Journal of Environmental Health and Sustainable Development

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

Yetrie Ludang [1], Herry Palangka Jaya [2], 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 chlorine [1]. Ethanol and sodium hypochlorite are included in the recommendations of the World Health Organization (WHO) and researchers to prevent the spread of COVID-19 [1–3]. 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

[DOR: 20.1001.1.24766267.2022.7.1.2.1]
[DOI: 10.18502/jehsd.v7i1.8968]

conditions. Due to wastewater toxicity, direct wastewater treatment using microbiological processes has the potential to be hampered [4]. 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 wastewater [5]. 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 process [6].

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 plant [7–9], 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 plants [7].

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.

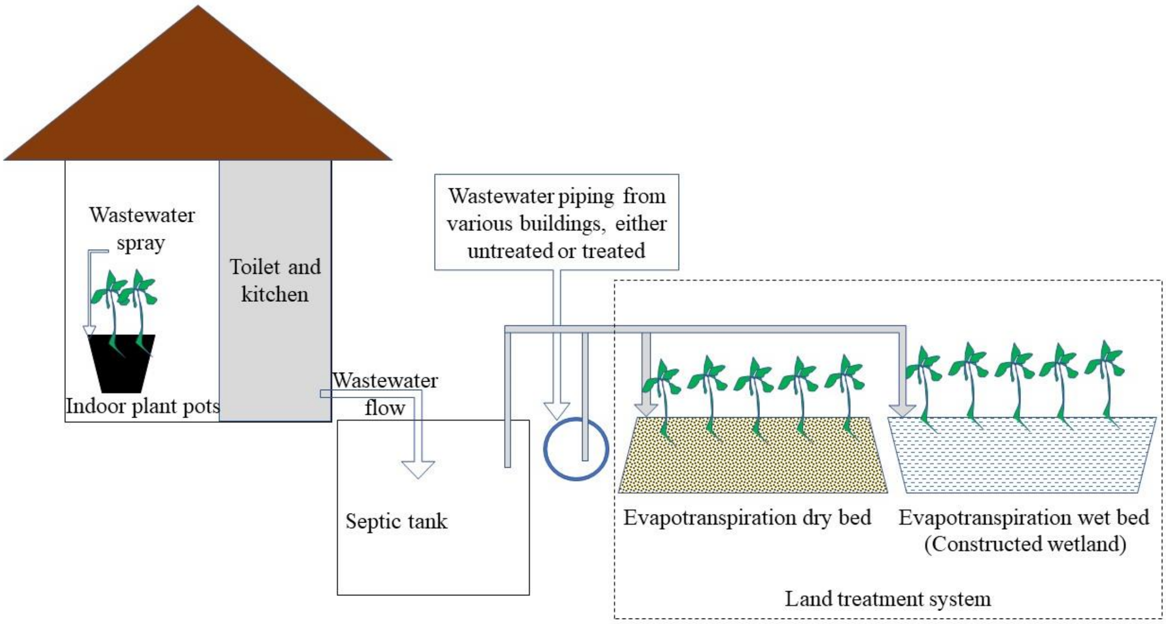

Figure 1: Land treatment system for wastewater

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 vapotranspiration 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 system [10–14], which has long been used in human life in the world. Specifically, the indoor phytoremediation application uses decorative plant pots [15–17] 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 pond [18–20].

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 evapotranspiration [21–25].

Constructed wetlands are generally considered unsuitable for wide deployment due to their relatively large need for direct land area [26–28] compared to a centralized wastewater treatment system. However, researchers [29–32] 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 studies [43] 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 researchers [44]. 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 treatment [48]. 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 researchers [49]. 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 annuum, Coriandrum sativum,* and *Lactuca sativa* [50]. The problem arises with an

[DOR: 20.1001.1.24766267.2022.7.1.2.1]

[DOI: 10.18502/jehsd.v7i1.8968]

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 roots [51].

Investigation of the effect of iodine species and solution concentration on iodine uptake by spinach (*Spinacia oleracea* L.) was carried out hydrophonically [52]. The results showed that a higher concentration of I- (≥ 10 μM) 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 compounds [53]. 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 system [54].

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 plants [55].

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 significantly [56].

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 ($I^- \leq$ 0.25 mg/L or $IO_3^- \leq$ 0.50 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.

[DOR: 20.1001.1.24766267.2022.7.1.2.1]

[DOI: 10.18502/jehsd.v7i1.8968]

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 plant [57].

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 effects [58]. 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 out [60]. 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 bromochloroacetonitrile [61]. Researchers [62] conducted a study on the formation of dozens of DBP and the results showed that 9 haloaceticacids (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 investigations [63–65] 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	• 1 mg/L of chlorine dioxide eliminates of the amount of *E. coli*. • 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	• I- (≥ 10 μM) had a detrimental effect on plant growth. • Up to 0.5 mg/L ○ 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.

[DOR: 20.1001.1.24766267.2022.7.1.2.1]

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