Journal of Materials and Environmental Science
ISSN : 2028-2508
CODEN : JMESCN

J. Mater. Environ. Sci., 2021, Volume 12, Issue 12, Page 1614-1626

http://www.jmaterenvironsci.com

Wastewater pretreatment methods for constructed wetland: Review

Petro Karungamye[1,2]

[1]*Department of Chemistry, The University of Dodoma, Tanzania*

[2]*School of Materials Energy Water and Environmental Sciences (MEWES), The Nelson Mandela African Institution of Science and Technology (NM-AIST), Tanzania*

Corresponding author, Email address: Petro Karungamye, petro.karungamye@udom.ac.tz, karungamyep@nm-aist.ac.tz

Received 20 Dec 2021,
Revised 30 Dec 2021,
Accepted 31 Dec 2021

Keywords
- ✓ *Coagulation*
- ✓ *Constructed wetland*
- ✓ *Effluent*
- ✓ *Pretreatment*
- ✓ *Wastewater*
- ✓ *Septic tank*

petrokarungamye@gmail.com
Phone: +255763750792

Abstract

One of the most interesting research topics has been the constructed wetlands (CWs) for wastewater treatment. The primary operating issue of CWs is medium clogging, which is caused by the accumulation of varying sorts of solids, resulting in a reduction in the infiltration capacity of the gravel substrate. It is commonly recognized that effective wastewater pretreatment is necessary for the long-term operation of CW. Pre-treatment is crucial because it prepares the influent for CW treatment. The primary treatment's goal is to reduce the solid load on the wetland, and the suspended solids concentration should not exceed 100 mg L^1. This review paper describes the methods employed for wastewater pretreatment for constructed wetland performance. Three technologies namely septic tank, coagulation waste stabilization ponds and biofilters have been described.

1 Introduction

The world's waste generation is growing in lockstep with the increase in population and development. One of the main issues of the governments is the management of the waste generated [1]. Approximately 80% of anthropogenic wastewater is discharged into the environment without being treated or reused. This is not only an environmental issue, but also a serious health risk [2]. Pollutant removal from municipal wastewater has been accomplished through a variety of techniques which are grouped as conventional and non-conventional methods. In comparison to non-conventional wastewater treatment, conventional approaches feature a relatively high level of mechanization. Pumping and power supplies are typically required, as well as qualified manpower for system processing and preservation [3]. Conventional techniques include chemical precipitation, carbon adsorption, ion exchange, evaporation, and membrane processes have been proven to be efficient. These methods are either becoming unable to meet current strict regulations effluent limits or are getting more expensive. [4]. Due to global water scarcity issues, it is critical to consider non-conventional water resources to meet the increased demand for clean freshwater. Inadequate sanitation and wastewater disposal technologies may cause environmental and public health consequences [5]. Wastewater parameters are summarized in **table 1**.

Table 1: Concerning parameters in organic wastewaters that require treatment

Parameter	Common levels in wastewater	Desired effluent level	Desired removal rate
Total suspended solids	150 mg L^{-1}	<30 mg L^{-1}	>80%
BOD5	150 mg L^{-1}	<30 mg L^{-1}	>80%
Ammonia-N	25 mg L^{-1}	<2.5 mg L^{-1}	>90%
Phosphorus	10 mg L^{-1}	<1 mg L^{-1}	>80%
Pathogenic microbes	10^4 L^{-1}		>99%
Odour and colour		Low level	>90%
Toxic substances		Prohibited	>90%

Source [6] modified

Constructed wetlands (CWs) are manmade facilities that have been developed and built to effectively treat wastewaters by utilizing natural processes including aquatic plants, substrates, and associated bacterial communities. They're made to mimic many of the same processes that occur in natural wetlands, but in a more controlled conditions [7]. Constructed wetlands have been increasingly to be used for a range of wastewaters, including domestic wastewater, industrial and municipal wastewaters [8], heavy oil-produced water, urban and agricultural runoff, and acid mine drainage, as a sustainable, cheap, and energy-efficient treatment technology [9].

There are two main types of constructed wetlands depending on the flow channel in the system: free water surface constructed wetlands (FWS CWs) and subsurface flow constructed wetlands (SSF CWs). In FWS CWs, water gently flows above a substrate material, forming a free water surface and a water column depth of just few centimeters. In contrast, water flows inside a porous substrate in SSF CWs. SSF CWs are classified as horizontal (HSSF) or vertical flow depending on the direction of the flow route (VSSF) [10] [11]. This classification is summarized in **figure 1**.

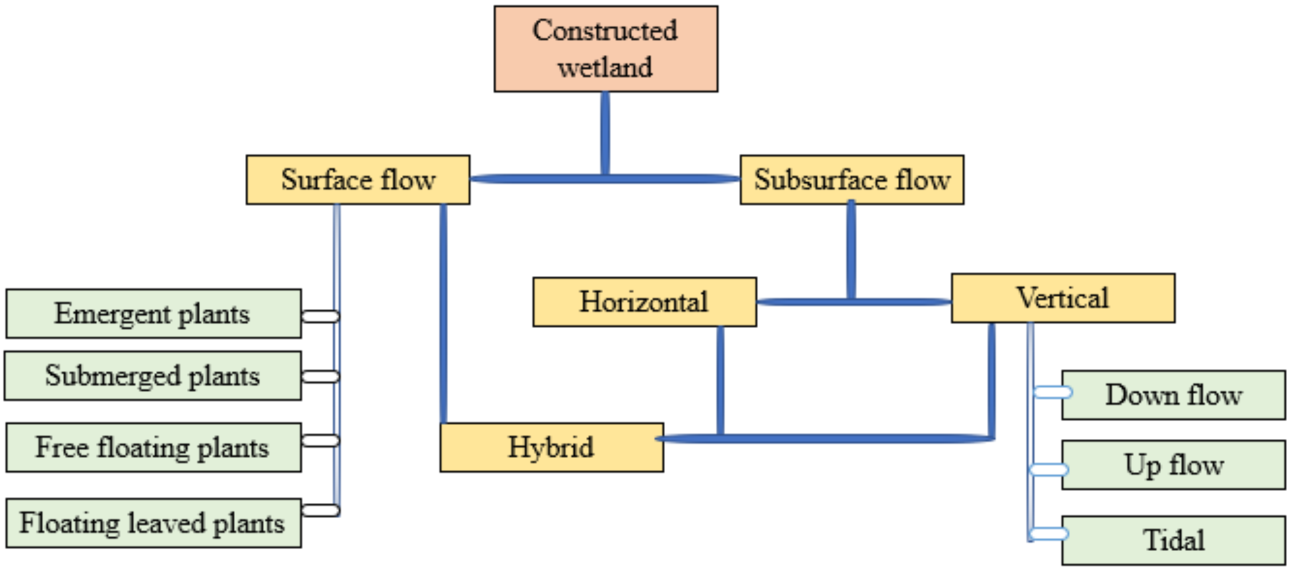

Figure 1: Classification of constructed wetlands.

In comparison to convectional wastewater treatment systems, the usage of CW in wastewater treatment has proved that contaminants in wastewater can be reduced to acceptable levels [12]. CW are less expensive, easier to operate and maintain than traditional treatment systems, and have a bright future in developing countries [13]. Studies from different CWs shows clogging or flooding to be major problems the reason being the lack of suitable pretreatment [14][15]. Physical, chemical, and biological factors can contribute to CW blockage. The suspended solids enter the CW system to minimize its porosity, which is a physical component. The chemical factor is pore clogging caused by the development of insoluble inorganic salt precipitates between the substrate and other components entering the CW, whereas the biological factor is clogging caused by extracellular polymers released by bacteria accumulating in the CW [16]. The amount of sewage solids that can accumulate in the gravel substrate of CW is related to influent parameters and rate of flow, according to several studies [17]. As the result the efficiency of CW towards wastewater purification decreases [16][18][19]. Clogging in CWs can be controlled in two ways: prevention and restoration. Prevention is done by physical, chemical, and biological pretreatment of wastewater to delay clogging by eliminating organic and suspended particles loads. Restoration is done by resting operations and renovation by substrate replacement and backwashing [18]. Long term studies on CWs recommends not more than 25 g BOD/m^2 d organic load in vertical SSF CWs and 6 g BOD/m^2 d in horizontal SSF CWs [20]. This means, appropriate pretreatment could be a solution to minimize clogging [21], allowing CW systems to be long-term functional [9]. Screening, settling basins, stabilizing ponds, and anaerobic treatment units are some of the pretreatment options. They are, nevertheless, commonly referred to as efficient, cost-effective, and long-term decentralization choices. So, in this review, different methods used in pretreatment of wastewater for CW have been described.

2 Methods of wastewater pretreatment

2.1 Septic tanks

The septic tank is the most commonly utilized collection system for onsite disposal and treatment of domestic wastewater worldwide. They're especially popular in rural locations where connecting to the main sewerage system is either impossible or too expensive [23]. This is a waterproof, covered container designed and built to take domestic wastewater, in which two processes occur: solids settling and anaerobic digestion of the collected solids [24]. Urine, fecal matter, flushing water, dry-anal cleansing materials, anal cleansing water, and/or greywater are all examples of septic tank inputs. A standard septic tank is capable of eliminating up to 50% of the input organic materials and suspended solids, which will be further degraded by anaerobic digestion in the sludge layer, and roughly 30% of the nitrogenous waste from domestic wastewater [25]. The primary function of the septic tank is to remove the solids from wastewater, to accumulate and store the sludge and scum, anaerobically digestion of solid material, and eventually discharging of partially treated effluent to soak away soil for further treatment. Most septic tank can efficiently treat household wastewater at a cheap cost provided they are properly located, designed, built, and maintained [23]. A septic tank has three zones: a scum layer that forms a crust on the surface of the tank liquid, wastewater from which particles settle, and a bottom sludge layer of deposited material. The organic stuff in the tank may be digested anaerobically. The degree of digestion is determined by the size of the tank, the frequency with which it is cleaned, and the temperature. The tank's capacity is determined by the amount of people it serves and the desludging interval. Although flotation and sedimentation remove a portion of the particle material, practically all entering dissolved organics pass through the septic tank untreated [26].

2.1.1 Performance of septic tank

Hydraulic and organic shock loads have little impact on treatment efficiency; it can tolerate long pauses in feeding a smaller land area. It does not require skilled staff to run, requires far less operation and maintenance, and has a lower building cost. Furthermore, anaerobic digestion stabilizes the sludge, minimizing the amount of sludge created. Many of the settleable solids, oils, greases, and floating debris in raw wastewater are removed by a septic tank, which eliminates 60–80 percent of them [26]. A two-compartment septic system is shown in **figure 2**. However, because nutrients and pathogens are not eliminated in the septic tank, further treatment is required before the effluent may be discharged into ecosystems. In several countries, a septic tank seems to be the only treatment option, leading to the release of contaminated effluent, which causes anoxia, eutrophication, and the spread of possibly harmful bacteria and viruses [27]. The septic tank effluent characteristics are presented in **table 2**.

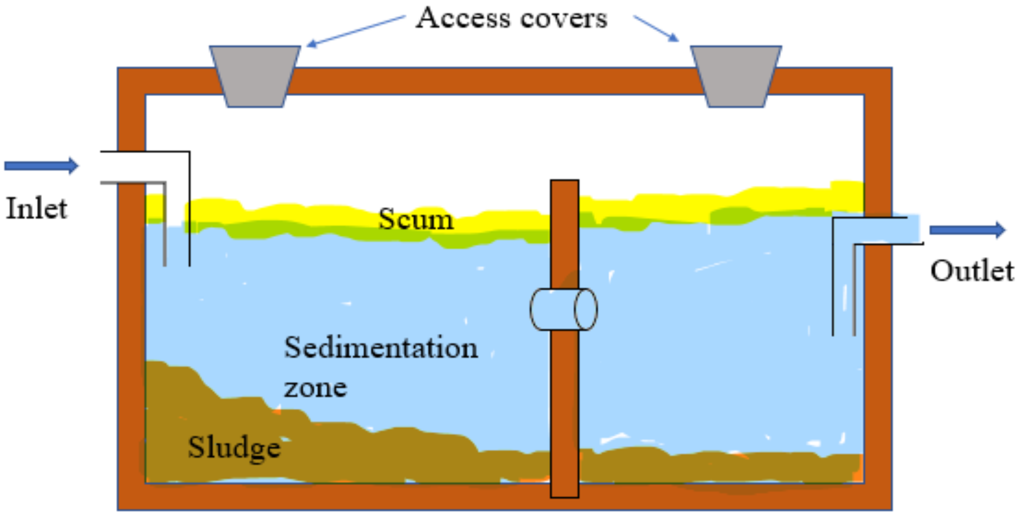

Figure 2: Schematic diagram of a two-compartment septic system.

Table 2: Characteristic of septic tank effluent

Parameter	Concentration Range
BOD5	284-715 mg/l
COD	397-1236 mg/l
TSS	324-793 mg/l
TS	1736-2589 mg/l
TDS	981-1796 mg/l
NH_3-N	58.40-93.47 mg/l
PO_4-P	24.21-62.47 mg/l
NO_3-N	18.38-56.27 mg/l
FC	1743-3974 Nos/100ml
pH	6.32-8.20

Source: [28]

The performance of a septic tank is determined by the properties of the influent and the tank design. The following septic tank removal efficiencies have been reported: BOD 46 – 68 %, TSS 30 – 81 %, phosphate 20 – 65 %, fecal coliform 25 – 66 % [29]. The effluent from the tank is greatly concentrated in reduced inorganic nutrients and faecal indicator organisms [30]. The composition of domestic wastewater affects greatly the performance of the septic tank. The performance with only toilet wastewater is poor compared to when the wastewater comprises toilet, bathroom and kitchen wastewater [29]. The key parameters influencing tank design and performance are tank volume, hydraulic retention time (HRT), and the amount of collected sludge [31].

2.1.2 Septic tank and CWs

In studies where septic tanks were coupled with a CWs, the pollutants removal efficiency was satisfactory [32]. Using three baffle flow CWs for removal of nitrogen and phosphorus from septic tank effluent under different hydraulic retention times (HRT) the maximum removal efficiency was 58.50 % for nitrogen and 95.97 %, for phosphorus at 2 days HRT [33]. In a pilot study on performance of CW for treatment of solar septic tank effluents, the data shows effective performance in removing organic matter, solids, nutrients, and pathogens [34]. A study was done in Egypt to investigate the integration of a septic tank with a CW. The COD and BOD levels of organic load were decreased by 87% and 89 %, respectively, while the fecal coliform count was reduced by around 5 log units, according to the findings [35]. A hybrid tidal flow CW system was employed in another investigation to remove excess nutrients from septic tank effluent. TP, NH3-N, and TN elimination ranged from 35.55 to 77.68%, 33.30 to 72.71%, and 16.25 to 53.17%, respectively. In general, increasing the recirculation frequency could enhance the effluent treatment volume [36]. From all these studies it is evident that septic tank is an effective pretreatment technology for constructed wetland performance in wastewater treatment.

2.2 Coagulation/flocculation

Coagulation/flocculation is the oldest method of treating wastewater for both stable and intermediate leachates. In this process, chemicals are added to create an insoluble end product. Moreover, this technique tries to eliminate other leachate characteristics, such as organic materials that are not biodegradable via ionic mechanisms [21] and all these processes increase the rate of sedimentation [19]. Coagulants of different varieties have the potential to be used in the treatment of water and wastewater. Coagulant types range from chemical to non-chemical, synthesized or natural coagulant with +ve charge characteristics. These positive charge would bind to the -ve charged particles in the aqueous system, causing turbidity [37]. Coagulation-flocculation is used to agglomerate fine particles and colloids into bigger particles in order to minimize turbidity, organic matters, and other soluble organic and inorganic pollutants [38]. Coagulation/flocculation chemistry consists of three stages: flash mix, coagulation, and flocculation as shown in **figure 3** [39].

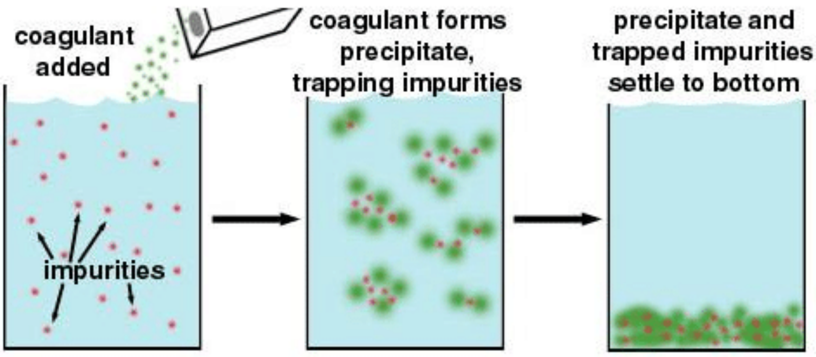

Figure 3: Coagulation process. Source [39]

Temperature, pH, wastewater quality, dosages, and type of coagulant are all aspects that influence coagulation–flocculation. The source, compositional charges, particle size, shape, and density of the suspended particles vary greatly. Understanding of the interactions of these aspects is essential for the proper application of coagulation and flocculation processes, as well as the selection of coagulants [40]. Coagulants are chemicals that are applied to the coagulation flocculation processes [41]. They are typically composed of inorganic salts, with iron salts being more effective than aluminum salts. The coagulation–flocculation technique is strongly recommended for removal of suspended solids from liquid solutions.

2.2.1 Critical parameters for coagulation

Turbidity reflects the suspended solids in a solution and is the primary measure of solids removal from wastewater, whereas high COD indicates the presence of all forms of organic matter, both biodegradable and nonbiodegradable. As a result, two metrics (turbidity and COD) are the most critical for determining the efficacy of a coagulation–flocculation process [14]. Nevertheless, this process has certain drawbacks, including the generation of aluminum and iron, as well as high operational and maintenance expenses, large volumes of mud, and the potential for health disruption by causing diseases such as Alzheimer's and neurological diseases. These issues urge the execution of several studies in order to determine the potential use of natural coagulants in the coagulation and flocculation in wastewater treatment [42].

2.2.2 Coagulation and CWs

Coagulation can be coupled with constructed wetland as shown in **figure 4**.

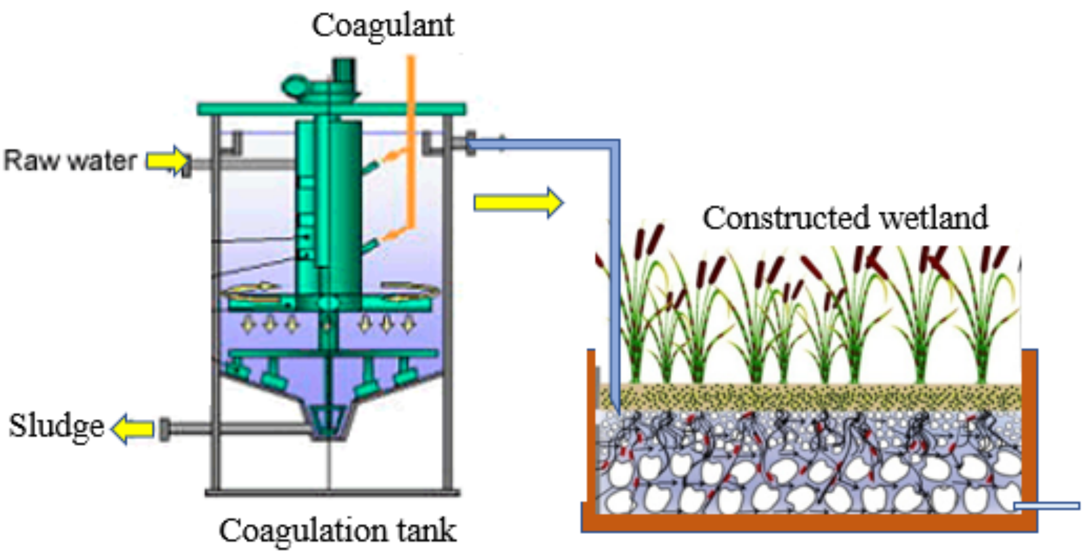

Figure 4: Simple illustration of coagulation system coupled with constructed wetland

In a study to explore the performance of the coagulation process and CW on the treatment of landfill leachate, the results show that combining both technologies yield a promising efficiency [43]. In treating the batik wastewater, the combination of coagulation using moringa oleifera seeds powder and horizontal subsurface CW eliminated 89.33 % of COD, 98.11 % of TSS, and 92.05 % of fat, oil, and grease [42].

2.3 Waste stabilization ponds

WSPs (waste stabilization ponds) also called oxidation ponds or facultative ponds are shallow open basins surrounded by earthen embankments and occasionally lined with concrete or synthetic geofabrics [44] in which raw sewage is cleaned totally by natural processes involving algae and bacteria [45]. Biodegradation occur with the aid of wind aeration and sunlight energy for photosynthesis when wastewater travels slowly through wide shallow basins. Despite the need for a significant amount of area, the energy and chemical requirements are negligible [46]. They are one of the most cost-effective, reliable, and simple-to-operate techniques for treating home and industrial wastewater in temperate and tropical regions. They are also efficient, environmentally friendly, and have a low danger of malfunction if correctly planned and built. The country's favorable climatic conditions should also encourage their wider adoption for wastewater treatment [47].

2.3.1 Classification of WSPs

WSP systems are classified into three types: anaerobic, facultative, and maturation. These various ponds are placed in series; at any one location, there is frequently more than one series, with each series consisting of an anaerobic pond, a facultative pond, and, depending on the effluent quality desired, one or more maturation ponds [48]. **Figure 5** shows a series of ponds in WSPs.

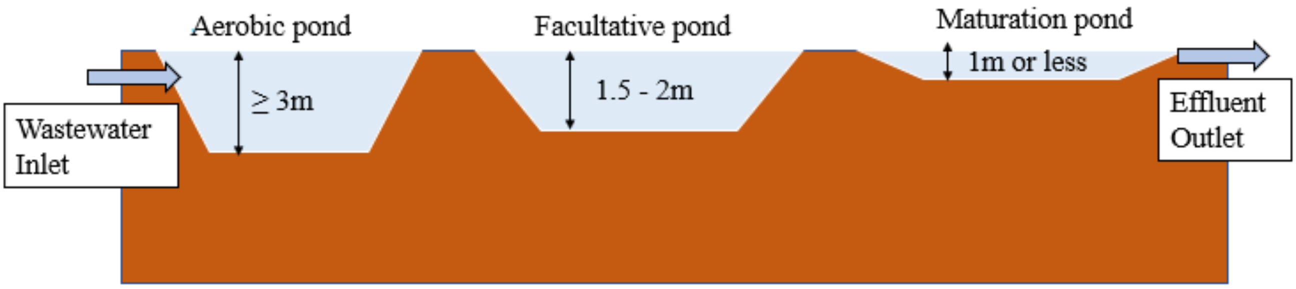

Figure 5: Series of ponds in WSPs

2.3.2 Performance of WSPs

The performance of different ponds is summarized in **table 3**.

Table 3: The treatment performance of various waste stabilization ponds is compared

Pond	BOD Removal	Pathogen Removal	HRT
Anaerobic Pond	50 to 85%		1 to 7 days
Facultative Pond	80 to 95%		5 to 30 days
Maturation Pond	60 to 80%	90%	15 to 20 days

Source:[49]

Combination of WSPs and Constructed Wetlands (CW) have proven to be effective wastewater treatment alternatives, and the development of low-energy-consuming ecosystems that use natural processes, as opposed to complex high-maintenance treatment systems, will hopefully lead to more ecologically sustainable wastewater treatment in the future. When compared to conventional methods, CWs and WSPs can also meet the demand for a high percentage eradication of microorganisms [50]. **Figure 6** shows the major processes in WSPs. In a Tanzanian investigation, the addition of CW after stabilization pond was able to entirely eradicate helminths. There were no helminths identified in the wastewater effluent [52]. A substantial reduction in nitrogen concentrations was seen when a CW was combined with WSP [53]. In another investigation where waste stabilization ponds was combined with 8 vertical flow CWs, and monitored for 2 years, the results shows lower TSS and BOD_5 concentrations in CWs' effluents than in the final maturation pond's effluent [47]. Generally, WSPs have some benefits such as low building and operating costs, low energy consumption, able to withstand surge loadings, minimal chemical use and fewer mechanical issues. The drawbacks includes large land need, possible groundwater contamination as a result of leaks, weather conditions have an impact on treatment and possibility of suspended solids issues (algae) [54].

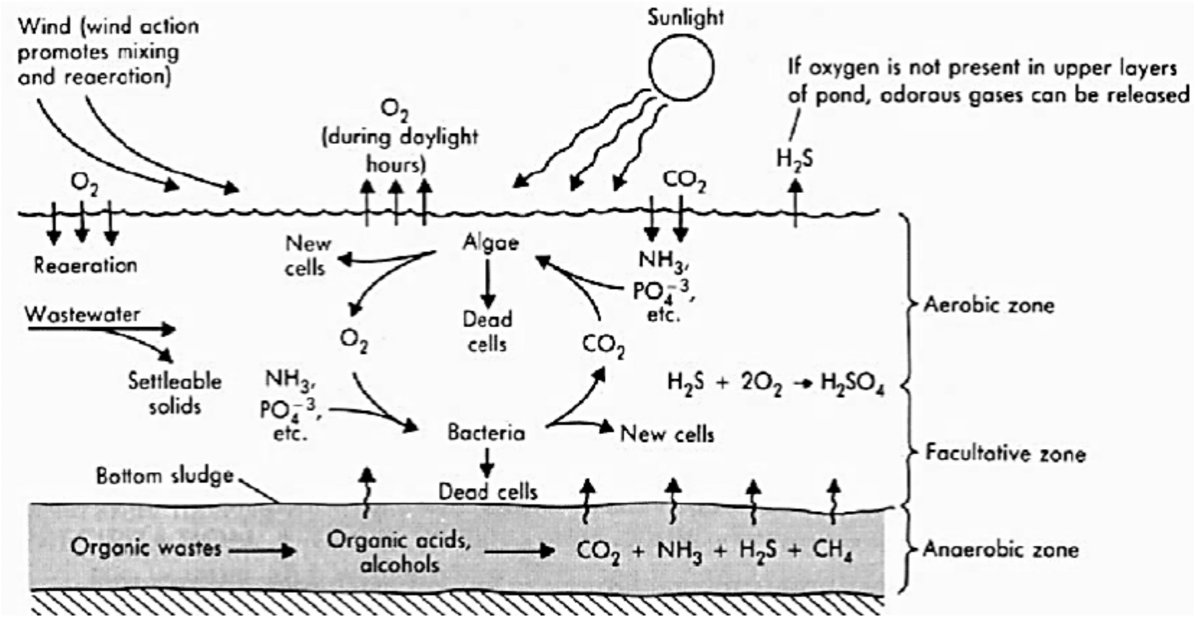

Figure 6: Major processes in WSPs. Source [51]

2.4 *Biofilters*

One of the most significant processes in wastewater treatment is filtration [55]. This is an important treatment technique in the removal of various pollutants. It is used in water treatment to purify surface water for potable use, whereas it is utilized in wastewater treatment to generate effluent with quality for multiple uses [56]. A biofilter is any filter that has biomass attached to the filter media where the microorganisms adhering to the filter media biodegrading pollutants by a mix of biological oxidation, adsorption, and filtration processes [57]. They have been used to treat air, water, and wastewater with great effectiveness [56]. Biofiltration has been utilized for organic degradation and ammonia removal, and in certain cases, it has been combined with pre-ozonation to give primary disinfection. Biofiltration, on the other hand, has some disadvantages, including the necessity for complex water and air distribution systems, backwashing requirements, large biofilm sloughing on occasion, and a high nitrite residue in the effluent [46]. The growing and preservation of microorganisms adhered to the filler surface determine the filter's removal effectiveness. Depending on the type of substrate used whether is sand, soil, bark, charcoal or activated carbon will also affect the performance of the biofilter [58].

2.4.1 *Performance of biofilters*

Performance of different biofiltration systems is summarised in **Table 4**.

2.4.2 *Biofilters and CWs*

In an investigation on treatment of highly polluted water using a system consisting of biofilter and CW the final effluent had COD 30 mg/L, TN 15 mg/L, NH_4^+-N 5 mg/L and TP 0.5 mg/L [60]. A system combining biofilter followed by a horizontal flow CW with roughly 0.11m^2 surface area/person can remove more than 70% of BOD and reduce indicator bacteria by up to 5 logs [61]. The results of a pilot scale system comprising of biofilters and CW utilized for greywater treatment revealed that the influent dissolved oxygen of less than 1 mg/L improved to 3.4-4.6 mg/L. BOD removal was 99 % while COD removal was 95 % [62].

Table 4: Performance of different biofiltration systems [59].

Parameter	Unit	Slow sand filter	Rapid sand filter	Granular active carbon
Particle size	mm	0.15–1	0.4–3	0.5–4
Filtration rates	$m\ h^{-1}$	0.1–0.3	5–25	5–15
Biomass load	ng ATP cm^{-1}	20–100	20–2000	30–4000
Total organic carbon	% Removal	10–50	1–40	10–50
Assimilable organic carbon	% Removal	20–90	25–90	30–90
Viruses	log reduction	0.5–4	0.5–1.5	0.5–1.5
Protozoa	log reduction	2–5	0.5–4	0.5–3
Bacteria	log reduction	0.2–6	0.5–2	0.1–2

3 Conclusion

Constructed wetlands are capable of treating wastewater from a range of sources household level to community. While the specific roles of some of the natural treatment processes in CWs are still unclear, expert wastewater experts now have enough information to design systems that are effective and meet environmental treatment requirements. The wastewater treated in CWs are normally already pretreated to remove solids through some techniques like septic tank, lagoon, aerobic unit, or treatment plants. When well designed and coupled with good method of pretreatment, CWs can impose and maximize the biological, chemical, and physical processes of natural wetland ecosystems while also efficiently removing contaminants and excess nutrient loads. Future study should investigate the compatibility of CWs with pretreatment methods for better treatment of wastewater.

References

[1] S. B. Nayan, Q. H. Bari, P. K. Debnath, and J. Ahmed, 'Influence of Different Hydraulic Retention Time on Modified Septic Tank System for Faecal Sludge Treatment', *Sci. Lett.*, April (2021) 18–24, doi: 10.46890/SL.2020.v02i04.001.

[2] A. Torrens, D. De Varga, and A. K. Ndiaye, 'Innovative Multistage Constructed Wetland for Municipal Wastewater Treatment and Reuse for Agriculture in Senegal', *Water*, 12 (2020) 1–12, doi:10.3390/w12113139

[3] A. Fahad and R. M. Saphira Mohamed, 'Wastewater and its Treatment Techniques: An Ample Review', *Indian J. Sci. Technol.*, 12 (25) (2019) 1–13, doi: 10.17485/ijst/2019/v12i25/146059.

[4] P. Rajasulochana and V. Preethy, 'Comparison on efficiency of various techniques in treatment of waste and sewage water – A comprehensive review', *Resour. Technol.*, 2 (4) (2016) 175–184, doi: 10.1016/j.reffit.2016.09.004.

[5] S. A. A. A. N. Almuktar, S. N. Abed, and M. Scholz, 'Wetlands for wastewater treatment and subsequent recycling of treated effluent : a review', *Environmental Science and Pollution Research,* 25 (2018) 23595–23623, doi.org/10.1007/s11356-018-2629-3

[6] H. G. Peterson, 'Use of constructed wetlands to process agricultural wastewater', *Can. J. Plant Sci.*, 78 (2) (1998) 199–210, doi: 10.4141/P97-142.

[7] J. Vymazal, 'Constructed wetlands for wastewater treatment', *Water*, 2 (3) (2010) 530–549, doi: 10.3390/w2030530.

[8] C. J. Varnell, S. Thawaba, and J. Van Brahana, 'Constructed Wetlands for the Pre-Treatment of Drinking Water Obtained from Coal Mines', *Open Environ. Eng. J.*, 2 (1) (2009)1–8, doi: 10.2174/1874829500902010001.

[9] Y. Shui, Q. Li, H. Song, A. Shui, and Y. Li, 'Effect of different temperature on Sewage treatment of constructed wetlands pretreatment system', *Appl. Mech. Mater.*, 370 (2013) 491–495, doi: 10.4028/www.scientific.net/AMM.368-370.491.

[10] K. Skrzypiecbcef and M. H. Gajewskaad, 'The use of constructed wetlands for the treatment of industrial wastewater', *J. Water L. Dev.*, 34 (1) (2017) 233–240, doi: 10.1515/jwld-2017-0058.

[11] Q. Mahmood *et al.*, 'Natural treatment systems as sustainable ecotechnologies for the developing countries', *Biomed Res. Int.*, 2013 (May) (2013) 1-19, doi: 10.1155/2013/796373.

[12] M. Mthembu, C. Odinga, F. Swalaha, and F. Bux, 'Constructed wetlands: A future alternative wastewater treatment technology', *African J. Biotechnol.*, 12 (29) (2013) 4542–4553, doi: 10.5897/ajb2013.12978.

[13] A. Mustafa, 'Constructed Wetland for Wastewater Treatment and Reuse: A Case Study of Developing Country', *Int. J. Environ. Sci. Dev.*, 4 (1) (2013) 20–24, doi: 10.7763/ijesd.2013.v4.296.

[14] O. El, M. Kessler, M. Ang, T. Fechtali, A. F. Cano, and J. A. Acosta, 'Turbidity and Chemical Oxygen Demand Reduction from Pig Slurry through a Coagulation Flocculation Process', *Agronomy*, 11 (2158) (2021) 1–14, , doi.org/10.3390/agronomy11112158.

[15] V. Phillips, 'Anatomy of a Constructed Wastewater Wetland', *Restor. Reclam. Rev.*, 2 (4) (1997) 1–6.

[16] H. Wang, L. Sheng, and J. Xu, 'Clogging mechanisms of constructed wetlands: A critical review', *J. Clean. Prod.*, 295 (2021) 1-16, , doi: 10.1016/j.jclepro.2021.126455.

[17] D. De la Varga, M. A. Díaz, I. Ruiz, and M. Soto, 'Avoiding clogging in constructed wetlands by using anaerobic digesters as pre-treatment', *Ecol. Eng.*, 52 (2013) 262–269, doi: 10.1016/j.ecoleng.2012.11.005.

[18] Y. Cao *et al.*, 'Bio-clogging mitigation in vertical subsurface flow constructed wetlands using rhamnolipids-citric acid compound', *Chem. Eng. J.*, 426 (2021) 1-14, doi: 10.1016/j.cej.2021.131278.

[19] Z. Ying *et al.*, 'Coagulation pretreatment for constructed Wetlands', *Fresenius Environ. Bull.*, 20 (9) (2011) 2326–2334.

[20] A. Caselles-Osorio and J. Garcia, 'Effect of physico-chemical pretreatment on the removal efficiency of horizontal subsurface-flow constructed wetlands', *Environ. Pollut.*, 146 (1) (2007) 55–63, doi: 10.1016/j.envpol.2006.06.022.

[21] E. Rahmadyanti, M. S. H. Saputro, and N. W. Hidajati, 'The feasibility of combined coagulation flocculation and constructed wetland as green technology for sustainable leachate treatment', *IOP Conf. Ser. Mater. Sci. Eng.*, 5 (2021) 1-11, doi: 10.1088/1757-899x/1098/5/052077.

[22] A. Valipor, Y. Ahn, A, "Review and Perspective of Constructed Wetlands as a Green Technology in Decentralization Practices", *Green technologies and environmental sustainability*, R. Singh and S. Kumar, Springer International Publishing, (2017), Doi

10.1007/978-3-319-50654-8_1.
[23] S. Richards, E. Paterson, P. J. A. Withers, and M. Stutter, 'Septic tank discharges as multi-pollutant hotspots in catchments', *Sci. Total Environ.*, 542 (2016) 854–863, doi: 10.1016/j.scitotenv.2015.10.160.
[24] V.-A. Nguyen, N.-T. Pham, T. H. Nguyen, A. Morel, and K. Tonderski, 'Improved septic tank with constructed wetland, a promising decentralized wastewater treatment alternative in Vietnam', *NOWRA 16th Annu. Tech. Educ. Conf. Expo.*, no. (March) (2007) 1–17.
[25] A. A. Adegoke and T.-A. Stenstrom, 'Septic Systems', *Global Water Pathogen Project. Part 4 Management Of Risk from Excreta and Wastewater),* J.B. Rose and B. Jiménez-Cisneros, (eds) *Proj*, 2019, doi: 10.14321/waterpathogens.59.
[26] F. A. Nasr and B. Mikhaeil, 'Treatment of domestic wastewater using modified septic tank', *Desalin. Water Treat.*, 56 (8) (2015) 2073–2081, doi: 10.1080/19443994.2014.961174.
[27] L. Olsson, 'Effect of design and dosing regime on the treatment performance of vertical flow constructed wetlands', *Masters thesis, Linköpings universitet* (2011)
[28] S. B. Nayan, Q. H. Bari, P. K. Debnath, and J. A. S. Saju, 'Performance Study of Pilot-Scale Anaerobic-Aerobic Filter System for Faecal Sludge Treatment', *Proc. 5th Int. Conf. Civ. Eng. Sustain. Dev. (ICCESD 2020)*, February (2020),
[29] M. M. Rahman, M. A. Ali, and A. H. M. Shahidullah, 'An evaluation of septic tank performance', in *Integrated Development for Water Supply and Sanitation: Proceedings of the 25th WEDC Conference*, (1999) 61–64.
[30] P. J. A. Withers, H. P. Jarvie, and C. Stoate, 'Quantifying the impact of septic tank systems on eutrophication risk in rural headwaters', *Environ. Int.*, 37 (3) (2011) 644–653, doi: 10.1016/j.envint.2011.01.002.
[31] T. Elmitwalli, 'Sludge accumulation and conversion to methane in a septic tank treating domestic wastewater or black water', *Water Sci. Technol.*, 68 (4) (2013) 956–964, doi: 10.2166/wst.2013.337.
[32] T. Saeed, R. Afrin, A. Al-Muyeed, M. J. Miah, and H. Jahan, 'Bioreactor septic tank for on-site wastewater treatment: Floating constructed wetland integration', *J. Environ. Chem. Eng.*, 9 (4) (2021) 1-11, doi: 10.1016/j.jece.2021.105606.
[33] L. Cui, Y. Ouyang, W. Yang, Z. Huang, Q. Xu, and G. Yu, 'Removal of nutrients from septic tank effluent with baffle subsurface-flow constructed wetlands', *J. Environ. Manage.*, 153 (2015) 33–39, doi: 10.1016/j.jenvman.2015.01.035.
[34] T. Koottatep, T. Pussayanavin, S. Khamyai, and C. Polprasert, 'Performance of novel constructed wetlands for treating solar septic tank effluent', *Sci. Total Environ.*, 754 (6) (2021) 1-13, doi: 10.1016/j.scitotenv.2020.142447.
[35] H. I. Abdel-Shafy and M. A. El-Khateeb, 'Integration of septic tank and constructed wetland for the treatment of wastewater in Egypt', *Desalin. Water Treat.*, 51 (16–18) (2013) 3539–3546, doi: 10.1080/19443994.2012.749585.
[36] L. Cui, J. Feng, Y. Ouyang, and P. Deng, 'Removal of nutrients from septic effluent with re-circulated hybrid tidal flow constructed wetland', *Ecol. Eng.*, 46 (2021) 112–115, doi: 10.1016/j.ecoleng.2012.06.003.
[37] V. Kumar, N. Othman, and S. Asharuddin, 'Applications of Natural Coagulants to Treat Wastewater - A Review', *MATEC Web Conf.*, 103 (2017) 1–9, doi: 10.1051/matecconf/201710306016.
[38] C. Y. Teh, P. M. Budiman, K. P. Y. Shak, and T. Y. Wu, 'Recent Advancement of Coagulation-

Flocculation and Its Application in Wastewater Treatment', *Ind. Eng. Chem. Res.*, 55 (16) (2016) 4363–4389, doi: 10.1021/acs.iecr.5b04703.
[39] R. Olanrewaju and T. O. Salawudeen, 'An intelligent modeling of coagulant dosing system for water treatment plants based on artificial neural network', *Aust. J. Basic Appl. Sci.*, 6 (1) (2012) 93–99.
[40] V. S. N. Srinivas and N. V. S. Vuppala, 'Analysis and optimization of coagulation and flocculation process', *Appl. Water Sci.*, 7 (2017) 451–460, doi: 10.1007/s13201-014-0262-y.
[41] A. M. Hansen, T. E. C. Kraus, S. M. Bachand, W. R. Horwath, and P. A. M. Bachand, 'Wetlands receiving water treated with coagulants improve water quality by removing dissolved organic carbon and disinfection byproduct precursors', *Sci. Total Environ.*, 622 (2018) 603–613, doi: 10.1016/j.scitotenv.2017.11.205.
[42] E. Rahmadyanti and C. P. Febriyanti, 'Feasibility of Constructed Wetland Using Coagulation Flocculation Technology in Batik Wastewater Treatment', *J. Ecol. Eng.*, 21 (6) (2020) 67–77, doi.org/10.12911/22998993/123253
[43] R. Thivyatharsan and M. Rajendran, 'Efficiency of Coagulation Process and Constructed Wetland for the Treatment of Municipal Solid Waste Landfill Leachate', *Sch. J. Eng. Technol.*, 5 (November) (2017) 497–501, doi: 10.21276/sjet.2017.5.9.8.
[44] M. Verbyla and M. Von Sperling, 'Waste stabilisation ponds', *Global Water Pathogens Project,* J.B. Rose and B. Jiménez-Cisneros, (eds) Michigan State University, UNESCO, (2017).
[45] I. Abdullahi, I. Nasiru, A. Saminu, L. Sagir, and E. Charity, 'Design Of Waste Stabilization Pond For Sewage Treatment At Nigerian Defence Academy Staff Quarters, Permanent Site Mando Kaduna', *Int. J. Eng. Appl. Sci.*, 1 (2) (2014) 9–15, ISSN: 2394-3661.
[46] B. S. Yildiz, 'Water and wastewater treatment: Biological processes', in *Metropolitan Sustainability: Understanding and Improving the Urban Environment*, Woodhead Publishing Limited, (2012).
[47] M. Tsalkatidou, M. Gratziou, and N. Kotsovinos, 'Combined stabilization ponds – constructed wetland system', *Desalination*, 248 (2009) 988–997, doi: 10.1016/j.desal.2008.10.015.
[48] D. Mara, "Waste Stabilization Ponds: A Highly Appropriate Wastewater Treatment Technology for Mediterranean Countries", *Efficient Management of Wastewater : Its Treatment and Reuse in Water Scarce Countries.* Al Baz, I., Otterpohl, I. & Wendland, C. (eds) Springer , Heidelberg, (2008) 113-123, http://dx.doi.org/10.1007/978-3-540-74492-4_10
[49] P. R. and C. Z. Elizabeth Tilley, Lukas Ulrich, Christoph Lüthi, 'Compendium of Sanitation Systems and Technologies', 2nd Revised Edition. Swiss Federal Institute of Aquatic Science and Technology (Eawag). Dübendorf, Switzerland, (2014), ISBN: ISBN: 978-3-906484-57-0.
[50] S. Kayombo and N. Ladegaard, 'Waste stabilization ponds and constructed wetlands design manual' *UNEP-IETC/Danida, Dar es Salaam, TZ/Copenhagen, Denmark.* (2004).
[51] M. N. D. Liady, E. D. Fiogbe, and J. L. Vasel, 'Contribution to the modelling of shellfish zooplankton production in waste stabilization ponds', *8th World Wide Workshop for Young Environmental Scientists WWW-YES 2009: Urban waters: resource or risks?,* Arcueil : France June, (2009).
[52] A. H. Outwater, A. Zachariah, A. Nyomora, F. Francis, and J. H. Y. Katima, 'Potential of Adding Constructed Wetland/Fishpond to Waste Stabilization Ponds to Improve Helminths Removal in Morogoro Municipality, Tanzania', *J. Appl. Sci. Environ. Manag.*, 23(12) (2020) 2201-2203, doi: 10.4314/jasem.v23i12.18.
[53] A. W. Mayo, 'Effect of pre-treatment of wastewater in HRAP on nitrogen removal in subsurface

flow gravel bed constructed wetland', *Phys. Chem. Earth*, (March) (2020) doi: 10.1016/j.pce.2020.102868.

[54] F. R. Spellman and J. E. Drinan, *Wastewater stabilization ponds*. Taylor & Francis Group Boca Raton London New York, (2014). ISBN -13: 978-1-4665-9319-0

[55] E. Rahmadyanti, A. Wiyono, and G. A. Firmansyah, 'Integrated system of biofilter and constructed wetland for sustainable batik industry', *Int. J. GEOMATE*, 18 (70) (2020) 138–148, doi: 10.21660/2020.70.61681.

[56] D. S. Chaudhary, S. Vigneswaran, H. H. Ngo, W. G. Shim, and H. Moon, 'Biofilter in Water and Wastewater Treatment', *Korean J. Chem. Eng.*, 20 (6) (2003) 1054–1065, doi: 10.1007/BF02706936.

[57] R. Permatasari, A. Rinanti, and R. Ratnaningsih, 'Treating domestic effluent wastewater treatment by aerobic biofilter with bioballs medium', *IOP Conf. Ser. Earth Environ. Sci.*, 106 (1) (2018) doi: 10.1088/1755-1315/106/1/012048.

[58] R. P. Singh, D. Fu, J. Jia, and J. Wu, 'Performance of earthworm-enhanced horizontal sub-surface flow filter and constructedwetland', *Water*, 10 (10) (2018) 1–12, doi: 10.3390/w10101309.

[59] F. Hammes, S. Velten, T. Egli, and T. Juhna, 'Biotreatment of Drinking Water', in *Comprehensive Biotechnology,* (2nd Ed), Elsevier B.V. 6 (2011) 517–530. ISBN: 9780080885049

[60] Z. Jing, R. He, Y. Hu, Q. Niu, S. Cao, and Y. Y. Li, 'Practice of integrated system of biofilter and constructed wetland in highly polluted surface water treatment', *Ecol. Eng.*, 75 (2015) 462–469, doi: 10.1016/j.ecoleng.2014.12.015.

[61] D. Jenssen P and Vrale L, 'Greywater Treatment in combined Biofilter/Constructed Wetlands in Cold Climate', in *Ecosan – closing the loop. Proc. 2nd int. symp. ecological sanitation,* (2003) 875–881.

[62] T.-Y. Ling, K. Apun, and S.-R. Zainuddin, 'Performance of a Pilot-Scale Biofilters and Constructed Wetland with Ornamental Plants in Greywater Treatment', *World Appl. Sci. J.*, 6 (11) (2009) 1555–1562.

(2021) ; http://www.jmaterenvironsci.com