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From pollutant to valuable product: A novel reutilization strategy of wastewater

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Abstract

The world is currently experiencing an impending water crisis, which is certain to have a significant effect on developing economies. Industrialization and increasing population create several problems on earth or increasing demand of water, there is an essential need to supplement the current water supply with additional sources of water which comprises of wastewater reclamation. The gap that has developed between water supply and demand and sewage production and treatment may be filled by the reuse of wastewater. The objective of this paper is to investigate the necessity of incorporating wastewater reclamation for domestic, agriculture or industrial uses or direct or indirect potable uses and the scope of wastewater reuse in different sectors. In domestic grey or black color water is reuse. Various schemes have been adopted by industries across the world to treat wastewater like microbial fuel cell, membrane filtration method or nanotechnology. These are advanced methods to treat wastewater to reuse it. The paper attempts to discuss the various policies and guidelines available for wastewater reuse.

Keywords: wastewater, fuel cell, nanotechnology, groundwater, purification techniques

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1. Introduction

Industrialization and increased population produced a large number of organic pollutants so the availability of freshwater is declining which has forced society to reuse and recycle wastewater [1]. Water is becoming an increasingly scarce resource in many urbanized areas of the world. In these conditions of natural supply shortage, the water demand to satisfy domestic and industrial consumption stimulated various forms of effluent reuse, by mean of treatment processes. Reusing wastewater has environmental advantages since it reduces pollutant discharge and collects high-quality water from underground and above-ground aquifers. Additionally, wastewater recycling enables industry to reduce expenses for purification procedures and freshwater availability [2]. There is a continuous lack of clean water in developing nations like those in the Middle East due to a number of issues including the hard environment, extreme dryness, climate change, and other potential wastes/contaminants. Therefore, growth in water demand and wastewater discharge due to rapid agricultural and industrial growth provides an opening for wastewater reuse [3]. Additionally, socioeconomic issues and technological problems have made national and/or international water planning in these countries with arid and/or semi-arid environments even more complicated. The world now employs wastewater reuse for non-potable purposes, including irrigation, industrial use, and discharge into drinking water resources [4].

The dependence on groundwater has expanded as a result of the growing scarcity of canal water, but groundwater is costly and generally of poor quality due to high electrical conductivity (EC), sodium adsorption ratio (SAR), residual sodium carbonate (RSC), and heavy metals [5-6]. Wastewater can be recycled or reused as a source of water for a variety of water-intensive activities, including agriculture, aquifer recharge, aquaculture, firefighting, flushing toilets, melting snow, industrial cooling, watering parks and golf courses, creating wetlands for wildlife habitats, creating recreational impoundments, and essentially for several other non-potable requirements [7].

2. Water issue and water reclamation

Reusing water can be viewed as a practical solution to difficulties with water scarcity and declining water quality. Additionally, there is a developing trend toward the eventual resource usage of wastewater [8-9]. Wastewater recycling is becoming a crucial component of water demand management, supporting the maintenance of high-quality freshwater supplies as well as possibly lowering environmental pollution and expenses overall [10-11]. Water quality is the most crucial factor in water reuse systems in providing sustainable and effective wastewater reuse. The primary water quality parameters that determine whether recycled water can be used for irrigation, salinity, trace elements and nutrients [12].

3. Water reuse strategy and regulation

A list of features was provided to guarantee the implementation of reuse programs, and these features include

- Enough public relations and social media marketing from the project's outset
- The government and several stakeholders have set up adequate financial resources
- The intensity of water stress and the extent to which the public is aware of it
- Raising public knowledge of the reuse program's potential and the availability of other water resources
- The public's general trust and belief in the water reuse authorities
- It is possible to properly clean and reuse grey water from bathrooms, kitchens, and other washings for non-potable uses like irrigation and flushing.
- It is cost-effective to separate the grey and black waters by installing multiple plumbing lines while building a structure [13-14].

4. Types of wastewaters

Grey water and black water are the two kinds of domestic wastewater that are classified.

4.1. Grey water

Grey water's composition varies widely depending on where it comes from (e.g., bathroom, laundry, or kitchen grey water), and it is affected by the local water quality [15]. Fig.1 shows the percentages of grey water resources from household wastewater [16].

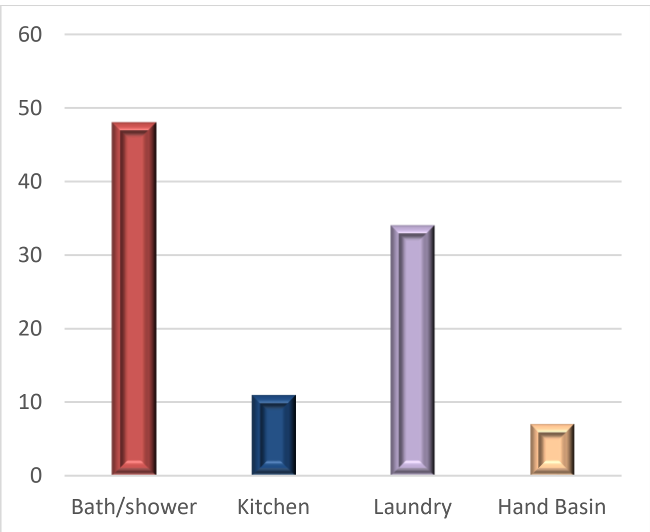

Fig. 1. Percentages of greywater resources from household wastewater [16]

Grey water is likely to contain a number of contaminants, such as pathogenic organisms, heavy metals, suspended and dissolved solids, suspended and dissolved solids, fats, oil, and grease [17]. Table 1 shows the typical composition of grey water [16].

Table 1. Typical Composition of Grey Water [16]

Parameter	Unit	Typical Greywater	
		Range	**Mean**
Suspended Solids	mg/L	45-330	115
Turbidity	NTU	22-200	100
BOD	mg/L	9-290	160
COD	mg/L	100-633	456.7
Total Nitrogen	mg/L	2.1-31.5	12
Total Phosphorous	mg/L	0.6-87	8
pH	-	6.6-8.7	7.5
Conductivity	mS/cm	325-1140	600

4.2. Black water

Black water is the wastewater that comes out of toilets and has a high level of organic, nitrogen, and phosphorus content [18]. Table 2 shows the typical composition of black water [19]. Black water is dumped directly into land holes at a rate of about 5% in urban areas and 24% in rural regions, potentially contaminating groundwater [20].

Table 2. Typical Composition of Black Water [19]

Parameter	Unit	Black Water
Temperature	℃	28.7±0.8
Conductivity	µs/cm	1,858 ± 226.7
TSS	mg/L	184.3 ± 76
TDS	mg/L	840.3 ± 152.1
Oil and Grease	mg/L	14 ± 16.9
Total Nitrogen	mg/L	653.3 ± 166.2
Total Phosphorous	mg/L	18.4 ± 2.6
Ammonia	mg/L	111.8 ± 48.2
pH	-	7.4 ± 0.4
COD	mS/cm	508.6 ± 140.1

5. Application of reuse wastewater in various areas

Urban reuse, agricultural reuse, impoundments, environmental reuse, industrial reuse, groundwater recharge/non-potable reuse, and potable reuse are the seven categories into which recovered water applications can be grouped [21]. It's important to note that water reuse applications vary by country and depend on a number of variables, including the degree of treatment, the state of the water resources, the environment, and public acceptance [22]. Reusing water for agriculture is by far the most common use of water in the world. 91% of the recycled water in this zone is used to irrigate crops and pastures, including cotton, grain, cottonseed, and fruit, tree nut, and vegetable production [23].

5.1. Industrial reuse of wastewater

In many populous places of the world, water is a rare resource that is getting more difficult to obtain. Due to the lack of natural supplies, several forms of effluent reuse were prompted by the need for water to meet industrial use through treatment procedure [24]. Advanced wastewater treatments are required for recycling wastewater for industrial uses, such as membrane processes (micro, ultra, and nano-filtration, and reverse osmosis), in combination with chemical-physical (sand or activated carbon filtration, ozonation), or biological processes [2]. Recycling water for industrial uses reduces the amount of freshwater needed for drinking water production, allowing for less water to be withdrawn from the environment. The plant is capable of producing 47,000 cubic metres of additional drinking water each day, which is equal to 13 Olympic-size swimming pools [25].

5.2. Reuse of wastewater for agriculture irrigation

Fresh water is in short supply, thus it is vital to protect it, conserve it, and utilize irrigation water of poorer quality [26-27]. Agriculture, which is highly reliant on freshwater and consumes the majority of it globally, may suffer serious consequences if water scarcity is worse in areas like dry and semi-arid countries [28]. In arid and semi-arid areas of the world, agricultural irrigation uses around 70% of the water that is collected. As a result, it is crucial to find additional alternative water sources to supplement the current freshwater sources, such as desalinated seawater and treated wastewater (surface water, groundwater). Over time, using treated wastewater as a substitute for freshwater for irrigation [29-30]. In Pakistan, 64% of wastewater is dumped into rivers without being treated, compared to 30% that is directly used to irrigate.

5.2.1. Environmental impact of using wastewater for irrigation

Reusing treated wastewater for irrigation presents numerous environmental benefits and challenges. The extent of impacts is dependent on the quality of the treated effluent and other external factors. Wastewater effluent quality is characterized by the physicochemical and microbial compositions [30].

5.2.2. Soil impacts

5.2.2.1. Nutrients supply

Important macro- and micronutrients are added to the soil via wastewater irrigation. Due to its composition, wastewater is an important source of nitrogen (N), zinc (Zn), phosphorus (P), iron (Fe), manganese (Mn), potassium (K) and copper (Cu). Numerous studies have shown that wastewater irrigation increases soil micro- and macronutrient levels [31].

5.2.2.2. Organic carbon/matter

When contrast to other water sources, wastewater may have higher organic carbon/matter content (e.g. groundwater). Reusing wastewater could therefore be a beneficial and accessible source of natural carbon for soils to encourage plant development [32].

6. Ways of water reuse

There are numerous ways to reuse water in an urban environment. For urban areas that are under water stress, both direct and indirect potable reuse modes offer an alternate water supply without the use of expensive dual distribution network [33-34].

6.1. Direct potable reuse (DPR)

Due to severe water shortages and a lack of alternate supply sources, communities embrace DPR. Communities suffering a water shortage are increasingly taking DPR into consideration as the severe droughts worsen. For larger, wealthier coastal areas, there may be various direct potable reuse alternatives than for mid-sized or smaller inland communities [35]. Determining the necessary level of treatment is one of the first technological problems a community encounters when considering a DPR project. In order to address public concerns about the use of wastewater for potable supply and to ensure public health, it is evident that more treatment is required before it can be utilized [36].

6.2. Indirect potable reuse

One of the uses for recycled water that has grown is indirect potable reuse (IPR), which is partly due to improvements in treatment technology that make it possible to produce high-quality recycled water at ever-lower costs and with less energy input [37]. Because IPR is a water supply alternative that is not dependent on rainfall and because it is feasible to achieve high quality recycled water in compliance with drinking water standards and guidelines, cities with limited water resources are considering IPR as a realistic option for the sustainable management of water [38]. IPR has the potential to significantly help with urban water resource needs, however in order to control the health risk connected with drinking recycled water, caution is needed [37].

6.3. Segregation of wastewater

The high grade rubber (STR20) processing plant's effluent is a mixture of low polluted effluent and high polluted effluent from the rotary screen, creeper, and molding (washing, wet scrubber and sanitary effluent) [39]. By separating wastewater Direct, it produces two types of waste: one that is strong and has a smaller volume and another that is weak and about equal in size to the original, unsegregated waste. A small volume of concentrated garbage is simpler and more affordable to treat than a big volume of dilute waste [40].

6.4. Low strength wastewater

Anaerobic biological treatment for low-strength wastewater has gained popularity recently due to benefits like reduced energy usage, less sludge production, and biogas production. It is a problem to maintain slow-growing anaerobic bacteria with short hydraulic retention times (HRT) [41]. However, the use of membrane separation in anaerobic processes could overcome this problem because they can efficiently retain biomass, provide solids-free effluent, and avoid unwanted sludge waste [42].

7. Technologies for wastewater reutilization

7.1. Microbial fuel cell

The treatment of wastewater using microbial fuel cells (MFCs) is a promising new technology [43]. The primary cause of numerous environmental consequences, such as oxygen depletion of surface waters, hypoxia, and algae growth degrading potential drinking water supplies, is the direct disposal of wastewater generated from diverse sources, including home, agricultural, and industrial establishments. The current methods of wastewater treatment are expensive, chemically and energy intensive, and don't provide any income. It was determined that using high value energy or chemical products would be preferable to traditional sewage treatment systems to eliminate excess sludge and energy problems [44]. Wastewater is now recognized as a critical resource for reusing water and saving energy. But current wastewater has a number of drawbacks, including high energy costs, a lot of residuals being produced, and a lack of prospective resources. Microbial fuel cells (MFCs) have received a lot of attention lately because of their mellow working conditions and ability to use a variety of biodegradable substrates as fuel [45]. MFCs have been studied for use as a biosensor, such as a sensor for biological oxygen that requires monitoring, and they can be used in wastewater treatment facilities to break down organic materials. Microbial fuel cells (MFCs) have gained recognition as an innovative technology that can reduce energy use while simultaneously treating wastewater and addressing environmental issues [46].

7.2. Nanotechnology

Although numerous technologies for wastewater treatment have been investigated in recent decades, their application is restricted by a variety of factors, such as the need for chemicals, the production of disinfection byproducts (DBPs), the length of the process, and the cost. The main goal of nanotechnology is to create new structures, devices, and systems with superior electrical, optical, magnetic, conductive, and mechanical qualities by manipulating matter at the molecular and atomic level. Nanotechnology is being investigated as a potentially useful technology and has already made outstanding progress in a number of areas, including wastewater treatment [47]. Due to their tiny size, wide surface area, and simplicity of functionalization, nanostructures present unmatched prospects to create more efficient catalysts and redox active media for wastewater purification. Numerous pollutants from wastewater, including heavy metals, organic and inorganic solvents, and biological-based poisons, and microorganisms that cause illnesses like typhoid, have been discovered to be successfully eliminated using nanomaterial's [48]. Some potential applications of nanotechnology in wastewater treatment are listed in Table 3 [48].

Table 3. Potential applications of nanotechnology in wastewater treatment [48]

Applications	Representative nanomaterials	Desired characteristics	Enabled Technologies
Adsorption	CNTs	High surface area, more adsorption sites, tunable surface chemistry, reusable	Contaminant detection
	Nanofibers	Selective adsorption, reactive core for degradation	Reactive nano-adsorbents
Photocatalysis	Nano-TiO_2	Photocatalytic effect in visible and UV regions, less human toxicity, more stability, cost-effectiveness	Photocatalytic reactors and solar disinfection (SODIS) systems
Sensing and monitoring	Quantum dots	Broad absorption spectrum, narrow, stable, and bright emission	Optical detection
	Magnetic nanoparticles	Tunable surface chemistry, Para-magnetism	Sample purification
Microbial control/Disinfection	Nano-silver	Wide and strong spectrum antimicrobial activity, less toxic to humans, easy to use	water disinfection
	Carbon nanotubes	Antimicrobial activity and conductivity	anti-biofouling surface

7.3. Membrane filtration method

The removal of particles from a feed stream is referred to as membrane filtration. The membrane filtering process has two variations: ultrafiltration (UF) and microfiltration (MF) [49]. Reverse osmosis (RO) and nanofiltration are two additional significant membrane techniques utilized in the treatment of water and wastewater (NF). The purpose of the RO and NF processes is not to filter the feed stream; rather, they are meant to remove dissolved organisms. In fact, pre-treatment for NF and OR is frequently provided by membrane filtering [50]. Due to its remarkable compatibility with sustainable development and process intensification, membrane technology has expanded recently. Additionally, it provides real advantages in the production processes, including significant equipment size reduction, increased efficiency, energy savings, decreased capital costs, reduced environmental impact, increased safety, and the use of remote control and automation control. Membrane operations are already well-known around the world as effective tools for addressing some significant global issues and creating new industrial processes required for long-term industrial progress [51]

8.Advantages and challenges of using wastewater

Wastewater can be used for a variety of productive purposes, either after being treated or hardly treated [52]. Although there are many different regulatory settings, wastewater is reused. Wastewater reclamation and reuse can therefore be used to the advantage of both northern and southern Eureau countries due to its many potential benefits (protection of water resources, prevention of coastal pollution, recovery of nutrient content for agriculture, improvement of river flow, savings in wastewater treatment, groundwater recharge, and sustainability of water resource management, among others) [53]. European criteria for the majority of applications must be created in order to promote wastewater reclamation and reuse in all EU member states and to establish its safety practice [54]. Reusing wastewater has positive effects on the environment because it reduces pollution discharge and collects high-quality water from surface and subterranean aquifers. Additionally, wastewater recycling enables business to cut costs for purification procedures and freshwater availability [55].

9. Guidelines for the use of wastewater treatment technologies

The overall objectives for wastewater treatment include protecting human health and aquatic life, minimizing resource loss, minimizing water and energy use, recycling nutrients, and lowering waste emissions into the environment. Technology related to wastewater, however, may have certain downsides. Effluents from wastewater treatment facilities, for instance, contain a variety of pathogens as well as other chemical contaminants from the wastewater itself. When wastewater is reused, these pose a hazard to the public's health and build up in the food chain. Furthermore, high energy consumption in wastewater treatment procedures might lead to higher energy costs or carbon emissions [56]

10. Conclusions

This review highlights the reutilization of wastewater for domestic, industrial, agriculture irrigation and environmental or recreational purposes due to shortage of fresh water. Re-use of waste water for domestic or agricultural or industrial purposes have negative impact on human health and aquatic life, so it is necessary to treat this water before use. Advance wastewater treatment microbial fuel cell, membrane filtration method used to treat wastewater and reuse this water in different areas.

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