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Review Article

Constructed Wetlands for Treatment of Acid Mine Drainage: A Review

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Abstract

The coal mining industry is an industrial activity that impacts the environment. This activity generates acid mine drainage due to the interaction of water, air and sulfide minerals. Acid mine drainage is wastewater with low pH and heavy metals content. These conditions have some negatives impact on the environment and human health. The low-cost, applicable and straightforward method to solve acid mine drainage in mining areas is constructed wetlands. Hence, this paper aims to describe the potential of wetlands as a low-cost and applicable method for acid mine drainage treatment. This paper also describes the holistic information about an overview of constructed wetlands, Acid Mine Drainage (AMD) production and their negative impacts, recent trends in constructed wetlands, recommendation components of wetlands, potential application in rural areas and future considerations.

Keywords: Wetlands; constructed wetlands; acid mine drainage; heavy metals; mining industry

1. Introduction

Environmental damage has been reported worldwide (Ray & Rathore, 2014). The decline in air, land, and water quality continues with increasing human needs. The first industrial revolution in the early 18th till 19th century initiated various environmental degradation due to the high industrial activities. This condition continued until the 20th century due to the high energy demand. The use of electrical energy and consumption of fossil fuel-based fuels on an industrial scale causes environmental degradation to continue to occur. The coal mining industry still supports the world's electrical energy through steam power plants, and various sectors still use diesel as a fossil fuel to drive the machines used. A study reports that emissions generated by coal exploitation and the use of fossil fuels have caused the release of carbon into the atmosphere so that it can trigger climate change.

Coal exploitation activities are reported to have caused a very significant decrease in water quality. A study reported that surface water in coal exploitation sites contains Fe, Mn, Al, Ca and other species that harm the environment and human life (Wibowo et al., 2022). In addition, coal exploitation can also reduce the pH content of surface water; this condition occurs not only when water is in contact with coal but also when water is in contact with overburden. A study reported that this happens because of the connection between water, air and sulfide minerals trapped under the soil surface (source). Another study also said that the oxidation process between sulfide minerals and water in the mining area could occur up to six times faster if there are *T. ferrooxidans* and *T. Thiooxidans bacteria* (Piriya et al., 2020).

Various efforts have been made to prevent and reduce heavy metals' content and keep the pH from turning acidic. Preventing Acid Mine Drainage (AMD) cannot be done by utilizing drainage and dewatering systems in mining areas, making perimeter drainage, sumps, and settling ponds combined with proper piping and pumping systems to prevent runoff water from entering the mining area. However, this effort cannot wholly solve the problem; using the drainage and dewatering system can only control some of the runoff water from coming into contact with rocks containing sulfide minerals (Wibowo et al., 2018). Some water sources that cannot be prevented by utilizing a drainage and dewatering system are direct rainfall. This condition requires processing water that has entered and is in contact with sulfide minerals so that it turns into AMD. One of AMD's most widely reported methods for reducing pollutant parameters is adsorption (Wibowo et al., 2022). This method utilizes an adsorbent material to absorb pollutant parameters in AMD (Crini et al., 2019). Still, this method has the disadvantage that it is difficult to make contact between the adsorbent and AMD when applied to actual conditions in the mining area. The passive treatment method by making wetlands is the simplest, cheapest, and most effective method to treat AMD directly in the field.

Constructed wetlands (CW) exist in mining areas and are used to reduce pollutant parameters in AMD. Reducing pollutant parameters in AMD through CW occurs through bioremediation and adsorption. The bioremediation process occurs due to contact with microorganisms in the wetlands and can reduce heavy metals and increase pH; besides, the absorption process through vegetation is reported to be effective in lowering rich metal content in AMD (Pat-Espadas et al., 2018). This paper will explain in full, including an overview of wetlands, AMD impact on the environment, recent trends of CW for treating AMD and their potential application in rural areas. This paper aims to describe the overview of AMD, AMD treatment using CW, and their possible utilizations.

2. Methods

A systematic review was done by Constructed wetlands utilization collected from Google Scholar. The keywords used to find the literature are constructed wetland, constructed wetland for acid mine drainage, passive treatment of acid mine drainage, and acid mine drainage treatment.

3. Result and Discussion

3.1. Overview of CW

CW has a long history, one of which is reducing nitrate gas into oxygen (denitrification), which improves water quality such as wastewater, black water, and grey water. Therefore, flowing back into river bodies is safe to maintain environmentally friendly stability for all humanity (Fitch, 2014). Wetlands are an occurrence that can be discovered in all types of biomes, including that of the Arctic biome, which, by the way, lacks vegetation that could also facilitate anaerobic and aerobic processes. Then many researchers define a wetland as a medium basin with two regions, one immersed in water (inundated) and the other a vegetated part where vegetation thrives (Campbell, 2020). CW seems to be an engineered wetland that has already been developed for numerous purposes. The other is to detoxify wastewater or greywater from households and many companies using physical and chemical characteristics with minimal energy consumption and low maintenance and maintenance repair expenses (Vymazal, 2014). The conditions for a comprehensive indication of a constructed wetland include vegetation and vegetation as a place for bioremediation (primarily in plant roots), a non-porous layer that prevents water from penetrating the system accidentally, and a substrate that functions as a support for plant life (Donde & Atalitsa, 2020). The flow stream in the wetland determines the classification of constructed wetlands. In the CW, there are two trends involving surface and subsurface movement, the two primary lines that characterize subsurface flow are vertical and horizontal flow (Hdidou et al., 2022).

The role of vegetation within CW applications can influence efficiency in removing heavy metals from the mining sector, such as applying *Phragmites australis* that either showed a substantial reduction in heavy metal concentrations of Copper, Zinc and Lead in one literature review (Guzman et al., 2022). Not only the vegetation cover utilized but the flow variable in the CW can have a beneficial influence on absorbing heavy metal particles (on a macro scale) and decreasing them, according to one of the research undertaken. That demonstrates that CW is adjusted to address the requirements and challenges that may arise, coupled in this manner (Saeed et al., 2021). As stated previously, CW has a flow stream variation that located on a water-free surface, in which the denitrification process (transforming nitrate or nitrite to nitrogen that is then released into the atmosphere) is dominant and produced by anaerobic processes that underlie plant microbes and are given a waterproof layer to prevent water from attempting to escape the system. Subsurface flow, on the other hand, necessitates the usage of a porous media (usually connected to hydraulic conductivity and also porosity) of soil and substrate (gravel) as a place for water to transfer (indirectly related to oxygen transfer) and many events are happening, involving soil adsorption, microbiological absorption, and the filtration process on the substrate (Bednarek et al., 2014).

Suppose treatment is not carried off without being spread to river systems. In that case, the same issue of AMD with a pH concentration is perceived as threatening and endangers components in mining, and the landscape will be affected. Therefore, the additional configuration is needed, as in previous research on CW, such as adding $CaCO_3$ material. Because the potential of materials surrounding the environment, especially calcium carbonate, can be found easily, it is also a significant consideration in many studies as a substrate that can reduce the pH of AMD and absorb metals with an approximate amount of above 80% (Nguyen et al., 2022).). Not only in AMD, but Phosphorus can be easily removed in the CW system by adsorption, which can then be overcome by substrate (mostly gravel) or other porous media, along with precipitation (Vymazal, 2014). The role of microbes in wetlands influences the level of Biological Oxygen Demand under aerobic conditions, which indirectly decomposes organic compounds in the water. It is also related to dissolved oxygen consumption, while Total Suspended Solid and Total Dissolved Solid are other solubility indicators.

Research that was conducted utilizing the *Phragmites australis* plant with good results indicates that perhaps the supporting parameters are needed because then the plant's efficiency and the substrate employed would have optimal and even maximal outcomes (Dadban Shahamat et al., 2018). The effect of the substrate as a medium for macrophyte plant roots plays a significant role in absorbing large enough particles that plant roots cannot surpass; however, the most important thing is to grow microbes capable of carrying out the nitrification and denitrification processes, as well as a place for plant media. Of course, it should expand. There are several significant criteria to consider while absorbing big particles in the substrate, including the height or thickness of the substrate utilized; the more profound the substrate, therefore more metal absorbed in the substrate (Ji et al., 2022).

3.2. AMD Production

Oxygen, iron, and other minerals that act as catalysts are the primary materials that promote the complex sulfide metal weathering process (García-Lorenzo et al., 2016). The biological reaction by microorganisms also takes part in the process giving outputs in the form of a healthy acidity environment, sulfates, oxidized iron, and other metallic products. Pyrite is a sulfide mineral plentifully spread among the others and studied most of its weathering process with air and water. During mining activity or even after the mine is closed, due to AMD created from it, pyrite contributes the most to sulfide metal that causes water quality degradation and environmental pollution in general (Evangelou, 1995).

The reaction between pyrite and other agents to crate acid shows following:

$FeS^2 + O_2 + H_2O \rightarrow Fe\ (ii) + 2SO_4^{2-} + 2H^+$ (1)

$Fe(ii) + O_2 + H^+ \rightarrow Fe(iii) + H_2O$ (2)

$Fe(iii) + 3H_2O \rightarrow Fe(OH)_3 + 3H^+$ (3)

$FeS_2 + 14Fe(iii) + 8H_2O \rightarrow 15Fe(ii) + 2SO_4^{2-}\ 16H^+$ (4

Reaction (1) shows the oxidation of pyrite resulting in ferrous iron. In this process, the produced acid is reduced where pH is maintained above 4.5 because the sufficient amount of water alkalinity controls the oxidation rate of pyrite by oxygen, oxidation and microbial action are comparable and relatively slow, and the sulfate concentration is high. As shown in reaction (2), ferrous iron is oxidized and forms ferric. The alkalinity capacity of water that works to neutralize the system in this second stage is starting to decrease, resulting in the acid accumulating, leading to a reduction in pH (around 2.5 and 4.5) and an increase in Fe concentration. pH in reaction (3) around pyrite is lower than 3, varies the acid rate of production known due to solubility Fe increase along with precipitation of Fe oxides and hydroxides reduction (Anawar, 2015; Evangelou, 1995; Roldan-Hernandez et al., 2020; Thomson & Turney, 1994; Tutu et al., 2008).

Other sulfide minerals (gersdorffite, galena, chalcopyrite, etc.) are generally present in addition to pyrite (Ren et al., 2021). These minerals contribute to acidification because oxidation may occur as well. The acid environment needs to use the acid to react with other minerals. This action will buffer the pH. Dissolved bicarbonate consumption and dissolution of silicates, carbonates, hydroxides, metal, and oxides, as well as exchange in ions, are crucial reactions (Emili et al., 2016). Aluminium and other ion are extracted from the rock and transported, which cause heavy metal (As, Sb, Cu, Pb, Cd, Mn, Zn, and Fe) contamination in the waterway (Anawar, 2015). The sediment will contain these heavy metals through adsorption and serve as a long-term source of metal pollution, disrupting ecological and human health (Thomson & Turney, 1994). The significant heavy metals release process follows three main stages. First and second phases, the heavy metals set free by sulfates and oxidation from sulfide remain from the tailing. Oxidation of sulfide remains in the third stage was still controlled, although precipitation of some Fe occurred (Khoeurn et al., 2019).

3.3. Acid Mine Drainage Impact

Mining sectors are one of the biggest key holders of the global circular economy. The produced minerals are essential for a country to know how much improvement it gives to the economy, infrastructure, military, and other aspects (Upadhyay et al., 2021). Nevertheless, there are studies made to discuss how mining activity brought not only positive effects but also some backlash, especially to the environment, such as global climate change (Tolvanen et al., 2019), biotic life (Kayet et al., 2022; Kløcker Larsen et al., 2022; Sun et al., 2022), and human health (Rentier & Cammeraat, 2022).

Methods to extract mineral deposits from below the earth's crust have consequences for the environment. Many sulfide materials initially settled down inside the planet are transported and exposed to air and surface water along with the activity of bacteria. This encounter will cause weathering oxidation processes and create the perfect conditions for acidic environments (Besser et al., 2015). The sulfates are the primary materials, while microorganisms shape sulfates, oxygen, and water into AMD. Water acts as a medium where the reaction occurs and a transportation unit for the acidic output (Favas et al., 2016). The effluent from mining waste, known as AMD, depends on their situation and setting. It may cause long-term damage to their surrounding environment, knowing AMD contains high acid followed by intolerable toxic heavy metal (Anawar, 2013).

Mining operation consists of stages in which AMD presence is highly possible reckon that mining activity constantly disrupts the surface of the earth and the materials beneath it. Vegetation clearing distribute sulfide materials, drilling and blasting work create fracture and increase the surface area that promotes AMD transport and uncover submerged geological materials to the surface ground, rock breaking during excavation stages expose the sulfate materials to the oxidizing agents that promote AMD formation, so on almost every step in mining activity will promote the ADM production (Simate & Ndlovu, 2021; Tolvanen et al., 2019).

3.4. Impact on Water Quality

AMD-polluted water is visually detected by its yellow or reddish bright colour on streams water, margin or bed that give unpleasant effect, heavy metal concentration also an indicator AMD contamination as a result of metal that percolates inside aquifers contaminating both groundwater and surface water. AMD-polluted water function will be limited because it already contains a high concentration of a wide range of unwelcome maters (Anawar, 2013; Bahurudeen et al., 2015; McDonald, 2018; Mohanty et al., 2018; Ren et al., 2021; Simate & Ndlovu, 2021).

3.5. Impact on Water Ecosystem

Biotic life living in an ecosystem contaminated by AMD is experiencing a crucial effect. An acidic environment and above the tolerable level of toxic metals cause the loss of animals, microorganisms, and vegetation residing within it. When AMD enters an uncontaminated waterway, high acid and heavy metal exceeding limits the species tolerance are the main factors that cause the food chains to become shorter since the key organism is lost, biotic diversity reduced, or disappearance entire food web (Thomas et al., 2021).

AMD has a critical character which contaminates algae, mainly green algae, which are coated by hydroxide metal deposits that lead to close access for invertebrates and smaller animals diversity to consume it because they are incapable of bearing AMD-polluted conditions (Chu et al., 2019). The food chain structure became smaller due to the elimination of bigger fish and disturbed relations among species. In the river bed system, organic waste accumulates due to decomposer agents' vanishing, and the energy and nutrient transfer cycle are critically low (Ferreira et al., 2021; Gray, 1998; Hogsden & Harding, 2012; Sun et al., 2022). The embryonic stage, growth performance, and reproduction of fish that live in AMD-contaminated water are seriously damaged (Taslima et al., 2022). Though the fish may live, humans who consume the fish are exposed to dangerous heavy metals.

3.6. Impact on Human Health

Heavy metal presence in AMD is hazardous to humans, infecting adults, developing stage in children, even fetus in pregnancy period and cause serious health problems within the impacted environment. Direct contacts with contamination sources are the main route to heavy metals exposure. The interaction may happen from inhaling polluted air, skin contact, and consuming AMD-affected foods ((Achparaki et al., 2012; Fernández-Caliani et al., 2019). Acute health complication varies from neurological disorders (cognitive function, sensory function loss), growth process, memory trouble, learning ability, mental issues, internal organ failure, diabetes, hypertension, and cancer (Kothapalli, 2021). Excessive exposure to Mn (cell death), Tl (brain and peripheral nerve damage), Cd (learning problems, change in behaviours, glucosuria), As (Parkinson, Alzheimer, cancer risk, DNA damage, hyperkeratosis), Zn (neuro-development), Hg (cancer risk), Pb (kidney failure, liver damage) and Cu (Wilson's disease) are the leading cause of health complications. Mitra et al. (2022) generally categorized damages caused by heavy metals as neurotoxicity, dermatologic, hepatotoxic, carcinogenesis, cardiovascular toxicity, nephrotoxicity, immunological toxicity, genotoxicity, reproductive toxicity, and developmental disorders.

3.7. Recent Trends of Constructed Wetlands for AMD

Mining operations are often associated with AMD, which contains various types of potentially damaging chemicals such as nitrates (Kornilov et al., 2019), sulfates (Mamelkina et al., 2019), and heavy metals (J. Chen et al., 2021). Therefore, in most countries, the disposal of contaminated drainage is not treated to the environment is required to treat mine drainage before discharging it into the atmosphere.

AMD management technology often used is active management, namely the addition of lime. Mines with abandoned metal and coal commodities still active mines unleash massive numbers of trace metals that harm system performance and human health. The losses caused by acid mine emptying can amendment soil pH, scale back soil organic carbon and impact soil microorganism communities and, a result, can have severe effects on nutrient uptake and plant growth (Lamers et al., 2012).

Though acid mine drainage severely damages most of the collection and the setting laid low with acid mine drainage, it also provides a crucial niche for microorganisms adapting to those extreme conditions (Chen et al., 2016). These adapted organisms have an increased metabolic capacity to cycle and transform iron, sulfur, carbon and other metals while removing their acidity (Johnson & Hallberg, 2008). Fe precipitates to ferrihydrite, and the reduction of sulfate produces hydrogen sulfide Raises the pH and has metal sulfide particles to reduce the concentration of dissolved metals in the water column. Fe content is one of the most common heavy metals found in acid mine drainage (Chen et al., 2021). Fe is known to be very dangerous for the environment and human health. A study even found plants that had been contaminated with Fe so that it was harmful to human health, such as in an abandoned mine in Rosalgar (Setubal District, SW Portugal) (Sabina et al., 2019).

3.8. Recommended Components for Constructed Wetlands

Constructed Wetlands use various treatment methods to remove metals from acid mine drainage. However, the removal of metals from acid mine drainage solutions results from the interactions and synergies between them. Each component material of the constructed wetlands is involved in metal removal: (i) supporting materials like minerals and organics that primarily contribute to removal by the adsorption process, and (ii) plants that primarily contribute directly. (iii) microorganisms contribute by promoting reduction and resultant metal deposition.

3.9. The Function of Vegetation for The Removal of Heavy Metals

Plants are components in Constructed Wetlands which significantly impact adsorption and deposition systems assisted by various bacteria and other supporting materials. Passive contribution from organic particles from plant parts provides metal trapping, sedimentation, and surface area, creating a mutually beneficial symbiosis between plants and bacteria. This symbiosis gives good advantages in metal reduction, adsorption, and precipitation. If a constructed wetland does not use plants as its material, the results will be less efficient than constructed wetlands that utilise plants as their component.

3.10. The Advantages of Using Plants as The Components

The Constructed Wetlands system uses various plant species as components in acid mine drainage systems. These plants come from multiple continents, such as the Australian continent, the Asian continent, the European continent, and others. The plant species used are *P. australis, P. arundinacea, T. domingensis, T. latifolia, P. karka, and P. australis* (Ghimire et al., 2019; Kalu et al., 2022; Rai, 2021; Saleem et al., 2019; Santosa et al., 2021). This plant species can add value to the adsorption to the substrate so that the absorption of heavy metals results in the effective retention of heavy metals. Second, plants whose surroundings are in the water, or we can call them floating plants, cannot add worth through the substrate used—however, the addition was made to the plant biomass section. Samples of floating plants embrace species comparable to *Echhorniacrassipes, Pistiastratiotes, and Salviniaherzoggi*. The submerged plant is the last type used as a component of Constructed Wetlands. This plant species can be used for AMD treatment because it can accumulate metals in the pit biomass. However, this type of plant has a drawback if its roots used to precipitate Fe. That limits the plant's photosynthesis and can even reduce its metal absorption ability. The vegetation species for this treatment such as *Potamogeton spp., Ceratophylumdemersum,* *Myriophylumspicatum,* and *Hydrillaverticilata* and can be found in Modern Yellow River Delta, China (Li et al., 2013).

The potency of CW for serious metal removal varies and depends on several factors, which are together with the physical and chemical characteristics of the acid mine, composition of the support material, operational time, and others. According to various studies conducted to increase plant potential and removal efficiency, considerations such as using local native plants are encouraged. That is encouraged because local native plants show relatively long survival rates and are better able to adapt. The local native plants have a sound adaptation system because the adaptability of these plants is not long, and they are used to the region's climate. For example, CW treats mine waste and boron (B) using native plants such as *T. latifolia*, and *P.australis* gave survival rates of 87.5% and 100% (Türker, Türe, et al., 2013). Still, the effectiveness of these native plants has more to do with variations in their susceptibility to environmental factors than with metal tolerance properties (Marchand et al., 2010). The growth process of plants in CW becomes an essential factor in increasing or decreasing the value of heavy metal content because mature plants are better able to change the environment and fix metals in the rhizosphere. During this process, age-appropriate plants for the metal process have far more developed parenchyma, higher oxygen transport, and fewer radial oxygen loss. This condition causes the respiration of microorganisms in the rhizosphere to promote the bacteria elimination mechanism (Leung et al., 2017). The season can affect the effectiveness of heavy metal removal in the CW, as both winter and summer conditions have been shown to affect the number of heavy metals present (Sheoran, 2017). (4) The selection of the plant species used in the AMD system is essential because the metal uptake and accumulation capacities are specific and based on the AMD characteristics. There are a variety of reports with information about plants and their accumulation of heavy metals, which can be consulted and considered for CW design (Türker et al., 2013). The selection of plant species in the AMD system is essential because metal absorption and accumulation are specific and based on AMD characteristics.

Many reports with information about plants and their heavy metal accumulation were viewed and considered for the design of the CW. For example, Leung et al. (2017) found that *T. latifolia* has a better ability than *C. malacencis* and *P. australis* to remove Pb, Zn, and Cd in AMD. Türker et al. (2013) found that higher consumption of fruits and vegetables was associated with a lower risk of mortality and that *T. latifolia* was better able to accumulate boron (B) in its tissues than *P. australis*. The effectiveness of CW heavy metal removal varies depending on many factors, including the physical and chemical properties of the acid mine, the composition of the support material, the operating time, and other factors.

3.11. Potential Application in Rural Areas

Environmental problems and laws regulating them are the responsibility of all humans in protecting the environment for the benefit of the planet and humans themselves (Ichinari et al., 2008). Wetlands are a system which many are not considered conservation in urban cities due to the many developments carried out so that there is a decrease in the use of wetlands as water filtration that regarded as (Koo et al., 2013; Lantz et al., 2013; Schleupner & Schneider, 2013). The wastewater disposal system in households still depends on the on-site treatment system in treating wastewater from households, including septic tanks, sewers and CW (Abegglen et al., 2008; Nakajima et al., 1999). On-site wastewater treatment is a way and an effort that can be done, of course, economically and environmentally friendly. Generally, wastewater in a rural area comes from faecal waste, which needs to be considered before being discharged into river bodies, such as solid suspension, phosphorus and nitrogen levels (Carroll et al., 2006; Wu et al., 2011). In general, sewage infiltration will experience disturbances in areas with thick clay, reducing the infiltration rate. The treatment factor will also be more difficult because it relies on a natural system that acts as a catchment area and has the efficiency in removing waste water pollutants from households. Still, it also depends on the weather and season (referring to the four seasons country). The treatments will also vary (Brix & Arias, 2005; Siracusa & La Rosa, 2006). Domestic wastewater contains physical and chemical organisms that must be reduced or eliminated. CW is a method that does not require a large amount of money, is environmentally friendly and is undoubtedly competent in dealing with this problem (Nivala et al., 2019).

Another source of pollutants in domestic wastewater is the form of nitrogen which can cause eutrophication if released directly into flowing water bodies (Lee et al., 2009). The nitrification-denitrification process requires a strict pH and temperature for the process to occur. Nevertheless, in rural areas, it is challenging to implement because it takes conditions that support for this to happen. In general, constructed wetlands with horizontal flow can stabilize anaerobic conditions but have low oxygen content, so it isn't easy to carry out the nitrification process (Vymazal, 2013). CW in the rural area is classified into three main areas according to their purpose and function (Stefanakis et al., 2019). CW could provide a habitat system for wildlife living in the area. Not only does CW have their role as a treatment acility, but it also uses CW as a habitat system to exploit the main environmental benefits of CW. The main characteristics of CWs, which are the presence of water and vegetation, make them quite suitable for creating ecological habitats. This environment is attractive to wildlife species, especially birds, which at a time provide a green area for the rural area (Al-Isawi et al., 2017). These CW generally present as ponds which also have a suitable place for fish if given the correct depth, a marsh that is usually a shallow aquatic area with herbaceous plants, swamps with tall woody plantations and ephemeral wetlands which collect water on a seasonal basis. These systems can be used as a source of food, fibre, and public amusement sites (Lu et al., 2015).

Flood control in rural areas is a critical task fulfilled. CW for flood control is built to receive the runoff during heavy rain that causes flood events. Their implementation may increase the capacity to store stormwater and the volume of water infiltration while reducing the water volume reaching the canal system and the treatment plants. Within the urban hydrologic cycle, these systems may contribute to Integrated Urban Water Management and provide the ability to recycle the stored water volume (Vepraskas and Craft, 2016). The depth of the water column may or may not affect the treatment efficiency of FTWs significantly. However, depth involves the aeration, light penetration, and attachment/detachment of roots to sediments. Plant absorption is also a key benefactor for cleaning off a greater concentration of pollutants from urban runoff. By harvesting growing plants on floating mats and dredging sediment, heavy metals are removed from stormwater as the plants have absorbed the metals and because some metal pollutants also settle on residues (Sharma et al., 2021). These engineered artificial wetlands are also essential to receive and purify wastewater of various types based on the naturally occurring treatment processes. That is why CW for wastewater treatment needs to be noticed (Kiiza et al., 2020; Wu et al., 2011). The effect of therapy through wetland has a relatively significant correlation with factors such as planting arrangement, temperature variation and influent contaminant concentration. When the temperature is above 24°C, the higher the planting density adopted and the lower the influent contaminant concentration, the better wastewater treatment's effect would be realized (Al-Isawi et al., 2017).

3.12. Cost Analysis of CW Utilization

Analysis of the cost of using CW is cheaper than other methods. This condition is due to the use of CW does not require the cost of making materials. Several studies reporting the use of CW in wastewater management can be seen in table 1. Table 1 informed the price of CW in different studies. The economic analysis of the use of CW is very dependent on the conditions of the surrounding area and the types of plants in the area. Utilization of CW may cost nothing if you get to the correct location. The right aquatic plants, suitable CW conditions and abundant microbial communities are easy to find in parts of Indonesia.

Table 2 informs the various methods of water treatment om multiple sources. Unfortunately, each method cannot be compared valid because each method used has a different area and concentration of wast.

Table 1. Cost analysis of CW

No	Location	Cost	Source
1	Guntung Paikat, South Kalimantan, Indonesia (block 1)	IDR. 94,328,929,73 (all in)	(Prihatini et al., 2022)
2	Guntung Paikat, South Kalimantan, Indonesia (block 2)	IDR. 118,656,468,90 (all in)	
3	Lake Manzala Water Research Station, northeast of Egypt	US$ 6.17, $6.17 per cubic meter $1.25 per cubic meter	(El Hawary & Shaban, 2018)
4	Sao Paulo, Brazil	US$1.55/m3	(Resende et al., 2019)

Table 2. CW VS other wastewater treatment

Wastewater treatment type	Treatment capacity	Economic analysis				Reference
		Construction	Management	Size	Cost	
CW	100 m^3/day	220, 000	300	800 m^3	N/A	(Lee et al., 2009)
Conventional treatment	N/A	300, 000	2000	450 m^3	N/A	
Bioreactor membrane	0.069 m^3/day	N/A	43.02 USD/day	33.4 m^2	N/A	(Ningtyas, 2015)
Activated sludge	0.963 m^3/day	N/A	12.213 USD/day	N/A	N/A	
Bio-cell	N/A	N/A	N/A	N/A	53.4 USD/m^3	(Rosanti et al., 2020)
Bioventing	N/A	N/A	N/A	N/A	210 USD/m^3	
Bio-slurry	N/A	N/A	N/A	N/A	75.35 USD/m^3	
Land Venting	N/A	N/A	N/A	N/A	70 USD/m^3	

3.13. Future Consideration

There is more than 5000 sub-surface CW and more than 650 CW in Europe for wastewater treatment. This information confirmed that the utilization of CW is robust and applicable in every condition. The future research consideration of utilization of CW is an analysis of different vegetation, soil construction and height of each structure. Next, research should analyze the potential of the combination of adsorption by land/soil and phytoremediation. The following future consideration should be to improve the operational design parameters of CW substrate types, water depth, hydraulic retention and load, time contact and feeding the related models of sustainable operation. In addition, the real CW in industrial areas showed land degradation.

Several areas of the coal mining industry showed decreased soil quality and made some plants dead. In addition, the economic analysis of CW is essential, including operation and maintenance, protection the groundwater pollution by CW utilization, and topography area to decrease the construction cost. Another consideration of CW utilization is the type of AMD. The different types of AMD will need other CW. The other microbial communities also need to be analyzed The other microbial communities in the roots of vegetation and soil will impact the effectiveness of CW.

4. Conclusion

Constructed wetlands are of low-cost and applicable method to solve AMD. Several studies showed that CW could decrease metal ions and low pH conditions in mining areas. This phenomenon happened due to the microbial communities in the roots of vegetation and soil. In addition, heavy metals decreased due to the adsorption process in soil. The high pH condition of constructed wetlands can solve the low-pH problems in AMD. Besides, the neutralization of AMD pH can precipitate metals ion. This paper also provided general information, historical and description of CW and AMD. This paper also described the impact of AMD on water quality, water ecosystem and human health. The recent trends of AMD treatment using CW are explained well, including composites recommendation for soil construction, variation of vegetation and the advantages of plants as the component of CW. Finally, this paper described the potential of CW application in rural areas and their future consideration.

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