Toward Zero Liquid Discharge from Integrated Advanced Wastewater Treatment Plant.

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Abstract: *Water is considered among the most important, vital and crucial resources on earth. It is one of the basic ingredients utilized by living organisms and it is essential for achieving economic and social development in all countries over the world. The Mediterranean Countries, such as Palestine suffer from scarcity of fresh water and a significant water shortage while the demand of clean water is increasing. The water shortage can be attributed to different factors including agriculture consumption, industrialization, over pump of fresh water from aquifers, urbanization and socioeconomic development. The use of recycled water could help solving part of the region's water problems. Moreover, many lands in the Mediterranean Countries, including Palestine, are affected by incoming desertification processes, which hinder the development and conservation of a normal agricultural and touristic economy. The specific problems to be addressed in the near future are the fresh water shortage and quality and the use of the recycled water to fill part of the gap.*

In this paper we discuss different approaches for wastewater recycling and water purification.

The treatment of wastewater is capable of generating new water resources as an alternative for water shortage, for reuse in agriculture, and for protection of the ground water from pollution and health hazardous.

Keywords: *wastewater treatment, micelle clay complex, Naproxen, Non-steroidal anti-inflammatory drugs, Cr(VI).*

1. Introduction

1.1 Background

Water is considered one of the most important resources on the earth. It is a basic ingredient in living organisms and it is essential to achieve economic and social development in all countries. The Mediterranean region is suffering from significant water shortage while the demand of clean water is increasing [1]. The water shortage can be attributed to different factors including agriculture consumption, industrialization, over pump of fresh water from aquifers, urbanization and socioeconomic development. Additionally, rapid population growth, elevation of living standard, climate change and hydrological effect also contribute significantly to water shortage. Hence water demand in these countries is much higher than the water supply [2].

Palestine is one of the Mediterranean countries that are located in a semi-arid region; it suffers from acute fresh water shortage and its associated problems [3]-[5]. The water usage in Palestine is divided among three principle sectors: agriculture, domestic and industrial. Agriculture is the largest water consuming sector in Palestine with 70% of total water consumption. On the other hand, domestic and industrial sectors consume 27% and 3% of the total water consumption, respectively [6]-[7]. It is evident that most of the available water in Palestine, as well as in many regions around the world, is used in agricultural production [8].

Groundwater is the primary source of water in Palestine. The major groundwater supply is originated from three aquifers in the West Bank and one aquifer in Gaza strip. The three aquifers in the West Bank are western, eastern and northeastern basins.

The total annual replenishable water in this area is approximately 600 MCM for the three West Bank aquifers, and 80 MCM for Gaza aquifer [9]-[10].

Surface water is mainly represented by the Jordan River and it is not accessible to the Palestinians yet. The annual average flow of Jordan valley 1320 MCM is distributed among Israel 870 MCM, Jordan and Syria 160 MCM Lebanon 5 MCM, Dead Sea 95 MCM and Palestine zero MCM [11]-[12].

Two strategies are currently implemented in Palestine to decrease the gap between water supply and water demand. The first one involves the import of water from external sources, while the second one involves the development of additional water sources such as treated wastewater [13-14].

The treatment of wastewater will create new water resource as an alternative for water shortage, the reuse in agriculture, protects the ground water pollution and eliminates health hazardous [7], [15].

The protection of environment and reuse of reclaimed wastewater is a national interest in Palestine and it is considered as an important issue adopted by the Palestinian water Authority PWA and Ministry of Environmental affairs MEnA [6],[10].

1.2. Wastewater management in Palestine

The collection and treatment of wastewater was and still a critical issue in Palestine due to the increase of population rate and wastewater disposed as a result of increasing water consumption [15].

1.2.1. Wastewater impact and collections

The Palestinian wastewater contains a high organic matter [16], domestic and industrial wastewater in Palestine are mixed and non-separated [6], the sewage network system is limited to main cities (about 6.33% is treated using centralized and collective wastewater treatment plants in the West Bank) while rural communities used the cesspits and septic tanks (93.7% of wastewater discharged in environment without any treatment) [16]-[17].

1.2.2. Wastewater treatment

As a result of the lack or partially available sewer network collection systems, the instillation of Centralized Waste Water Treatment Plants (CWWTP) in main cities of Palestine is very limited, in spite of the presence of some small onsite treatment plants in rural areas. The present situation of CWWTP's in Palestine is usually inhibited by limited capacity, poor maintenance, process malfunction, poor maintenance practice and lack of training experiences [6]. Most of CWWTP's are poorly designed and old except of Al-Bireh waste water treatment plant which is the only functional one [6], [16]. Table 1 in (Appendix A) summarizes the wastewater treatment plants situation in the West Bank [6].
The small installed low-cost onsite treatment plants in rural areas were converted to unhealthy projects due to a sustainable causing of environmental pollution as a result of overloading, faulty design and implementation, maintenance and poor public awareness [18-19].

1.2.3. Reuse of treated Wastewater

The reclamation of wastewater and its reuse in agriculture is widespread in Mediterranean regions due to water scarcity, and environmental protection [20]-21]. The reuse of reclaimed wastewater for irrigation of landscape, public parks, sport fields and recreational sites is widely spread in different countries [22].
Treated wastewater is reused for various crops such as vegetable, orchard plantation and pastures irrigation throughout South and Latin America, the Mediterranean regions, widespread in Northern Africa, Southern Europe, Western Asian, the Arabian Peninsular, South Asia and the United States of America [23]-[24].
The regulators of water sector in different countries have developed national guidelines based on recommended rules issued by the World Health Organization (WHO) to ensure protection of public health and the environment from the discharge of untreated or inadequately treated wastewater effluents [25]-[26]. Therefore, treated wastewater reuse is covered through a number of regulation and standards which already is established in Palestine [27].
The use of advanced wastewater treatment and technologies are required in order to maintain adequate level of sustainability in agriculture production, decelerating salinity of the ground waters and preventing long range adverse effects of gradual environmental pollution [28].

1.3. Wastewater

The main constituents of untreated wastewater are organic material, various pathogenic microorganisms, in addition to nutrients and toxic compounds. Wastewater must be treated, appropriately before final disposal. The goal of wastewater treatment and management is the protection of the natural environment and human health from various pollutants that might damage the environment and cause severe health effects [29].
Municipal wastewater is the combination of flow used water from dwellings, commercial or industrial facilities and institutions, in addition to runoff of groundwater, surface water and storm water [29].

1.3.1. Definition of wastewater and its characteristics

Wastewater is defined as dilute mixture of various wastes from residential, commercial, industrial and other public places. Wastewater contains 99.9% water by mass while other pollutants are suspended solids, biodegradable dissolved organic compound, inorganic compounds, recalcitrant compounds, nutrients, and pathogenic microorganisms [30]-[31].
Wastewater quality may be characterized by its physical, chemical, and biological parameters. Physical parameters include color, odor, temperature and turbidity. Insoluble contents such as solids, oil and grease, are included in this category. Solids may be 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 ionized metals such as iron and manganese, and anionic entities such as chlorides, sulfates, sulfides, nitrates and phosphates [32]-[33]. The organic part may be either nitrogenous or nitrogen-free. The major sources of nitrogenous matter are urea and protein, while carbohydrates, fats and soaps are nitrogen-free compounds [32-33]. Inorganic or mineral matters (such as salts, sand, mud etc.) in wastewater mainly contribute to the hardness of the water. The living organisms in wastewater may be plant life (such as algae, fungi etc), animal life (such as protozoa) as well as bacteria [34]. Additionally, nonliving organisms such as viruses of human origin may be found in raw sewage influent. The organic and inorganic matter may be in dissolved, suspended or colloidal state [34]-[35].

1.3.2. Classification of wastewater

Wastewater is categorized and defined according to its sources of origin. The term domestic wastewater refers to flows discharged principally from residential sources generated by such activities as food preparation, laundry, cleaning and personal hygiene. Industrial/commercial wastewater is flow generated and discharged from manufacturing and commercial activities such as printing, food and beverage processing and production. Institutional wastewater is characterized as a wastewater generated by large institutions such as hospitals and educational facilities [29]. Run off wastewater generated from streets and might include petroleum and oil. Wastewater can be also classified as black wastewater which includes wastewater originates from toilet fixture; and grey wastewater which originates from other domestic sources such as showers, dish washers, laundry and kitchen [36]-[37].

1.4. Overview of wastewater treatment

The main objective of wastewater treatment is to eliminate pollutants or to level them down such that it is harmless to environmental resources. The disposed of industrial and domestic wastewater after treatment will protect natural environmental and public health from harmful materials [31].

1.4.1. Wastewater treatment systems

Wastewater treatment refers to the series of operation and process to remove solids, organic matters and nutrients from wastewater [31]. Conventional wastewater treatment systems are a combination of physical, chemical and biological processes. They include four treatment stages: preliminary (physical), primary (physical), secondary (biological) and tertiary stage which could be combination of physical, chemical and biological processes [34].

1.4.2. Preliminary treatment

Preliminary treatment is the first stage in any wastewater treatment plant. Its function is to screen wastewater from large objects and debris such as wood, rags, plastic and others. Removal of these materials will protect the plant's piping and dawn stream equipment from blocking or damage. Preliminary stage consists of physical unit operation which include flow measuring devices, flow regulators, racks, screen, comminuting device (grinder, cutters and shredders), grit chambers and pre-aeration [31],[34].

1.4.3. Primary treatment

The objective of primary treatment is to reduce settleable suspended solids. It consists of large settling circular or clarifiers. Floating materials can be removed by skimming [34]. Approximately 25-50% of biochemical oxygen demand BOD_5, 50-70% total suspended solids and 65% of oil and grease can be removed during the primary treatment [31].

1.4.4. Secondary treatment

Secondary stages are biological treatment processes that can be aerobic or anaerobic. Their main purpose is the removal of biodegradable soluble and colloidal organic and suspended solids that have escaped the primary treatment process [34]. Aerobic processes are performed in the presence of oxygen and aerobic microorganisms (principally bacteria). These microorganisms degrade soluble and colloidal organic matters in wastewater by metabolism, thereby producing more microorganisms and inorganic end-products (mainly carbon dioxide, ammonia and water) [31]. Aerobic processes can be divided into two groups. The first group is based on attached growth process. It includes trickling filters, and rotating biological contactors (RBC). The second group is based on suspended growth processes. It includes activated sludge, and sequential batch reactor SBR [34].
Although the secondary treatment processes are not efficient in removal of nutrients, however, they are highly efficient in removing biodegradable organic compounds and suspended solids [30]. In activated sludge processes, wastewater is continuously aerated in an aeration tank using submerged diffuser, surface mechanical aeration, or combinations of both [38].

1.4.5. Tertiary or Advanced treatment

The tertiary treatment stage follows the secondary treatment stage. The secondary effluent in general contains low concentration of nutrients, dissolved solids and pathogens that could risk sustainable agriculture production and pollution of aquifers when they are reused for irrigation [39].
The objective of tertiary treatment to remove nitrogen, phosphorus, suspended solids, heavy metals and dissolved solids to a level down that meets non-restricted reuse [31],[35]. Hence, tertiary treatment restores wastewater approximately to its original quality [40]. Tertiary treatment unit operations include coagulation/flocculation, sand filtration, membrane filtration, adsorption and disinfection [41].
Filtration is required after the chemical and biological process. Ultrafiltration will enhance the reduction bacteria, viruses and large molecules. RO enhances the removal of soluble low molecular weight compounds and salts [34].
Membrane treatment is an advanced and improved technology process which is applied for removing particles, turbidity, bacteria, viruses, nematodes and cysts with minimal disinfection use, it is based primarily on the use of microfiltration MF and ultrafiltration UF membranes [42]-[43].

1.4.6. Membrane filtration technology

Membrane filtration is widely used as an industrial separation technology in the filtration of aqueous mixtures. Its application to water treatment has dramatically increased in the past decade [44]-[46].
Membranes treatments are post stage of conventional wastewater treatment plants. Membranes are commonly used for the removal of dissolved solids, color and hardness in drinking water while in wastewater reclamation and reuse, it is necessary to reduce suspended solids, dissolved solids, and selected constituent's such as nitrates, chlorides, and natural and synthetics organic compounds.
There are several advantages related to implementation of membrane technology in wastewater treatment plants: these are separations of broad range of contaminants characterized by simplicity of operation, ease of adaption to existing treatment facilities, continuous processing which can be automated, low chemical requirement and no generation of bio-product disinfection [47].
There are two basic types of membrane separation processes. The first type is pressure driven, while the second is electrical driven. In electrical driven type, current is used to move ions across the membrane leaving purified water behind. In this process ions are collected in concentrate effluent for disposal, while the product is purified water [48]. In pressure driven type, hydraulic pressure is used to force water molecule through membranes. Impurities are retained and concentrated in re-circulated flow. The outflow of re-circulated water is collected in special containers called brine. On the other hand, water passing through the membrane is called permeate.
The treatment process employs several types of technological membranes [49]; they include microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO). Each type is

characterized by its membrane pore size, molecular weight cutoff (MWCO), operation pressure, and rejected pollutants [50]-[51].

1.4.6.1. Membrane material and modules

The pressure driven processes include MF, UF, NF and RO [52]. Lots of membranes are synthetic polymer or ceramic materials, the MF and UF are made of the same material but with different manufacturing conditions to produce different pore sizes [53]. The MF and UF membranes consist of polymers such as polyvinylidene fluoride, polysulphone, ploy acrylonitrile, polyvinylchloride poly (ether sulfones), cellulose acetate, Nylon and Polytetrafluoroethylene [52]. RO membranes include either cellulose-acetate or polysulphone coated with aromatic polyamide [52]. NF membranes are made of cellulose acetate or polyamide composts or sulfonated polysulphone [54].

The principal types of membrane modules are used for water and wastewater treatment they are hollow fiber and spiral wound [35].

The major components of spiral wound are membrane, feed and permeate channel, spacers, the membrane's tube and membrane's box [55-56]. The operation conditions which are adjustable are the feed inlet flow rate, feed concentration, feed pressure and permeate tube pressure [52].

Spiral wound elements are mainly used in MF, UF and RO. They consist of two flat membrane sheets separated by a thin, mesh-like porous support or spacer and they are sealed on three sides like an envelope. The fourth side is fixed onto a perforated plastic center tube that collected the water's product. The membranes are rolled up around the tube that collected the water's product [57].

Feed water enters the spacer channels at the end of the spiral wound element in a path parallel to the central tube. As feed water flows through the spacers, a portion permeates through either of the two surrounding membrane layers and into the permeate carrier, leaving behind any dissolved and particulate contaminates that are rejected by the membrane, feed water is pumped or enter through the layers and water's product passes through the membrane and follows the spiral configuration to central perforated tube, the water that doesn't penetrate the membrane is called a concentrate [57].

The applications of spiral wound module include desalination, water treatment, water reclamation, treatment of industrial wastewater, product treatment in the dairy industry and recovery of valuable products in the pharmaceutical industry [58]-[60].

Hollow fibers are commonly used in low pressure driven membranes with different application in industry and water treatment [61]; these modules are comprised of hollow fiber membrane which is long and very narrow tubes. Fibers can be bundled together longitudinally potted in resin on both ends and in encased in pressure vessel. The modules mounted vertically or horizontally. The module may be assembled of more 100000 fibers with different fiber dimensions it depends on the manufacture. The diameter of hollow fiber varies over wide range from 50-3000 µm. Many fibers must pack up into bundles and potted into tubes to form membrane module with large surface area [62].

Feed water flow through the center of fiber and related filtration is shown in Figure (1) (Appendix A). Two operation models are used in hollow fiber membrane inside-out mode and outside–in mode. In the outside-in mode, the feed water enters in the module through an inlet port located in the center and it is filtered into the fiber lumen, where the filter is collected prior to exiting through a port at one end of the module. In the inside-out mode, the pressurized feed water may enter in the fiber lumen at either end of the module, while the filtrate exits through a filtrate port located at the center or end of the module [57].

1.5. Occurrence of Pharmaceuticals and Heavy metals in wastewater

Wastewater generated from different sources like household, industrial, natural runoff, and agriculture runoff have a variety of characteristics. Different studies have been emerged recently to assess the environmental impact of pharmaceutical compounds and heavy metals as well as to investigate different removal methods and strategies [63]-[64].

1.5.1. Occurrence of Pharmaceutical compounds in Environment

Pharmaceuticals active compounds (PhACs) are a diverse group of chemical that are designed to interfere with biological system. They are used for diagnosis, treatment and prevention of diseases, health condition, and function of human body or animals [65]-[66].

Pharmaceuticals active compounds (PhACs) (antibiotics, anticonvulsants, antipyretics drugs and hormones) have recently been detected in sewage effluents [67], surface and ground water, [68].and even in drinking water [69]-[70]. Their possible environmental impacts are an emerging environmental issue [65], [71]-[72], [68].

Among the most commonly used pharmaceuticals are the non-steroidal anti-inflammatory drugs (NSAID) used to reduce pain and treat inflammation. This class of drugs includes acetylsalicylic acid, Paracetamol, Ibuprofen, Naproxen, and Diclofenac. All these drugs are consumed daily in large quantities and were found in stream and river water in the low ng l^{-1} range [72]. The current estimated annual consumption of these non steroidal anti-inflammatory drugs in developed countries is, unfortunately, several hundred tons [65].

The numbers of pharmaceuticals found in wastewater treatment plant effluents, rivers, estuaries, seawater, ground water and drinking water are increasing year by year [73]-[75]. Municipal wastewater contains a complex of organic compounds originating from different sources such waters from institutions, and industry [76]-[77]. Thousands of xenobiotic organic compounds were detected in wastewater [78]; Kolpin and coworkers have identified over 95 organic compounds found in streams and rivers in the USA [79]. Occurrence of eight active pharmaceutical in fifteen sewage treatment plants in South Australia were detected and their medium concentration ranges between 26 ng l^{-1} to 710 ng l^{-1} [80]. In Canadian treated wastewater carbamazepine, naproxen and diclofenac were detected in concentrations up to 2 µg l^{-1} [35]. Moreover, 30 pharmaceutical compounds were detected in different Italian wastewater treatment plants [81].

1.5.1.2. Sources, fate and effect of pharmaceutical compounds in Environment.

Pharmaceutical compounds may enter the environment by many pathways. These include discharge of treated wastewater, landfills, septic systems, sewer lines, runoff from animal wastes as well as land application of manure fertilizers [82]-[84].
The main source of pharmaceutical compounds which are discharged into the environment, are medicines used by humans. These pharmaceuticals and their metabolites are excreted via urine and feces and end into wastewater. The pharmaceuticals and their metabolites that are not degraded within the plant are discharged with wastewater effluents and can reach different fresh water resources.
Pharmaceuticals that are used for veterinary purposes could be introduced in the environment via animal excretions [85]. Antibiotics and growth promoters as food additives compromise another sources of pharmaceuticals in water and soil [86]. Expired and unwanted medicine in pharmaceutical factories and households are additional sources of pharmaceuticals in the environment [87].
The pharmaceutical compounds are designed to produce specific biological effect on human and living tissue so it is expected that they cause unwanted effects to humans and other living organisms [88]. The presence of pharmaceuticals in low concentrations can have adverse effects on aquatic organisms. This effect depends on the exposure and the degradability of the pharmaceutical [89]-[94]. Content of micro-pollutants in water can induce the feminization of freshwater fish [95], alteration of reproduction strategies and high incidences of hermaphrodism [96].The effect of pharmaceuticals in human body showed reduction in sperm and increase incidents of testicle and prostate cancer and increased endometriosis [97].

1.5.1.3. Removal of pharmaceuticals from environment

Various recent studies have been carried out to explore the suitable method for the removal of pharmaceuticals from wastewater.
The activated sludge technology used in conventional wastewater treatment plants are not capable of completely removing organic pollutants and trace elements [98]-[101]; this technology was found to remove only 60-90% of polar and semi polar pharmaceutical compounds [84].
The most important removal process for acid pharmaceuticals in activated sludge process is the microbial degradation. The removal of more than 80% of different pharmaceutical compounds was evident when the solid retention time in activated sludge (SRT) was in the range of 5 and 10 days [102]. Generally the methods used for wastewater treatment are biodegradation [102], deconjugation [103], partitioning [104], and removal during sludge treatment [105], and photodegradation [106]-[107]. Several pharmaceutical compounds have been shown to degrade by sunlight (ex. Diclofenac) [108]. Activated carbon has been documented as an efficient process to remove volatile and polar pharmaceuticals and personal care products (PPCPs) [109],[102].The low pressure membrane such as MF and UF are not efficient in rejecting pharmaceutical compounds based on their size. However, high pressure membranes such as NF and RO are very effective in the removal of different pharmaceutical compounds from water [110].

1.5.2. Heavy metals in the Environment

Heavy metals refer to a group of metals with relatively high density (greater 5g/cm^3) and high atomic mass (> 20) [111]: they can't be degraded to harmless products [112] or processed by living organisms. Examples of heavy metals are mercury, cadmium, chromium, arsenic, thallium and lead [113]-[115]. Heavy metals are natural compounds of earth crust that occur in rocks and soil. The Natural volcanic, weathering of rocks and soil can release heavy metals into environment. The human activities contribute to the release of heavy metals into the environment. The heavy metals contamination can affect biosphere, lithosphere and hydrosphere [116].

1.5.2.1. Occurrence, source and fate of heavy metals in the environment

The natural and anthropogenic activities are the main sources of heavy metal in environment; both emit metals into soil, water and air [117]-[122]. Figure (2) (Appendix A) summarizes the different pathways by which heavy metals can reach the environment.
The rapid expansion in industry occurred in the last century lead to an increase in complexity of toxic effluents from several industrial processes generating waste which contains heavy metals. The agriculture drainages (fertilizers and pesticides), effluent from industrial activities (like metal painting, mining operations, tanneries choralkali, radiator manufacturing, smelling, alloy industries and storage industries), runoff water and sewage effluents are the heavy metals contamination sources [123]-[124]. Further, the most anthropogenic sources of heavy metals are the industrial petroleum contamination and sewage disposal. Unfortunately, these compounds cause environmental problems [125]-[127].
Dredging shipping channel and atmospheric deposition are other sources of heavy metals into the aquatic environment [128]-[132]. In addition, the soil erosion as a result of acid rain causes heavy metals releasing into streams, rivers and ground water [133].

1.5.2.2. Effect of heavy metals in Environment

Heavy metals deriving from different pollutant sources arrive in all environmental sectors: soil, water and air. The contamination of soil with heavy metals poses a serious hazard to both humans and to ecosystem because they accumulate in living organisms through the food chain causing a serious harm to human health [134]-[136].
Trace elements (Cr, Mn, Fe, Co, Cu, Zn, Mo, Se, F and I) belong to micronutrients required by body in very small quantities, generally less than 100 mg/day. However, deficiency in any of these trace elements will lead to undesirable pathological conditions [137]. For example, heavy metals are essential in low concentrations for the body such as Fe in hemoglobin, Co in Vitamin B12, Zn and Mn for enzymes [138], [117]. The other

elements Pb, Cd, Hg and As have no beneficial effect on homeostasis for humans [139]-[140]. The increase of heavy metals in drinking water and food will cause health problems:

- Cd (II) is a carcinogenic compound, which damages kidneys and bones [141].
- As, if taken up by inhalation, increases the risk of skin and lung cancer [140].
- Pb, can cause different damages to children: gastrointestinal, renal and nervous [142]-[143] and Cr is related with allergic dermatitis [144].

The micronutrients, such as Zn, Mn, Ni, and Co are necessary in small concentration for plant growth while other elements, such as Hg, Pb, and Cd have no biological function [145].

The heavy metals as a result of wastewater irrigation cause an accumulation in agriculture soil [146] and thus have negative effect on food quality: the heavy metals present in edible part of leafy vegetables can cause clinical problems [147]-[149]. Accumulation of Fe and Mn was found in mint and spinach and the concentrations of Cu and Zn were found to increase in carrot after irrigation with wastewater [150].

The increased concentration of heavy metals in aquatic system causes, also, bioaccumulation in aquatic organisms. For example, high concentration of Hg was found in tuna, halibut, redfish, shark and swordfish [151], and was detected in several species such as sardine, chub mackerel, horse mackerel, blue fish, carp, mullet tuna and salmon [140],[152].

1.5.2.3. Removal Methods of heavy metals

Numerous advanced techniques are used to clean up the environment from the risk of heavy metals contaminations prior to their discharge into environment. These techniques include chemical, physical and biological processes [153]. Some of the methods used to remove dissolved heavy metals are: ion exchange, precipitation, photo-extraction, ultrafiltration, reverse osmosis and electro dialysis [154]-[157].

The chemical methods involve flotation, conventional oxidation, irradiation and electrochemical processes. The high energy demand and costs are the most disadvantages of the chemical treatment methods [153]. The physical process includes membrane filtration and adsorption. Hani et al 2004 [158], showed that high removal efficiency of the heavy metals copper and cadmium could be achieved by RO process. Uiang [159] documented that low pressure RO process could remove zinc and copper from wastewater in the presence of EDTA as a chelating agent.

The most disadvantages of nanofiltration and reverse osmosis techniques are fouling of membrane, high energy consumption and treatment of concentrated brine generated from the treatment units, while adsorption is the most popular method for removing pollutants because it produces high quality effluents [153].

Activated carbon is considered as effective process for heavy metals removal when they are in trace quantities [160]. Ion exchange is considered to be low cost and effective method if zeolites are used [161]. Furthermore, different low cost agricultural waste by-products such as sugarcane biogases, rice husk and sawdust were used for heavy metals removal from wastewater [162]-[165]. Biopolymers are adsorbents mainly used for heavy metals removal because they are cheap and freely available [166]. Several studies demonstrate the ability of soil, clays and oxides to selectively adsorb metal cations [167]-[169]. The disadvantages of biological processes are the large area perquisite, toxicity of some chemicals and less flexibility in the design and operation [170]-[171].

The removal efficiency of wastewater treatment plant using activated sludge may be affected by increasing the concentration of heavy metals. Concentrated heavy metals in effluent stream and sludge could cause environment hazards upon sludge disposal [172], [128]. The accumulation of heavy metals also affects the activated sludge process by inhibitory effect on the activity of both heterotrophic and autotrophic biomass [173].

CONCLUSIONS

The salient points emerged from this study include: (i) closing the gap between water demand and supply we should maximize the re-use of closed wells and waste water. An implementation of such strategy will overcome the water problems associated with a decline in water quality and in water levels, deterioration of aquifers, sea water intrusion, and increase in water demand as a result of growth of population in the Mediterranean Countries, especially Palestine, (ii) development of new technologies for efficient water purification by filtration and sedimentation based on natural and modified nano-materials, (iii) development of new technologies for efficient water purification by photodegradation based on natural and modified nano-materials and solar energy, (iv) construction and operation of pilot equipment for water purification from wells, grey water and wastewater based on optimized filtration technologies, photodegradation technology, (v) endorsement of a new political conception aimed at a sustainable use of water with the consequent reduction of water recovery costs adopting recently developed tools founded on scientific devices, which resort to nanotechnologies, (vi) dissemination of a new cultural attitude founded on the use of transportable and miniaturized equipment that can be used exactly where they are needed to obtain a reduction of water consumption and remediation of polluted surface and ground water, and (vii) improvement of professional abilities and technical knowledge of technicians and researchers aiming at the acquisition of theoretical and practical abilities on the operative use of produced devices for recycling of wastewater and grey water.

REFERNCES

[1] G. Oron, L. Gillerman, N. Buriakosky, A. Bick, M. Gargir, Y. Dolan, Y. Monar, L. Katz, and J. Hagin, “Membrane technology for advanced wastewater reclamation for sustainable agriculture production,” Desalination, 218, pp.170-180, 2008.

[2] G. Oron, L. Gillerman, A. Bick, Y. Monar, N. Buriakosky, and J. Hagin, “Advanced low quality waters treatment for unrestricted use purpose: imminent challenges,” Desalination, 213, pp. 189-198, 2007.

[3] D. Nazer, M. Siebel, P. Van der Zaag, Z. Mimi, and H. Gijzen “Water footprint of the Palestinians in the west bank,” American Water Resources Association, 44(2), pp. 449-458, 2008.

[4] L. McNeill, M. Almasri, and N. Mizyed, “A sustainable approach for reusing treated wastewater in agricultural irrigation in the West Bank – Palestine,” Desalination, 251, pp. 315-321, 2010.
[5] S. Lonergan, and D. Brooks, “Watershed: The Role of Fresh Water in the Israeli Palestinian-Conflict”, International Development Research Centre, Ottawa. Canada, **1994**.
[6] Birzeit University, “Prospects of efficient wastewater management and water reuse in Palestine. EMWATER-Project. Efficient Management of Wastewater, its Treatment and Reuse in the Mediterranean Countries,” Institute for Water Studies, Birzeit, West Bank, Palestine, 2005.
[7] Y.M. Sbeih, “Recycling of treated wastewater in Palestine: Urgency, obstacles and experience to date,” Desalination, 106, pp. 165-178, 1996.
[8] T. Goto, **“**East and South East Asia,” Desalination and water reuse, 12(1), pp. 28-30, 2002.
[9] Applied Research Institute-Jerusalem (ARIJ), “Environmental profile for the West Bank,” Jerusalem, Palestine, 1996.
[10] Palestinian Water Authority, “Background information and water resources management strategy,” Ramallah, Palestine, 1997.
[11] Palestinian Water Authority, “Water Data base for wells and springs,” Ramallah, Palestine, 2003.
[12] A. A’Bed, and S. Washahi, “Geology of Palestine – West Bank and Gaza Strip”, pp 400, 1999.
[13] T. Asano, “Multiple uses of waters: Reclamation and reuse,” Water efficiency, GAIA, 4, pp. 277-278. 2002
[14] G. Oron, **“**Management modeling of integrative wastewater treatment and reuse system,” Water science and technology, 33(10-11), pp. 95-105.1996.
[15] M. Nashashibi, and L.A. Van Duijl, “Wastewater characteristics in Palestine”. Wat. Sci. Tech, 32(11), pp. 65-75.1995
[16] N. Mahmoud, M. Amarneh, R. Al-Sa’ed, G. Zeeman, H. Gijzen, and G. Lettinga, “Sewage Characterization as a tool for the application of anaerobic in Palestine”. Environmental Pollutio, 126(1), pp. 115-122. 2003
[17] Applied research institute –Jerusalem ARIJ, “Evaluation of “Introducing small scale activated sludge filtration system of wastewater treatment in rural area of Bethlehem and Hebron Governorates in West Bank-Palestine project”. Jerusalem, Palestine. 2011.
[18] R. Al-Sa’ed, “Sustainability of natural and mechanized aerated ponds for domestic and municipal wastewater treatment in Palestine”. Water Int., 32(2), pp. 310-324, 2007b.
[19] R. Al-Sa`ed, and S. Mubarak, “Sustainability assessment of onsite sanitation facilities in Ramallah-Al-bireh district with emphasis on technical, socio-cultural and financial aspects”. Manage. Environ. Quality: An Int. J, 17(2), pp. 140-156, 2006.
[20] A.N. Angelakis, M.H.F.M. Do Monte, L. Bontoux, and T. Asano, “The status of wastewater reuse practice in the Mediterranean basin: need for guidelines,” Water Res., 33(10), pp. 2201-2217.1999.
[21] E. Friedler, “The Jeezrael valley project for wastewater reclamation and reuse, Israel,” Water Sci. Technol, 40(4-5), pp. 347-354. 1999.
[22] M. Abu Madi, and R. Al-Sa’ed, “Toward sustainable wastewater reuse in Middle East and North Africa,” Consilience –The journal of sustainable development, 2(3), pp. 1475-1481, 2010.
[23] A. Havelaar, U.J. Blumenthal, M. Strauss, D. Kay, and J. Bartram, **“**Guidelines: the current position. Water Quality — Guidelines, Standards and Health: Assessment of Risk and Risk Management for Water- Related Infectious Disease”. IWA Publishing. London. Pp. 17–42. 2001
[24] V.E. Tzanakakis, N.V. Paranychianakis, and A.N. Angelakis, “Treatment of municipal wastewater with slow rate systems”. Paper presented at the IWA specialty conference on wastewater reclamation and reuses for sustainability, WRRS 2005, 8–11 November. Jeku, Korea, 2005.
[25] World Health Organization (WHO), “Guidelines for wastewater reuse in agriculture and aquaculture: recommended revisions based on new research evidence. *WELL Study*. Task No. 68 (1),”2000, Available online at: http://www.bvsde.paho.org/bvsacd/cd25/well.pdf. Accessed: October, 2010.
[26] World Health Organization (WHO), “Guidelines for the Safe Use of Wastewater, Excreta and Grey water: Wastewater Use in Agriculture,” 3rd ed., Vol. (1), 2006, Geneva Available online at: http://whqlibdoc.who.int/publications/2006/9241546824_eng.pdf . Accessed: October, 2010.
[27] Palestinian Standard Institute PSI “Technical regulation for treated effluent reuse in agricultural irrigation, TR34-2012”, Al-Bireh-West Bank, Palestine, 2012.
[28] M. Rebhun, “Desalination of reclaimed wastewater to prevent salination of solids and groundwater,” Desalination, 160(2), pp. 143-149. 2004.
[29] Metcalf and Eddy, Inc.**,** “Wastewater Engineering: Treatment, Disposal and Reuse”, third edition, McGraw-Hill, New York, USA, 1991.
[30] M. Temleton, and D. Butler, “An introduction of wastewater treatment”, First edition, Bookboon, UK, 2011
[31] M.B. Pescod, “Wastewater treatment and use in agriculture – FAO irrigation and drainage paper 47,” FAO, Rome, Ital, 1992.
[32] T.H.Y. Tebbutt**, “**Principles of water quality control,” 5th edition. Butterworth-Heinemann, 1998.
[33] J.E. Drinan, “Water and wastewater treatment. A guide for the non engineering Professional,” CRC press, Washington DC, USA, 2001.
[34] C.C. Lee, D.L. Shun, “Handbook of Environmental engineering calculation,” McGraw Hill Inc., New York, USA, 2000.
[35] Metcalf and Eddy, Inc.**,** “Wastewater engineering. Treatment, disposal and reuse,” 4th edition, McGraw-Hill, New York, USA, 2003.
[36] E. Eriksson, K. Auffarthk, M. Henze, and A. Ledin. “Characteristic of grey wastewater”. Urban water, 499, pp. 85-104, 2002.
[37] G. Emmerson, “Every drop is precious: Grey water as an alternative water source,” Queensland Parliamentary Library, Brisbane, Australia, 1998.

[38] J.C. Crittenden, R.R. Trussell, D.W. Hand, K.J. Howe, and G. Tchobanoglous, "Water Treatment - Principles and Design," 2ed Edition, John Wiley & Son, New York, USA, 2005.
[39] A.G. Fane, "Sustainability and membrane processing of water reuse," Paper presented at IWA specialty conference on Wastewater reclamation and reuse for sustainability,WRRS2005, 8-11 November, Jeju Island, Korea, 2005.
[39] M.J. Hammer, "Water and Wastewater Technology," 4th edition, Prentice Hall publisher, upper Saddle River, USA, 2001.
[40] J. Acero, F. Benitez, A. Leal, F. Real, and F. Teva, **"**Membrane filtration technologies applied to municipal secondary effluents for potential reuse," Journal of Hazardous Materials, 177, pp. 390–398. 2010.
[41] T. Asano, D. Richard, R.W. Crites, and G. Tchobanoglous, "Evolution of tertiary treatment requirements in California," Water Environ. Technol., 3(2), pp. 37–41. 1992.
[42] A. Bick, L. Gillerman, T. Shatz, M. Dagan, M. Negrin, Y. Manor, and G. Oron, "Membrane technology for effective irrigation with secondary effluent", Int. water irrigate. 21, pp. 34-42, 2000.
[43] A. Guadix, E. Sorensen, L.G. Papagerorgiou, and E.M. Guadix, "Optimal design and operation of continuous ultrafiltration plants," J. Membr. Sci., 235, pp. 131-138. 2004.
[44] J.G. Jacangelo, S. Chellam, and R.R. Trussell, "The membrane treatment," Civil Eng., 68(9), pp. 42–45, 1998.
[45] J.G. Jacangelo, R.R. Trussell and M. Watson, "Role of membrane technology in drinking water treatment in the United States," Desalination, 113(2-3), pp. 119–127, 1997.
[46] S. Atkinson, "US membrane separation technology market analyzed," Membr. Technol., 9, pp. 10–12, 2002.
[47] L. Gillerman, A. Bick, N. Buriakovsky, and G. Oron, "Secondary wastewater polishing with ultrafiltration membrane for unrestricted reuse: Fouling and Flushing Modeling," Environ Sci. Technol., 40, pp. 6830-6836, 2006.
[48] S.P. Beier, **"**Pressure driven membrane processes, Academic article, Bookboon Publisher, Second edition, London, UK, 2007.
[49] Z. Amjad, "Reverse Osmosis: Membrane Technology, Water Chemistry, and Industrial Applications; Van Nostrand Reinhold, New York, USA. 1993.
[50] R. H. Perry, and D. W. Green, "Perry's Chemical Engineers' Handbook," 7th edition, McGraw-Hill, New York, USA, 1997.
[51] R.W. Baker, "Membrane Technology and Applications," 2nd edition, John Wiley & Sons Ltd., Chichester, USA, 2004.
[52] J. Schwinge, P.R. Neal, D.E. Wiley, D.F. Fletcher, and A.G. Fane, "Spiral wound modules and spacers, Review and analysis," Journal of membrane science, 242, pp. 129-153, 2004.
[53] I. Pinnau, and B.D. Freeman, "Membrane formation and Modification. Formation and Mod ification of polymeric membranes," American Chemical Society, Washington D.C. Chapter 1.744, pp. 1-22, 2000
[54] S.P. Nunes, and K.V. Peinemann, "Membrane Technology in the chemical industry. Membrane preparation," Wiley-VCH, Weinheim, Chapter 3, pp. 1-6, 2001.
[55] A. Ratenbach, and R. Albrecht, "Membrane process," John Wiley and Sons, New York, USA, 1998.
[56] J.M. Dickson, J. Spencer, and M.L. Costa, "Dilute single and mix solute system in spiral wound reverse osmosis module, Part I, Theoretical model evelopment," Desalination, 89, pp. 63-88,1992.
[57] L.K. Wang, J.P. Chen, Y.T. Hung, and N.K. Shammas, "Handbook of environmental engineering. Membrane and desalination technologies," Volume 13, Springes science +Business media, New York, USA, 2001.
[58] M. Cheryan, "Ultrafiltration and Microfiltration Handbook," Technomic Publishing Co. Inc., Lancaster, Basel, UK, 1998.
[59] M. Mulder, "Basic principle of membrane technology," 2ed edition, Kluwer Academic Publishers, London, UK, 1996.
[60] A. Rautenbach, and R. Albrecht, "Membrane Processes," John Wiley & Sons, New York, USA, 1989.
[61] J. Kinel, K.P. Dolece, and J. Cakl, "Filtration mode for hollow fiber membranes with compressible cake formation," Desalination, 240, pp. 99-107, 2009.
[62] W.B. Richeard, **"**Membrane technology and application," John Wiley and sons, 2ed edition, New York, USA, 2004.
[63] K.R. Gurpreet, and S.K. Jagdev, **"**Bioremediation of Pharmaceuticals, Pesticides, and Petrochemicals with Gomeya/Cow Dung," ISRN Pharmacol, 2011: 362459, 2011.
[64] R.J. Slacka, J.R. Gronowb, and N. Voulvoulisa, "Household hazardous waste in municipal landfills: contaminants in leachate," Science of the Total Environment, 337, pp. 119–137, 2005.
[65] C.G. Daughton, and T.A. Ternes, "Pharmaceuticals and personal care products in the environment: agent of subtle change?" Environmental health perspectives, 107(6), pp. 907-938, 1999.
[66] K. Kummerer, "The presence of pharmaceuticals in the environment due to human use -present knowledge and future challenges- a review," Journal of Environmental Management, 90(8), pp. 2354–2366, 2009.
[67] M. Carballa, F. Omil, J.M. Lema, M. Llompart, C. Garcia-Jares, I. Rodriguez, M. Gomez, and T. Ternes, "Behavior of pharmaceuticals, cosmetics and hormones in a sewage treatment plant," Water Res., 38 (12), pp. 2918–2926, 2004.
[68] D.W. Kolpin, E.T. Furlong, M.T. Meyer, E.M. Thurman, S.D. Zaugg, L.B. Barber, H.T. Buxton, "Pharmaceuticals, hormones, and other organic wastewater contaminants in US streams, 1999–2000: a national reconnaissance," Environ. Sci. Technol**,"** 36(6), pp. 1202–1211, 2002.
[69] P.E. Stackelberg, E.T. Furlong, M.T. Meyer, S.D. Zaugg, Henderson, A.K., and Reissman, D.B, "Persistence of pharmaceutical compounds and other organic wastewater contaminants n a conventional drinking-water treatment plant," Sci. Total Environ**,** 329 (1–3), pp. 99-113, 2004.
[70] L.D. Arcand-Hoy, A.C. Nimrod, and W.H. Benson, "Endocrine modulating substances in the environment estrogenic effects of pharmaceutical products," Int. J. Toxicol., 17(2), pp. 139–158, 1998.
[71] C.G. Daughton, "Non-regulated water contaminants: emerging research," Environ. Impact Assessment Rev., 24, pp. 711–732. 2004.
[72] K. Fent, A.A. Weston, and D. Caminada, "Ecotoxicology of human pharmaceuticals," Aquat Toxicol, 76, pp. 122–159, 2006.
[73] M.L. Richarson, and J.N. Bowron, "The fate of pharmaceutical chemical in aquatic environment," Journal of Pharmaceutical and pharmacology, 37, pp. 1-12, 1985.

[74] F.M. Stumpf, T.A. Ternes, R.D. Wilken, S. Silvana vianna, and W. Baumann, "Polar drug residues in sewage and natural water in the state of Rio de Janeiro, Brazil," Science of the total environment, 255, pp. 125-141, 1999.
[75] S. Zorita, L. Martensson, and L. Mathiasson, "Occurrence and removal of pharmaceutical in municipal sewage treatment system in South Sweden," Science of the total environment, 407, pp. 2670-2770, 2009.
[76] E. Eriksson, K. Auffath, A.M. Eilersen, H. Henz, and A. Ledin, "Household chemical and personal care product as sources of Xenobiotic organic compounds in grey wastewater," Water SA, 29, pp. 135-146, 2003.
[77] E. Eriksson, H.J. Albrechtsen , A. Baun, R. Boc-Hansen, P.S Mikkelsen, A. Ledin, "Hazard identification of rainwater collected for non-portable reuse in household. Discharged urban waters –resources or risk?" First world wide workshop for junior environmental scientists, 21-24 May, Vitry sur Seine – France, 2002.
[78] K. Press-Kristensen, A. Ledin, J.E. Schmdt, and M. Henze, "Identifying model pollutants to investigate biodegradation of hazardous XOCs in wastewater treatment plants," Science of total Environment, 373(1), pp. 122-130, 2007.
[79] D.W. Kolpin, E.T. Furlong, M.T. Meyer, E.M. Thurman, S.D. Zaugg, L.R. Barber, and H.T. Buxton, "Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999–2000: a national reconnaissance," Environ Sci Technol., 36, pp. 1202–1211, 2002.
[80] G. Ying, R.S. Kookana, and D.W. Kolpin, "Occurrence and removal of pharmaceutically active compounds in sewage treatment plants with different technologies," Journal of Environmental monitoring, 11(8), pp. 1498-1505, 2009.
[81] S. Castiglioni, R. Bagnati, C. Calamari, D. Fanelli, and R. Zuccato, "A multi residue analytical method using solid-phase extraction and high pressure liquid chromatography tandem mass spectroscopy to measure pharmaceutical of different therapeutic class in urban wastewater," Journal of chromatography A, 1092, pp. 206-215, 2005.
[82] S.T. Glassmeyer, E.T. Furlong, D.W. Kolpin, J.D. Cahill, S.D. Zaugg, and S.L. Werner, "Transport of chemical and microbial contaminants from known wastewater discharge: potential for use as indicators of human fecal contamination," Environ Sci Technol, 36, pp. 5157–69, 2005.
[83] M. Wu, D. Atchley, L. Greer, S. Janssen, D. Rosenberg, and J. Sass, "Dosed without prescription: preventing pharmaceutical contamination of our nation's drinking water," Natural Resources Defense Council, USA, 2009.
[84] T.A Ternes, "Occurrence of drugs in German sewage treatment plants and rivers," Water Recourse, 32, pp. 3245–3260. 1998.
[85] A.B.A. Boxall, "The environmental side effect of medication. How are human and veterinary medicines in soils and water bodies affecting human and environmental health?" EMBO report, 5(12), pp. 1110-1116, 2004.
[86] M.S. Diaz-Cruz, M.J. Lopez de Alda, and D. Barcelo, "Environmental behavior and analysis of veterinary and human drugs in soil, sediment and sludge," Trends in Analytical chemistry, 22, pp. 340-351, 2003.
[87] J. Bound, and N. Voulvoulis, "Household disposal of pharmaceutical as pathway contamination in United Kingdom," Environ. Health perspective, 13, pp. 1705-1711, 2005.
[88] J.L. Okas, M. Gilbert, M.Z. Virani, R.T. Watson, C.U. Meteyer, B.A. Rideout, H.L. Shivaprasad, S. Ahmed, M.J.I. Chaudhry, M. Arshad, S. Mahmood, A. Ali, and A.A. Khann, "Diclofenac residues as the cause of vulture decline in Pakistan," Nature. 427, pp. 630-633, 2004.
[89] P.K. Jjemba, "Excretion and ecotoxicity of pharmaceutical and personal care products in the environment," Ecotoxicol Environ Saf., 63, pp. 113–130, 2006.
[90] R. Karaman "The Effective Molarity (EM) – a Computational Approach," Bioorganic Chemistry, 38, pp. 165-172, 2010.
[91]. O. Almarsson, R. Karaman, T.C. Bruice, "The Kinetic Importance of Conformations of Nicotinamide Adenine Dinucleotide in the Reactions of Dehydrogenase Enzymes," J. Am. Chem. Soc., 114, pp. 8702-8704, 1992.
[92] R. Karaman, "Prodrugs Design Based On Inter- And Intramolecular Processes," in "Prodrugs Design – A New Era", R. Karaman (editor), Nova Publisher, USA, pp. 1-76, 2014.
[93] A. Abu-Jaish, G. Mecca, S. Jumaa, A. Thawabteh, R. Karaman, "Mefenamic acid Prodrugs and Codrugs- Two Decades of Development" World Journal of Pharmaceutical Research, 4(6), pp. 2408-2429, 2015.
[94] Y. Khawaja, R. Karaman, "A Novel Mathematical Equation For Calculating The Number of ATP Molecules Generated From Sugars In Cells," World Journal of Pharmaceutical Research, 4(4), pp. 303-312, 2015.
[95] S. Jobling, M. Nolan, C.R. Tyler, G. Brighty, and J.P. Sumpter, "Widespread sexual disruption in wild fish," Environ. Sci Technol, 32(17), pp. 2498-2506, 1998.
[96] J.P. Sumpter, and A.C. Johnson, "10th Anniversary Perspective: Reflections on endocrine disruption in the aquatic environment: from known to unknown unknowns (and many things in between)," J. Environ. Monit, 10 (12), pp. 1476–1485, 2008.
[97] S. Esplugas, D. Bila, L. Krause, and M. Dezotti, "Ozonation and advanced oxidation technologies to remove endocrine disrupting chemicals [EDC] and pharmaceutical and personal care product (PPCPs) in water effluents," Journal of Hazardous material, 149(3), pp. 631-642, 2007.
[98] M. Stumpf, T.A. Ternes, K. Heberer, P. Seel, and W. Baumann, "Determination of pharmaceutics in sewage plants and river water," Vom wasser, 86, pp. 291-303, 1996 b
[99] T. Herberer, K. Reddersen, and A. Mechlinski, "From municipal sewage to drinking water: fate and removal of pharmaceutical residues in the aquatic environment in urban areas," Water Sci. Technol., 46(3) pp. 81-86, 2002.
[100] J.B. Quintana, and T. Reemtsma, "Sensitive determination of acidic drugs and triclosan in surface and wastewater by ion-pair reversed-phase liquid chromatography/tandem mass spectrometry," Rapid commune. Mass Spectrom, 18 pp. 765-744, 2004.
[101] D. Ashton, M. Hilton, and K.V. Thomas, "Investigation the environmental transport of human pharmaceuticals to streams in the United Kingdom," Sci. Total Enviro., 333 pp. 167-184, 2004.
[102] J. Oppenheimer and R. Stephenson, "Time Out –Longer Retention time can remove some PPCPs. Water Environment and

Technology," Water Environment Federation, December, pp77-82, 2006.
[103] G. Bitton, "Wastewater Microbiology," Third Edition, Wiley-Liss, New York, USA, 1994.
[104] J.V. Headley, J. Gandrass, J. Kuballa, K.M. Peru, and Y. Gong, "Rates of sorption and partitioning of contaminants in river biofilm," Environ. Sci. Technol., 32, pp. 3968–3973, 1998.
[105] T.F Guerin, "Co-composting of pharmaceutical wastes in soil," Lett. Appl. Microbiol, 33, pp. 256–263, 2001.
[106] A.L. Boreen, W.A. Arnold, and K. McNeill, "Photodegradation of pharmaceuticals in the aquatic environment: A review," Aquat. Sci., 65, pp. 320–341, 2003.
[107] T. Poiger, H.R. Buser, and M.D. Muller, "Photodegradation of the pharmaceutical drug diclofenac in a lake: Pathway, field measurements, and mathematical modeling," Environ. Toxicol. Chem., 20, pp. 256–263, 2011.
[108] O.A.H. Jones, N. Voulvoulis, J.N. Lester, "Human pharmaceuticals in wastewater treatment processes," Critical Reviews in Environmental Science and Technology, 35, pp. 401–442, 2005.
[109] S.A. Snyder, S .Adham, A.M. Redding, F.S. Cannon, and J. DeCarolis J. Oppenheimer, E.C Wert and Y.Yoon, "Role of membranes and activated carbon in the removal of endocrine disruptors and pharmaceuticals," Desalination, 202(1-3), pp. 156–181,2007.
[110] C. Bellona, G. Oelker, , J. Luna, G. Filteau, G. Amy, and J.E. Drewes, "Comparing nanofiltration and reverse osmosis for drinking water augmentation," J. American Water Works Association, 100(9), pp. 102-116, 2008.
[111] C. Gakwisiri, N. Raul, A. Al-Saad, S. Al-Aisri, A. Al-Al-ajimi, "A Critical review of removal of zinc from wastewater," Proceeding of the world Congress on Engineering, WEC, 4-6 July, London, UK, 2012.
[112] V.R. Gupta, M. Gupta, and S. Sharma, "Process development for the removal of Lead and Chromium from aqueous solution using red mud – an aluminum industry waste," Water Res., 35(5), pp. 1125-1134.2001.
[113] P. Harrison, and G. Waites, "The Cassell dictionary of chemistry," 6th edition. Cassell, London, UK, 1998.
[114] K.B. Chipasa, "Accumulation and fate of selected heavy metals in a biological wastewater treatment systems," Waste Management, 23(2), pp. 135-143, 2003
[115] J. A. Adekoya, B. Williams, and O.O. Ayejuyo, "Distribution of heavy metals in sediments of Igbede, Ojo and Ojora rivers of Lagos, Nigeria, Environmentalist, 26(4), pp. 277-280, 2006.
[116] Lenntech Water Treatment and Air Purification. Water Treatment, Published by Lenntech, Rotterdamseweg, Netherlands. (www.excelwater.com/thp/filters/Water-Purification.htm). 2004
[117] E. Meria, (Ed), "Metals and Their Compounds in the Environment, Occurrence, Analysis and Biological Relevance," Verlag Chemie, New York, USA, 1991.
[118] B.J. Alloway, and D.C. Ayres, "Chemical principles of environmental pollution (In Polish)," PWN, Warszawa, 1999.
[119] A. Bielicka, I. Bojanowska, and A. Wiśniewski, "Two Faces of Chromium - Pollutant and Bioelement," Polish Journal of Environmental Studies. 14(1), pp.5-10 included (P. Backlund, B. Holmbom, and E. Leppakski, "Industrial emissions and toxic pollutants," Abo Akademi University, Baltic University Programme, Uppsala, 1993), 2005.
[120] A. Bielicka I. Bojanowska, and A. Wiśniewski, "Two Faces of Chromium-Pollutant and Bioelement," Polish Journal of Environmental Studies.14 (1), pp. 5-10 included (J.E. Kihlstrom, "Toxicology - the environmental impact of pollutants," Abo Akademi University, Baltic University Programme, Uppsala, 1992), 2005.
[121] J.J. Ziolkowski, "Environmental Chemistry and Protection. Education in advanced chemistry," Vol. 3, Poznań – Wrocław, Wydawnictwo Studio Sense, 1996.
[122] A. Bielicka, I. Bojanowska, and A. Wimniewskia, "Two Faces of chromium polluted and bioelemnt," Polish Journal of environmental studies, 14(1), pp. 5-10, 2005.
[123] ECDG European Commission DG ENV, E3 Project ENV, E.3/ETU/OO58, "Heavy metals in waste," Final report, Denmark, 2002.
[124] R. Kadirvelu, K. Thamaraiselvi, and C. Namasivayam, "Removal of heavy metal from industrial wastewater by adsorption onto activated carbon prepared from an agriculture solid waste," Bioresource Techn., 76, pp. 63-65, 2001.
[125] I.R.E.V. Santos, S.C.E. Silva-Filho, M.R. Albuquerque-Filho , and l.S. Campos, " Heavy metals contamination in coastal sediments and soils near the Brazilian Antarctic station," King George Island, Mar. Poll. Bull, 50, pp. 85-140, 2005.
[126] Y. Chen, C. Wang, and Z. Wang, "Residues and source identification of persistent organic pollutants in farmland soils irrigated by effluents from biological treatment plants," Environment International, 31, pp. 778–783, 2005.
[127] K. P. Singh, D. Mohan, S. Sinha, and R. Dalwani, "Impact assessment of treated/ untreated wastewater toxicants discharged by sewage treatment plants on health, agricultural, and environmental quality in the wastewater disposal area," Chemosphere. 55(2), pp. 227–255, 2004
[128] E.A. Alvarez, M.C. Mochon, J.C. Sanchez, M.T Rodriguez, Heavy metals extractable forms in sludge from wastewater treatment plants, Chemosphere, 47(7), pp. 765-775, 2002.
[129] Y. Sanayei, N. Ismail, and S.M. Taleb, Determination of Heavy Metals in Zayandeh Rood River, Isfahan-Iran. World Applied Sciences Journal, 6(9), pp. 1209-1214, 2009.
[130] D.J.H. Phillips, "The chemistries and environmental fates of trace metals and organchlorines in aquatic ecosystems," Mar Pollut Bull, 31, pp. 193-200, 1995.
[131] M.H. Depledge, J.M. Weeks, and P. Bierregaard, "Heavy metals. In: Callow P (Ed.) Handbook of Ecotoxicology," Blackwell Science, Oxford, pp543-569, 1998.
[132] O.O. Olujimi, O. Fatoki, J. Odendaal, A.P. Daso, and O. Oputu, "Preliminary investigation into occurrence and removal of Arsenic, Cadmium, Mercury, and Zinc in wastewater treatment plants in Cape Town and Stellenbosch," Polish Journal of environmental studies, 21(6), pp. 1755-1765, 2012.
[133] K. Abraham, R. Sridevi, B. Suresh, and T. Damedharam, "Effect of heavy metals (Cd, Pb and Cu) of seed germination of Arachis hypogeae L," Asian Journal of plant science and research, 3(1), pp. 10-12, 2013.
[134] M.J. Mclaughlin, B.A. Zarcinas, D.P. Stevers, and N. Cook, "Soil testing for heavy metals," communication in soil science and plant analysis, 31(11-14), pp. 1661-1700, 2000.

[135] W. Ling, Q. Shen, Y. Gao, X. Gu, and Z.Yang, "Use of bentonite to control release from contaminated soils," Australian Journal of soil research, 45(8), pp. 618-623.2007.
[136] B. Volesky, "Detoxification of metal-bearing effluents: biosorption for the next century," Hydrometallurgy, 59, pp. 203–216. 2001.
[137] Cesar G.F**,** "Relevance, essential and toxicity of trace elements in human health," Molecular Aspects of Medicine, 26, pp. 235-244. 2005.
[138] U. Forster, and G.T.W. Whittmann, "Metal Pollution in the Aquatic Environment," Springer- Verlag, Berlin, 1983.
[139] C. Draghici, G. Coman, , C. Jelescu, , C. Dima, and E. Chirila, "Heavy metals determination in environmental and biological samples, In: Environmental Heavy Metal Pollution and Effects on Child Mental Development- Risk Assessment and Prevention Strategies," NATO Advanced Research Workshop, 28 April-1 May, Sofia, Bulgaria, 2012.
[140] C. Vieira, S. Morais, , S. Ramos, , C. Delerue-Matos, & M.B.P.P. Oliveira, "Mercury, cadmium, lead and arsenic levels in three pelagic fish species from the Atlantic Ocean: intra- and inter-specific variability and human health risks for consumption," Food & Chemical Toxicology, 49(4), pp. 923-932, 2011.
[141] V. Hiatt, and J.E**.** Huff, "The environmental impact of Cadmium: an overview," Int. J. Env. Studies, 7(4), pp. 277-285, 1975.
[142] Lars Jarup, "Hazards of heavy metals contamination," British Medical Bulletin, 68, pp. 167-182. 2013.
[143] R.A. Wuana, and F.E. Okieimen, "Heavy metals in contaminated soils: Review of sources, chemistry, risks and best available strategies for remediation," International scholarly research network ISRN Ecology, 2011, pp. 1-20, 2011.
[144] A. Scrag, "Environmental Biotechnology," Oxford press, Second edition, Oxford, UK, 2006.
[145] A. Gaurari, and A. Adholeya, **"**Review**: Prospects** of arbuscular mycorrhizal fungi in phytoremediation of heavy metal contaminated soil," Current Science, 86(4), pp. 528-534, 2004.
[146] M. Muchuweti, J.W. Birkett, E. Chinyanga, R. Zvauya, M. D. Scrimshaw, and J. N. Lester, "Heavy metal content of vegetables irrigated with mixture of wastewater and sewage sludge in Zimbabwe: implications for human health," Agriculture, Ecosystem and Environment, 112(1), pp. 41–48. 2006.
[147] T. E. Bahemuka, and E. B. Mubofu, "Heavy metals in edible green vegetables grown along the sites of the Sinza and Msimbazi rivers in Dar es Salaam, Tanzania, Food Chemistry, 66(1), pp. 63–66, 1991.
[148] F. Mapanda, E. N. Mangwayana, J. Nyamangara, and K.E. Giller, **"**The effects of long-term irrigation using wastewater on heavy metal contents of soils under vegetables in Harare, "Agriculture, Ecosystem and Environment, 107, pp. 151–156, 2005.
[149] M. G. M. Alam, E. T. Snow, and A. Tanaka, "Arsenic and heavy metal contamination of vegetables grown in Santa village, Bangladesh," Science of the Total Environment, 308, pp. 83–96, 2003.
[150] A. Monu, K. Bala, R. Shweta, R. Anchal, K. Barinder, and M. Neeraj, **"**Heavy metal accumulation in vegetables irrigated with water from different sources," Food Chemistry, 111(4), pp. 811–815, 2008.
[151] J**.** Oehlenschläger, "Identifying heavy metals in fish. In: Bremner H.A (ed.): Safety and quality issues in fish processing," CRC press LLC, USA, 507, pp. 95-113, 2002.
[152] M.I. Castro-González, and M. Méndez-Armenta, "Heavy metals: Implications associated to fish consumption," Environmental Toxicology & Pharmacology, 26(3), pp. 263-271, 2008.
[153] V.Y. Satya, V. Sridevi, and M.V.V**.** Chandana, "A Review on Adsorption of Heavy Metals from Aqueous Solution," Journal of Chemical, Biological and Physical Sciences, 2(3), pp. 1585-1593, 2012.
[154] L. E. Applegate, "Membrane separation processes, "Chemical Engineering in field," 12, pp. 64-89, 1984.
[155] A.K. Sengupta and D**.** Clifford, **"**Important Process Variables in Chromate Ion Exchange," Environ. Sci. Technol, 20, pp. 149-155, 1986.
[156] J. Geselbarcht, "Micro Filtration/Reverse Osmosis Pilot Trials for Livermore, California, Advanced Water Reclamation," Water Reuse Conference Proceedings, Sep 13-15, California, AWWA, USA, 1996.
[157] J.L. Schnoor, "Phytoremediation, TE-97-01, Ground-Water Remediation," Technologies Analysis Center, Pittsburgh, 1997.
[158] A.Q. Hani, and M. Hassan, "Removal of heavy metals from wastewater by membrane processes: a comparative study, Desalination, 164, pp. 105-110, 2004.
[159] Z. Ujang, and G.K. Anderson, "Application of low pressure reverse osmosis membrane for Zn^{+2} and Cu^{+2} removal from wastewater," Water Sci. Technol., 34, pp. 247-253, 1996.
[160] C. P. Huang and D.W. Blankenship, "The Removal of Mercury (II) from Dilute Aqueous Solution," Water Research, 18(1), pp. 37-46, 1984.
[161] S.E. Bailey, T.J. Olin, R.M. Bricka, and D.D. Adrian, "A review of potentially low-cost sorbents for heavy metals," Water Res. 33(11), pp. 2469-2479, 1999.
[162] D. Mohan, and K.P. Singh, "Single and Multi-Component Adsorption of Cadmium and Zinc using Activated Carbon Derived from Bagasse – An Agricultural Waste," Water Research, 36(9), pp. 2304-2318, 2002.
[163] E. Munaf, and R. Zein, "The Use of Rice Husk for Removal of Toxic Metals from Wastewater," Environmental Technology, 18(3), pp. 359-362, 1997.
[164] R. Suemitsu, R. Venishi, I. Akashi, and M. Nakano, "The Use of Dyestuff-treated Rice Hulls for Removal of Heavy Metals from Waste Water," Journal of Applied Polymer Science, 31(1), pp. 75-83, 1986.
[165] K. Kadirvelu, M. Kavipriya, , C. Karthika, , M. Radhika, , N. Vennilamani, , and S. Pattabhi, "Utilization of Various Agricultural Wastes for Activated Carbon Preparation and Application for the removal of dyes and metal ions from Aqueous Solution," Bioresource Tech., 87(1), pp. 129-132, 2003
[166] H. Niu, and B. Volesky, "Characteristics of anionic metal species biosorption with waste crab shells, "Hydrometallurgy, 71(1-2), pp. 209-215, 2003.
[167] B. Zhu, and A.K. Alva, "Differential adsorption of trace metals by soils as influenced by exchangeable cations and ionic strength," Soil Sci., 155(1), pp. 61-66, 1993.

[168] T.M. Christensen, "Cadmium soil sorption at low concentrations," Water Air Soil Poll, 21, pp. 105-115, 1984.
[169] P.L. Carey, R.G. McLaren, and J.A. Adams, "Sorption of cupric dichromate and arsenate ions in some New Zealand soils," Water Air Soil Poll., 87, pp. 189-203, 1996.
[170] M. Fumiaki, M. Shingo and S. Yoko, "Adsorption removal of lead and cadmium ions from aqueous solution with coal fly ash-derived zeolite/sepiolite composite, "Journal of the ceramic society of Japan, 118(11), pp. 1062-1066, 2010.
[171] A. Mohammad, A.K.R. Rifaqat, and A. Rais, "Adsorption studies of heavy metals on Tectona grandis: Removal and recovery of Zn (II) from electroplating wastes," Journal of Dispersion science and Technology, 32(6), pp. 851-856. 2011
[172] M.K. Jamali, T.G. Kazi, M.B. Arain, H.N. Afridi, N. Jalbni, A.R. Memon, and A, Shah, "Heavy metals from soil and domestic sewage sludge and their transfer to Sorghum plants," Environmental Chemistry Letter, 6(2), p. 119, 2008.
[173] S.R. Juliastuti, J. Baeyens, C. Creemers, D. Bixio, E. Lodewyckx, "The inhibitory effects of heavy metals and organic compounds on the net maximum specific growth rate of the autotrophic biomass in activated sludge," Journal of Hazardous Materials, 100(1-3), pp. 271-283, 2003.

Appendix A

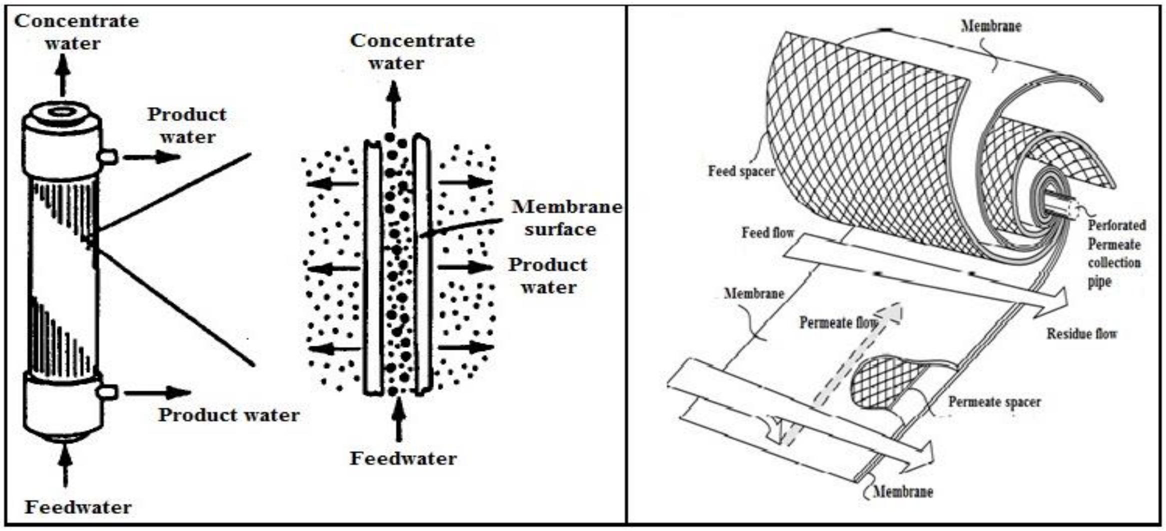

Fig.1 Hollow fiber module (left), and Spiral-Wound module (right) [62].

Heavy metals

Natural Sources

1. Geochemical (Volcanic, eruptions)
2. Soil and Rock erosion
3. Forest wildfires

Anthropogenic Sources

1. Mining (Coal, metals ores, minerals)
2. Energy (fuel combustion)
3. Metalluragy (Cast iron, steel, Nickel production)
4. Metals (various metals processing)
5. Minerals (cement production)
6. Chemical industry
7. Waste dump.

Fig.2. Sources of heavy metals in Environment [122]

Appendix B

Table 1 Wastewater treatment plants (WWTP) in the West Bank (status and information) [6].

Name of T.P	Status of T.P	No. of population served by T.P * 1000 (year)	Capacity of T.P (mcm/year)	Funding Agency	Estimated cost for construction (million US$)	Technology
Nablus East	Planning phase	240(2021)	9.2	Germany KFW	25	Extended Aeration
Nablus West	Approved	225(2021)	9.0	Germany KFW	25	Extended Aeration
Salfit	Detailed study	24(2025)	2.3	Germany KFW	13	Extended Aeration
Jenin*	Rehabilitation is needed	13.5(1997)	0.5	Israel		Waste stabilization ponds
Al-Bireh	Constructed	40(2000)	1.1	Germany KFW	7	Oxidation Ditch
Tulkarem**	No study yet	223(2030)	7.5	Germany KFW	50	Extended Aeration Process
Abu-Dees	Feasibility study	26(2020)	1	Norway		Oxidation Ditch
Tafuh	Feasibility study	16	0.5	UNDP		Anaerobic Rock Filter
Halhul	Preliminary design	42(2020)	1.0	Not funded	5.5	Aerated Pond System
Birzeit area	Preliminary Study	28(1994)	1.2	Not funded	4.5	Imhoff tank and trickling Filter
Hebron	Planning stage	695(2020)	25.0	USA	45	Activated Sludge
Jericho	Preliminary Study	26 (2000)	1.2	Not funded		
Biddya	Preliminary Study	24 (2000)	1.1	Not funded	10.0	
Ramallah***	Feasibility Study	40 (North)	1.5	Not funded	7.0	Extended Aeration
		40 (South)	1.5		7.0	
Al-Ram	Preliminary Study	86.5(2000)	3.3	Germany KFW	11.0	Aerobic sludge Stabilization+ Activated Sludge
Total		**1789**	**66.3**		**210**	

Note: *Old and non-functioning sewage treatment plant exists. **Currently rehabilitation of the sewage treatment plant takes place. *** Currently rehabilitation of the old sewage treatment plant takes place as a partial solution. (KFW: KreditanstaltFuerWiederaufbau, T.P: Treatment Plant).