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Review Article

Efficient Wastewater Management for Sustainable Development: Challenges and Prospects an Indian Scenario

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ABSTRACT

The past few decades have witnessed a drastic decrease in the availability on natural water reserve, as a result of increasing global population and industrialisation. Understanding the need of the available resources is of utmost importance for any nation to function efficiently. Adversely affected water generates wastewater which contains potential hazards such as organic as well as inorganic pollutants which intern have a detrimental effect on the environment and human health. The amount of wastewater generated to the amount of wastewater treated varies greatly, depending on the economy of the country, at the same time the amount of wastewater reused is very less. The declining trend and cause of reduction in water availability is a serious concern which is indicated in the present study. The present study also focuses on the aspects of wastewater management and its importance for reuse along with suggestions of improved technologies for wastewater treatment. The motive of the study is to understand the importance of wastewater reuse in an efficient manner so that sustainable development can be maintained, thus reducing encumbrance on the natural resources.

Key words: Water scarcity, Water availability, Sustainable development, Membrane aerated biofilm reactors (MABR), Bioreactor, Nanotechnology.

INTRODUCTION

Water is the primary source of survival of any form of living organism on the earth, oceans seas and bays harbor 96.5% of the available water which cannot be consumed due to its high salinity (3.5%), glaciers and ice caps hold up 1.74% of fresh water, however the rise in sea temperatures have been causing an irreplaceable damage. Hence the only source of fresh water is from lakes and rivers which amount to 0.013% and 0.0002% respectively, [1] such volume isn't feasible to quench the human consumption and well as industrial requirements.

Wastewater is defined as any water which has been adversely affected in quality by anthropogenic influence, sources of wastewater include domestic, industrial, commercial or agricultural, surface runoff or stormwater and from sewers inflow. [2] Treating such water before being letting into the natural reservoirs could abate the issue of pollution, as well as use treated water for the purpose of irrigation. Wastewater treatment is adopted throughout the world with modifications of its own, although Physical, Chemical and Biological methods are the basis for any wastewater treatment.

Understanding the nature of wastewater is important prior to development of treatment plant and selection of appropriate treatment technologies. Waste-water quality are characterised by its physical, chemical, and biological properties. Physical characteristics of wastewater include temperature, colour, odour, and turbidity. Physical parameters also include Insoluble contents such as solids, oil and grease. Solids are further subdivided into suspended and dissolved solids as well as organic (volatile) and inorganic (fixed) fractions. Chemical parameters associated with the organic content of wastewater include biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), and total oxygen demand (TOD). Inorganic chemical parameters include salinity, hardness, pH, acidity and alkalinity, as well as concentrations of ionized metals such as iron and manganese, and anionic entities such as chlorides, sulphates, sulphides, nitrates and phosphates. Bacteriological parameters include coliforms, faecal coliforms, specific pathogens, and viruses. [3]

Statistics on global wastewater generation, treatment and reuse

Based on the global distribution of wastewater (reporting duration 2008-2012), a study was carried out in 2013 on the generation, treatment and reuse, although from the literature in published or electronic form for 181 countries, only 55 countries had the available data of all three aspects of wastewater generated, treatment, and reuse, whereas no data was available from 57 countries, the recommended data suggests that high-income countries treat around 70% of wastewater generated, followed by upper-middle-income nations which is 38%, 28% from lower middle-income countries and finally low-income nations where only 8% of the wastewater generated is treated. The following table is the summation of the data available from the study by Sato *et al.* [4]

Table 1: Country-wise statistics of wastewater generated, treated, reused and reuse percentage.

Country	Wastewater generated (km^3/year)	Wastewater treated (km^3/year)	Wastewater reused (km^3/year)	Wastewater percentage reused (%)
North America	84.968	61.119	2.345	3.8
Latin America	29.752	5.4702	0.5525	10.1
Europe	52.4422	30.512	1.384	4.5
Russian Federation & independent states from the former Soviet Union	27.481	20.155	0.9932	4.9
Middle East & North Africa	22.644	11.899	3.685	30.99
Sub-Saharan Africa	3.707	3.2947	0.0638	1.9
Australia	2.094	1.779	0.348	19.56
Asia	133.12	27.5222	14.403	52.33

The statistics indicates that developed nations such as America uses only 3.8% of treated wastewater, the highest water reuse percentage is observed in the Asia, which accounts for 52.33%, the study suggests that China uses 1.3 million ha land for irrigated using treated wastewater, thus making it among the highest wastewater reuse nations. The second highest region to make use of treated wastewater is Middle East & Africa which accounts for 30.99, being one of the most arid regions Middle East, have a better wastewater management system, thus making a significant use of treated wastewater.

An overview of wastewater reuse and treatment

In order to reuse wastewater for productive purposes such as irrigation, industrial reuse, gardening etc, treatment standards are prescribed by the EPA, which suggest primary treatment, secondary treatment and tertiary treatment; primary treatment which involves sedimentation, at this stage there is no recommended reuse of wastewater, the secondary treatment involves biological oxidation and disinfection water at this stage could be used for various purposes such as surface irrigation of orchards and vineyards, non-food crop irrigation, restricted landscape impoundments, ground water recharge of non-potable aquifers, wildlife habitat, wetlands, stream augmentation and industrial cooling processes, and finally tertiary or advanced treatment includes chemical coagulation, filtration and disinfection; the water from this treatment could be used for landscape and golf course irrigation, toilet flushing, vehicle washing, food crop irrigation, unrestricted impoundment, groundwater recharge of potable aquifer and surface water reservoir augmentation. [5]

CPCB (India) has developed a concept called as "designated best use" where wastewater is categorised on the basis of the quality for reuse, class A is assigned for water bodies which could be used for drinking purpose prior to disinfection, class B water which could be used for outdoor bathing, water treated using conventional methods and potable for drinking are termed as Class C, water used for propagation of wildlife and fisheries is termed as Class D, water suitable for irrigation, cooling and controlled waste disposal is termed as Class E water, each class categorised has respective water quality criteria specified by CPCB. [6]

The conventional treatment method adopted by EPA, as well as CPCB, follow a similar process, of preliminary treatment, primary treatment, secondary treatment and tertiary treatment which is described below

(i) Preliminary treatment: This treatment involves the removal of coarse solids and other large materials from raw effluent. Screens and grates are used for removal of large materials, comminutors for the grinding of coarse solids and pre-aeration for odour control. PH correction and removal of grease and oil is also carried at this stage.

(ii) Primary treatment: Physical separation of suspended solids from effluent using primary clarifiers is carried out in this stage, thus helpful in reducing total suspended solids (TSS) and associated biochemical oxygen demand (BOD) levels. The primary objective for this treatment is the removal of settleable organic and inorganic solids by sedimentation and removal of materials that float through skimming, as well as organic nitrogen, organic phosphorus, & heavy metals associated with solids are removed during primary sedimentation. Apart from sedimentation chambers, auxiliary processes such as flotation, flocculation and screening may also be used.

Flocculation may be preceded by a chemical treatment usually with lime and alum in order to remove metals by precipitation; it also helps in the removal of colloidal associated with BOD. Mainly used chemical treatments include pH neutralization using acids such as sulphuric or hydrochloric or alkalis such as dehydrated lime or sodium hydroxide, the second method includes precipitation, wherein precipitants are mixed with the effluent allowing the formation of insoluble metal precipitants and then later their removal through clarification or filtration. [7]

(iii) Secondary treatment: This treatment involves decomposition of dissolved and suspended organic matter using microbes. Biological treatments can be either aerobic or anaerobic and treatment can be carried out using Activated sludge where microbes are unattached in a liquid suspension or Biological filters such as a trickling filter where microbes are attached onto the surface of the filters. Anaerobic processes are not commonly used in wastewater treatment as they are slower than aerobic degradation and tend to release hydrogen sulphide gas when sulphur is present in the effluent. [7]

(iv)Tertiary treatment: The final process in the effluent treatment involves the removal of persistent contaminants that secondary treatment is unable to remove. Tertiary treatment is considered as the final cleaning process that improves wastewater quality for reuse or safe for discharge into the environment. This process is used for effluent polishing (BOD, TSS), Nutrient removal (N, P) and toxin removal (pesticides, VOCs, metals). Some of the tertiary processes include Granular Media Filtration such as Sand filters or Dual/ Multimedia filtration and Membrane filtration as well as Reverse osmosis systems, Ion exchange, and Activated carbon and UV disinfection. [7]

Wastewater outbreaks

Mixing of untreated wastewater into natural reservoirs causes a grave damage not only to the environment but also to health of animals and humans who come in contact with it. On May 29th, 2017, Bangalore city (India) witnessed toxic foam over the Varthur Lake which later spilled over the neighbouring roadways due to heavy winds, however the incident previously occurred in April 2015, the reason for the toxic foam generated due to dumping of waste and wastewater from industries which resulted in high levels of ammonia and phosphate and very low levels of dissolved oxygen in wastewater. [8] On April 2016, 70 tonnes of dead fishes were washed shore of the Vietnams central coastline, this was a result of toxic discharge such as cyanide and carbolic acids were dumped into the sea by Taiwan's Formosa Plastic group, while carrying out test runs of the plant, reports suggested that the scenario continued for almost 15 days where dead fish was being washed ashore. [9] Another disastrous effect of wastewater was caused in Colorado at the Gold King Mine, on the 5th of August 2015, when EPA personnel along with workers of Environmental Restoration LLC accidentally discharged the water trapped inside the mine, which caused 3 million gallons of waste water and tailings to spill into the Cement Creek, a tributary of the Animas river in Colorado, the wastewater contained heavy metals such as Cadmium, Lead, Arsenic, Beryllium, Zinc, Iron and copper, within days the waste contaminated the rivers in New Mexico. [10]

Decline in water availability (India)

In 2014, an article published in the Times of India, indicated the decrease in water availability in India from 1947 to 2011 along with a future prediction for 2025 to 2050, the alarming rate at which water availability seems to decline, the country wouldn't be able to achieve its future demands, unless the aquifers are replenished or alternate methods are employed. The bar graph accounts for the data made available from Times of India and represents the decrease in the water availability from 1947-2050. [11]

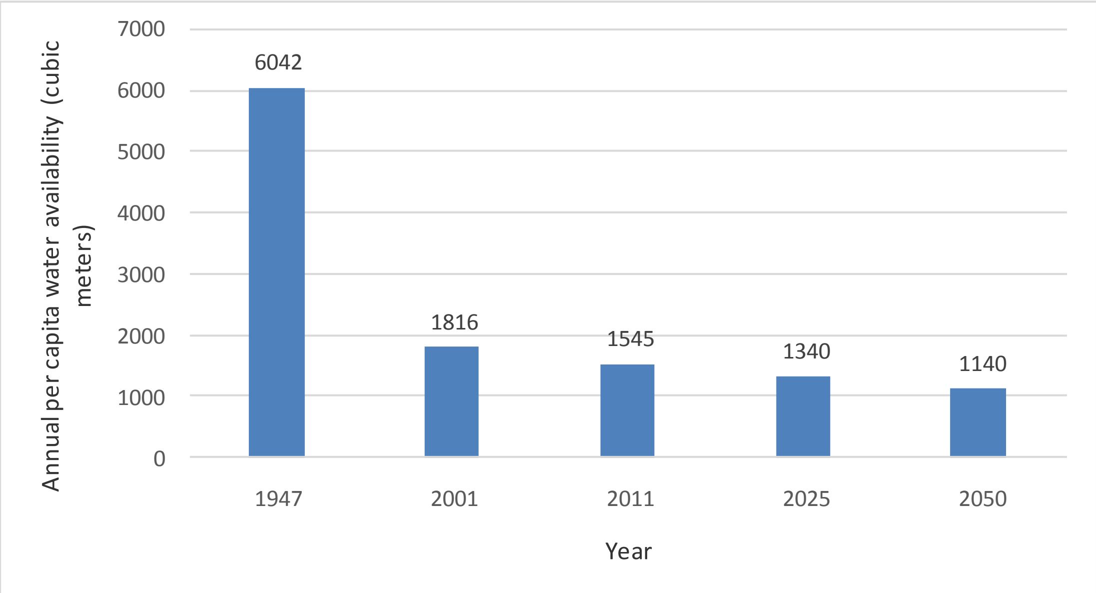

Fig 1: Annual per capita water availability decrease pattern in India from 1947-2050

The decreasing pattern in the water availability is similar throughout the world thus making it the need of the hour to develop better water management as well as wastewater management systems, as the decline in water availability is inversely proportional to the water requirement.

Water scarcity & the need to recycle wastewater

According to the World Wildlife Organisation (WWO), around 1.1 billion people around the world lack access to water and around 2.7 billion find water scare at least once a month of the year, and an estimation that by 2025 two-thirds of the global population may face water shortage, as well as the ecosystem, will suffer even more. [12] Water scarcity stems from various reasons such as the following

- **Water overuse:** Increasing global population is the major cause of water overuse, as well water may be overused on animals, land as well as heedless overuse for recreational activities around the world.
- **Agriculture:** Agriculture generally makes use of the major freshwater available from rivers and lakes, and the data suggests around 60% of this water gets wasted due to inefficient agricultural methods as well as leaks in the irrigation system.
- **Water pollution:** Pollution deteriorates water quality which is a huge problem making it unfit for consumption as well as harmful if used for the irrigation purpose.
- **Drought:** Lack of rainfall over the years has been the reason for drought for many cities around the world. Certain regions are in perpetual drought whereas other regions deal with drought occasionally.
- **Distance:** Many regions throughout the world deal with water scarcity, only because they aren't close enough to any place that has water, arid and semi-arid regions such as deserts or secluded areas generally are water deficient.
- **Governmental access:** Countries specifically those with dictatorship have a strict control over the use of water, thus causing a lack of sufficient water supply for the population living in those regions of the world.
- **Conflict:** Conflict over land may make it difficult for people to access water, in the worst-case scenarios; people end up in violence in order to access water from these areas.

The points mentioned above are a few considerations which have led to the water scarcity, hence making it a priority to conserve and understand the importance of water. [13,14] Water is not only getting depleted and deteriorated from rivers and lakes, but also the recent years have seen a colossal reduction in the groundwater table. The upper 2km of continental crust contains approximately 22.6 million km^3 groundwater of which, 0.1-5.0 million km^3 is less than 50-year-old. [15] This ground has seen a rapid depletion due to following reasons

- **Overuse or excessive pumping:** The past few decades has seen an excessive overuse of groundwater especially in the agricultural sector, in 2000 groundwater accounted for 20% of the worlds irrigation, over the next ten years groundwater depletion increased 22%, this quantum jump over the decade was powered by countries such as China, which register 102% increase in the groundwater depletion, along with US which accounted for 31% and India was responsible for another 23%. [16]
- **Climate change:** Rising temperatures throughout the globe could have negative impact on the groundwater table. The Intergovernmental Panel on Climate Change (IPCC) has estimated the global mean surface temperature rise of 0.6+/- 0.2^{0}c rise since 1861 and predict a further rise of 2to 4^{0}c over the next 100 years, the rising temperature has affected the hydrologic cycle by directly increasing evaporation of available surface water and vegetation transpiration, subsequently influencing the precipitation amount, timings, and intensity rates and indirectly impacting the flux and storage of water in subsurface reservoirs. [17]

Need to recycle wastewater has not been a recent effort, although the rising concern of water scarcity and pollution has made it inevitable and logical in recent times. The treatment and use of recycled wastewater dates back to 1700 BC, where King Minos installed the first water closet with a flushing device in the Knossos Palace, in the intervening 3700 years various societies and governments sought this process to improve removal of human wastes from indoor areas and treatment of that waste to reduce threat to public health and ecological resources. [18]

(i) Irrigation: Water consumed for irrigation in developed nations accounts to 70% of the water used worldwide, whereas for developing countries it's as high as 95%, thus playing a significant role in food production and food security. On the other hand, water used agriculture seems to be facing an increasing competition from other water use sectors thus posing a threat to the environment. [19] Middle Eastern and Mediterranean countries such as Cyprus, Turkey, Jordan, and Morocco are characterized by severe water shortage, especially during the summer months. This water shortage is a result of a cumulative reason such as high temperatures, uneven distribution of precipitation, increasing demands for irrigation and impact of tourism, thus dependency on the reuse and reclamation of wastewater has been given serious consideration. The MEDAWARE project, funded by the Euro-Mediterranean partnership and more specifically by its Regional Program for Local Water Management, are focused on the development of specification of urban wastewater treatment technologies and reuse, development of tools and databases to monitor wastewater treatment plants, organising series of training workshops, conferences, pilot studies aiming at growing awareness etc, thus providing a better wastewater management system in the Mediterranean countries.[20] The importance of wastewater treatment before reuse for purpose of irrigation in India was studied by Anupam Khajuria. Khajuria emphasized on the fact that wastewater is disposed of in rivers as the growing cities cannot handle the sewage produced, thus contaminating the rivers, which is then in turn used for irrigation. Untreated sewage water contains potential hazards such as organic and inorganic pollutants, thus affecting the growth of the plants. With the problem at hand, the author recommends changes in policies and economic opportunities to reduce risk and optimize wastewater treatment, recommendations include adoption of a multi-sectoral approach to wastewater management, merging public and private sectors, forward thinking and innovative planning, development and implementation of wastewater treatment plants as well as socio-economic benefits. [21]

(ii) Phosphorus extraction: Wastewater may contain 5-20mg/l of total phosphorus wherein 1-5 mg/l is organic and the rest is present as inorganic form. Secondary treatment can, however, remove only 1-2mg/l of phosphorus, discharging the excess in the final effluent causing eutrophication in surface water. [22] Phosphorus is widely used as a fertilizer, which is expensive due to availability thus extraction of phosphorus from wastewater as mean to be used as fertilizer without any further treatment could be a viable option to reduce eutrophication as well as economically reasonable for agriculture. Denmark is among the few countries which have become initiative, Struvite is a crystalline form of phosphorus, has been approved in Denmark as a fertilizer product, although the recovery technology is still under development the Danish water utilities and companies are developing much more efficient process solution, and the expected P-recovery is estimated around 165 tonnes P/year, 3.6 tonnes of struvite fertilizer per day.[23] Apart from decreasing eutrophication phosphorus recovery could reduce the load of contamination of groundwater, being cost efficient makes it feasible for small-scale industries make use of such process.

(iii) Energy generation: Energy required for a typical domestic wastewater treatment plant using aerobic activated sludge treatment and anaerobic sludge digestion is 0.6 kWh/m^3 of wastewater treated, of which 50% is consumed for electrical energy to supply air for the aeration basins. [24] Wastewater and its biosolids/biogases exceed the energy potential by 10 times the energy used for the treatment of effluent; certain wastewater treatment plants are capable of producing 100% or more energy and could potentially meet 10% of the national electricity demands. [25] Wastewater could be used to generate electricity, by diverting the treated sewage effluent through a penstock under pressure into a turbine to generate electricity, which could be used on site instead of the energy bill of the treatment works or could be exported to the grid for sale. [26] An estimated 21 million metric tons of greenhouse gas (GHG) is emitted from municipal wastewater treatment, and biogas being the main of (GHG), if such emissions can be captured and managed efficiently the sludge generated at effluent treatment plants could produce substantial energy in the form of biogas, with a potential to turn effluent treatment plants into a net energy producer. [27] Developing nations could adapt to such changes to alleviate the energy crisis and turn towards green energy production.

MOST EFFLUENT GENERATING ACTIVITIES

(i) Textile industry: The textile industry is of great economic significance as it provides the basic need of clothing. This sector ranges from small-scale units that use traditional manufacturing process to large integrated mills which use modern machineries and equipment, however, pollution problems in textile industries range from colour, dissolved solids, toxic metals, and residual chlorine. As per the findings of CPCB (India), the textile industry in India discharges 575 Kilo litre per day (KLD) of effluent of which 10% of the total waste generated is dye bath effluent and the remaining is wash water. [28] Presence of vat dyes, sulphur, naphthol, nitrates, acetic acid, soaps, chromium compounds and heavy metals such as copper, arsenic, lead, cadmium, mercury, cobalt, nickel and certain auxiliary chemicals collectively make the effluent highly toxic, other harmful compounds may include formaldehyde based dye fixing agents, hydrocarbon based softeners and non-bio degradable dyeing chemicals. [29] China, India, Italy, Germany and Bangladesh are the top 5 nations which run the largest textile industries. [30]

(ii) Effluent from city and municipal waste: City and municipal waste effluent is considered as domestic effluent, as it is discharged from household, agricultural runoff and stormwater. Studies have shown that 38354 million litres sewage is generated per day in from the major cities of India, whereas the sewage treatment capacity is 11786 MLD. [31] Municipal or city effluent is characterised by 99% water with relatively small concentrations of suspended and dissolved organic and inorganic solids such as carbohydrates, lignin, fats, soaps, synthetic detergents, proteins and their decomposition productions, along with various natural and synthetic organic chemicals. [32]

(iii) Biomedical liquid waste: Biomedical waste is defined as any waste generated during healthcare or research activities. Biomedical waste has been a major challenge for the government and health sector; however, the liquid biomedical waste generated is considered the most difficult to handle, as it is far more mobile and moves to a widespread area after entering the water bodies or underground aquifers. [33] Depending on medical practice liquid waste may include blood, spinal fluids, saliva, dialysis waste, amniotic fluid, other bodily secretions and fluids, medication such as chemotherapy drugs and lab culture and specimen. [34] These fluids are highly infectious and potential hazard for anyone who comes in contact. In 2004 an audit carried out at the Choitram Hospital and Research centre Indore (India) with an occupancy of 250 beds generated 480 litres of liquid waste along with 33000 litres per month liquid waste generated from labware washing and laboratory cleaning and 162 litres of chemical waste per month. [35] Although the ratio of infectious to non-infectious waste generated is low, improper handling and management of BMW could be detrimental, causing the entire waste to be infectious and hazardous.

(iv)Pharma industries: With the burgeoning diseases, the pharmaceutical industry has witnessed a rapid growth. Patneedi and Prasadu studied the impact of pharmaceutical waste on human life and environment in 2015, their study indicates the presence of Non-steroidal anti-inflammatory drugs (NSAIDs) such as ibuprofen, ketoprofen, naproxen, indomethacin, diclofenac, acetyl salicylic acid and phenazone in surface water system whereas diclofenac, ibuprofen, propyphenazone and clofibric acid are most commonly in water bodies, similarly monitoring study of drinking water exhibited drugs such as acetaminophen, codeine, p-xanthine, sulfamethoxazole, caffeine, carbamazepine and trimethoprim; the health risk associated with long term exposure to such complex pharmaceutical mixtures on the stream biota may result in acute and chronic damages, along with behavioural changes, reproductive damage, even fishes exposed to traces of birth control pharmaceuticals have found to exhibit dramatic decrease in reproductive capabilities. [36] Although United States of America ranks among the highest pharmaceutical production, developing nations such as India and China with insufficiency of treatment methods and management are of greater concern, cases of illegal dumping and improper treatment generally result in pollution of water bodies and in turn affecting the aquatic life forms, not only is the reproductive capability compromised but microorganisms exposed to a wide range of antibiotics in the water bodies also gain resistance and result in the spread of multiple drug-resistant organisms.

(v) Dairy Industries: Considering the food market around the globe, milk and dairy industries are among the largest segments, dairy industry consumes 33.96% out of the total water required by the food industry. [37] Water in dairy industries are used for purposes such as hydrating the cows, cleaning parlor floors, walls and milking equipment etc. [38] This effluent generated from dairy industry generally constitutes suspended solids, chlorides, sulphates, oil and grease along with milk constituents like casein, inorganic salts, besides detergents and sanitizers which is used for washing purpose as well as high sodium content from the application of caustic soda used for cleaning. [39] Hazards of dairy effluent include rapid decomposition and depletion of the dissolved oxygen levels of the receiving stream and resulting in anaerobic conditions and release of foul odour, the precipitation of casein causes further decomposition into a highly odorous black sludge, certain dilutions of dairy waste was found to be toxic to fish and other aquatic life forms and in turn becoming a breeding place for flies and mosquitoes, soluble organics, suspended solids degrade and promote release of gases, odour and also responsible for eutrophication. [40]

(vi)Brewery/Beverages Industry: The brewery industry is considered as the largest water consumption industry in the world. It is estimated that the brewing process requires roughly around 20 gallons of water to make a pint of beer and 132 gallons of water to make 2 litre bottle of soda. [41] For every 1 L of beer produced, 3-10L of effluent is generate depending on the production,[42] this effluent generally constitutes suspended solids, organic discharges such as spent grains, waste yeast, spent hops and grit, [43] the high organic content is broken down by microorganisms which in turn consume oxygen while doing so, thus causing the depletion of oxygen content and in turn polluting the receiving stream.

(vii) Animal husbandry: Animal husbandry deals with feeding, breeding, housing and health care of livestock, it may also include poultry farming and fisheries, [44] with India being the largest livestock producer in the world followed by Brazil and China. Livestock industry is the fastest growing agricultural sector, with 8% of the global water supply being used for intensive, feed-based production. [45] The effluent generated from animal husbandry generally contains manure, nutrients particularly Nitrogen and Phosphorus, solids, organic matter, pathogens and odorous/volatile compounds from animal waste, manure can also contain salts and trace elements and to a lesser extent antibiotics, hormones and pesticides. [46] The high nutrient content is responsible for eutrophication of surface water when discharged into stream, damaging wetlands and fragile coastal flora, fuelling algal bloom which in turn reduce the oxygen content and harming aquatic life, phosphates and nitrates leach into groundwater thus threatening the drinking water supply, build-up of excessive nutrients and heavy metals from manure could as well damage the soil fertility, decomposition of the organic matter from livestock effluent generally results in release of gases such as ammonia, methane and other gases thus causing environmental hazards. [47]

(viii) Leather tanning industry: The tanning industry deals with converting raw animal skin and hide into leather using agents such as tannin (plant source), fish or animal oil and salts of chromium (usually trivalent chromium), [48] with China, Italy and India being the largest exporters of leather in the world. Sundar *et al* in his study, indicates that approximately 40-45L water/kg skin or rawhide is required for processing of finished leather, with an annual production of 690000 tonnes, the water requirement for the industry is around 30 billion litres, thus water availability and treatment of the effluent generated are the two major concerns for the tanning industry. [49] Effluents from leather processing industry, contains extremely high levels of total suspended solids, electric conductivity, total dissolved solids, total soils, BOD and COD as well as high concentrations of SO_4^2, Na, Cl, As, Cd, Pb, the order of concentration of chemicals in sludge were Cr>Na>Ca>S>Mg>P>Cu>TN>Zn>organic compound>Pb>As>Cd, thus the effluent generated is considered highly polluted and not suitable for irrigation or any other purposes. [50] The pollutants from the effluent are not only harmful to the environment but also to the workers working in the tanning industries, many of the chemical agents used by the industry as well as the presence of heavy metals are carcinogenic, the effluent generated if disposed of into water bodies without treatment could cause poisoning of fishes and damage to the ecosystem.

RECENT DEVELOPMENTS IN EFFLUENT TREATMENT METHODS

The need of effluent treatment is based on preventing water pollution and encouraging sustainable development of any society, however, the current prescribed methods still fall back on achieving optimum treatment of wastewater due to the increasing load of pollutants. Innovative technologies for effluent treatment are an urgent need as industrialization would keep expanding in the near future with the rising demands of the population around the globe.

- **Membrane aerated biofilm reactors:** The conventional aeration system used for wastewater treatment is flawed by high energy consumption, higher maintenance cost, which is 60 to 80% of the operational cost, and lesser oxygen transfer efficiency which accounts for less than 25-35%, the Membrane aerated biofilm reactor (MABR) is an improved technology which could be used as an alternative to the conventional aeration technique, the MABR contains a hollow fibre membrane which is inserted into the bioreactor separating into a liquid phase zone and a gas phase zone, thus satisfying two primary purposes of carrier for biofilm growth and secondly a diffuser for aeration to the biofilm; MABR possess a unique structure and stratification which could also be used for biodegradation of organic compounds as well as simultaneous nitrification and denitrification, another important features of this process is its bubble-less aeration, which is achieved through a gas permeable hydrophobic membrane. [51]

- **Bioreactor:** The European government initiative and the research carried out at the Water Research Institute (Italy) have developed the Sequencing Batch Biofilter Granular Reactor (SBBGR), an innovative system for municipal wastewater treatment to reduce the issue of excess sludge and organic matter during the treatment process, wherein the system allows microbes to grow in the form of a mixture consisting of biofilm and high-density granules packed in aplastic filling material in the reactor, thus allowing a longer retention and greater concentration of microbial mass and eliminating the requirement of additional clarifying process and in turn reducing biological sludge, this process is capable of 97% removal efficiency of suspended solids, COD, ammonia and up to 80% reduction of sludge production, as well as the techno economic assessment, has shown the overall cost reduction of up to 40% as compared to the existing biological wastewater treatment plants. [52]
- **Nanotechnology:** The presence of heavy metals in wastewater is inevitable; treatment carried out at the effluent plant, however, reduces the levels but cannot completely eliminate their presence in the final treated water. In the past decade nanocomposites of metal oxides, polymers and carbon have been developed and studied as a potential adsorbent for environmental remediation and a wide range of bioprocess for industrial application, nano materials possess certain properties which make their application unique, nanoparticles have a high surface to volume ratio, surface modifiability, reversibility, biocompatibility and comparatively low cost, the most common metal Nano adsorbent studied is the iron oxide nano particle also known as magnetic nano particle (MNPs); similarly carbon nano tubes (CNTs) are being explored in place of activated carbon due to their capability as an adsorbent for the removal of heavy metals from wastewater. [53] Nanoparticles possess the capability of removing more than one metal from wastewater as compared to removal of specific heavy metals, Magnetic hydroxyapatite (MNHAP) nanoparticles were used as an adsorbent for the removal of Cd(II) and Zn(II), aluminium oxide nanoparticles were used for the removal of Cd, Zn and other heavy metals from wastewater and soil solutions due to the property of high specific surface area to volume ratio, SDS coated MNPs were explored for the removal of Cu(II), Ni(II) and Zn(II),2,4-dinitrophenylhydrazine (DNPH) immobilised on SDS coated nanoalumina was developed for the removal of cations such as Pb(II), Cd(II), Cr(III), Co(II), Ni(II) and Mn(II) from water, and polymethacrylic acid grafted chitosan-bentonite nanocomposite (MACB) were effective in the removal of Hg(II), Pb(II) and Cd(II) metal ions. [53]

Developing countries around the world fall back on economic crisis which directly hinders the treatment of wastewater, thus draining untreated wastewater directly in the nearby flowing stream thus generating additional environmental and health issues. The above-mentioned advances have a common advantage of being cost effective as well as providing higher effluent treatment. Replacing the conventional methods with a combination of MABR, SBBGR and Nanocomposite complex in a single system is highly recommended.

MICROBIAL RESISTANCE TO WASTEWATER RESIDUE

Untreated wastewater discharged into waterbodies is a huge risk, knowing the potential hazards it harbours. A recent fact study by the UNEP has estimated that 30 million hectares of land is affected by untreated wastewater, which has witnessed a 50% rise as compared to the previous estimates. [54] Microorganisms have a unique stress response which is responsible for their survival in harsh environments, thus creating a virulence mechanism. Over the period of time and exposure of stress the organism gains resistance which is inherited by the microbial strain, however, such response could have its own advantages as well as disadvantages. The Wadi El Harrach river in Algeria river receives effluent from various local industries as well as agriculture and urban sewage which is finally discharged directly into the sea; studies revealed that Lead and Zinc were the major pollutants from the wastewater collected and out of the 40 heavy metal resistant bacteria isolated 13 isolates were selected and studied extensively based on their heavy metal resistance, of which 77% species were Gram-negative and 23% were Gram-positive bacteria, these wastewater isolates exhibited an MIC ranging from 100-1500ug/ml, the study also analysed the co-resistance of isolates to heavy metal and antibiotics wherein 9 isolates (69%) were multiple resistant to heavy metals, 15% organisms were resistant to a single antibiotic, & 85% were multi and bi-antibiotic resistant, the study suggests that the heavy metal resistance can be attributed to a variety of mechanisms such as metal efflux, intracellular sequestering or metal reduction, these mechanisms can be encoded in the plasmid gene thus facilitating the transfer of toxic metal resistance from one cell to another. [55]

CONCLUSION

It has been observed that decreasing pattern of water availability which is inversely related to the growing population, thus future nations wouldn't be able to fulfil the need of water for consumption. A viable solution to this problem would be to develop better developments in wastewater management systems, which would make treated wastewater available for purposes of irrigation, gardening and other industrial purposes. This would directly decrease the load from natural reservoirs thus maintaining the availability of naturally available water; this would even help groundwater to replenish over time. Better methodology for wastewater treatment suggested in this review could provide a solution for developing countries with low economy; the treatment methods are cost-efficient and effective.

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