Selection of Plants for Constructed Wetlands Based on Climate and Area in the Interest of Processing Pollutant Parameters on Leachate: A Review

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Abstract. The process of waste decomposition in landfills is a process that converts waste into organic fertilizer due to percolating rainwater from biochemical waste processes and wastewater content. Range of pollutants may affect public health and the ecosystem around the landfill location. Therefore, it is crucial to treat leachate before discharge to water bodies. Landfill leachate processing can be carried out through 3 processes, consisted of physical-chemical, biological, and the combination of physical-chemical and biological. Currently, constructed wetlands as natural treatment are considered environmentally friendly to deal with water pollution. This writing aimed to determine the differences in the leachate landfill characteristics, drainage system, and plant species used in the constructed wetland. This writing is based on a literature review of experimental research on water treatment carried out with the same parameters as leachate and leachate treatment. The literature review results show that leachate landfill processing depends on leachate characteristics and is influenced by age, type of waste, region, and climate.

1. Introduction
Increasing urban solid waste becomes a significant problem for society, as it creates environmental and economic issues coupled with poor solid waste management [1]. Ninety-five percent of urban solid waste worldwide is disposed of in landfills [2]. Leachate from landfills is still a severe problem for landfills since this leachate can pose a significant threat to soil, surface water, and groundwater [3], [4]. Leachate from landfills contains high organic substances, including COD ranging from 150-100,000 mg/L, nitrite ranging from 1-1,500 mg/L, and BOD 200-2,000 mg/L [5]. This hence makes leachate must be treated appropriately before discharge to the environment. Conventional leachate processing is classified into three major groups consisting of 1) physical-chemical processes, 2) biological processes, and 3) a combination of biological and physical-chemical processes [6], [7]. Biological leachate processing is generally used for leachate processing with pollutants containing high organic substances. This technique has low-cost effectiveness, simple operation, and is reliable as a leachate landfill treatment with a high BOD/COD ratio [8], [9]. Constructed wetland as a biological treatment has been successfully developed on a laboratory scale, pilot scale, and field-scale for processing landfill leachates with the advantage of high pollutant reduction efficiency [10]. Constructed wetland (CW) is a planned or controlled treatment system designed and built using natural processes involving vegetation, media, and microorganisms to treat wastewater [11]. Microorganism will break the organic material contained in wastewater into simpler compounds which will then be used by plants as nutrients, while the root system of aquatic plants will produce oxygen...
which can be used as an energy source/catalyst for a series of metabolic processes for microorganism life [11]. The advantage of this constructed wetland method is that it does not require high operation and maintenance costs as the process takes place naturally. Thus, this method can be a waste treatment solution with cost, technical and operational problems in the treatment system. Data from several studies show that the CW system can remove 33-77% COD [12]. The highest COD, BOD, and N removal percentage was found in the horizontal flow medium flows in CW are 64%, 64%, 93% for leachate treatment [13]. Based on these various studies, it can be concluded that the Constructed wetland method has been tested in reducing the contaminant content of wastewater.

Various previous researches conducted a literature study of these researches have been carried out on Constructed wetlands based on the system, media, and types of plants used to remove pollutants in wastewater and leachate. Based on the facts found, it is necessary to collect and study literature regarding the characteristics of leachate, the Constructed wetland drainage system, and the aquatic ability plants in constructed wetlands to reduce leachate contaminants so that the application can be carried out in suitable conditions.

2. Leachate characteristics

The quality of leachate landfill is generally characterized by several Physico-chemical parameters, such as pH, suspended solids (SS), (BOD), (COD), ammonia (NH₄-N) [14], total nitrogen (TN), chloride, phosphorus, heavy metals, and alkalinity [15]. The characteristics of leachate based on landfill age are classified into three types, young landfill with age (<1 year), medium landfill with age (1-5 years), and old landfill with age (> 5 years) [16], [17]. In addition to the landfill age, the leachate content can also differ by region. The leachate characteristics by region are presented in Table 1.

| Parameter | Asia      | America   | Europe   |
|-----------|-----------|-----------|----------|
| pH        | 5.4-8.55  | 5.3-8.2   | 7.8-43   |
| COD (mg/L) | 13-9,335 | 65.5-1,108 | 445-4,770 |
| BOD (mg/L) | 15.5-5.275 | 12.25-918 | 25-792   |
| BOD₅/COD  | 0.03-0.74 | 0.06-0.53 | 0.05-0.5 |
| TSS (mg/L) | 25.4-1,164 | 9.5-50.5  | 22-2,720 |
| TP (mg/L)  | 0.09-75   | 0.8       | 0.07-5.5 |
| PO₄ (mg/L) | 3.4-117   | 7.3       | 0.113-5  |
| Ammonia-N (mg/L) | 50-450   | 0.78-253  | 23.5-286.5 |
| TN (mg/L)  | <400      | 384       | 2.25-684 |
| NO₃ (mg/L) | 866-1200  | 0-166     | 0.1-159  |

Comparison of the landfill leachates parameter values in Asia, Europe, and America (Table 1) shows that landfill leachates in Asia are more contaminated in almost all quality parameters (except TN and EC). Higher rates of urbanization directly affect the waste composition. When associated with income levels and increased affluence, higher consumption tends to result in more paper and plastic packaging materials. Countries in Asia have a larger population and results in more organic waste, including kitchen waste. Many countries in Asia still use non-recycled goods, such as paper, metals, and plastics. Their concern about the importance of waste processing is still minimal, so data on the composition of waste in Asian countries are difficult to be obtained, even though it is available, it is often not the latest data [19]. On the other hand, countries in Europe and America have better data collection than Asia. Countries in Europe and America have the same characteristics and waste management to have almost the same concentration.

Many landfill locations are located around rivers and streams, which are the primary source of agriculture and productivity, industrial and domestic water supply. The characteristics of the leachate to be disposed of in the environment must not pollute the environment [20]. The main leachate...
parameters that should be measured along with the maximum daily concentration limits are presented in Table 2.

Table 2. The maximum daily concentration limits in leachate [21]–[23]

| Parameter | Unit     | Maximum (mg/L) | Maximum (mg/L) | Maximum (mg/L) |
|-----------|----------|----------------|----------------|----------------|
| pH        | -        | 6.9            | 6.5-9.0        | 6-9            |
| COD       | (mg/L)   | -              | 50             | 300            |
| TKN       | (mg/L)   | -              | 2              | -              |
| BOD5      | (mg/L)   | 220            | 20             | 150            |
| TSS       | (mg/L)   | 88             | 10             | 400            |
| NH₃       | (mg/L)   | 10             | 1              | 5              |
| Arsenic   | (mg/L)   | 1.1            | -              | -              |
| Chromium  | (mg/L)   | 1.1            | -              | 0.5            |

The quality standard’s purpose was to determine the acceptable/harmless concentration limit for the environment after the landfill leachate is processed. The results of landfill leachate processing must be below the specified quality standards. In the last decade, the imposed disposal standards have become increasingly stringent. Performance evaluation of landfill leachate processing is determined based on the output of COD, NO₃-N, and heavy metals concentrations compared to the quality standards and processing efficiency.

3. Constructed wetland system
1. Systems that use submerged water plants are generally used in the CW system with the Surface Flow (SF) type. The system’s advantage is its good ability in terms of filtering, absorption of particulates, nutrients, and pollutants in wastewater [24] with low construction costs. In this system, the wastewater will pass through the media located between the plant stems and through the surface debris. Sunlight that penetrates to the bottom of the system triggers algae growth rates faster than photosynthetic reactions [25].
2. The Sub-Surface Flow (SSF) system is divided into horizontal subsurface flow (HSSF) and vertical subsurface flow (VSSF) [26]. These two types of wetlands use water plants in their processing [24]. Aerobic and anaerobic processes take place in the filter media’s pores such as sand and gravel [27]. The weakness of the SSF system is the possibility of clogging (blockage) which is one of the main weaknesses of system performance [28].

4. Plant of constructed wetland
Many types of plants are used for constructed wetlands [29], [30]. The content in landfill leachate is divided into metal and metal contaminants. The ability of plants to remove non-metallic contaminants can be seen in Figure 1.
Referring to several research findings, it was found that the highest removal of COD contaminants was in *Cyperus papyrus* > *Canna indica* > mixed plant (*C. esculenta with C. indica*) > *Scirpus grossus* > *Typha domingensis* > *Phragmites australis* > *Vetiveria zizanoides* > *Hedychium coronarium*. The highest BOD contaminant removal was *Arundo donax* > *Cyperus papyrus* > mixed plant (*C. esculenta with C. indica*) > *Canna indica* > mixed plants (*Typha latifolia, P. australis, and Canna indica*). The highest TSS removal was *Canna indica* > *Arundo donax* > *Cyperus papyrus* > *Hedychium coronarium* > *Phragmites australis* > *Scirpus grossus* > *Vetiveria zizanoides* > mixed plants (*C. esculenta and C. indica*). While the ability of plants to remove metallic contaminants can be seen in Figure 2.
Figure 2. The ability of plants to remove non-metallic contaminants a) Subsurface Flow Wetlands, b) Surfaceflow Wetlands Wetlands Wetlands (Modified: [31], [38]–[41])

Meanwhile, the plants with the highest removal ability of Fe metal contaminants were *Phragmites australis* > *Juncus effussus*. *Phragmites australis* > *Juncus Efussus* > mixed plants (*Typha latifolia, P. australis,* and *C. indica*) had the highest removal of Cr metal. Cd metal can be absorbed optimally by plants in the highest constructed wetland, namely *Phragmites australis* > *Juncus effussus*. The best removal of Zn was *Phragmites australis* > *Juncus effussus*, while for Cu metal was the highest mixed plants (*Typha latifolia, P. australis,* and *C. indica*). Next, the Ni metal’s removal with the most optimal ability in the Constructed wetland was by *Phragmites australis* > *Juncus effussus* > mixed plants (*Typha latifolia, P. australis,* and *C. indica*). In this case, Pb is best absorbed by the highest mixed plants (*E. crassipes, S. molesta,* and *P. stratiotes*) > *E. crassipes* > *Imperata cylindrica*.

There are four types of plants in the world that are most commonly used in Constructed wetlands, consisting of *Canna, Iris, Heliconia, Zantedeschia, Phragmites* and *Typhas*. These plants have been recommended as the main species that can be grown in constructed wetlands because they have high effectiveness in terms of absorbing pollutants [42]. A common plant grown on the constructed
wetlands developed in North America was cattails (*Typha latifolia*). The results of research in Japan revealed that the photosynthetic rate of *Hibiscus cannabinus* was very high and suitable for use in tropical climates [43]. Plant species selection for leachate processing depends on the type of waste and the area that can support plant growth in the constructed wetland [31], [44]. Alternative leachate processing schemes based on the type of landfill leachate, the Constructed wetland system, and plants are presented in Figure 3.

**Figure 3.** Alternative leachate processing schemes

Based on this scheme, leachate characteristics are divided into three categories. The first category with high pollutant concentrations is young landfills (<1 year) or in areas with tropical/subtropical climates, or the Asian region, and/or landfills for urban/domestic waste types. The second category is the category with moderate pollutant concentrations, namely medium age landfills (1-5 years) or in areas...
with moderate climates, or in the American/European region, and/or landfills for the type of urban waste (mixed). The third category is constructed wetlands with a lower concentration than the first and second categories, namely old landfills (>5 years) or in areas with cold climates, or in the American/European region, and/or landfills for separate types of waste. These three categories can be applied in Constructed wetland processing with SSF and SF systems. The types of plants used in the constructed wetland in this case depend on the climate in an area [45]. The climate in the world is divided into 4 climates, namely tropical, sub-tropical, temperate, and cold (Steiner, 2020).

5. Conclusion
Referring to the data obtained from studies, it is concluded that factors that need to be considered first in using of a constructed wetland are related to the characteristics of the waste, the Constructed wetland system, and plant species. The conclusion is as follows:

1. The characteristics of leachate in landfills can be divided based on age, namely young (<1 year), medium (1-5 years), and old (> 5 years). Climatic conditions are also found to affect the characteristics of leachate landfills divided by region (Asia, Europe, America), where the ones with the highest leachate concentration are in the Asian region.
2. Types suitable for processing landfill leachate in tropical climatic conditions that have efficiency > 90% with the SSF. The SF system in leachate processing with tropical climatic conditions that has an efficiency of > 90% is suitable for using Imperata cylindrica plants and the use of floating plant species.
3. Landfill leachate processing in sub-tropical climatic conditions with various concentrations can be carried out by processing the Constructed wetland, which has an efficiency of > 90% using the SSF system. The SF system in leachate processing with sub-tropical climatic conditions has an efficiency of up to 89%, as well as floating plants with an efficiency of up to 76%.
4. Landfill leachate processing in moderate climatic conditions with various concentrations can be processed with a Constructed wetland which has an efficiency of > 90% through the SSF system. The SF system in leachate processing with moderate climatic conditions which has an efficiency of up to 82%.
5. Landfill leachate processing in cold climatic conditions with various concentrations can be done with the Constructed wetland which has an efficiency of > 90% by the SSF system. Meanwhile, the SF system in leachate processing with cold climatic conditions which has an efficiency of up to 57%.

A different modification is required in the use of the constructed wetland for future studies in leachate treatment. Besides, it is important to explain the factors that influence the leachate processing process in wetlands in the future to make it more effective, such as (1) Types of landfills and characteristics of leachates (2) Types of flow in Constructed wetlands (3) Types of plants that are suitable for climate and characteristics leachate.

6. References
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**Acknowledgments**
The authors would like to show gratitude to The Ministry of Research and Technology, Program of Research Technology National Research and Innovation Agency in the PMDSU program for the full financial support.