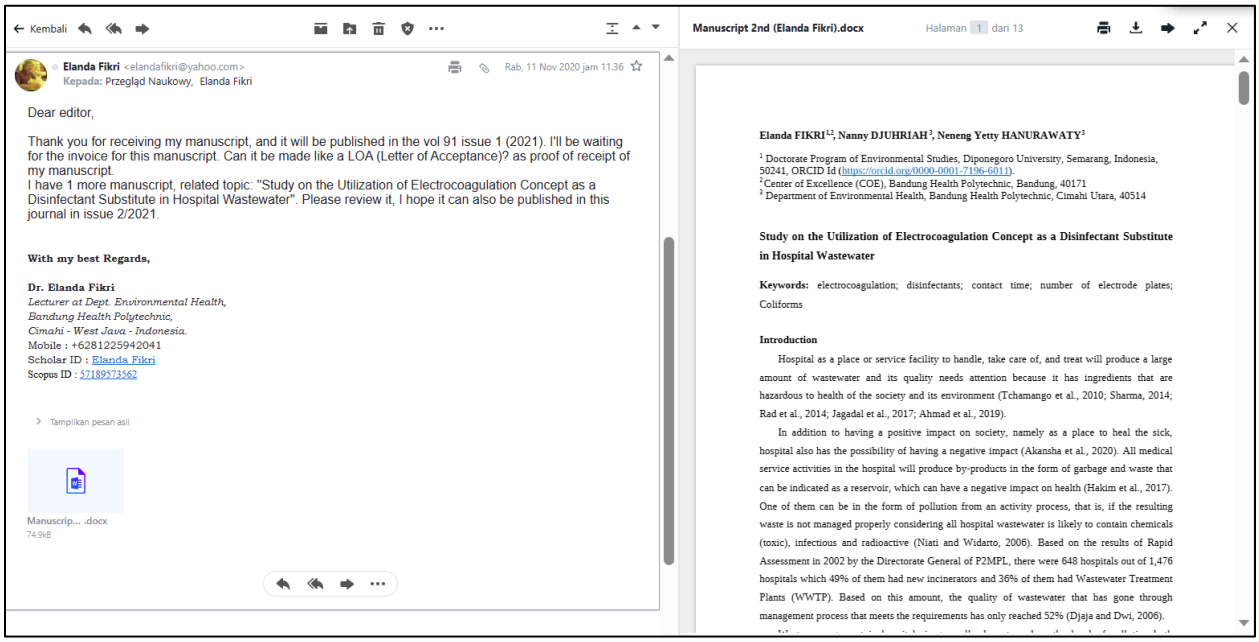
**BUKTI KORESPONDENSI**

Nama : Dr. Elanda Fikri, S.KM., M.Kes
NIP : 198903112015031002
NIDN : 4011038901
Jabatan : Lektor Kepala
Unit Kerja : Poltekkes Kemenkes Bandung

| | | |
|---|---|---|
| Jurnal internasional bereputasi (terindeks pada database internasional bereputasi dan berfaktor dampak)<br><br>Penulis pertama : (60%x40=24) | Study on the utilization of electrocoagulation concept as a disinfectant substitute in hospital wastewater | Scientific Review Engineering and Environmental Sciences, Volume 30, Issue 2, 2021, Pages 261-270, Penulis pertama, ISSN: 17329353, DOI: 10.22630/PNIKS.2021.30.2.22, Publisher: WULS - SGGW Press, SCOPUS Q4 (**Elanda Fikri**, Nanny Djuhriah, Neneng Yetty Hanurawaty)<br><br>Link DOI :<br>https://doi.org/10.22630/PNIKS.2021.30.2.22<br><br>Link WEB :<br>https://srees.sggw.edu.pl/article/view/1896<br><br>URL DOKUMEN :<br>https://srees.sggw.edu.pl/article/view/1896/1812<br><br>URL H-INDEKS/SJR:<br>https://www.scimagojr.com/journalsearch.php?q=21100238408&tip=sid&clean=0<br><br>URL SIMILARITY :<br>https://repo.poltekkesbandung.ac.id/5772/1/Studi%20Elektrokoagulasi%20Turnitin.pdf |

## SUBMIT PAPER, 11 NOVEMBER 2020



← Kembali

**Elanda Fikri** <elandafikri@yahoo.com>
**Kepada:** Przegląd Naukowy, Elanda Fikri

Rab, 11 Nov 2020 jam 11.36

Dear editor,

Thank you for receiving my manuscript, and it will be published in the vol 91 issue 1 (2021). I'll be waiting for the invoice for this manuscript. Can it be made like a LOA (Letter of Acceptance)? as proof of receipt of my manuscript.
I have 1 more manuscript, related topic: "Study on the Utilization of Electrocoagulation Concept as a Disinfectant Substitute in Hospital Wastewater". Please review it, I hope it can also be published in this journal in issue 2/2021.

**With my best Regards,**

**Dr. Elanda Fikri**
*Lecturer at Dept. Environmental Health,*
*Bandung Health Polytechnic,*
*Cimahi - West Java - Indonesia.*
Mobile : +6281225942041
Scholar ID : Elanda Fikri
Scopus ID : 57189573562

Tampilkan pesan asli

Manuscrip... .docx
74.9kB

Manuscript 2nd (Elanda Fikri).docx — Halaman 1 dari 13

**Elanda FIKRI[1,2], Nanny DJUHRIAH[2], Neneng Yetty HANURAWATY[2]**

[1] Doctorate Program of Environmental Studies, Diponegoro University, Semarang, Indonesia, 50241, ORCID Id (https://orcid.org/0000-0001-7196-6011).
[2] Center of Excellence (COE), Bandung Health Polytechnic, Bandung, 40171
[3] Department of Environmental Health, Bandung Health Polytechnic, Cimahi Utara, 40514

**Study on the Utilization of Electrocoagulation Concept as a Disinfectant Substitute in Hospital Wastewater**

**Keywords:** electrocoagulation; disinfectants; contact time; number of electrode plates; Coliforms

**Introduction**

Hospital as a place or service facility to handle, take care of, and treat will produce a large amount of wastewater and its quality needs attention because it has ingredients that are hazardous to health of the society and its environment (Tchamango et al., 2010; Sharma, 2014; Rad et al., 2014; Jagadal et al., 2017; Ahmad et al., 2019).

In addition to having a positive impact on society, namely as a place to heal the sick, hospital also has the possibility of having a negative impact (Akansha et al., 2020). All medical service activities in the hospital will produce by-products in the form of garbage and waste that can be indicated as a reservoir, which can have a negative impact on health (Hakim et al., 2017). One of them can be in the form of pollution from an activity process, that is, if the resulting waste is not managed properly considering all hospital wastewater is likely to contain chemicals (toxic), infectious and radioactive (Niati and Widarto, 2006). Based on the results of Rapid Assessment in 2002 by the Directorate General of P2MPL, there were 648 hospitals out of 1,476 hospitals which 49% of them had new incinerators and 36% of them had Wastewater Treatment Plants (WWTP). Based on this amount, the quality of wastewater that has gone through management process that meets the requirements has only reached 52% (Djaja and Dwi, 2006).

## PENERIMAAN PAPER DAN MENDAPATKAN FEEDBACK TERKAIT REVIEWER KE-2 (12 November 2020)

**Przegląd Naukowy** <iks_pn@sggw.edu.pl>
**Kepada:** Elanda Fikri

Kam, 12 Nov 2020 jam 02.52

Dear Elanda Fikri,

thank you for your 2nd submission.
Could you recommend 2 reviewers from different countries for your manuscript?

Best regards,
Grzegorz Wrzesinski

Tampilkan pesan asli

**Elanda Fikri** <elandafikri@yahoo.com>
**Kepada:** Przegląd Naukowy, Elanda Fikri

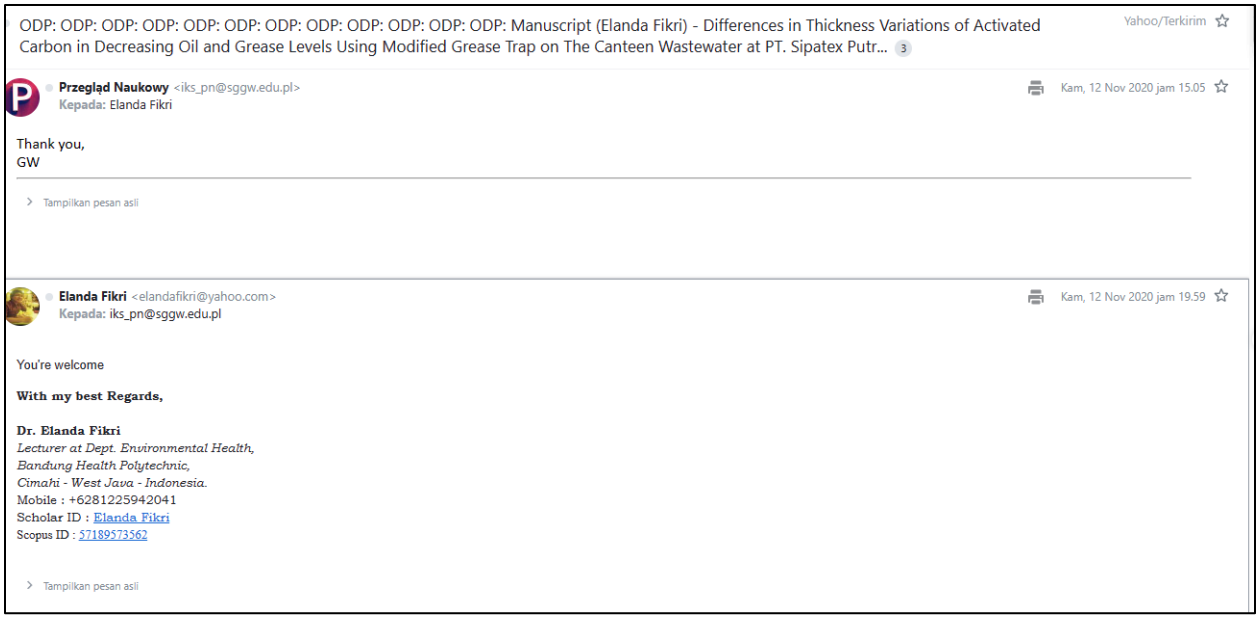
Kam, 12 Nov 2020 jam 09.45

Dear editor,
Yes, I have...
1). Febi Dwirahmadi, SKM, MSc.PH, Ph.D, Griffith University Queensland, Australia. (f.dwirahmadi@griffith.edu.au).
2). Dr. Amar Sharaf Eldin Khair, (Lecturer at Omdurman Islamic University, Geography and Environmental Science Department, Omdurman city – Sudan) (amar77600@gmail.com).

You can contact them,

**With my best Regards,**

**Dr. Elanda Fikri**
*Lecturer at Dept. Environmental Health,*
*Bandung Health Polytechnic,*
*Cimahi - West Java - Indonesia.*
Mobile : +6281225942041
Scholar ID : Elanda Fikri



ODP: ODP: ODP: ODP: ODP: ODP: ODP: ODP: ODP: ODP: ODP: Manuscript (Elanda Fikri) - Differences in Thickness Variations of Activated Carbon in Decreasing Oil and Grease Levels Using Modified Grease Trap on The Canteen Wastewater at PT. Sipatex Putr... 3

Yahoo/Terkirim

**Przegląd Naukowy** <iks_pn@sggw.edu.pl>
**Kepada:** Elanda Fikri

Kam, 12 Nov 2020 jam 15.05

Thank you,
GW

Tampilkan pesan asli

**Elanda Fikri** <elandafikri@yahoo.com>
**Kepada:** iks_pn@sggw.edu.pl

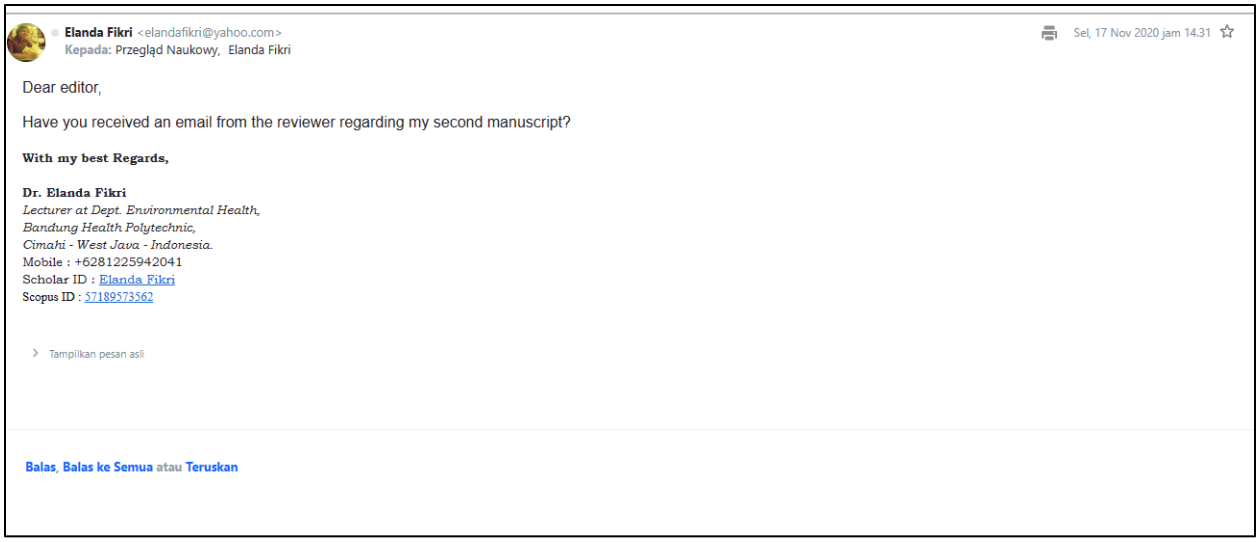
Kam, 12 Nov 2020 jam 19.59

You're welcome

**With my best Regards,**

**Dr. Elanda Fikri**
*Lecturer at Dept. Environmental Health,*
*Bandung Health Polytechnic,*
*Cimahi - West Java - Indonesia.*
Mobile : +6281225942041
Scholar ID : Elanda Fikri
Scopus ID : 57189573562

Tampilkan pesan asli



**Elanda Fikri** <elandafikri@yahoo.com>
**Kepada:** Przegląd Naukowy, Elanda Fikri

Sel, 17 Nov 2020 jam 14.31

Dear editor,

Have you received an email from the reviewer regarding my second manuscript?

**With my best Regards,**

**Dr. Elanda Fikri**
*Lecturer at Dept. Environmental Health,*
*Bandung Health Polytechnic,*
*Cimahi - West Java - Indonesia.*
Mobile : +6281225942041
Scholar ID : Elanda Fikri
Scopus ID : 57189573562

Tampilkan pesan asli

**Balas**, **Balas ke Semua** atau **Teruskan**

## MENDAPATKAN FEEDBACK MASIH DALAM REVIEW (20 Juni 2020)

**Przegląd Naukowy** <iks_pn@sggw.edu.pl>
**Kepada:** Elanda Fikri

Jum, 20 Nov 2020 jam 15.33

the paper is under review. After review we will contact you.

Best regards,
Grzegorz Wrzesinski

Tampilkan pesan asli

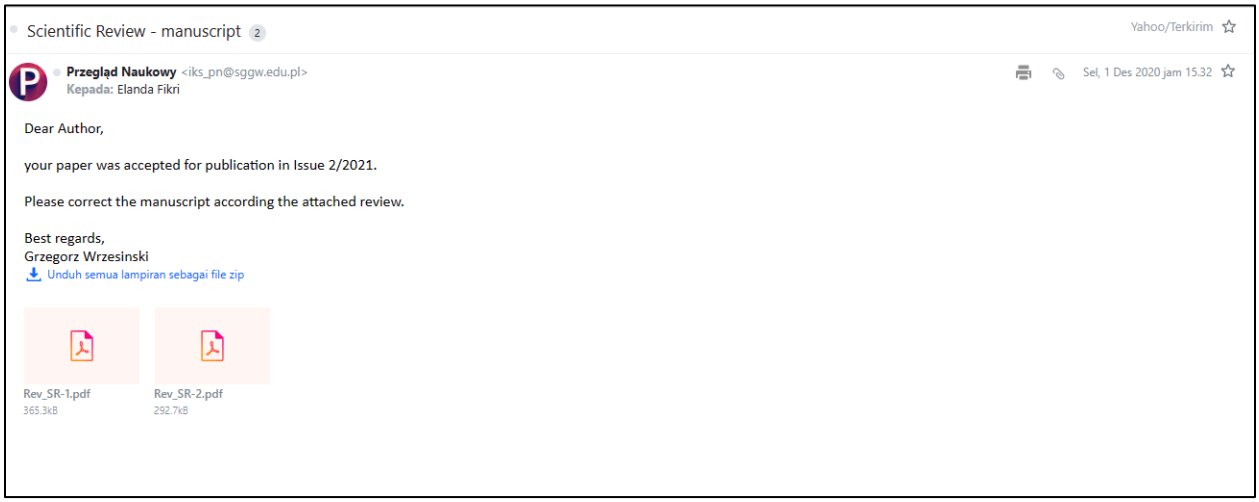
**Elanda Fikri** <elandafikri@yahoo.com>
**Kepada:** iks_pn@sggw.edu.pl
**Cc:** Elanda Fikri

Jum, 20 Nov 2020 jam 17.29

Dear editor,
Okay, I will wait.
Thank you Grzegorz Wrzesinski

Best regards
Dr. Elanda Fikri

## MENDAPATKAN REVIEW DARI PAPER YANG DISUBMIT (1 Desember 2020)



Scientific Review - manuscript 2

Yahoo/Terkirim

**Przegląd Naukowy** <iks_pn@sggw.edu.pl>
**Kepada:** Elanda Fikri

Sel, 1 Des 2020 jam 15.32

Dear Author,

your paper was accepted for publication in Issue 2/2021.

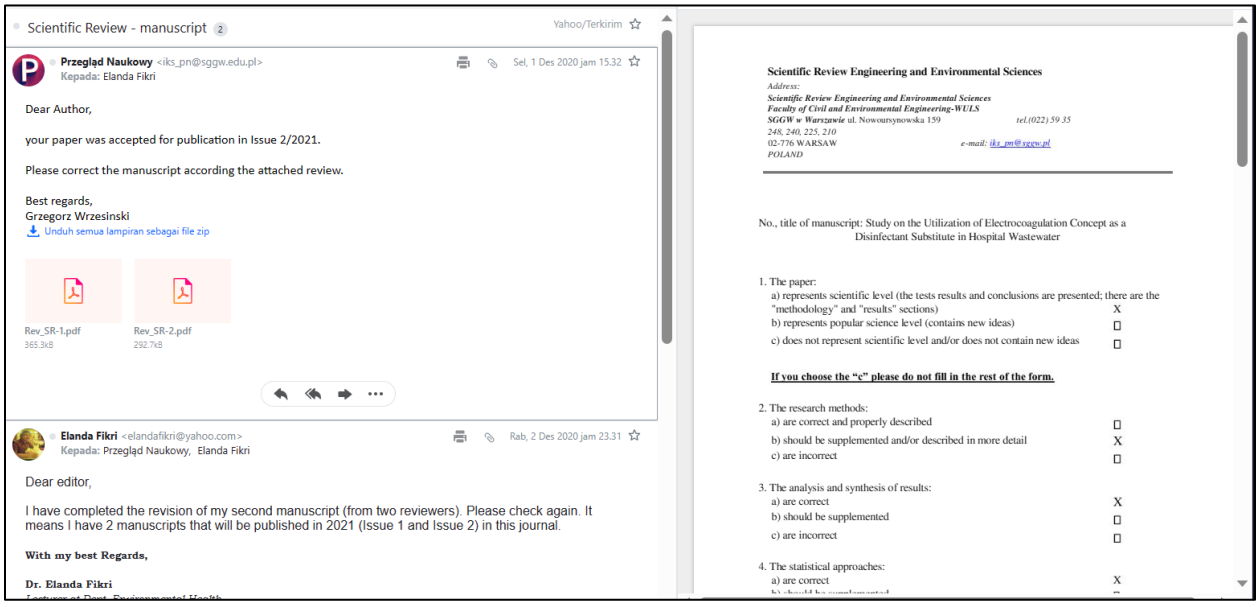
Please correct the manuscript according the attached review.

Best regards,
Grzegorz Wrzesinski

Unduh semua lampiran sebagai file zip

Rev_SR-1.pdf
365.3kB

Rev_SR-2.pdf
292.7kB



Scientific Review - manuscript 2

Yahoo/Terkirim

**Przegląd Naukowy** <iks_pn@sggw.edu.pl>
**Kepada:** Elanda Fikri

Sel, 1 Des 2020 jam 15.32

Dear Author,

your paper was accepted for publication in Issue 2/2021.

Please correct the manuscript according the attached review.

Best regards,
Grzegorz Wrzesinski

Unduh semua lampiran sebagai file zip

Rev_SR-1.pdf
365.3kB

Rev_SR-2.pdf
292.7kB

**Elanda Fikri** <elandafikri@yahoo.com>
**Kepada:** Przegląd Naukowy, Elanda Fikri

Rab, 2 Des 2020 jam 23.31

Dear editor,

I have completed the revision of my second manuscript (from two reviewers). Please check again. It means I have 2 manuscripts that will be published in 2021 (Issue 1 and Issue 2) in this journal.

**With my best Regards,**

**Dr. Elanda Fikri**

**Scientific Review Engineering and Environmental Sciences**

*Address:*
***Scientific Review Engineering and Environmental Sciences***
***Faculty of Civil and Environmental Engineering-WULS***
***SGGW w Warszawie*** ul. Nowoursynowska 159 *tel.(022) 59 35*
*248, 240, 225, 210*
02-776 WARSAW *e-mail: iks_pn@sggw.pl*
*POLAND*

No., title of manuscript: Study on the Utilization of Electrocoagulation Concept as a Disinfectant Substitute in Hospital Wastewater

1. The paper:
   a) represents scientific level (the tests results and conclusions are presented; there are the "methodology" and "results" sections) X
   b) represents popular science level (contains new ideas) ☐
   c) does not represent scientific level and/or does not contain new ideas ☐

**If you choose the "c" please do not fill in the rest of the form.**

2. The research methods:
   a) are correct and properly described ☐
   b) should be supplemented and/or described in more detail X
   c) are incorrect ☐

3. The analysis and synthesis of results:
   a) are correct X
   b) should be supplemented ☐
   c) are incorrect ☐

4. The statistical approaches:
   a) are correct X

**HASIL REVIEW DARI REVIEWER 1 :**

**Scientific Review Engineering and Environmental Sciences**

*Address:*
***Scientific Review Engineering and Environmental Sciences***
***Faculty of Civil and Environmental Engineering-WULS***
***SGGW w Warszawie*** ul. Nowoursynowska 159 *tel.(022) 59 35*
*248, 240, 225, 210*
02-776 WARSAW *e-mail: iks_pn@sggw.pl*
*POLAND*

No., title of manuscript: Study on the Utilization of Electrocoagulation Concept as a Disinfectant Substitute in Hospital Wastewater

1. The paper:
   a) represents scientific level (the tests results and conclusions are presented; there are the "methodology" and "results" sections) X
   b) represents popular science level (contains new ideas) ☐
   c) does not represent scientific level and/or does not contain new ideas ☐

**If you choose the "c" please do not fill in the rest of the form.**

2. The research methods:
   a) are correct and properly described ☐
   b) should be supplemented and/or described in more detail X
   c) are incorrect ☐

3. The analysis and synthesis of results:
   a) are correct X
   b) should be supplemented ☐
   c) are incorrect ☐

4. The statistical approaches:
   a) are correct X
   b) should be supplemented ☐
   c) have incorrect assumption ☐
   d) are needless ☐

5. Tables and figures:
   a) are correct; have descriptions X
   b are correct; do not have descriptions ☐

c) should be supplemented ☐
d) are inappropriate ☐

6. The abstract and key words:
a) are correct ☐
b) should be supplemented X
c) are inappropriate (they do not reflect the essence of the tests results) ☐

7. Title of the manuscript is correct and corresponding to the text yes X no ☐

8. The conclusions:
a) are correct and resulted from research presented in the paper ☐
b) should be supplemented X
c) are inappropriate (they do not reflect the essence of the tests results) ☐

9. The references included recent publications (especially from the last two years) and are:
a) sufficient ☐
b) insufficient X

10. Manuscript language:
a) is correct ☐
b) should be edited X
c) is incorrect ☐

11. **Overall assessment**
a) **very good – submit without any amendments** ☐
b) **good - submit with an amendments** **X**
c) **submit corrected paper without second review** ☐
d) **submit corrected paper after second review** ☐
e) **poor – unable to publish** ☐

12. To the best of my knowledge, the paper had been already published in the same or similar form yes ☐ no ☐

The place for comments – especially for issues which should be supplemented and/or corrected

- Keywords – "hospital wastewater" should be listed as one of the keywords.
- Line 17 – For the first time usage, provide the abbreviation of P2MPL
- Line 17 – 2002 data, is this the most recent data for hospital in Indonesia? It is important to provide the most updated data on this part to set the scene properly.
- Line 28-29, "not only but also" is not approprioate to be used here, it would have been better to use "however"

- Line 79 – Population and sample – should provide number of hospital involved in this project.
- Discussion – should cover briefly about the applicability of this method in the practical environment – e.g. in Bandung City
- Discussion or conclusion – what is the implications/significance of this paper? should discuss the key recommendations for the policy makers or end users –

---

The reviewer' name only for Editorial Office knowledge. The names of the reviewers assisting the editorial board will be listed in the last issue of each year and on the website.

**KOMENTAR DARI REVIEWER 2**

No., title of manuscript: Study on the Utilization of Electrocoagulation Concept as disinfectant substitute in Hospital Wastewater -

1. The paper:
   a) represents scientific level (the tests results and conclusions are presented; there are the "methodology" and "results" sections) ☑
   b) represents popular science level (contains new ideas) ☐
   c) does not represent scientific level and/or does not contain new ideas ☐

**If you choose the "c" please do not fill in the rest of the form.**

2. The research methods:
   a) are correct and properly described ☑
   b) should be supplemented and/or described in more detail ☐
   c) are incorrect ☐

3. The analysis and synthesis of results:
   a) are correct ☑
   b) should be supplemented ☐
   c) are incorrect ☐

4. The statistical approaches:
   a) are correct ☑
   b) should be supplemented ☐
   c) have incorrect assumption ☐
   d) are needless ☐

5. Tables and figures:
   a) are correct; have descriptions ☑
   b are correct; do not have descriptions ☐
   c) should be supplemented ☐
   d) are inappropriate ☐

6. The abstract and key words:
   a) are correct ☑
   b) should be supplemented ☐
   c) are inappropriate (they do not reflect the essence of the tests results) ☐

7. Title of the manuscript is correct and corresponding to the text yes ☑ no ☐

8. The conclusions:

a) are correct and resulted from research presented in the paper ☑

b) should be supplemented ☐

c) are inappropriate (they do not reflect the essence of the tests results) ☐

9. The references included recent publications (especially from the last two years) and are:

a) sufficient ☑

b) insufficient ☐

10. Manuscript language:

a) is correct ☑

b) should be edited ☐

c) is incorrect ☐

**11. Overall assessment**

**a) very good – submit without any amendments** ☑

**b) good - submit with an amendments** ☐

**c) submit corrected paper without second review** ☐

**d) submit corrected paper after second review** ☐

**e) poor – unable to publish** ☐

12. To the best of my knowledge, the paper had been already published in the same or similar form yes ☐ no ☑

The place for comments – especially for issues which should be supplemented and/or corrected

This research is very good and original. The study discusses the use of Electrocoagulation method to reduce coliform bacteria in wastewater. Meanwhile, we know that usually to kill microorganism using disinfectants. That is so interesting Topic finding. The Topic method is correct, The discussion is correct by Comparing with the most recent study.

The conclusion has discribed The Contents of the manuscript.

References used are good and up to date.

I recommed to Publish but, there are some few revisions that need to be corrected in Table 1, 2, 3 and 4, Please use instead of comma.

## HASIL KOMENTAR REVIEWER - DISELESAIKAN

### REVISION TABLE

**Reviewer 1 :**

| No | Reviewer Comments | Revision or Comment |
|---|---|---|
| 1 | Keywords – "hospital wastewater" should be listed as one of the keywords | **Keywords:** electrocoagulation; disinfectants; contact time; number of electrode plates; *Coliforms*, hospital wastewater (line 7 and 8) |
| 2 | Line 17 – For the first time usage, provide the abbreviation of P2MPL | Based on the results of Rapid Assessment in 2002 by the Directorate General of P2MPL (Pemberantasan Penyakit Menular dan Penyehatan Lingkungan) (line 24,25) |
| 3 | Line 17 – 2002 data, is this the most recent data for hospital in Indonesia? It is important to provide the most updated data on this part to set the scene properly | I only found official data from the government published in 2002. |
| 4 | Line 28-29, "not only but also" is not approprioate to be used here, it would have been better to use "however" | However chlorine is beneficial for human life, and toxic to the environment and human health (line 36). |
| 5 | Line 79 – Population and sample – should provide number of hospital involved in this project. | The number of hospitals sampled in this study is one sample, namely Kebon Jati Hospital, Bandung City (line 90-91). |
| 6 | Discussion – should cover briefly about the applicability of this method in the practical environment – e.g. in Bandung City | This method has only been applied on a laboratory scale, and needs further research on a field scale |
| 7 | Discussion or conclusion – what is the implications/significance of this paper? should discuss the key recommendations for the policy makers or end users – | Recommendations for the policy makers or end users is to try implement this method as a substitute for disinfectant. Because so far, chemical disinfectants used to reduce microbiological parameters (total Coliforms) have a negative impact on humans and the environment. (line 223-226). |

## REVISION TABLE

### Reviewer 2 :

<table>
<tr><th>No</th><th>Reviewer Comments</th><th>Revision or Comment</th></tr>
<tr><td>1</td><td>This research is very good and original. This study discusses the use of electrocoagulation methods to reduce coliform bacteria in wastewater. Meanwhile, we know that usually to kill microorganism using disinfectants. This is an interesting research finding. The research method used is correct, the discussion is correct by comparing the most recent previous studies. The conclusion has described the contents of the manuscript. References used are good and up to date. I recommend to publish. But there are a few revisions that need to be corrected in table 1, 2, 3 and 4. Please use ‘.’ instead of comma.</td><td>
Table 1. Average temperature of wastewater based on number of plates and contact time
<table>
<tr><th>Number of Plates</th><th>Contact Time</th><th>Temperature (Average)</th><th>pH (Average)</th></tr>
<tr><td rowspan="3">4 Plates</td><td>30 minutes</td><td>25.833</td><td>7.750</td></tr>
<tr><td>60 minutes</td><td>25.750</td><td>7.617</td></tr>
<tr><td>90 minutes</td><td>25.667</td><td>7.583</td></tr>
<tr><td rowspan="3">6 Plates</td><td>30 minutes</td><td>25.833</td><td>7.750</td></tr>
<tr><td>60 minutes</td><td>25.750</td><td>7.500</td></tr>
<tr><td>90 minutes</td><td>25.917</td><td>7.733</td></tr>
<tr><td rowspan="3">8 Plates</td><td>30 minutes</td><td>25.833</td><td>7.717</td></tr>
<tr><td>60 minutes</td><td>26.333</td><td>7.583</td></tr>
<tr><td>90 minutes</td><td>25.833</td><td>7.767</td></tr>
</table>
Table 2 Analysis of differences in temperature and pH values based on the number of plates and contact time in electrocoagulation process
<table>
<tr><th>Source</th><th>Sig. (Temperature)</th><th>Sig. (pH)</th></tr>
<tr><td>Corrected Model</td><td>0.940</td><td>0.514</td></tr>
<tr><td>Intercept</td><td>0.000</td><td>0.000</td></tr>
<tr><td>Number of Plates</td><td>0.628</td><td>0.890</td></tr>
<tr><td>Contact Time</td><td>0.856</td><td>0.108</td></tr>
<tr><td>Number of Plates * Contact Time</td><td>0.814</td><td>0.664</td></tr>
</table>
</td></tr>
</table>

Table 3. Average total Coliforms in wastewater based on number of plates and contact time

| Number of Plates | Contact Time | Mean |
|---|---|---|
| 4 Plates | 30 Minutes | 294.167 |
| | 60 Minutes | 669.167 |
| | 90 Minutes | 580.000 |
| 6 Plates | 30 Minutes | 183.333 |
| | 60 Minutes | 300.000 |
| | 90 Minutes | 138.333 |
| 8 Plates | 30 Minutes | 140.667 |
| | 60 Minutes | 228.667 |
| | 90 Minutes | 463.333 |

Table 4. Bivariate analysis of total Coliform differences based on number of plates and contact time in electrocoagulation process

| Source | Sig. |
|---|---|
| Corrected Model | 0.727 |
| Intercept | 0.000 |
| Number of Plates | 0.269 |
| Contact Time | 0.537 |
| Number of Plates * Contact Time | 0.863 |

Table 5. Effectiveness of the use of electrocoagulation in reducing Coliforms

| Number of Plates / Contact Time | 30 Minutes | 60 Minutes | 90 Minutes |
|---|---|---|---|
| 4 Plates | 80.49% | 76.78% | 48.06% |
| 6 Plates | 73.87% | 82.68% | 88.38% |
| 8 Plates | 78.30% | 78.01% | 84.45% |

# Study on the Utilization of Electrocoagulation Concept as a Disinfectant Substitute in Hospital Wastewater

**Keywords:** electrocoagulation; disinfectants; contact time; number of electrode plates; Coliforms

## Introduction

Hospital as a place or service facility to handle, take care of, and treat will produce a large amount of wastewater and its quality needs attention because it has ingredients that are hazardous to health of the society and its environment (Tchamango et al., 2010; Sharma, 2014; Rad et al., 2014; Jagadal et al., 2017; Ahmad et al., 2019).

In addition to having a positive impact on society, namely as a place to heal the sick, hospital also has the possibility of having a negative impact (Akansha et al., 2020). All medical service activities in the hospital will produce by-products in the form of garbage and waste that can be indicated as a reservoir, which can have a negative impact on health (Hakim et al., 2017). One of them can be in the form of pollution from an activity process, that is, if the resulting waste is not managed properly considering all hospital wastewater is likely to contain chemicals (toxic), infectious and radioactive (Niati and Widarto, 2006). Based on the results of Rapid Assessment in 2002 by the Directorate General of P2MPL, there were 648 hospitals out of 1,476 hospitals which 49% of them had new incinerators and 36% of them had Wastewater Treatment Plants (WWTP). Based on this amount, the quality of wastewater that has gone through management process that meets the requirements has only reached 52% (Djaja and Dwi, 2006).

Waste management in hospitals is generally done to reduce the level of pollution both physically, chemically, and microbiologically. Specifically, for microbiological management, the waste management unit in this hospital uses Coliform bacteria as an indicator of its parameters. These bacteria are a large and heterogeneous group of gram-negative rods that are within certain limits similar to Escherichia coli (Tapotubun et al., 2016).

There are various methods used in deriving microbiological parameters in wastewater. Most hospitals in Indonesia use chlorine (chlorination) in the process of disinfection of waste water, because it is considered the cheapest on the market. Chlorine is not only beneficial for human life, but also toxic to the environment and human health. The chlorine nature as a strong oxidizer makes

it easy to bind to other compounds, forming toxic compounds such as organochlorine which has a carcinogenic effect. Therefore, there needs to be other alternatives that are more environmentally friendly and have minimal impact on human health. One method that can be developed is the Electrocoagulation system.

Electrocoagulation is a water purification method (Liu et al., 2019). The working principle of electrocoagulation is to use two electrode plates inserted into a vessel filled with water to be purified. Furthermore, the two electrodes are electrified with direct current so that an electrochemical process occurs which causes the cation to move toward the cathode and the anion to move toward the anode (Hakizimana et al., 2017). Flocculants are eventually formed which will bind contaminants or particles from the raw water. There are anodes and cathodes in electrocoagulation. At the anode occurs the release of active coagulant in the form of metal ions into the solution, while at the cathode an electrolysis reaction occurs in the form of hydrogen gas release (Önder et al., 2007; Miwa et al., 2006).

Electrocoagulation requires simple equipment and is easy to operate (Lakshmanan et al., 2010; Cañizares et al., 2007; Chen et al., 2002). Electrocoagulation can reduce colloidal/smallest particle content faster, and can provide high enough process efficiency for various conditions, no pH regulation is needed, without the use of chemical additives, deposits formed from the electrocoagulation process are more easily separated from water, can move particles smaller colloidal particles, and the electric current can be regulated (Lu et al., 2015; Van et al., 2012).

Existing researches related to electrocoagulation are limited to decreasing physical and chemical parameters of wastewater (Silva et al., 2018), phosphates (Dura et al., 2019), suspended solids (Sadedin et al., 2011), Cu, Ni, Zn, and Cr (Kim et al., 2020), oil (Chen et al., 2000; Fajardo et al., 2015), and arsenic contaminated water (Nidheesh et al., 2017; Syam and Nidheesh, 2020), they are not applied to microbiological parameters. Research conducted by Wiyanto et al., (2014) shows that the electrocoagulation process can reduce the percentage of sulfide levels in water. Research conducted by Setianingrum et al (2016) shows that at 10-volt electricity voltage and contact time for 60 minutes can reduce the color parameters in batik waste water reaching 80% and COD of 71.3% (distance between electrode plates is 3 cm). Whereas the research of Darmawanti et al (2010) shows that a contact time of 180 minutes and a current of 2.5A can reduce the color of waste reaching 88.51%. Furthermore, research from Ni'am et al (2017) shows that

using a 12-volt voltage, 4 electrodes, and a 45-minute contact time, can reduce COD level to 61% in wastewater (Ni'am et al., 2017).

Based on these limitations, it is necessary to conduct a research by applying electrocoagulation in reducing microbiological parameters in wastewater. Anodes and cathodes use aluminum (Al) because aluminum is a reactive electrode, a good reductant, resistant to corrosion, cheap, and easy to obtain.

## Materials and Methods

Research Type and Strategies

An experimental type of research with factorial randomized design, namely looking for an effect of certain treatments on others, under controlled conditions (Notoatmodjo, 2010). Variables controlled in the study were:

- Current of 5A and 12V voltage.
- In order to overcome the absorption effect of electrodes, the type of electrode plate used was aluminum electrodes
- Distance between the electrodes was 8 cm.
- Thickness of the electrode plate was 1 mm.
- The pH should be less than 9.

Population and Sample

Population is a generalization area consisted of objects/subjects that have certain quantities and characteristics determined by researchers to be studied and then drawn conclusions. The population in this study was wastewater from effluent hospital in Bandung City (SNI, 2008).

The sample size was based on the number of treatments and repetitions in the study (Gomez and Gomez, 2007). The treatments used in this study were 3 treatments using a ratio of contact time for 30 minutes, 60 minutes, and 90 minutes, and the number of plates (4, 6, and 8 electrode plates). The sample size calculation used the Gomez formula:

$$t\,(r-1) \geq 15$$

Information:
t (treatment) = Many treatments
r (replica) = Many repetitions
Then:

$$t\,(r-1) \geq 15$$
$$3\,(r-1) \geq 15$$
$$3r - 3 \geq 15$$
$$3r \geq 18$$
$$r \geq 6$$

The number of repetitions in this study was 6 times. The amount of wastewater needed in one repetition was 12.5 liters, so the sample size for 3 treatments was:

3 treatments x 6 repetitions = 18 samples

18 samples x 12.5 liters = 225 liters of wastewater sample x 2 = 450 liters

The volume of the wastewater sample was adjusted to the needs of examination and analysis parameters in the laboratory, which was 100 ml (the minimum sample for Coliform examination in wastewater). The sampling technique used was grab sampling.

Data Analysis

Bivariate analysis was carried out on the variables suspected to be related or influence, and saw the magnitude of the influence of independent variable on dependent variable. Bivariate analysis used was two way ANOVA (with $\alpha = 5\%$).

## Results and discussion

### Average temperature and pH of wastewater based on number of plates and contact time

Based on table 1, it shows that the highest average temperature (26.3 $^{o}$C) occurred in the electrocoagulation process with 8 plates in 60 minutes contact time, while the lowest temperature (25.67 $^{o}$C) occurred in the electrocoagulation process with 4 plates in 90 minutes contact time.

Table 1. Average temperature of wastewater based on number of plates and contact time

| Number of Plates | Contact Time | Temperature (Average) | pH (Average) |
|---|---|---|---|
| 4 Plates | 30 minutes | 25,833 | 7,750 |
| | 60 minutes | 25,750 | 7,617 |
| | 90 minutes | 25,667 | 7,583 |
| 6 Plates | 30 minutes | 25,833 | 7,750 |
| | 60 minutes | 25,750 | 7,500 |
| | 90 minutes | 25,917 | 7,733 |
| 8 Plates | 30 minutes | 25,833 | 7,717 |
| | 60 minutes | 26,333 | 7,583 |

| Number of Plates | Contact Time | Temperature (Average) | pH (Average) |
|---|---|---|---|
| | 90 minutes | 25,833 | 7,767 |

The results of this study also showed an increase in temperature from 25.75$^{o}$C to 26.0$^{o}$C, and the highest average temperature (26.0$^{o}$C) was in the electrocoagulation process with 8 plates. Likewise, with the contact time variable, it also showed an increase in temperature from 25.83$^{o}$C to 25.94$^{o}$C, and the highest average temperature (25.94$^{o}$C) was in the electrocoagulation process with 60 minutes contact time.

The use of electrocoagulation method can increase temperature. This is in line with the increasing number of plates and contact time used. The increase in temperature is due to the strong electric current that spreads to the aluminum plate and direct contact with the wastewater to be treated. Another factor that can affect the high and low temperature is the temperature of the air during processing, the higher the air temperature will affect the temperature in the wastewater.

Table 1 also shows that the highest average pH (7,767) occurred in the electrocoagulation process with 8 plates in 90 minutes contact time, while the lowest average pH (7.5) occurred in the electrocoagulation process with 6 plates in 60 minutes contact time. The increase in pH value is caused by the accumulation of OH in the electrocoagulation process. Rindatami, et al (2016) states that cathode in the electrocoagulation process produces $OH^-$ ions which will increase the pH value. The pH value of the solution also affects the number of ions in the solution as well as the solubility of the formed product. The pH of the solution affects the overall efficiency and effectiveness of electrocoagulation. This is consistent with research conducted by Kobya and Demirbas (2015) which states that the range of $6 < pH < 9$ is effective in reducing COD in textile wastewater by electrocoagulation. The number of electrodes and the amount of voltage used affect the electrocoagulation process. Flocks that bind the contaminant are produced by interaction between the electrode and the voltage in the electrocoagulation process. The more flocks produced the better the electrocoagulation process (Hanif et al., 2012). This increase in pH is normally attributed to the water reduction reaction at the cathode, and this in turn will depend on the rate of the alloy dissolution reaction. The pH will influence the nature of the aluminum hydroxy species. It is evident that the monomeric hydroxy−aluminum cations are stable at low pH, while increasing the pH to values close to 7.0 leads to the production of cationic aluminum hydroxy species, and the $Al(OH)_3$ precipitate (Dura et al., 2019).

Table 2 Analysis of differences in temperature and pH values based on the number of plates and contact time in electrocoagulation process

| Source | Sig. (Temperature) | Sig. (pH) |
|---|---|---|
| Corrected Model | 0,940 | 0,514 |
| Intercept | 0,000 | 0,000 |
| Number of Plates | 0,628 | 0,890 |
| Contact Time | 0,856 | 0,108 |
| Number of Plates * Contact Time | 0,814 | 0,664 |

Table 2 shows that there was no significant difference between the number of plates (p-value = 0.628), contact time (p-value = 0.856), and the number of plates and contact time (p-value = 0.814) and the temperature in electrocoagulation process. The same results were also shown in pH analysis. The results showed that there was no significant difference between the number of plates (p-value = 0.89), contact time (p-value = 0.108), and the number of plates and contact time (p-value = 0.664) and the pH in electrocoagulation process.

**Total Coliforms in electrocoagulation process**

Table 3. Average total Coliforms in wastewater based on number of plates and contact time

| Number of Plates | Contact Time | Mean |
|---|---|---|
| 4 Plates | 30 Minutes | 294,167 |
| | 60 Minutes | 669,167 |
| | 90 Minutes | 580,000 |
| 6 Plates | 30 Minutes | 183,333 |
| | 60 Minutes | 300,000 |
| | 90 Minutes | 138,333 |
| 8 Plates | 30 Minutes | 140,667 |
| | 60 Minutes | 228,667 |
| | 90 Minutes | 463,333 |

The results related to total Coliforms in this study showed that the total Coliforms was in the range of 2 – 2.735 colonies, with an average of 333 colonies and a standard deviation of ± 572,102. Based on table 3, the lowest average total Coliform occurred in the electrocoagulation process was

with 6 plates at 90 minutes (138 colonies), and the highest was at 4 plates at 60 minutes contact time (669 colonies).

The results of bivariate analysis (two way Anova) shown in table 4 showed that there was no significant difference between the number of plates (p-value = 0.269), contact time (p-value = 0.537), and the number of plates and contact time (p- value = 0.863) and the total Coliforms in electrocoagulation process.

Table 4. Bivariate analysis of total Coliform differences based on number of plates and contact time in electrocoagulation process

| Source | Sig. |
|---|---|
| Corrected Model | 0,727 |
| Intercept | 0,000 |
| Number of Plates | 0,269 |
| Contact Time | 0,537 |
| Number of Plates * Contact Time | 0,863 |

The interaction between variables number of plates and contact time showed that the lowest average total Coliforms occurred in the electrocoagulation process with 6 plates at 90 minutes, i.e. only 138 Coliform colonies. Although the results of the bivariate analysis showed no significant difference between the number of plates (p-value = 0.269), contact time (p-value = 0.537), and number of plates and contact time (p-value = 0.863), these results indicate effectiveness in using the concept of electrocoagulation compared to the use of other disinfectants. This result can be seen in Figure 1 which shows that the use of other disinfectants commonly used in hospitals is not very effective in reducing total Coliforms, this is indicated by the presence of a value that exceeds the quality standards for wastewater set by the government, namely at the first inspection with a total Coliform of 11,067 colonies and a fifth examination with a total Coliform of 12,009 colonies (maximum standard = 3,000 colonies). Whereas in the use of electrocoagulation, everything is below the environmental quality standard set by the government. This means that this concept is quite effective in use, as a substitute for disinfectants.

FIGURE 1. Comparison of total Coliforms based on the use of disinfectants and electrocoagulation concept

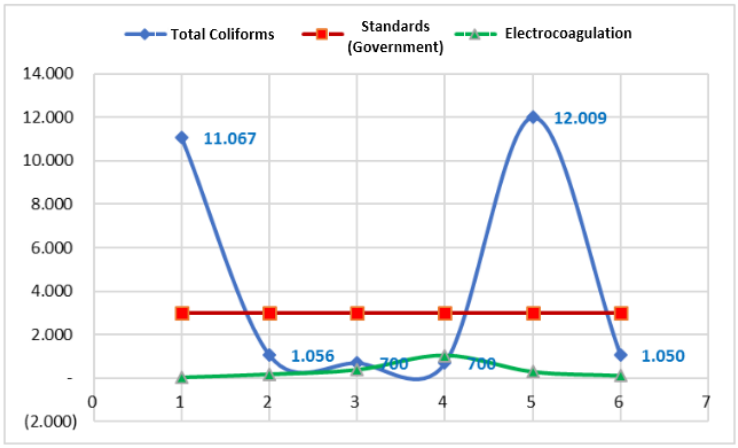



Table 5 shows effectiveness of the use of electrocoagulation concept based on the number of plates and contact time. The results showed that by using 6 plates and 90 minutes contact time showed the best results in reducing Coliforms (Effectiveness of 88.38%). While the lack of effectiveness was shown in the electrocoagulation process using 4 plates with 90 minutes contact time.

Table 5. Effectiveness of the use of electrocoagulation in reducing Coliforms

| Number of Plates / Contact Time | 30 Minutes | 60 Minutes | 90 Minutes |
|---|---|---|---|
| 4 Plates | 80,49% | 76,78% | 48,06% |
| 6 Plates | 73,87% | 82,68% | 88,38% |
| 8 Plates | 78,30% | 78,01% | 84,45% |

The mechanism of Coliform death in wastewater after electrocoagulation treatment is when hospital wastewater flows through the electrodes. Electron jumps in the electric field from the cathode (negative) to the anode (positive) will "shoot" Coliform bacteria in wastewater. Electric shock in the electrocoagulation system will break down cell walls, which will eventually kill the bacteria.

**Conclusion**

There is no significant difference between the contact time (p-value = 0.537), number of electrode plates (p-value = 0.269) and the total Coliforms in electrocoagulation process. The use of 6 plates and 90 minutes contact time shows the best results in reducing total Coliforms in the electrocoagulation process with an effectiveness reaching 88.38%. The concept of electrocoagulation can be used as a substitute for disinfectants in reducing total Coliforms in hospital wastewater.

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**Summary**

**Study on the Utilization of Electrocoagulation Concept as a Disinfectant Substitute in Hospital Wastewater.** The purpose of this study is to identify differences in variations of contact time and number of electrode plates in electrocoagulation process on the decrease of total Coliforms in Bandung City hospital wastewater. An experimental research with factorial randomized design. The volume of wastewater sample to check the total Coliforms was a minimum of 100 ml, using 3 treatments and 6 repetitions. Data analysis used was two-way ANOVA test. The results showed that there was no significant difference between the number of plates (p-value = 0.269), contact time (p-value = 0.537), and the number of plates and contact time (p-value = 0.863) with the total Coliforms in electrocoagulation process. The use of 6 plates and 90 minutes contact time showed the best results in reducing total Coliforms, with effectiveness reaching 88.38%. This means that the concept is quite effective to use as a substitute for disinfectant.

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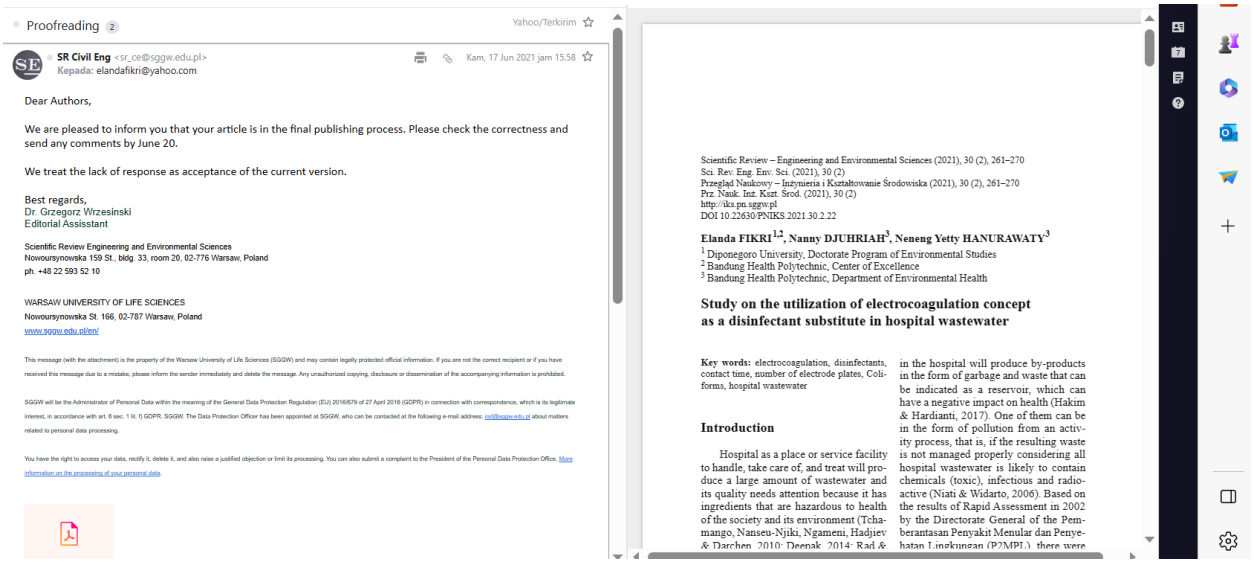

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Dear Authors,

We are pleased to inform you that your article is in the final publishing process. Please check the correctness and send any comments by June 20.

We treat the lack of response as acceptance of the current version.

Best regards,
Dr. Grzegorz Wrzesinski
Editorial Assisstant

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## Study on the utilization of electrocoagulation concept as a disinfectant substitute in hospital wastewater

**Key words:** electrocoagulation, disinfectants, contact time, number of electrode plates, Coliforms, hospital wastewater

### Introduction

Hospital as a place or service facility to handle, take care of, and treat will produce a large amount of wastewater and its quality needs attention because it has ingredients that are hazardous to health of the society and its environment (Tchamango, Nanseu-Njiki, Ngameni, Hadjiev & Darchen, 2010; Deepak, 2014; Rad &

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In addition to having a positive impact on society, namely as a place to heal the sick, hospital also has the possibility of having a negative impact (Akansha, Nidheesh, Gopinath, Anupama & Kumar, 2020). All medical service activities in the hospital will produce by-products in the form of garbage and waste that can be indicated as a reservoir, which can have a negative impact on health (Hakim & Hardianti, 2017). One of them can be in the form of pollution from an activity process, that is, if the resulting waste is not managed properly considering all hospital wastewater is likely to contain chemicals (toxic), infectious and radioactive (Niati & Widarto, 2006). Based on the results of Rapid Assessment in 2002 by the Directorate General of the Pemberantasan Penyakit Menular dan Penyehatan Lingkungan (P2MPL), there were 648 hospitals out of 1,476 hospitals which 49% of them had new incinerators and 36% of them had wastewater treatment plants (WWTP). Based on this amount, the quality of wastewater that has gone through management process that meets the requirements has only reached 52% (Djaja & Maniksulistya, 2006).