

Potential Applications of Land Treatment Systems for Disinfectant-Rich Wastewater in Response to the COVID-19 Health Protocol: A Narrative Review

Yetrie Ludang¹, Herry Palangka Jaya², Sarwoko Mangkoedihardjo^{3*}

¹ Department of Forestry, Faculty of Agriculture, Palangka Raya University, Palangka Raya, Indonesia.

² Agricultural Industrial Technology Study Program, Faculty of Agriculture, University of Palangka Raya, Indonesia.

³ Department of Environmental Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia.

ARTICLE INFO

NARRATIVE REVIEW

Article History:

Received: 13 November 2021

Accepted: 20 February 2022

*Corresponding Author:

Sarwoko Mangkoedihardjo

Email:

prosarwoko@gmail.com

Tel:

+62315948886

Keywords:

Disinfectants,

Wastewater Treatment,

Sanitation,

Plants.

ABSTRACT

Introduction: The use of antiseptics and disinfectants in daily health protocols has a consequence of changing the quality of wastewater to be toxic to microbes. As a result, microbiological wastewater treatment has the potential to not be processed properly. To solve the problem of disinfectant-rich wastewater, a plant-based treatment method can be useful, the implementation of which is a land treatment system for wastewater.

Materials and Methods: The data collection method was carried out through the Mendeley Reference Manager, searching for articles online, and placing the terms “land treatment system”, and “disinfectant-rich wastewater”. The selected articles were up-to-date and had a significant relationship between the two terms.

Results: This sanitation system can be a stretch of land and/or a pond of water, on which plants can grow and process. Normal concentrations of disinfectants for microbial elimination had no negative effects on the growth of various types of plants. Plants continue to live in the stress of water rich in disinfectants, as a condition of their ability to treat wastewater. The involvement of various wastewater treatment media makes evapotranspiration dry bed and evapotranspiration wet bed or wetland ponds capable of processing various pollutants. This approach can be implemented for on-site and off-site sanitation system.

Conclusion: In this context, under conditions of enrichment of disinfectants in wastewater during the COVID-19 era, the land treatment system becomes feasible to solve the problem of changing the quality of wastewater.

Citation: Ludang Y, Palangka Jaya H, Mangkoedihardjo S. *Potential Applications of Land Treatment Systems for Disinfectant-Rich Wastewater in Response to the COVID-19 Health Protocol: A Narrative Review*. J Environ Health Sustain Dev. 2022; 7(1): 1525-35.

Introduction

Since the beginning of the COVID-19 pandemic era, everyone is advised to use sterilizing agents, both antiseptics and disinfectants. Several types of antiseptics, which are commonly used in everyday life, are chemicals, such as alcohol, phenol, permanganate, and iodine. Although disinfectants can be in the form of physical substances, ozone, and ultraviolet light, what is often and commonly used as a chemical substance is chlorine¹. Ethanol

and sodium hypochlorite are included in the recommendations of the World Health Organization (WHO) and researchers to prevent the spread of COVID-19¹⁻³. The massive use of both forms of sterilization is of course accompanied by the use of water for personal hygiene. The logical consequence is that there is an increase in the amount of wastewater and an increase in its toxicity compared to pre-pandemic

conditions. Due to wastewater toxicity, direct wastewater treatment using microbiological processes has the potential to be hampered⁴. When flushing the toilet becomes difficult, this condition is an indication of a buildup of sludge in the septic tank. The accumulation of fecal sludge occurs due to the inactivity of anaerobic microbes which are eliminated by disinfectant-rich wastewater⁵. The problem condition in the on-site sanitation system can also occur for a centralized sanitation system in a wastewater treatment unit that uses a microbiological process⁶.

Centralized wastewater treatment receives wastewater from the sewerage piping system. In general, these systems are located in urban areas as a consequence of lack of land for the implementation of on-site sanitation systems as well as other needs, such as prevention of groundwater pollution. Centralized treatment systems, which use microbiological processes, are also potentially affected by the presence of disinfectant-rich wastewater. The impact of microbiological processes can continue until the final disposal stage, either in the form of water bodies or land.

The solution to the problem of disinfectant-rich wastewater is the need for methods of treating biological diversity, both microbial and plant⁷⁻⁹, which specifically is the wastewater treatment system in the land. This land management system can be implemented on a small scale, such as placing ornamental plant pots to collect handwashing wastewater, and on a large scale, which is in the form of plantations, such as gardens, various green open spaces, forests, and also ponds for aquatic plants⁷.

This method of treating wastewater in land has been studied from the point of view of the effect of chemical disinfectants on plants. The effects of the formation of by-products from the interaction of disinfectants with plant media have also been

discussed. Thus, the aim of this study is that the wastewater treatment system in land becomes the right choice in its implementation.

Materials and Methods

For the purpose of this study, the data collection method was carried out through the Mendeley Reference Manager. The tool was used to search for articles online, and 2.2 thousand articles were found by searching “land treatment system”, and 60 articles by “disinfectant-rich wastewater”. Article selection screening was based on the criteria, including journal document type, open access publication type, in English, and downloadable. The selected articles were up-to-date and had a significant relationship between the searched terms. Exception was made for the WHO reference, which was taken through its website.

Results

Land treatment system

An illustration of the land treatment system applications from various wastewater sources is presented in Figure 1. The figure shows the three components of a wastewater management system, i.e. sources of wastewater, microbiological-based wastewater treatment in septic tanks, and collective wastewater treatment based on a land treatment system. The source of wastewater comes from the daily activities in a building. The septic tank is a reservoir for wastewater, which is also used to treat wastewater anaerobically. The results of the septic tank processing are channeled into the land treatment system, which involves plant processes known as plant-based treatment method. Wastewater sources can come from a building or a group of various buildings in a residential area, and a centralized wastewater treatment system. However, the land treatment system can be an evapotranspiration dry bed or evapotranspiration wet bed, commonly known as constructed wetland.

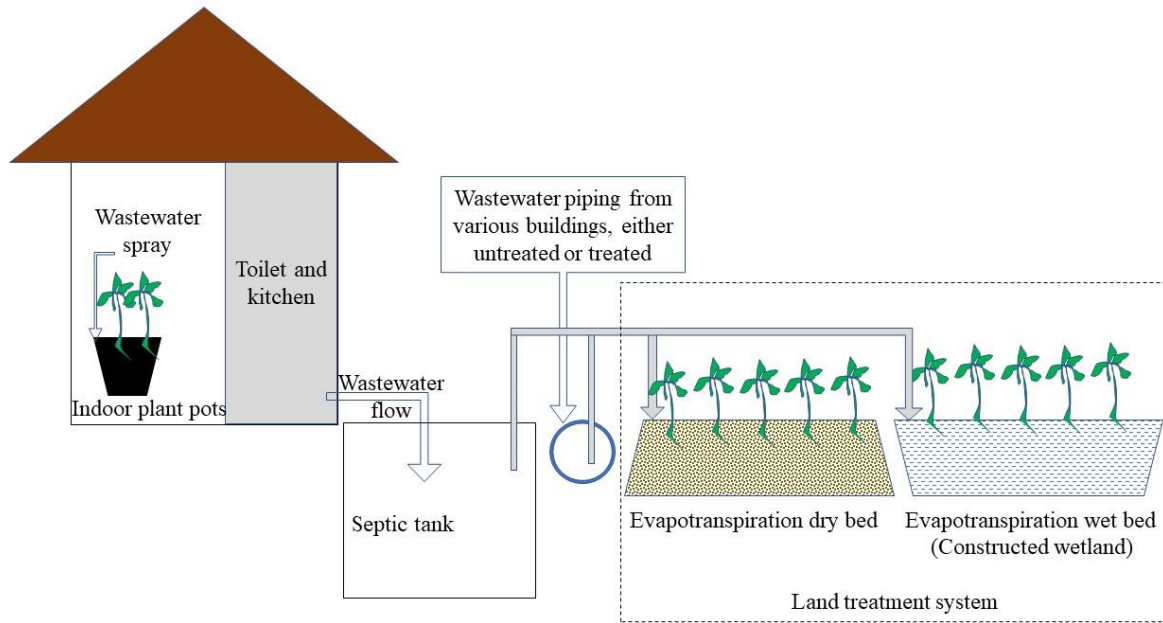


Figure 1: Land treatment system for wastewater

For buildings, which use an on-site sanitation system, the septic tank effluent is collected into the tank, which is then sent to the evapotranspiration bed. For buildings, which use a sewerage system followed by centralized wastewater treatment, the wastewater is channeled into the evapotranspiration bed. The use of dry beds or wet beds is determined based on local conditions, related to land availability, operation and maintenance, community acceptance, and supporting environmental factors.

The land treatment system can be initiated by a conventional wastewater treatment system in a septic tank, where the effluent is infiltrated into the soil. This system is an example of the application of an individual small-scale on-site sanitation system¹⁰⁻¹⁴, which has long been used in human life in the world. Specifically, the indoor phytoremediation application uses decorative plant pots¹⁵⁻¹⁷ as a form of a mini land treatment system. By developing environmental quality demands, the need for system improvement is also increasing. System development is directed at modifying soil absorption into evapotranspiration dry bed. The evapotranspiration dry bed is basically a mound of land, on which plants are grown. With this evapotranspiration dry bed, the effluent of wastewater undergoes a treatment

process by soil and plants. The evapotranspiration dry bed is a dry land medium, which is then aligned with the technology using a wetland medium, which is termed here as evapotranspiration wet bed or constructed wetland. In fact, the two media can be implemented into one sustainable system, namely during the dry season it takes the form of an evapotranspiration dry bed and during the rainy season it becomes a wetland pond¹⁸⁻²⁰.

More broadly, in land applications, soil is used as a natural filter to remove pollutants from wastewater. Soil also acts as a medium for receiving wastewater and as a reactor due to physico-chemical and biological reactions, occurring in the soil-water-plant ecosystem. This non-conventional treatment is effective in removing pollutants, such as suspended solids, organic matter, nitrogen, phosphorus, and microorganisms from the waste stream^{15,16}, in addition to increasing the amount of evapotranspiration²¹⁻²⁵.

Constructed wetlands are generally considered unsuitable for wide deployment due to their relatively large need for direct land area²⁶⁻²⁸ compared to a centralized wastewater treatment system. However, researchers²⁹⁻³² found that constructed wetlands could be more efficient in

land use than centralized wastewater treatment systems. The difference in results may be due to operational factors and the urgency of local environmental protection needs. Previous researchers stated that the key to success is in the operational management of the land treatment system^{33–36}, including the function as a medium for producing additional benefits, such as harvesting plant nutrients^{37–40}. Evapotranspiration bed is important for environmental protection, especially in areas where groundwater is the raw water source for drinking water consumption. This interest is due to the ability of the evapotranspiration bed to evaporate wastewater, so that the flow into groundwater can be minimized, and groundwater pollution can be suppressed. This approach can be implemented for on-site and off-site sanitation systems.

Both types of bed evapotranspiration can use one type of plant (monoculture), but it is better to use different types of plants (polyculture). The variety of plant species provides an opportunity to treat various pollutants in wastewater. Meanwhile, the effect of disinfectant-rich wastewater on plants is explained in the following section.

Disinfectant effect on plants

Chlorine disinfection of plants

Endophytic microorganisms have become important symbionts for plants, since they affect the response of plants to environmental stresses. Research results^{41,42} demonstrated the fact that endophytic disinfection did not have a significant negative effect on bluegrass on root morphology, leaf area or water use efficiency. However, when there is limited water, the disinfected plants experience greater leaf aging than the endophytic symbiotic plants. The solution to this problem is preserving the availability of water to maintain the growth of bluegrass plants. Similar studies⁴³ have tested the fungal endophytic symbiosis of a widespread native grass species (*Elymus virginicus*) against water availability. Under water-limited conditions, disinfected *E. virginicus* grass has half the biomass of plants with endophytes. Disinfectants significantly reduce plant biomass

and the number of tillers. To solve the problem, it is sufficient to maintain the availability of water to keep plants growing.

Recycling water disinfected with chlorine to eliminate pathogenic microbes for irrigation of 17 types of plants was carried out by researchers⁴⁴. It was reported that no visual symptoms of injury or decreased growth were observed in evergreen shrubs, but there was visual injury and/or decreased growth in some from deciduous shrubs. The presence of chlorine did not affect the chlorophyll content of the leaves, which is important for the continuation of the photosynthesis process, or its growth.

Plant disinfection using chlorine to suppress pathogenic microbial activity was investigated for its effect on spinach plant phytotoxicity^{45–47}. It was found that with 1 mg/L of chlorine dioxide, there was a significant elimination of the amount of *Escherichia coli* (*E. coli*), but it had no effect on the quality of baby spinach. In addition, there were problems with the accumulation of chlorate in plants. In other similar studies, chlorine dioxide was used for disinfection of wastewater for irrigation of baby lettuce fields in greenhouses. This disinfectant was effective for eliminating *E. coli* counts; however, baby lettuce accumulates chlorate. Chlorate accumulation in plant tissue must be considered because this is an adverse effect of disinfection treatment⁴⁸. The solution to the problem is the need to limit chlorine concentrations and/or pretreatment to produce chlorine concentrations that are safe for plant growth and their safety risks.

Disinfection of conidia and sclerotia in the management of olive plants (*Verticillium dahliae*) was carried out by researchers⁴⁹. The results showed that the disinfectant was able to eliminate the accumulation of conidia and sclerotia by more than 95%. However, disinfectants did not affect the growth characteristics of the olive plant.

Water disinfection can eliminate the number of bacteria, but does not affect germination, leaf growth, planting, and fruit production of the plants *Capsicum annum*, *Coriandrum sativum*, and *Lactuca sativa*⁵⁰. The problem arises with an

increase in secondary metabolites, such as phenols, flavonoids, and antioxidant activity.

Iodine disinfection of plants

Iodine disinfectants were also investigated for their effects on plants. The results showed that the germination percentage decreased in the seeds of most of the species germinated in iodized water. The germination rate of peanuts was halved due to iodine. However, there were no obstacles to the growth of the bean roots⁵¹.

Investigation of the effect of iodine species and solution concentration on iodine uptake by spinach (*Spinacia oleracea* L.) was carried out hydroponically⁵². The results showed that a higher concentration of I⁻ ($\geq 10 \mu\text{M}$) had a detrimental effect on plant growth, whereas IO_3^- had little effect on spinach plant biomass production. The increase in iodine concentration in the growth solution significantly increased the concentration of iodine in plant tissue. The detrimental effect of iodine (I) on plant growth may be due to too high accumulation of iodine in plant tissue according to the researchers.

The study of the effect of various forms of iodine on plant growth was based on the effect of mineral uptake (KI) and organoiodine in tomato plants at an early stage of vegetative growth. Organoiodine compounds accumulate mainly in the roots, while iodine accumulates at the top when administered as KI. The toxicity of iodine on plants is on the expression of genes related to metabolism of iodine and overall differences in plant uptake, transport of iodine in tomato plants based on the form of iodine compounds⁵³. This study continued to compare the uptake and effects of organic and mineral iodine compounds application on young tomato plants. At an early stage of development of tomato plants, it was concluded that organic iodine compounds, namely 3,5-diISA and 5-ISA, could be absorbed by the roots system⁵⁴.

Iodine absorption and translocation were studied in tomatoes and cabbage cultivated on various soil types using irrigation water, which contained iodine at concentrations up to 0.5 mg/L. In fact,

treatment of iodine at certain concentrations, under different growing media conditions, had no significant effect on chlorophyll concentration and photosynthetic efficiency of tomato and cabbage leaves. The growth of cabbage leaves cultivated on sandy and sandy silt soils with iodine treatment was slightly stimulated, while it did not change on silt soils. For different parts of tomato plants, regardless of soil type, the dry mass value remained constant. It can be concluded that iodine treatment had no negative effect on the physiological properties of cabbage and tomato plants⁵⁵.

Further research using irrigation water, which contained iodine at concentrations up to 0.5 mg/L was also applied for iodine accumulation by carrots (*Daucus carota* L. var. Sativus) and potato (*Solanum tuberosum* L.) cultivated on different soils, i.e. sand, sandy silt, and silt. The results showed that although iodine treatment did not significantly affect the biomass production of this crop, in potato tubers it resulted in lower magnesium (Mg) and P and higher concentrations of iron (Fe), whereas in carrot roots there was no similar trend. The accumulation of boron (B), copper (Cu), manganese (Mn), and zinc (Zn) in the edible parts of the plant was not affected by iodine treatment. Soil properties did not have a significant effect on biomass production under the same environmental conditions. The concentration and distribution of iodine in the two plants slightly altered by the growing medium. However, the index of chlorophyll content and photosynthetic efficiency of potato cultivated in silt soils increased significantly⁵⁶.

Hydroponic experiments were carried out to explore the characteristics of iodide and iodate uptake in strawberry plants, to measure the effects of iodine doses on plant growth and to evaluate their effects. Low levels of exogenous iodine ($\text{I}^- \leq 0.25 \text{ mg/L}$ or $\text{IO}_3^- \leq 0.50 \text{ mg/L}$) not only increase biomass and promote plant growth per plant, but also improve fruit quality by increasing vitamin C and sugar content dissolved from strawberries. However, excessive exogenous iodine inhibits plant growth and reduces biomass per plant.

Absorption of IO_3^- was found to increase the total acidity and nitrate content of fruits, thereby reducing the quality of strawberries. On the other hand, iodine uptake significantly reduced the total acidity and nitrate content of strawberries, thereby increasing fruit quality. It was concluded that giving KI with the right dose could improve the quality of the strawberry plant⁵⁷.

Some studies reported beneficial effects of iodine, including better growth, and changes in stress tolerance and antioxidant capacity, while other studies reported that iodine application elicits no response or even has side effects⁵⁸. However, these results are for consumption of crops, indicating that the use of non-consumable plants can be implemented to deal with disinfectant-rich wastewater.

Effect of disinfection by-products on plants

Chlorine is considered to be the most widely used chemical for water disinfection worldwide. However, chlorination of water can cause by-products formation that can be toxic to humans. Trihalomethanes (THMs) are the main chlorine disinfection by-products (DBP) in water treatment and distribution systems. Some studies have been carried out for a systematic review of the THMs toxicity through bioindicators. If it occurs at high concentrations in drinking water, it can cause serious adverse effects to human health^{26,59}.

Chlorination of water containing rich organic substances also produces DBP in the form of pentachlorophenols (PCP). Currently, PCP ecotoxicological tests on *Allium cepa* and *Vigna radiata* have been carried out⁶⁰. The results showed that there is a sensitivity effect on plant life; PCP is more toxic to *A. cepa* than to *V. radiata*.

Disinfectants, such as chlorine and chloramine react with organic matter in plant growth medium to produce DBP, such as chloral hydrate trichloronitromethane, chloroform, trichloroacetonitrile, dichloroacetonitrile, and bromochloroacetonitrile⁶¹. Researchers⁶² conducted a study on the formation of dozens of DBP and the results showed that 9 haloacetic acids

(HAA) and 9 haloacetonitriles (HANs) had a high ecological risk for green algae in chlorinated wastewater. So far, it has only been found that if someone consumes DBP has the potential to endanger human health. However, the harmful effects of DBP on plants still need further investigations⁶³⁻⁶⁵ in order to support the consideration of the feasibility of land treatment systems for disinfectant-rich wastewater.

There is limited information about the negative effects of DBP on plants. It is required to investigate the effects of DBP on plants, when disinfectants are intensively used in maintaining personal and environmental health. Disinfectants entering wastewater containing organic matter have great potential to produce DBP. In addition, the readiness of wastewater treatment using a land treatment system can determine the choices of dry beds or wet beds evapotranspiration, and the choice of various types of plants for biodiversity in eliminating DBP.

Discussion

The on-site sanitation system fully incorporates the capacity of the septic tank and local land to treat wastewater. Under conditions of disinfectant-rich wastewater, the consequences lead to microbiological processes in the septic tank. When the microbiological process is hampered, the disinfectant-rich effluent enters the soil matrix, which contains various organic materials. The presence of organic matter has the potential to transform the disinfectant into DBP. These potential problems also apply to off-site sanitation systems, which collect a lot of septic tank effluent, and of course can inhibit microbiological processes in conventional treatment systems.

Therefore, a land treatment system that involves plants to process disinfectant-rich wastewater is considered technically feasible to solve the above problems. The choice of dry bed application or wet bed land treatment system needs to be adjusted to local conditions, related to soil capabilities and choice of plant species. The results of the mentioned studies have proven that disinfectants do not have a significant negative effect on plants.

However, important attention needs to be paid to DBP, which requires in-depth study of the

toxicological studies of DBP on plants. The results of this study are presented in Table 1.

Table 1: Summary of land treatment systems for disinfectant-rich wastewater

Description	Specific characteristics	
Sanitation system	Individual small-scale on-site sanitation system	Collective centralized sanitation system
Land treatment system	Dry bed is suitable for individual and centralized wastewater treatment	Wet bed is suitable for centralized wastewater treatment
Disinfectant effects	<ul style="list-style-type: none"> • 1 mg/L of chlorine dioxide eliminates of the amount of <i>E. coli</i>. • No impact on the quality of baby spinach • Eliminate conidia and sclerotia by more than 95% • No effect on the growth characteristics of the olive plant 	<ul style="list-style-type: none"> • I- ($\geq 10 \mu\text{M}$) had a detrimental effect on plant growth. • Up to 0.5 mg/L <ul style="list-style-type: none"> ○ No significant effect on photosynthetic efficiency of tomato and cabbage leaves ○ Accumulated by carrots and potato
DBP	HAA and HANs have a high ecological risk for green algae	No sufficient information about the negative effects of DBP on plants

Conclusions

It is realized that there is an enrichment of disinfectants in wastewater as a consequence of the intensification of the use of disinfectants for personal and environmental health. Disinfectant enrichment in wastewater has the potential to hamper the performance of microbiological treatment processes in existing wastewater treatment systems. To maintain the existing system, it is necessary to consider the method of processing by plants in the land. Land treatment system using dry bed and wet bed evapotranspiration is technically feasible for the application of wastewater treatment containing disinfectant. At concentrations up to 1 mg/L for chlorine and iodine disinfectants in water, there were no significant negative effects on the growth of various plant species. Plants are still alive as a condition for being able to process pollutants, indicating that the disinfectant-rich wastewater is more feasible to treat in a plant-based sewage treatment system rather than microbiological treatment. The effluent is then applied to the land treatment system. This combination of processing is suitable to be applied during the COVID-19 era and beyond, in enhancing environmental safety.

The results of this study recommend applying a land treatment system, both dry bed and wet bed evapotranspiration, according to local conditions related to the content of various types of disinfectants in wastewater, and types of plants. In addition, a

phytotoxicological study of the disinfectant is required to establish the design and process of evapotranspiration beds. There are insufficient data by-products of disinfectants in growth media, and further research is needed to support the implementation of an efficient and effective processing system. It is also recommended for further investigation on ways of modifying the existing wastewater treatment system into a plant-based treatment system. Further research is also directed at conditioning land treatment for the readiness to dispose of the disinfectant-rich wastewater.

Abbreviations

DBP: Disinfection by-products; HAA: Haloaceticacids; HANs: Haloacetonitriles; IO₃⁻: Iodate ion; PCP pentachlorophenols; THMs: Trihalomethanes

Acknowledgments

The authors would like to thank Palangka Raya University, Palangka Raya; Institut Teknologi Sepuluh Nopember, Surabaya, by providing facilities to carry out this work.

Funding

This study was entirely self-financed by the authors.

Conflict of interest

The authors declare that there is no conflict of interest.

This is an Open-Access article distributed in accordance with the terms of the Creative Commons Attribution (CC BY 4.0) license, which permits others to distribute, remix, adapt, and build upon this work for commercial use.

References

1. WHO. Disinfectants and antiseptics [Internet]. 2004. Available from: <http://archives.who.in/eml/wmf/2004/English/> [cited 2020 Jul 12].
2. Meyers C, Kass R, Goldenberg D, et al. Ethanol and isopropanol inactivation of human coronavirus on hard surfaces. *J Hosp Infect.* 2021;107:45–9.
3. León Molina J, Abad-Corpa E. Disinfectants and antiseptics facing coronavirus: synthesis of evidence and recommendations. *Enferm Clin.* 2021;31:S84–8.
4. Vasiliadou IA, Molina R, Martinez F, et al. Toxicity assessment of pharmaceutical compounds on mixed culture from activated sludge using respirometric technique: The role of microbial community structure. *Sci Total Environ.* 2018;630:809–19.
5. Luukkonen T, Teeriniemi J, Prokkola H, et al. Chemical aspects of peracetic acid based wastewater disinfection. *Water SA.* 2014;40(1):73–80.
6. Ishii SKL, Boyer TH. Life cycle comparison of centralized wastewater treatment and urine source separation with struvite precipitation: Focus on urine nutrient management. *Water Res.* 2015;79:88–103.
7. Samudro H, Mangkoedihardjo S. Greening the environment in living a new lifestyle in the COVID-19 era. *Eurasian J Biosci.* 2020;14(2): 3285–90.
8. Ito T, Kato T, Hasegawa M, et al. Evaluation of virus reduction efficiency in wastewater treatment unit processes as a credit value in the multiplebarrier system for wastewater reclamation and reuse. *J Water Health.* 2016;14(6):879–89.
9. Nasser AM, Fawaqa H, Nitzan Y. The role of wastewater treatment plants in the environmental dissemination of antibiotic resistant bacteria (arb) and resistance genes (arg). *J Water Resour Prot.* 2019;11(08):981–94.
10. Mangkoedihardjo S. A new approach for the Surabaya sewerage and sanitation development programme 2020. *Advances in Natural and Applied Sciences.* 2010;4(3):233–5.
11. Samudro H, Mangkoedihardjo S. Indoor phytoremediation using decorative plants: An overview of application principles. *Journal of Phytology.* 2021;13:28–32.
12. Curneen S, Gill LW. Willow-based evapotranspiration systems for on-site wastewater effluent in areas of low permeability subsoils. *Ecol Eng.* 2016;92:199–209.
13. Patil YM, Munavalli GR. Performance evaluation of an integrated on-site greywater treatment system in a tropical region. *Ecol Eng.* 2016;95:492–500.
14. Yu ZLT, Bill BR, Stenstrom MK, et al. Feasibility of a semi-batch vertical-flow wetland for onsite residential graywater treatment. *Ecol Eng.* 2015;82:311–22.
15. Méndez-Mendoza AS, Bello-Mendoza R, Herrera-López D, et al. Performance of constructed wetlands with ornamental plants in the treatment of domestic wastewater under the tropical climate of South Mexico. *Water Pract Technol.* 2015;10(1):110–23.
16. Ludang Y, Jaya A, Inoue T. Microclimate conditions of the developed peatland in Central Kalimantan. *Journal of Applied Sciences.* 2007;7(18):2604–9.
17. Ben Saad M, Bousselmi L, Masi F, et al. A new approach for local wastewater management sanitation case study of rural school (Chorfech 24). *Water Pract Technol.* 2015;10(3):474–7.
18. Zheng Y, Wang X, Dzakpasu M, et al. Effects of interspecific competition on the growth of macrophytes and nutrient removal in constructed wetlands: A comparative assessment of free water surface and horizontal subsurface flow systems. *Bioresour Technol.* 2016;207:134–41.
19. Fernando, Jaya HP, Ludang Y. Sanitation implementation for Palangka Raya city based on carbon footprint balance. *International Journal of Civil Engineering and Technology.* 2018;9(9): 385–9.

20. Ludang Y. Application of phytotechnology in determining plant species for greenspace in the city of Palangka Raya. *International Journal of Advanced Research in Engineering and Technology*. 2019;11(1):1–6.
21. Mangkoedihardjo S. Leaf area for phytopumping of wastewater. *Appl Ecol Environ Res*. 2007;5(1):37–42.
22. Prasetyoko IA, Ludang Y, Heriamariaty, et al. Studies on the causes of forest and land fires in the palm oil plantation in central Kalimantan Province. *International Journal of Advanced Research in Engineering and Technology*. 2020;11(5):164–71.
23. Zaman B, Purwanto P, Mangkoedihardjo S. Reversible anaerob-evapotranspiration process for removal of high strength ammonium in leachate from tropical landfill. *Adv Sci Lett*. 2017;23(3): 2586–8.
24. Tsagkari E, Sloan WT. Impact of Methylobacterium in the drinking water microbiome on removal of trihalomethanes. *Int Biodeterior Biodegradation*. 2019;141:10–6.
25. Białowiec A, Sobieraj K, Pilarski G, et al. The oxygen transfer capacity of submerged plant *Elodea densa* in wastewater constructed wetlands. *Water (Switzerland)*. 2019;11(3):575.
26. Corzo A, Sanabria O. Adaptation of vegetation in high-rate constructed wetland using artificial carriers for bacterial growth: Assessment using phytopathological indicators. *Journal of Water Process Engineering*. 2019;32:100974.
27. Fan Y, Wu X, Shao L, et al. Can constructed wetlands be more land efficient than centralized wastewater treatment systems? A case study based on direct and indirect land use. *Sci Total Environ*. 2021;770:144841.
28. Christofilopoulos S, Kaliakatsos A, Triantafyllou K, et al. Evaluation of a constructed wetland for wastewater treatment: Addressing emerging organic contaminants and antibiotic resistant bacteria. *N Biotechnol*. 2019;52:94–103.
29. Caselles-Osorio A, Vega H, Lancheros JC, et al. Horizontal subsurface-flow constructed wetland removal efficiency using *Cyperus articulatus* L. *Ecol Eng*. 2017;99:479–85.
30. López-Rivera A, López-López A, Vallejo-Rodríguez R, et al. Effect of the organic loading rate in the stillage treatment in a constructed wetland with *Canna indica*. *Environ Prog Sustain Energy*. 2016;35(2):411–5.
31. Barbagallo S, Cirelli GL, Marzo A, et al. Effect of different plant species in pilot constructed wetlands for wastewater reuse in agriculture. *Journal of Agricultural Engineering*. 2013;44: 796–802.
32. Mangkoedihardjo S, Samudro G. Research strategy on kenaf for phytoremediation of organic matter and metals polluted soil. *Adv Environ Biol*. 2014;8(17):64–7.
33. Tamaki H, Zhang R, Angly FE, et al. Metagenomic analysis of DNA viruses in a wastewater treatment plant in tropical climate. *Environ Microbiol*. 2012;14(2):441–52.
34. Urase T, Sato T. Quantitative monitoring of resistance in *Escherichia Coli* to clinically important antimicrobials in an urban watershed. *J Water Environ Technol*. 2016;14(5):341–9.
35. Ludang Y, Supriyati W, Alpian. Assessment of saplings of mangosteen (*Garcinia Mangostana* L) in absorbing carbon dioxide. *International Journal of Civil Engineering and Technology*. 2018;9(11): 408–14.
36. Roman B, Brennan RA. A beneficial by-product of ecological wastewater treatment: An evaluation of wastewater-grown duckweed as a protein supplement for sustainable agriculture. *Ecol Eng*. 2019;142:100004.
37. Susilowati S, Ludang Y, Sinaga S. Design of quality structures for public greenspace in Palangka raya city. *International Journal of Advanced Research in Engineering and Technology*. 2020;11(5):172–82.
38. Tsihrintzis VA. The use of vertical flow constructed wetlands in wastewater treatment. *Water Resources Management*. 2017;31(10): 3245–70.
39. Samudro, H. Landscape intervention design strategy with application of Islamic ornamentation at Trunojoyo Park Malang, Jawa Timur, Indonesia. *Journal of Islamic Architecture*. 2020; 6(1):41-7.

40. Khorasani S, Azizi MH, Barzegar M, et al. Inhibitory effects of cinnamon, clove and celak extracts on growth of *Aspergillus flavus* and its aflatoxins after spraying on pistachio nuts before cold storage. *J Food Saf.* 2017;37(4):1-10.
41. Górski R, Szopińska D, Dorna H, et al. Effects of plant extracts and disinfectant huva-san TR 50 on the quality of carrot (*daucus carota* l.) Seeds. *Ecological Chemistry and Engineering.* 2020; 27(4):617–28.
42. Møretrø T, Schirmer BCT, Heir E, et al. Tolerance to quaternary ammonium compound disinfectants may enhance growth of *Listeria monocytogenes* in the food industry. *International Journal of Food Microbiology.* 2017;241:215–24.
43. Rudgers JA, Swafford AL. Benefits of a fungal endophyte in *Elymus virginicus* decline under drought stress. *Basic Appl Ecol.* 2009;10(1): 43–51.
44. Cayanan DF, Dixon M, Zheng Y, et al. Response of container-grown nursery plants to chlorine used to disinfect irrigation water. *HortScience.* 2009;44(1):164–7.
45. López-Gálvez F, Gil MI, Meireles A, et al. Demonstration tests of irrigation water disinfection with chlorine dioxide in open field cultivation of baby spinach. *J Sci Food Agric.* 2018;98(8):2973–80.
46. Hao F, Li J, Wang Z, et al. Influence of chlorine injection on soil enzyme activities and maize growth under drip irrigation with secondary sewage effluent. *Irrig Sci.* 2018;36(6):363-79.
47. Yang L, Zhu Z, Zhang J, et al. Response of kiwifruit yield and fruit quality to chloride-containing fertilizers. *Agron J.* 2020;112(2):1012–20.
48. Tombini Decol L, López-Gálvez F, Truchado P, et al. Suitability of chlorine dioxide as a tertiary treatment for municipal wastewater and use of reclaimed water for overhead irrigation of baby lettuce. *Food Control.* 2019;96:186–93.
49. Gómez-Gálvez FJ, Hidalgo-Moya JC, Vega-Macías V, et al. Reduced introduction of *Verticillium dahliae* through irrigation systems and accumulation in soil by injection of peroxygen-based disinfectants. *Plant Pathol.* 2019; 68(1):116–26.
50. Cordoba A, Hernández R, Viveros-Palma I, et al. Effect on plant growth parameters and secondary metabolite content of lettuce (*Lactuca sativa* L.), coriander (*Coriandrum sativum*), and chili pepper (*Capsicum annum* L.) watered with disinfected water by Ag-TiO₂ nanoparticles. *Environmental Science and Pollution Research.* 2021;28(28):37130–41.
51. Janik D, Macler B, Thorstenson Y, et al. Effect of iodine disinfection products on higher plants. *Adv Space Res.* 1989;9(8):117–20.
52. Zhu YG, Huang YZ, Hu Y, et al. Iodine uptake by spinach (*Spinacia oleracea* L.) plants grown in solution culture: Effects of iodine species and solution concentrations. *Environ Int.* 2003;29(1): 33–7.
53. Halka M, Klimek-Chodacka M, Smoleń S, et al. Organic iodine supply affects tomato plants differently than inorganic iodine. *Physiol Plant.* 2018;164(3):290–306.
54. Halka M, Smoleń S, Ledwożyw-Smoleń I, et al. Comparison of effects of potassium iodide and iodosalicylates on the antioxidant potential and iodine accumulation in young tomato plants. *J Plant Growth Regul.* 2020;39(1):282–95.
55. Dobosy P, Vetési V, Sandil S, et al. Effect of irrigation water containing iodine on plant physiological processes and elemental concentrations of cabbage (*brassica oleracea* l. var. *capitata* l.) and tomato (*solanum lycopersicum* l.) cultivated in different soils. *Agronomy.* 2020;10(5):720.
56. Dobosy P, Endrédi A, Sandil S, et al. Biofortification of potato and carrot with iodine by applying different soils and irrigation with iodine-containing water. *Front Plant Sci.* 2020;11: 593047.
57. Li R, Liu HP, Hong CL, et al. Iodide and iodate effects on the growth and fruit quality of strawberry. *J Sci Food Agric.* 2017;97(1):230–5.
58. Medrano-Macías J, Leija-Martínez P, González-Morales S, et al. Use of iodine to biofortify and promote growth and stress tolerance in crops. *Front Plant Sci.* 2016;27:1146.
59. de Castro Medeiros L, de Alencar FLS, Navoni

- JA, et al. Toxicological aspects of trihalomethanes: a systematic review. *Environ Sci Pollut Res.* 2019;26(6):5316–32.
60. Ranjan J, Joshi V, Mandal T, et al. Ecotoxicological risk assessment of pentachlorophenol, an emerging DBP to plants: evaluation of oxidative stress and antioxidant responses. *Environ Sci Pollut Res.* 2021;28(22): 27954–65.
61. Doederer K, Gernjak W, Weinberg HS, et al. Factors affecting the formation of disinfection by-products during chlorination and chloramination of secondary effluent for the production of high quality recycled water. *Water Res.* 2014;48:218–28.
62. Li Z, Liu X, Huang Z, et al. Occurrence and ecological risk assessment of disinfection byproducts from chlorination of wastewater effluents in East China. *Water Res.* 2019;157: 247–57.
63. López-Gálvez F, Andújar S, Marín A, et al. Disinfection by-products in baby lettuce irrigated with electrolysed water. *Journal of the Science of Food and Agriculture.* 2018;98(8):2981–8.
64. Garrido Y, Marín A, Tudela JA, et al. Chlorate accumulation in commercial lettuce cultivated in open field and irrigated with reclaimed water. *Food Control.* 2020;114:107283.
65. Truchado P, Gil MI, Suslow T, et al. Impact of chlorine dioxide disinfection of irrigation water on the epiphytic bacterial community of baby spinach and underlying soil. *PLoS One.* 2018;13(7): e0199291.