

Review Article

Technologies of Domestic Wastewater Treatment and Reuse: Options of Application in Developing Countries

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Submitted: 19 April, 2016

Accepted: 02 November, 2016

Published: 04 November, 2016

ISSN: 2333-7141

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Keywords

- Domestic wastewater
- Bio-waste
- Reuse
- Treatment
- Appropriate technologies

Abstract

In developing countries, a small proportion of the wastewater produced by sewer communities is treated. The accumulations of human and animal bio-waste are constant and unmanaged wastewater directly contributes to the contamination of locally available fresh water supplies. Additionally, the cumulative results of unmanaged wastewater can have broad degenerative effects on both public and ecosystem health. Domestic wastewater treatment is aimed to reduce the numbers of excreted pathogens to low levels and consequently the risks of further environmental transmission of emerging diseases are substantially reduced. Review article discussed how treated wastewaters can be profitably and safely used in agriculture, industries and aquaculture. In conclusion, an article revealed how innovative and appropriate technologies can contribute to wastewater treatment and reuse that are currently accepted in order to protect the environment, human being, and the animal health.

ABBREVIATIONS

NH₄-N: Ammonia; NO₃-N: Nitrate; CW: Centralized Constructed Wetlands; ETEC: Enterotoxigenic *E. coli*; EPEC: Enteropathogenic *E. coli*; EHEC: Enterohaemorrhagic *E. coli*; EAEC: Enteroaggregative *E. coli*; EIEC: Enteroinvasive *E. coli*; DAEC: Diffusively Adhesive *E. coli*; BOD: Biological Oxygen Demand; TOC: Total Organic Carbon; COD: Chemical Oxygen Demand; SR: Slow Rate; OF: Overflow; RI: Rapid Infiltration; FWS: Free Water Surface Systems; SFS: Subsurface Flow Systems; WWTPS: Wastewater Treatment Plants; MWRI: The Ministry Of Water Resources And Irrigation.

INTRODUCTION

Untreated wastewater generally contains high levels of organic material, numerous pathogenic microorganisms, as well as nutrients and toxic compounds. It thus entails environmental and health hazards, and, consequently, must immediately be conveyed away from its generation sources and treated appropriately before final disposal. The ultimate goal of wastewater management is the protection of the environment in a manner commensurate with public health and socio-economic concerns [1].

Over half the world's rivers, lakes and coastal waters are seriously polluted by untreated domestic, industrial and agricultural wastewaters [2,3] and they contain high numbers

of fecal bacteria. Effective wastewater treatment needs to be recognized, therefore, as an environmental and human health imperative [4].

Conventional wastewater treatment technologies are expensive to build and also have associated operational and maintenance problems. For example, by air stripping method, it is feasible to reduce ammonia level to 1 mg/L but special requirements of the process such as water temperature of over 15°C and carbonate deposition are disadvantages of this system. Thus, both physic-chemical and biological technologies have been applied for the elimination of ammonia from wastewaters for a long period [5,6]. However, with the ever stringent discharge limits of ammonia and nitrate (50 mg/L NH₄-N, 10 mg/L NO₃-N) for inland surface waters, it is essential to remove them to permissible levels. Bio-treatment, being cost effective, is normally adopted for wastewater treatments. There are many advantages of bioremediation over conventional methods [7].

Large-scale centralized constructed wetlands (CW) treatment systems are often used in developing countries and were regarded as a successful approach during the last century [8-11]. In recent years, studies have been conducted on the design, construction, and performance of constructed wetlands in treating different types of wastewater sewage, storm water, industrial wastewater, agricultural runoff, acid mine drainage, and landfill leachate, for example [12-15].

The removal of nitrogen from domestic sewage in constructed wetlands mainly depends on nitrification and denitrification [9,13,14,16]. A US Environmental Protection Agency publication has suggested that CWs are not successful in treating nitrogen and that earlier studies claiming that constructed wetland nitrogen removal is very efficient could not be reproduced in subsequent full-scale trials [17].

Today, planning of projects for the wastewater treatment and reuse of effluents is significantly increasing in several countries. The main (re)uses of treated wastewater are irrigation (both agricultural and landscape), recharge of aquifers, seawater barriers, industrial applications, dual distribution systems for toilet flushing, and other urban uses. International organizations, such as the World Bank, the Food and Agriculture Organization (FAO) of the United Nations, and the World Health Organization (WHO) estimate that the average annual increase in the reused volume of such water in the USA, China, Japan, Spain, Israel and Australia ranges from up to 25%. For example, in California, only 860 Mm³/year of treated wastewater effluent (4300 Mm³/year) was reused in 2010, whereas, over 80% (3440 Mm³/year) of treated wastewater effluent was discharged to the ocean. In 2030, 2470 Mm³/year is planned to be reused [18]. This article aimed to reveal how innovative and appropriate technologies can contribute to wastewater treatment and reuse in developing countries.

Origin and composition of domestic wastewater

Domestic wastewater is the water that has been used by a community and which contains all the materials added to the water during its use. It is thus composed of human body and animal wastes together with the water used for utensils cleaning, washing, and rinsing and food preparation. Fresh wastewater is a gray turbid liquid that has an earthy but inoffensive odor. It contains large floating and suspended solids as well as pollutants in true solution. It is objectionable in appearance and hazardous in content, mainly because of the number of disease-causing (pathogenic) organisms it contains. In warm climates wastewater can soon lose its content of dissolved oxygen and so become 'stale' or 'septic'. Septic wastewater has an offensive odor, usually of hydrogen sulfide [19].

Collection of domestic wastewater

Domestic wastewaters are collected in underground pipes which are called 'sewers'. The flow in sewers is normally by gravity, with pumped mains only being used when unavoidable. The design of conventional sewerage (the sewer system used in industrialized countries and in the central areas of many cities in developing countries). However, it is extremely expensive. A much lower cost alternative, which is suitable for use in both poor and rich areas alike, is 'simplified' sewerage, sometimes called 'condominial' sewerage. The design of simplified sewerage is fully described by Mara et al. [19].

Bacterial pathogens in wastewater

Wastewater contains many billions of bacteria, and most of these are fecal bacteria. However, these bacteria, once outside their normal habitat (ie when they are in the 'extra-intestinal' environment), are unable to survive for very long. This is because

they are outcompeted by the large numbers of *saprophytic* bacteria which grow naturally and profusely in the nutrient-rich aquatic environment of a microbiological wastewater treatment reactor [19].

Bacterial faeco-oral diseases

The transmission features of the bacterial excreted pathogens are that they are non-latent, have a medium-to-high persistence, are able to multiply, have a medium-to-low infectivity and do not have an intermediate host. The major excreted bacterial pathogens are *Campylobacter* spp, diarrhoeagenic *E. coli*, *Salmonella* spp, *Shigella* spp and *Vibrio cholera*. Most of the global incidence of bacterial diarrhoea is associated with *Campylobacter* and diarrhoeagenic *E. coli*. The two species of *Campylobacter* pathogenic to humans are *Campylobacter jejuni* and *Campylobacter coli*, and they are often present in water and wastewater [20].

In fact, most *E. coli* strains are non-pathogenic commensal inhabitants of the gastro-intestinal tract of humans and most animals. However, diarrhoeagenic *E. coli* strains are extremely pathogenic; they comprise several types termed (mainly after their pathogenesis) enterotoxigenic *E. coli* (ETEC), enteropathogenic *E. coli* (EPEC), enterohaemorrhagic *E. coli* (EHEC), enteroaggregative *E. coli* (EAEC), enteroinvasive *E. coli* (EIEC) and diffusively adhesive *E. coli* (DAEC) [21,22]. ETEC is a very common pathogen and is the second most important bacterial cause of diarrhea after *Campylobacter*. EHEC includes *E. coli* O157, a virulent serotype causing high mortality in the most vulnerable groups (the very old and the very young) [23].

APPROPRIATE TECHNOLOGIES FOR WASTEWATER TREATMENT

There are physical, chemical and biological methods are used to remove contaminants from waste-water (Figure 1). In order to achieve different levels of contaminant removal, individual waste-water treatment procedures are combined into a variety of systems, classified as primary, secondary, and tertiary waste-water treatment. More rigorous treatment of waste-water includes the removal of specific contaminants as well as the removal and control of nutrients. Natural systems are also used for the treatment of wastewater in land-based applications. Sludge resulting from wastewater treatment operations is treated by various methods in order to reduce its water and organic content and make it suitable for final disposal and reuse [24].

Physical treatment process

Among the first treatment methods used were physical treatment operations, in which physical forces are applied to remove contaminants. Today, they still form the basis of most process flow systems for wastewater treatment [1].

Chemical treatment process

Chemical processes used in wastewater treatment are designed to bring about some form of change by means of chemical reactions. They are always used in conjunction with physical unit operations and biological processes. In general, chemical unit processes have an inherent disadvantage compared to physical

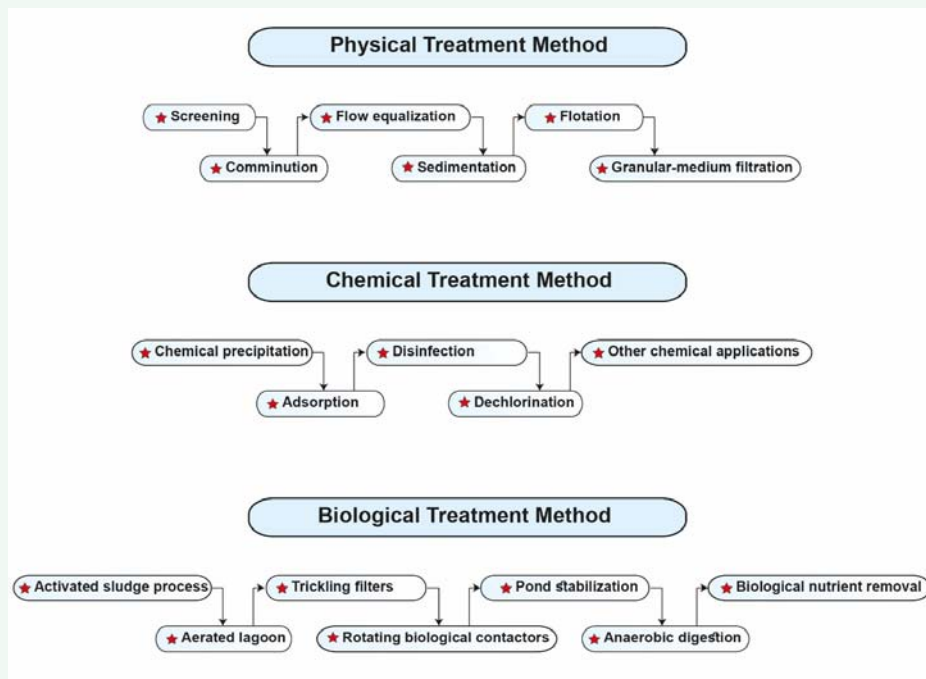


Figure 1 Waste-water treatment processes.

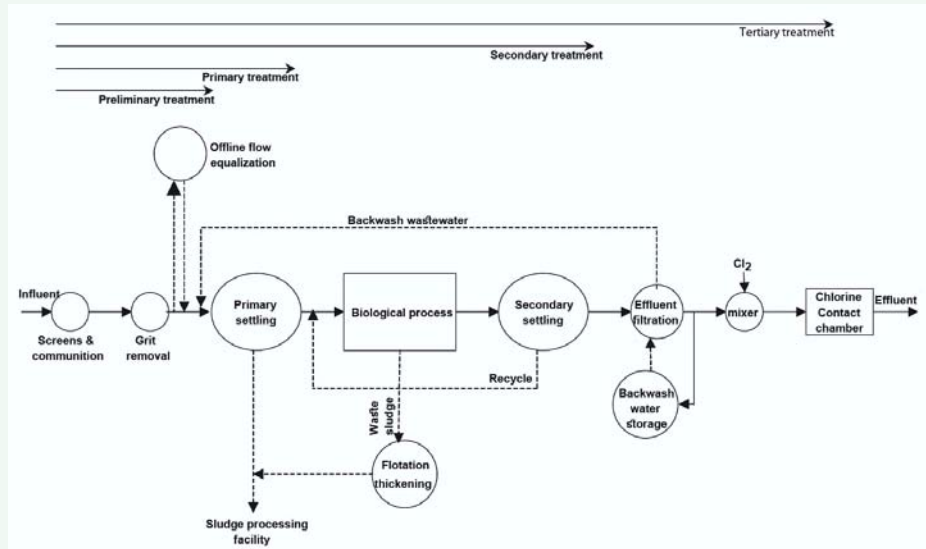


Figure 2 Diagram of various treatment levels in a waste-water treatment plant

Source: Metcalf and Eddy, Inc. Wastewater Engineering: Treatment Disposal and Reuse, third edition. New York: McGraw-Hill, 1991.

operations in that they are additive processes. That is to say, there is usually a net increase in the dissolved constituents of the waste-water. This can be a significant factor if the waste-water is to be reused. The main chemical unit processes are including chemical precipitation, adsorption, disinfection, dechlorination and other applications.

Biological treatment process

Biological unit processes are used to convert the finely divided and dissolved organic matter in wastewater into flocculent settle

able organic and inorganic solids. In these processes, micro-organisms, particularly bacteria, convert the colloidal and dissolved carbonaceous organic matter into various gasses and into cell tissue which is then removed in sedimentation tanks. Biological processes are usually used in conjunction with physical and chemical processes, with the main objective of reducing the organic content measured as [biological oxygen demand (BOD), total organic carbon (TOC) or chemical oxygen demand (COD)] and nutrient content (notably nitrogen and phosphorus) of waste-water. Biological processes used for waste-water treatment may

be classified under five major headings: (a) Aerobic processes; (b) Anoxic processes; (c) Anaerobic processes; (d) Combined processes; (e) Pond processes [19].

APPLICATION OF TREATMENT METHODS

In waste-water treatment plants, the unit operations and processes described in the previous section are grouped together in a variety of configurations to produce different levels of treatment, commonly referred to as preliminary, primary, secondary and tertiary or advanced treatment [1] (Figure 2).

Preliminary treatment

Preliminary treatment prepares wastewater effluent for further treatment by reducing or eliminating non-favorable wastewater characteristics that might otherwise impede operation or excessively increase maintenance of downstream processes and equipment. These characteristics include large solids and rags, abrasive grit, odors, and, in certain cases, unacceptably high peak hydraulic or organic loadings. Preliminary treatment processes consist of physical unit operations, namely screening and comminution for the removal of debris and rags, grit removal for the elimination of coarse suspended matter, and flotation for the removal of oil and grease. Other preliminary treatment operations include flow equalization, septage handling, and odor control methods.

Primary treatment

Primary treatment involves the partial removal of suspended solids and organic matter from the wastewater by means of physical operations such as screening and sedimentation. Mechanical flocculation with chemical additions can be used to enhance primary treatment. Primary treatment acts as a precursor for secondary treatment. It's aimed mainly at producing a liquid effluent suitable for downstream biological treatment and separating out solids as a sludge that can be conveniently and economically treated before ultimate disposal. The effluent from primary treatment contains a good deal of organic matter and is characterized by a relatively high (BOD).

Secondary treatment

The purpose of secondary treatment is the removal of soluble and colloidal organics and suspended solids that have escaped the primary treatment. This is typically done through biological

processes, namely treatment by activated sludge, fixed-film reactors, or lagoon systems and sedimentation.

Tertiary/ advanced wastewater treatment

The tertiary treatment goes beyond the level of conventional secondary treatment to remove significant amounts of nitrogen, phosphorus, heavy metals, biodegradable organics, bacteria and viruses. In addition to biological nutrient removal processes, unit operations frequently used for this purpose include chemical coagulation, flocculation, and sedimentation, followed by filtration and activated carbon. Less frequently used processes include ion exchange and reverse osmosis for specific ion removal or for dissolved solids reduction [1].

NATURAL TREATMENT SYSTEMS

Natural systems for wastewater treatment are designed to take advantage of the physical, chemical, and biological processes that occur in the natural environment when water, soil, plants, micro-organisms and the atmosphere interact [1]. Natural treatment systems include land treatment, floating aquatic plants and constructed wetlands. All natural treatment systems are preceded by some form of mechanical pretreatment for the removal of gross solids. Where sufficient land suitable for the purpose is available, these systems can often be the most cost-effective option in terms of both construction and operation. They are frequently violated for small communities and rural areas [1,25].

Land treatment

Land treatment is the controlled application of wastewater to the land at rates compatible with the natural physical, chemical and biological processes that occur on and in the soil. The three main types of land treatment systems used are the slow rate (SR), over flow rapid infiltration (OF) and rapid infiltration (RI) systems.

Floating aquatic plants

This system is similar to the free water surface system (FWS) except that the plants used are of the floating type, such as hyacinths and duckweeds. Water depths are greater than in the case of wetland systems, ranging from 1.6 to 6.0 feet (0.5-1.8 meters). The floating plants shield the water from sunlight and reduce the growth of algae. Systems of this kind have been

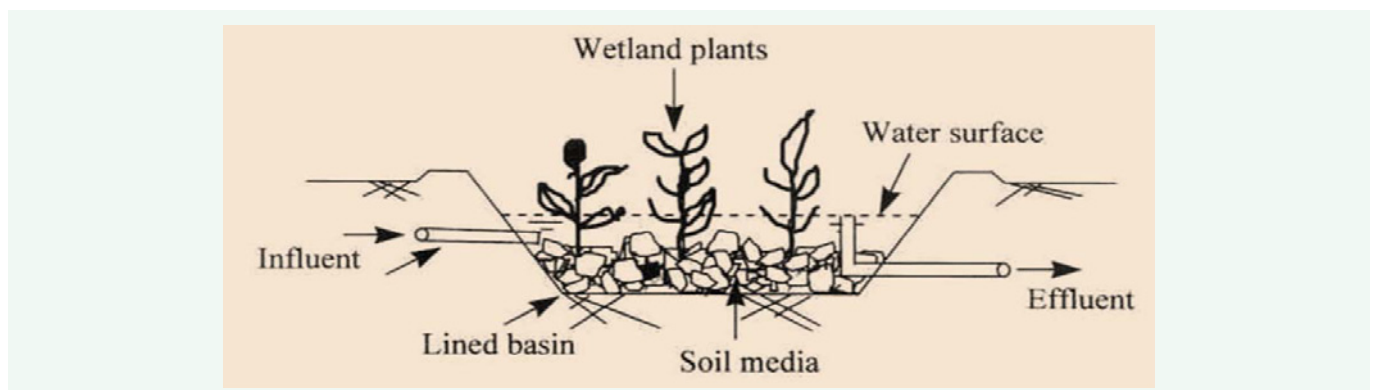


Figure 3 Free water surface systems.

effective in reducing (BOD), nitrogen, metals, and trace organics and in removing algae from lagoons and stabilization pond effluents. Supplementary aeration has been used with floating plant systems to increase treatment capacity and to maintain the aerobic conditions necessary for the biological control of mosquitoes [1].

Constructed wetlands

Wetlands are inundated land areas with water depths typically less than 2 ft (0.6 m) that support the growth of emergent plants such as cattail, bulrush, reeds, and sedges. The vegetation provides surfaces for the attachment of bacteria films, aids in the filtration and adsorption of waste-water constituents, transfers oxygen into the water column, and controls the growth of algae by restricting the penetration of sunlight. Two types of constructed wetlands have been developed for wastewater treatment, namely free water surface (FWS) systems, and subsurface flow systems (SFS) [26,27].

Free water surface systems: These systems consist of parallel shallow basins ranging from 0.3 to 2 feet (0.1-0.6 meter) or channels with relatively impermeable bottom soil or subsurface barrier and emergent vegetation. As a rule, preclarified wastewater is applied continuously to be treated as it flows through the stems and roots of the emergent vegetation (Figure 3).

Subsurface flow systems: SFS consist of beds or channels filled with gravel, sand, or other permeable media planted with emergent vegetation (Figure 4). Wastewater is treated as it flows horizontally through the media plant filter. Systems of this kind are designed for secondary or advanced levels of treatment.

Wastewater re-uses

Using treated wastewaters for crop irrigation or for fishpond fertilization is a very sensible thing to do, especially in water-short areas. However, it must not cause any excess transmission of excreta-related disease, and therefore the wastewaters must be treated to an appropriate microbiological quality. The World Health Organization has produced guidelines for the microbial quality of treated wastewaters used in agriculture and aquaculture [28-30]. Thus, treatment to remove fecal bacterial pathogens and human intestinal nematode and trematode eggs from the waste water is essential – but removal to what degree? The answer to this question is that they must be removed to a

level which does not cause excess disease in the people working in the wastewater-irrigated fields or wastewater-fertilized aquaculture ponds, or in those who consume the wastewater-irrigated crops or wastewater-fertilized aquaculture produce (for example, fish) [19].

The significance of water reuses in developing countries

The significance of water reuse may be evaluated through the comparison of water reuse potential with total water use. Water recycling and reuse is generally small compared with total water use but it is expected to increase significantly. It is and will become more significant in water scarce regions. In the United States, it was estimated that municipal water reuse accounted for 1.5% of total freshwater withdrawals in the year 2000. In Tunisia, recycled water accounted for 4.3% of available water resources in the year 1996, and may reach 11% in the year 2030. In Israel, it accounted for 15% of available water resources in the year 2000, and may reach 20% in the year 2010. The volume of treated wastewater compared to the irrigation water resources is actually about 7% in Tunisia, 8% in Jordan, 24% in Israel, and 32% in Kuwait. Approximately 10% of the treated effluent is being reused in Kuwait, 20-30% in Tunisia, 85% in Jordan, and 92% in Israel. In California, where the largest number of water reuse facilities existing in the United States is found, there is around 434 million m³ of municipal wastewater currently reused with, in 1999, water reuse for agricultural irrigation amounting to 68% of the total recycled water used [31]. In Japan, water reuse is mainly directed toward non-potable urban applications such as toilet flushing, urban environmental water, and industrial reuse [31]. In Tunisia, the expected amount of recycled water in the year 2020 is expected to be approximately 18% of the available groundwater resources and could be used to replace groundwater currently used for irrigation in areas where excessive groundwater mining is causing salt water intrusion in coastal aquifers.

Wastewater treatment and reuse practices in developing countries

Reuse of treated wastewater is already in practice in many countries. The supply of water is being augmented by domestic wastewater reuse in countries like Saudi Arabia, Kuwait, Tunisia, Jordan and Yemen. In water-scarce countries of the Gulf, the

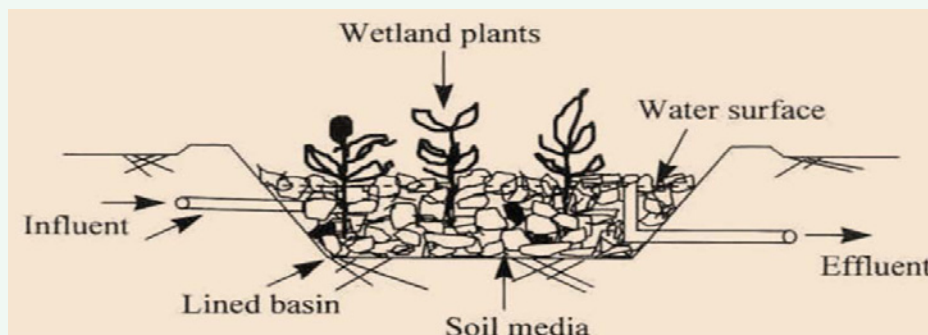


Figure 4 Subsurface flow systems.

contribution of wastewater reuse is substantial, especially since the cost of producing a unit of treated wastewater is estimated to be (8-18%) of that of desalinated sea water and (24-40%) of desalinated brackish water [32]. Use of treated or untreated wastewater in landscaping and agriculture is common in many countries such as UAE, Oman, Bahrain, Egypt, Yemen, Jordan, Syria, and Tunisia [33]. Water resources management strategies in several countries, such as Jordan, consider wastewater as part of its water budget [34].

CURRENT STATUS AND PROSPECTS OF WATER REUSE IN EGYPT

The major problems and issues related to the current use of treated sewage water in Egypt are summarized [35] (a) not enough infrastructure (treatment plants) to treat the amounts of wastewater produced, (b) only about 50% and 3% of the urban and rural populations, respectively, are connected to sewerage systems, (c) a significant volume of wastewater enters directly into water bodies without any treatment, (d) many wastewater treatment facilities are overloaded and/or not operating properly, (e) some industries still discharge their wastewater with limited or no treatment into natural water bodies, (f) domestic and industrial solid wastes are mainly deposited at uncontrolled sites and/or dumped into water bodies (especially outside Greater Cairo), (g) the quality of treated wastewater differs from one treatment station to another, depending on inflow quality, treatment level, plant operation efficiency, and other factors, and (h) negative impacts of the above problems on both health and environment [36].

Wastewater production is the only potential water source in Egypt which will increase as the population grows and the demand for fresh water increases. According to MWRI, the

available fresh water in Egypt in 1990 was 63.5 bcm from which the amount of water reuse was about 7 bcm/y. In the year 2025 – hoping that the share of Egypt from the River Nile water will remain the same – MWRI estimated the amount of available fresh water to be about 75 bcm [37,38] from which 18 bcm of water will be reused. As a matter of fact, the available fresh water covers all human activities and is divided between the different applications in Egypt according to the following: domestic ~7%, industrial ~7% and the rest i.e. ~86% is for agriculture.

According to [39] the ministry of water resources and irrigation is undertaking major projects for horizontal and expansion to divert considerable amounts of drainage water reused by the year 2017 to be 8.3 bcm/y. The potential to increase this reused amount depends on many factors among which are the quality of the drainage water, the salt balance of the Delta and the tolerance of the cultivated crops. Accordingly one may assume that by the year 2025 the amount of reused drainage water will hardly exceed 10 bcm/y, which is again much less than the available drainage water for reuse. The modest value of the reused wastewater in Egypt is mainly due to the lack of cost-effective and efficient treatment systems. The main treatment plant for the Greater Cairo Wastewater Project is the Gabal El Asfar Treatment Plant, which has an ultimate capacity of three million cubic meters/ day and is designed to serve a population of 3 million people [40]. It consists of components listed in (Figure 5).

In Morocco

Wastewater reuse is not a major issue for the management of water resources in Morocco at the moment. However, the authorities think that the situation may be different in a few years. Due to the increase of the urban population by 500,000 inh./yr a rapid increase in drinking water consumption in

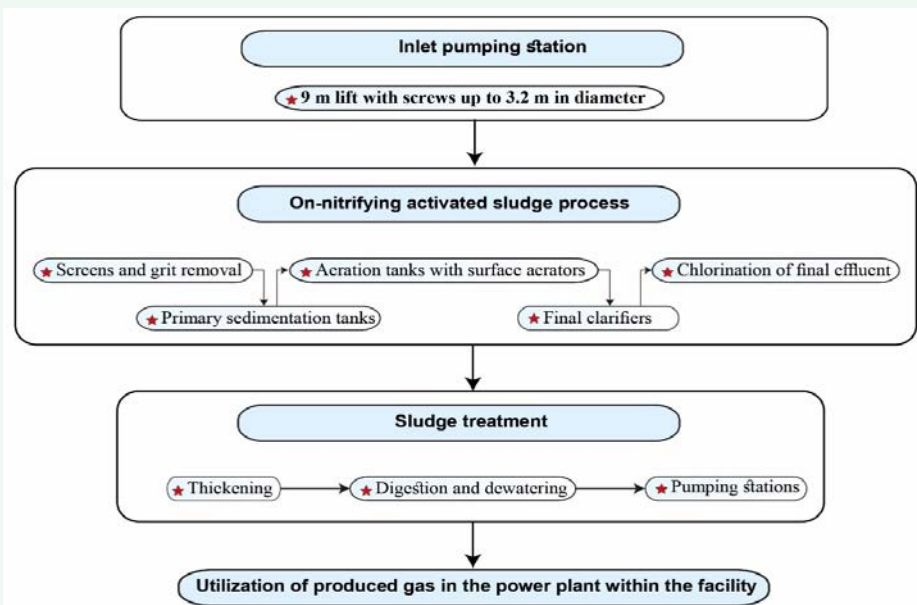


Figure 5 Wastewater treatment plant design in Egypt.

towns is expected. This will require the transfer of freshwater resources from one catchment area to another and the replacement of freshwater by wastewater for irrigation. The volume of wastewater available for reuse will increase with the improvement of sewerage networks. Under these conditions, the share of wastewater in the overall water resource could be several percentage points higher within a few decades, especially if the wastewater of coastal towns is also recycled (the figure of 10% sometimes mentioned seems excessive). Even though wastewater only represents a small share of water resources on a national scale, it can help solve local problems. This is particularly true for towns located in arid areas that are isolated from the major supply systems. This is also proven by the high rate of spontaneous wastewater reuse in inland towns. Most Moroccan towns are equipped with sewerage networks, frequently collecting also industrial effluent. The volumes of wastewater collected were estimated at 380 Mm³/yr in 1988 and are expected to reach 500 Mm³ in the year 2000 and 700 Mm³ in 2020. For Casablanca alone, the annual production of wastewater was estimated at 250 Mm³ in 1991, with forecasts of around 350 Mm³ in 2010. However, out of the 60 largest towns, only 7 have an MWTP, but both their design and operation are considered insufficient. As a consequence, most of the wastewater produced by the inland towns is used to irrigate about 7,235 ha of crops after insufficient or even no treatment. A high proportion of the remaining water is discharged to the sea [41].

In Libya

Reuse of wastewater in Libya, At Hadba El Khadra (5 km from Tripoli on sandy soil) started in 1971. Wastewater is treated in a conventional treatment plant followed by sand filtration and chlorination (12 mg/L). The recycled wastewater is then pumped and stored in tanks with a 3-day storage capacity. Reuse was first conducted over 1,000 ha to irrigate forage crops and windbreaks. An additional area covering 1970 ha: 1,160 ha forage, 290 ha vegetables like potatoes, onions, lettuce, etc. and 230 ha for windbreaks and sand dune stabilization) was also irrigated with recycled wastewater. 110,000 m³/d were applied using sprinkler irrigation (pivots). Reuse is also taking place in Al Marj (north-east of Benghazi: 50,000 inhabitants) after biological treatment, sand filtration, chlorination, and storage [42].

In Syria

The total volume of industrial and municipal wastewater effluent is estimated at 400, 700 and 1600 million m³/yr for 1990, 2000, 2025 years, respectively. The discharge of these wastes in a non-treated form into watercourses and rivers led to the degradation of surface water quality to the point where it became unsuitable for direct use for drinking purposes. The most important results of this noticeable pollution of rivers and other water bodies were the disappearances of living organisms because of the lack of oxygen, the appearance of undesirable plants and weeds that clog water canals in certain regions, hateful odors resulting from decomposition of organic materials and the abundance of insects and rodents. The health conditions of the population living in the areas of intensive use of untreated wastewater also degraded. Diseases such as typhoid and hepatitis spread at a much greater rate in these regions [43]. Animals were

also subjected to several waterborne diseases such as tapeworm and tuberculosis and other infectious diseases [36].

CHALLENGES ON WASTEWATER TREATMENT AND REUSE

As the human population continues to grow and urbanize, the challenges for securing water resources and disposing of waste water will become increasingly more difficult. Today, wastewater is usually transported through collection sewers to a centralized WWTP at the lowest elevation of the collection system near to the point of the disposal site to the environment. Because centralized WWTPs are generally arranged to route wastewater to these remote locations for treatment, water reuse in urban areas is often inhibited by the lack of dual distribution systems [44]. The infrastructure costs for storing and transporting reclaimed water to the points of use are often prohibitive, which is making reuse less economically viable. Thus, decentralized wastewater management systems should be more seriously considered in the future to treat wastewater at or near the points of waste generation. Also to the conventional approach of transporting reclaimed water from a central WWTP, the concept of decentralized (satellite) treatment at upstream locations with localized reuse and/or the recovery of wastewater solids is becoming more appreciated [44].

Advanced technologies in water reuse

Water reuse offers tremendous potential in augmenting already strained water resource portfolios, yet biosolids utilization/disposal remains challenging particularly for dense urban settings. In both water reuse and biosolids applications to land, the primary challenge remains public perception. While advanced technologies can help to lower energy footprint and to increase reliability, the obstacle of perception can be far more daunting. Emerging contaminants such as pharmaceuticals and antibiotic resistant bacteria are particularly difficult to explain to the public. Both historical and more recent examples of disease spread by water (such as cholera and cryptosporidiosis, respectively) weigh heavily on public concerns over the safety of water reuse. Advanced technologies such as on-line sensors, membranes, and advanced oxidation can help ease perception; however, a better understanding of how engineered reused water compares to existing source waters can be quite persuasive [45].

CONCLUSIONS AND RECOMMENDATIONS

New technologies have made growing numbers of water treatment alternatives available. Cost may be a major determining factor, especially in developing countries. Cost estimation is a difficult and even costly undertaking in itself, because of a large number of parameters involved and the fact that those parameters are usually unclear until the design process is well under way.

Effective wastewater collection and treatment are of great importance from the standpoint of both environmental and public health. Extensive research activity in this field has led to significant improvement and diversification in the processes and methods used for waste-water treatment and sludge management.

The present study begins with brief descriptions of the various technologies commonly used for waste-water treatment and later, current status and prospects of wastewater reuse in developing countries such as Egypt, Morocco, Syria, and Libya.

Advanced technologies can help to lower energy footprint and to increase reliability, the obstacle of perception can be far more daunting. Emerging contaminants such as pharmaceuticals and antibiotic resistant bacteria are particularly difficult to explain to the public

In recent years, there has been growing interest in wastewater reuse as a major component of water demand management. While many developing countries reuse treated wastewater for agricultural purposes, governments must address the issue of wastewater reuse as part of an integrated water management strategy, at the basin level, with multi-disciplinary coordination among various sectors including environment, health, industry, agriculture and municipal affairs. In this context, public health hazards are often associated with wastewater reuse, and consequently, it is essential to disseminate knowledge and information about the danger of raw wastewater reuse and issue safe reuse guidelines. Most importantly, governments must regulate and monitor effluent quality, reuse practices, public health, soil and ground water quality.

This article can be recommended the follows (a) Water reuse standards must protect both public health and the environment and must be suitable for end reuse objectives and the method of application,(b) Wastewater reuse projects should be designed as integral part of the overall wastewater network and water resources plan,(c) Innovative low-cost domestic wastewater treatment units should be encouraged,(d) Removal of the government subsidies on fertilizers and pesticides and ban on the use of some specific agricultural chemicals (herbicides and pesticides) should be considered, (e) Efficient wastewater treatment processes should be used to maximize wastewater reuse opportunities, (f) The reuse of treated wastewater in industrial applications, such as boiler water and cooling towers, should be encouraged.

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Cite this article

Mohammed AN, ElBably MA (2016) Technologies of Domestic Wastewater Treatment and Reuse: Options of Application in Developing Countries. *JSM Environ Sci Ecol* 4(3): 1033.