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Sludge Treatment and Disposal in MENA Countries

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Abstract
Sludge, or residual solids, is the end products of wastewater treatment processes, whether it is biological or physical-chemical treatment. Sludge production in MENA countries is increasing because of the growth in wastewater treatment systems. This chapter presents sludge management practices in some MENA countries, where there are various alternative processes available for sludge treatment and disposal. The processes selected depend primarily on the nature and characteristics of the sludge and on the final disposal method employed, in addition to the economic evaluation, beneficial use requirements, and local conditions. The system selected must be able to receive the sludge produced and to economically convert it to a product that is environmentally acceptable for disposal.

The sources of sludge and solids produced by wastewater treatment plants related to the wastewater types and sources. However, the characteristic of sludge is depending on its origin and on the treatment methods of wastewater treatment operational process. Various sludge treatment and disposal processes will be presented in this study, with emphasis on the most used technologies in MENA region.

There are some technologies are applied to produce sludge treatment process like dewatering, Thickening, and sludge drying to minimizing sludge volume by removing water from sludge. Aerobic or anaerobic digestion and composting are used to treat or stabilize the organic material in the sludge. Final disposal methods like incineration, land application and sanitary landfill will be discussed in terms of environmental constraints, and public health, as well as legislation for the reuse and disposal of sludge. Case studies will be provided to discuss practices and trends in sludge management in selected MENA countries.

Keywords: sludge treatment, sludge disposal, MENA region, biosolids, land application.

Introduction
Over the last few decades, there has been in countries of the Middle East and North Africa (MENA) a significant expansion in constructing and operating wastewater treatment plants in urban and rural areas, leading to produce a large quantity of municipal sludge which requires treatment and disposal. The treatment of sludge represents up to 50% of the current operating costs of a wastewater treatment plant. Also, the wastewater treatment processes concentrate most of the pollutants and pathogens in the sludge. Treatment process in wastewater treatment plants normally occurs in several treatment stages like primary, secondary, and advanced treatment process, Sludge originating from these wastewater treatment processes it is generated during the primary treatment process like (physical and/or chemical), also via the secondary wastewater treatment stages (biological process) and the tertiary wastewater treatment (nutrient removal) and other organic parts. The term biosolids, as defined by the Water Environment Federation (WEF), reflects the fact that wastewater solids are organic products that can be used beneficially after treatment with processes such as stabilization and composting, it is normally used when municipal sludge is applied for agricultural purposes. The term sludge is used only before beneficial use criteria have been achieved (Metcalf & EDDY 2003).

It has been a major change in municipal sludge treatment and disposal ways. The purposes of sludge treatment include reducing sludge volume to minimize handling and transport costs, reducing the number of pathogens in sludge and safe disposal of produced biosolids (Evans 2016). Solutions have long been sought for better stabilization and disposal methods which are reliable and economic and able to render sludge either inert or stable (USEPA 1978). Nowadays, there is a high need to improve and develop the innovations systems to maximize the risik of sludge polution and to recover of useful sludge material like (phosphorous, and organice matteres), in addition the energy in a sustainable way, as this is has become very necessary issues. To achieve effective sustainability in sludge management systems, three elements are of fundamental importance and cannot be separately considered. They are environmental, economic, and social elements (Spinosa et al. 2011).

Sludge Qualities, and Quantities

For sludge treatment process and disposal, sludge characteristics, sources, and more information related to the quality and quantities are important to be well known. This will guide the sludge expert to be able handling the product in safe way.

Sources

The sources of sludge in a wastewater treatment plant related to wastewater type and treatment process operation. Primary settling produces an anaerobic sludge of raw organics that are being actively decomposed by bacteria. Secondary settling tank constitutes a sludge source. In comparison with secondary biological waste, primary Sludge thickens and dewaters readily because of its fibrous and coarse nature (Hammer 1977). Sludge treatment process like dewatering, thickening, and drying of sludge produced from primary and secondary settling tanks also constitute sources Metcalf & Eddy 2003). Tertiary municipal sludge produced by advanced wastewater treatment processes such as chemical precipitation and filtration.

Chemicals used in several stages in wastewater treatment processes especially in advanced treatment stages such as aluminum or iron salts, lime, or organic polymers, increase sludge mass and affect sludge quality at the same time. Generally, by adding chemicals to sludge treatment stages, characteristics of sludge will be improved, and sludge index will be better, by using lime or polymers. But in case of using iron or aluminum salts, the dewatering and thickening capacity of the sludge will be reduced after the reference (USEPA 1995a).

Characteristics

Wastewater sludge produced by primary treatment stages and biological stages in wastewater treatment plants, this depends principally on the characteristics of the wastewater influent entering the wastewater treatment plants and the treatment process used. “To identify potential alternatives for a sustainable treatment, it is useful to evaluate the composition of the sludge. This composition can be roughly characterized by five groups of components, which are present in the sludge” (Zorpas et al. 2011):

- Organic carbon compounds which is not toxic, Organic nitrogen and Ammonia (Kjeldahl-N), phosphorus-containing components.
- Toxic matters whice occur pollutants as inorganic parts: Heavy metals, such as Zn, Pb, Cu, Cr, Ni, Cd, Hg, As (from 1000 ppm to less than 1ppm), and *Organic parts like* the range of organic compounds known to presence is extensive and diverse, the respective lists include: detergent (e. g. linear alkyl sulfonates, nonylphenol (NP), ethoxylates (EO)), product of incomplete combustion (polycyclic aromatic hydrocarbons (PAHs)), polychlorinated biphenyls (PCBs), solvents, dioxins, pesticides, pharmaceuticals and personal care products (Fuerhacker & Haile 2011);
- Pathogens and other microbiological pollutants, including viruses, bacteria, parasitic protozoa, and helminths, which might transmit to soil, food, or groundwater.
- Compounds inorganic parts such as the following but not limited to silicates, aluminates, calcium, and magnesium containing compounds.
- Water, varying from a small percent to more than ninety-five percent.

Quantities

Sludge disposal methods for design and operation technologies are based on the water percentage parts in the sludge which increase the volume to be very high and dry solids parts. This mean the sludge quantity can be measured in two ways: the sludge volume including water as wet sludge, which includes the water content and solids content, or the mass of the dry sewage sludge solids. Key factors affecting sewage sludge volume and mass are wastewater sources and wastewater and sludge treatment processes. Typical solids concentration in waste sludge are raw primary sludge only, 6 to 8 percent; primary plus humus from secondary filtration, 4 to 6; primary plus waste activated sludge from secondary aeration,3 to 6 percent; and excess activated sludge only, 0.5 to 2.0 percent. For a given quantity of dry solids, the percentage concentration dramatically influences the sludge volume (Hammer 1977).

Sludge Treatment

There are many technologies of municipal sludge treatment, most of them need special pre-treatment to improve sludge characteristics before subsequent treatment. Wastewater pretreatment technologies are nowadays available include physical, chemical, mechanical, or biological hydrolysis or a combination of these methods to meet the treated wastewater level requested locally. (Carrère et al. 2010). Sludge thickening process improves sludge characters and increases solids concentration of a dilute sludge, up to a limit of about 10-12%. Thickening is contrasted with dewatering which increases the total solids concentration to the range of 15-30%. Thickening operations are intended to reduce the volume of sludge to be further processed and normally constitute an intermediate step preceding dewatering or stabilization. The characteristics of sludge before thickening will generally depend upon the type of wastewater treated, the sludge origin, the degree of chemical addition, and the sludge age. Especially in the MENA region, sludge can be dried by natural methods in hot weather via evaporation in the open air. Such methos were widely practiced in the past in the MENA countries and it is still appropriate in many MENA Countries where land is available in most cases and drying conditions are predictable, where drying conditions are predictable, and land is not too expensive. Sludge stabilization is useful for land applications but has moderate significance to other forms of final disposal, such as incineration or landfill disposal (Andreoli et al. 2007). a modern sludge integrated systems were improved and developed for sustainable sludge management and solutions in the region.

Therefore, sludge developed system includes three main sludge treatment processes: Anaerobic digestion, dewatering/drying, and thermal treatment by Pyrolysis/Gasification, which are efficiently coupled for the recovery of products for material reuse, and/or for energy purposes. (Spinosa et al. 2011).

Pretreatment Operations

A good pretreatment technology can be used to improve sludge stabilization and dewatering by implanting several treatment processes, which also help improve biogas production, recover materials such as proteins, volatile fatty acids (VFAs), nitrogen, and phosphorus. There are many pretreatment technologies available involving physical, chemical, mechanical, or biological hydrolysis or combination of these methods (Carrère et al. 2010; Tyagi and Lo 2013). Pretreatment technologies used to anaerobic digestion include biological (thermal phased anaerobic), thermal hydrolysis, mechanical such as ultrasound, a chemical with oxidation and alkali treatment. Biological treatment in pretreatment phase leads to intensification by enhancing the hydrolysis process in an additional stage before the digestion process. The most common type is temperature-phased anaerobic digestion, which uses a higher stage at either thermophilic (around 55ºC) or hyper-thermophilic (between 60 and 70 ºC) conditions, anaerobic and aerobic (Carrère et al. 2010). As an effective thermal method for sludge treatment, the microwave (MW) technology has gained widespread popularity (Tyagi ana Lo 2011; Wang et al. 2015). The most widely used mechanical method is ultrasound, which has started to become an established sludge pretreatment method before anaerobic, ultrasonic treatment can disintegrate sludge, enhance microbial activity, and improve sludge dewaterability at different energy input (Huan et al. 2009). Advanced oxidation processes (AOPs) can be applied as post-treatment or pretreatment of biological processes. AOPs include a series of robust technologies to treat waste activated sludge, they can implement ozone (O_3), hydrogen peroxide (H_2O_2), and oxygen (O_2), some of the most typical AOPs are the Fenton process, ozonation, and catalytic wet peroxide oxidation, regarding the methodology to generate hydroxyl radicals, AOPs can be divided into chemical, electrochemical, sonochemical and photochemical processes (Babuponnusamia and Muthukumar 2014). The treatment of organic sludge by wet electrolytic oxidation increased the biodegradability of organic sludge due to the formation of organic acids (Serikawa 2007).

Combination of different pretreatment that accelerated the sludge reduction process: combined microwave-ultrasonic pretreatment resulted in significant improvement in gas production, solid removal and dewaterability of municipal sludge compared to the individual ultrasonic or microwave pretreatment approaches (Yeneneh et al. 2013a). Sludge integration and increased biodegradability and methane production is due to rapid internal heating of microwave radiation and the floc destruction achieved by ultrasonic treatment (Yeneneh et al. 2013b). The application of electrolysis in combination with H_2O_2 oxidation pretreatment, electro-oxidation, for improving waste activated sludge anaerobic digestion (Feki et al 2015). Combined treatment of ultrasound and ozone improves solubilization and anaerobic biodegradability of waste activated sludge (Xu et al. 2010). Microsludge is a chemical and pressure pre-treatment process that significantly changes both the rate and the extent of waste activated sludge (WAS) in a conventional mesophilic anaerobic digester. This process uses alkaline pre-treatment and an industrial scale homogenizer to provide an enormous and sudden pressure change to burst the cells. The resulting liquefied WAS is readily degraded in an anaerobic digester to form methane and carbon dioxide (Kennedy 2003). Integration of sludge pretreatment with aerobic biological treatment system is one of the exciting approaches in controlling excess sludge production. Thermochemical sludge pretreatment enhances the biodegradability of anaerobic/anoxic/oxic process which plays a vital role in the reduction of sludge production (Uan 2013).

Thickening

Sludge thickening is mainly used in primary treatment, activated sludge and trickling filter processes. Thickening of wastewater is very important to prepare sludge for the biological treatment process with less volume, it is a procedure used to decrease sludge volume by increasing the dry mass concentration, and this is by removing water part from sludge in wastewater treatment plant. In general, Thickening is achieved by physical methods, sedimentation, including co-settling, gravity settling, flotation, centrifugation, gravity belt and others. Sludge volume reduction is an important process to avoid large volume of disaster tank in addition to that this will makes the biological treatment more efficient in many processes like sludge digestion, dewatering, sludge drying and other treatment process. Therefore, the tanks capacity in wastewater treatment plant will be increased and the treatment efficiency will be improved. Sludge thickening reduces tanks volume, this leads to reduce the capital and operational cost of the sludge treatment units, also reduces chemicals amount required and the cost of sludge digester heating especially in winter. Co-settling thickening, primary clarifiers are often used to thicken solids for downstream processing. Gravity thickening is one of the most common methods used and normally accomplished in a circular tank. The most common Thickening process can be achieved by centrifugation methods. This makes the solid parts settling because the influence of centrifugal forces. The gravity-belt thickener has been used for thickening waste-activated sludge, anaerobically and aerobically digested sludge, polymer addition is required. Rotary-drum thickeners can be used as a pre-thickening step before belt-press dewatering and are typically used in small- to medium-sized plants for waste-activated sludge thickening (Metcalf & Eddy 2003; Andreoli et al. 2007). Sludge conditioning is used to enhance thickening process through the utilization of inorganic chemicals, organic chemicals, or thermal treatment. Sludge conditioning with chemical has been employed widely to improve thickening and dewatering process. Adding cement kiln dust to sewage sludge could improve the sludge thickening, dewatering as well as stabilization (Aboulftoh & Dohdoh 2017).

Stabilization

Stabilization sludge process treatment were improved and developed with the purpose of stabilizing the biodegradable organic matters in the wastewater sludge, thus reducing the risk of putrefaction as well as reducing of pathogens from sludge. Some wastewater treatment processes produce stabilized sludge such as facultative ponds, extended aeration, and sequences batch reactor, while some produce non-stabilized sludge such as conventional activated sludge with or without biological nutrients removal. The principal methods used for stabilization of sludge are chemical stabilization (alkaline stabilization); biological stabilization (anaerobic digestion, and aerobic digestion); and thermal stabilization. When designing a stabilization process, sludge volume and quality has to be considered by sludge treatment process applied, this is an important issue for the integration of the sludge stabilization process in wastewater treatment plants, with the other treatment units, and the stabilization process it is important to consider the sludge quantity to be treated, the integration of the stabilization process with the other treatment units, and the objectives of the stabilization process (Metcalf & Eddy 2003; Andreoli et al. 2007).

Alkaline Stabilization

There are some methods to achieve sludge stabilization is lime treatment which is the most commonly methods used addition of lime to sludge to improve the dewatering process, and advanced alkaline stabilization technology. Lime stabilized sludge is suitable for application to agricultural land; however, lime stabilized sludge has lower soluble phosphate, ammonia nitrogen, total Kjeldahl nitrogen, and total solids concentrations than anaerobically digested sludge (USEPA 1978). In addition to commonly use hydrated lime, or quicklime for lime stabilization, fly ash and cement kiln dust are also used (Samaras et al. 2008).

Anaerobic Digestion

Anaerobic digestion of municipal wastewater sludge is widely used as the most-effective way for stabilization and energy recovery. This involves the organic matteres to be digested in absence of oxygen. Anaerobic digestion is a two-step, very complex biochemical process, which depends on many physical (temperature, solid concentration, the degree of mixing, organic loading, and detention time), chemical (pH, alkalinity, volatile acid level, nutrients, toxic materials) factors. In the first step, facultative microorganisms convert the complex organic material into simple organic fatty acid by hydrolysis and fermentation. In the second step, strictly anaerobic microorganisms convert the organic acids to methane, carbon dioxide, and other trace gases (USEPA 1978). Anaerobic digestion continues to be the dominant process for stabilizing sludge, because of the emphasis on energy conservation and obtained of beneficial biosolids. Furthermore, anaerobic digestion of municipal wastewater sludge can, in many cases, produce sufficient digester gas to meet most of the energy needs for plant operation (Metcalf & Eddy 2003). New developments in anaerobic digestion include disintegration, microaerobic conditions, and thermal hydrolysis. Co-Digestion municipal sludge obtained from El-Berka wastewater treatment plant in Egypt using rice straw and Effective Microorganisms (EM1) anaerobically has increased efficiency of the anaerobic process and produced suitable sludge for land application (Rashed et al. 2014).

Thermophilic Anaerobic Digestion

Thermophilic anaerobic digestion occurs at temperatures between 50 and 57ºC in conditions suitable for thermophilic bacteria. Thermophilic digestion is much faster than mesophilic digestion, increased solids destruction capacity, improved dewatering, and increases bacteria destruction (Metcalf & Eddy 2003). In the search for improved anaerobic digestion performance, several options for phasing or staging the digestion process in multiple reactors have been investigated. The application of two-phase anaerobic digestion of waste activated sludge showed higher organic matter removal and biogas production than single phase (Rogério et al. 2016).

Aerobic Digestion

activated sludge system is mostly used for biological aerobic treatment process of wastewater sludge plants operating in the extended aeration system.as well as in plants with biological nutrient removal Aerobic sludge treatment in extended aeration processes takes place in the aeration tank, simultaneously with the oxidation of the influent organic matter process.

- Conventional aerobic sludge treatment process (mesophilic) stabilizes the activated sludge system in unheated aeration tank through the diffused air or surface mechanical aeration. Normally, aerobic sludge digestion takes place at warm atmosphere not cold so the temperature should be suitable for this process. Sludge has to be thickened by any of method applied for that, this is needed to reduce the sludge volume by increasing the solid concentration in sludge to be not higher than 3%.
- Aeration digestion with pure oxygen is a variant of the conventional aerobic digestion, in which oxygen instead of air is directly supplied to the medium. This process is suitable for large wastewater treatment plants, where the area is a prime factor, and in which the pure oxygen is already being used in the biological reactor.

Thermophilic aerobic digestion (TAD) started in Germany in the early 1970s aiming at the stabilization and disinfection of sewage sludge. Sludge from thermophilic aerobic digesters comply with class "A" biosolids rating of the US Environmental Protection Agency (USEPA) and can be unrestrictedly used in agriculture. TAD's future is promising, mainly due to increasing measures for the agricultural reuse of sludge. The process still requires development, especially in terms of operational control (Andreoli et al. 2007).Batch experiments applied a combined of mesophilic (<35ºC) anaerobic digestion with the thermophilic (55ºC) aerobic digestion process (AN-TAD), the produced sludge achieved the requirement for Class-A sludge standards (Cheng et al 2015).

Dewatering

Dewatering is a physical unit of operation used to reduce the moisture content of sludge and biosolids because dewatered sludge and biosolids are generally easier to handle than thickened or liquid sludge. Dewatering is required before the incineration of the sludge to increase the calorific value by the removal of excess moisture, dewatering is required before composting to reduce the requirements for supplemental bulking agents or amendments and is also required before landfilling to reduce leachate production at the landfill site. The selection of the dewatering device is determined by the type of sludge to be dewatered, characteristics of the dewatered product, and the space available. For smaller plants where land availability is not a problem, drying bed or lagoons are generally used. Conversely, for the facilities situated on constrained sites, mechanical dewatering devices are often chosen. The dewatering processes that are commonly used include centrifuges, belt-filter presses and recessed-plate filter presses, the decanting type of paved drying bed is advantageous for warm, arid and semiarid climates. This type of drying bed uses low cost impermeable paved beds that depend on decanting of the supernatant and mixing of the drying sludge for enhanced evaporation (Metcalf & Eddy 2003). The solar drying of wastewater sludge was applied in the region of Marrakesh in Morocco. Drying pans and open greenhouse sludge dryer were investigated in summer and winter seasons. The results show that the solar greenhouse drying was practical and beneficial to wastewater sludge management and can be recommended as an alternative to drying pans in arid climate regions (Belloulid et al. 2018). In Jordan, the predominant treatment technology of sludge dewatering used is drying beds. Modifications of conventional sand drying beds and the intensive utilization of solar energy for sludge drying will reduce required drying time by 30%. Heating of sludge improves its characteristics such as increasing organic content and reducing pathogenic content. The reduced sludge is suitable for land application practices (Radaidah and Al-Zboon 2011). Advanced sludge treatment (AST) processes such as thermal hydrolysis and pre-oxidation have been developed to improve sludge dewatering and to facilitate ultimate disposal. The implementation of these methods in wastewater treatment plants: slightly reduces or increases the filtration rate, decreases the amounts of dry solids (DS) to be dewatered, and increases the DS content in the dewatered cake. AST methods degrade the extracellular polymeric substances (EPS) in two ways: degradation of the ESP reduces their water retention properties thereby releasing the EPS-bound water and increasing the dewatering efficiency of activated sludge, degradation of the EPS reduces cell stability but increases the size of sludge flocs. The presence of a net surface charge on sludge surfaces creates electrostatic repulsion that prevents close contact of sludge micro-organisms. These repulsive interactions are minimized in the pH range of 2.6-3.6, near the isoelectric point, so that the dissociation constant of sludge flocs is also at a minimum. For this reason, the flocculation of activated sludge improved as the pH decreased. The improved flocculation phenomena (bridging, ionic action) moreover reduce the amount of fine floc, thus facilitating cake dewatering. This statement was underlined by conducting experiments on the size of the distribution of sludge samples treated by different AST methods (Neyens et al. 2004).

Composting

Composting is a cost-effective and environmentally sound alternative for the stabilization of wastewater biosolids. Increasingly stringent air pollution regulations and biosolids disposal requirements coupled with the anticipated shortage of available landfills have accelerated the development of composting as a viable sludge management option. Sludge is composting aims at biologically stabilizing sludge while controlling pollution risks to develop agriculture or another end-use outlets exploiting the nutrient or organic value of sludge. It can be applied either to non-digested sludge or digested sludge. Composting is a process in which organic material undergoes biological degradation to a stable end product. As the organic material in the sludge decomposes, the compost heats to temperature in the pasteurization range of 50 to 70ºC and enteric pathogenic organisms are destroyed. Although composting may be accomplished under anaerobic or aerobic conditions, essentially all municipal wastewater biosolids composting applications are under mostly aerobic conditions. Aerobic composting accelerates material decomposition and result in the higher rise in temperature necessary for pathogen destruction. Aerobic composting also minimizes the potential for nuisance odors. The composting process involves the complex destruction of organic material coupled with the production of humic acid to produce a stabilized end product. During the composting process, the three separate stages of activity and associated temperature are observed: mesophilic, thermophilic, and cooling. During the initial mesophilic stage, the temperature in the compost pile increases ambient to 40 ºC with the appearance of fungi and acid producing bacteria. As the temperature in the composting mass increases to the thermophilic range of 40-70ºC, these microorganisms are replaced by thermophilic bacteria, actinomycetes, and thermophilic fungi. The cooling stage is characterized by a reduction in microbial activity, and replacement of the thermophilic organisms with mesophilic bacteria and fungi (Metcalf & Eddy 2003). The addition of bulking agents such as straw, woodchips, and sawdust to municipal sludge mixture resulted in a reduction of the moisture content and an increase of the organic matter C/N ratio and significantly increased air-filled porosity (Malińska and Zabochnicka 2013). Vermicomposting is an innovative technology for the treatment of wastewater sludge. It can be one of the most environmentally sustainable solutions, providing valuable humus as the outcome of the process, another advantage of vermicomposting is the relative low-level investment. The further advantages of vermicomposting are reducing the number of pathogens, increasing the hummus and nutrient contents, and decreasing the heavy metals content of compost, this is probably due to the fact that these compounds are accumulated in the bodies of earthworms, which at the end of the process are removed from the finished product (Suleiman et al. 2017; Kasza et al. 2015). The most important disadvantages of the technology are that the worms utilized for vermicomposting, while can adapt to sewage sludge of different sources, require some basic conditions for living in and reproduction. Composting offers several advantages in comparison with other treatment methods, such as control of compost material specifications, which results in a well-defined, stable end product composition with the potential of improving the soil humus layer and nutrient levels, control of nutrient content as defined by application and vegetation standards, and product hygiene control before agricultural application (European Environmental Agency 1997).

Incineration

Incineration is the sludge stabilization process which provides the greatest volume reduction. The residual ashes volume is usually less than 4% of the dewatered sludge volume fed to incineration (Andreoli et al. 2007). Incineration is a two-step process involving drying and combustion. In addition to fuel and air, time, temperature, and turbulence are necessary for a complete reaction. The two major incineration systems employed are the multiple hearth furnace and the fluidized bed incinerator. Incineration of sludge involves the total conversion of organic solids to oxidized end products, primarily, carbon dioxide and ash. The major advantages of incineration are maximum volume reduction, destruction of pathogens and toxic compounds, and energy recovery potential. On the other hand, the disadvantages of incineration include high capital and operating cost, highly skilled operating and maintenance staff are required, the residual produced (air emissions and ash) may have adverse environmental effects. Sludge may be incinerated separately or in combination with municipal solid wastes. Combustion emissions of particular concern are particulates, oxides of nitrogen, acid gases, hydrocarbons and heavy metals Metcalf & Eddy 2003). A new thermochemical process for sewage sludge ash treatment was developed that transforms the ash into marketable fertilizer products. Sewage sludge ash was thermochemically treated with sodium and potassium additives under reducing conditions, whereby the phosphate-bearing mineral phases were transformed into plant available phosphates (Herzel et al. 2016). Sewage sludge incinerators potentially emit significant quantities of pollutants. The major pollutants emitted are particulate matter, metals, carbon monoxide (CO), nitrogen oxides (NOX), sulfur dioxide (SO2), and unburned hydrocarbons. Partial combustion of sludge can result in emissions of intermediate products of incomplete combustion (PIC), including toxic organic compounds. Atmospheric emissions from incinerators are controlled by optimizing the combustion process and using air filters (Andreoli et al. 2007).

Sludge Disposal

In developing an optimum conceptual design for a wastewater treatment plant, it is significant that the determination of the method of final disposal is a major consideration. The method of final disposal determines the acceptable form of sludge residue and thus influences the choice of both sludge and liquid unit process to be employed. The acceptable form of sludge for disposal or utilization is partially determined by the sludge treatment method. The sludge may be in the form of a liquid, dewatered cake, incinerator ash, compost product, or dried powder (USEPA 1974). The method chosen should be in accordance with local requirements and should not result in any significant degradation of surface or groundwater, and air or land surface. The landfill method has been used for final disposal of sludge for many years, however, in the future,, the use of the landfill in EU countries will have the lowest priority in the waste hierarchy and will only be chosen when no other ways to dispose of sludge exist (European Environmental Agency 1997). The application of biosolids to land is a popular utilization method because it can be both economical and simple. Limitations include heavy metals, public resistance, and the unavailability of suitable land. Adequate monitoring of any landfill site or land application is essential. The monitoring plan should include groundwater observation wells, surface water, sludge and soil for heavy metals, persistent organics, pathogens, and nitrates.

Landfilling

Landfilling has become less desirable because of the reduced lifetime of landfill sites resulted from an overloaded leachate system. In Europe, because of the public dissatisfaction and ban on the landfilling of organic wastes, the portion of sludge ending up in landfills is expected to decrease significantly, from 14% in 2010 to 7% in 2020 (European Commission). If an acceptable site is convenient, landfilling can be used for disposal of sludge; stabilization may be required depending on local regulation. Dewatering of sludge is usually required to reduce the volume to be transported and to control the generation of leachate from the landfill (Metcalf & Eddy 2003).

Application of Biosolids to Land

Land application is currently one of the most favored alternatives for sludge treatment. In European member states, approximately 40% of sludge generated is applied to agriculture land. Land application is also the most widely used process for sludge treatment in the USA, where around 55% of the municipal wastewater sludge is ending up on land (Zhang et al. 2014. Over the years, land application has been increasingly managed to protect human health and environment from various potentially harmful constituents typically found in sewage sludge, such as bacteria, viruses, and other pathogens; metals (e.g., cadmium and lead); toxic organic chemicals (e. g., PCBs); and nutrients (e.g., nitrogen as nitrate). Biosolids may be applied to agriculture land, forest land, disturbed land, and dedicated land disposal sites. In all four cases, the land application is designed with the objective of providing further biosolids treatment. Sunlight, soil microorganisms, and desiccation combine to destroy pathogens and many toxic organic substances. Trace metals are trapped in the soil matrix, and nutrients are taken up by plants and converted to useful biomass. The application of biosolids to land for agricultural purposes is beneficial because organic matter improves soil structure, water holding capacity, water infiltration and soil aeration, also macronutrients (nitrogen, phosphorus, potassium) and micronutrients (iron, manganese, copper, chromium, selenium, and zinc) aid plant growth (Metcalf & Eddy 2003). Varying climatic and soil conditions, as well as varying sludge composition, require evaluation for a variety of sludge with the optimum combination of soil and vegetation (USEPA 1978). Biosolids must meet regulatory requirements for stabilization, nutrient contents, and metals content.

The constraints for application of municipal sludge to land include geographical, climatic, agriculture and groundwater (USEPA 1995a). *Geographical Constraints*: Sludge cannot be safely applied to steep slopes, to areas where it is likely to contaminate water resources or other particular features of the landscape. Ideal sites for land application of biosolids have deep silty loam to sandy loam soils, groundwater is deeper than 3m, and the slope at 0 to 3 percent, no wells, wetlands, or streams (Metcalf & Eddy 2003). *Climatic Constraints*: Seasonal variation in rainfall, temperature, wind and other climatic factors are an important consideration in sludge application. Heavy rainfall may generate leachate and erosion, high temperatures increase soil salinity, and high wind may lift dried sludge and cause dust. *Agriculture Constraints:* It is necessary to coordinate the timing of sludge applications with planting, grazing or harvesting. Under European regulations, no gazing is permitted for three weeks after treated sludge has been applied to grassland and the sludge must be injected into the soil instead of spread on the surface. Treated sludge can only be applied to cereal crops' turf, but not for three months before harvesting, and fruit trees but not for ten months before harvesting. Untreated sludge can only be injected into the soil before planting. *Groundwater constraints:* Groundwater is recharged by infiltration of water from the land surface, the vulnerability of an aquifer system to pollution as well as the current and future uses of the system need to be determined to assess the potential risk of bio solid application. Key factors to be considered are the level of pathogen reduction and nutrient content of the bio solids product, the proposed bio solids loading rate and the potential effects of other land practices within the aquifer recharge area.

Regulations for Land Application

Management stringent compliance criteria have been set by environmental agencies, around the world, and to manage the safe practice of land application. In 1993, the U.S. Environmental Protection Agency (USEPA) promulgated 40 CFR Part 503, Standards for the Use and Disposal of Sewage sludge, to address the Clean Water Act's (CWA) requirements. The CWA required that this regulation protect public health and environment from any reasonably anticipated adverse effects of pollutants in sewage sludge. The 40 CFR Part 503 regulations divide the quality of bio solids into two categories: Class A biosolids must meet specific criteria to ensure they are safe to be used by the general public and for gardens. Class B bio solids have lesser treatment requirements than class A, and typically are used for application to agricultural land or disposed in a landfill. The rule requires that the density of fecal coliforms is less than 1,000 Most Probable Number (MPN) per gram total solids (dry weight) or that Salmonella sp. Bacteria be less than 3 MPN per 4 grams of total dry solids (USEPA 1995a). The European Union Council Directive 86/278/EEC 86/278/EEC on the use of sludge in agriculture defines in Article 2(a) that sewage sludge is: "(i) residual sludge from sewage sludge plants treating domestic or urban wastewaters and from other sewage plants treating wastewaters of a composition similar to domestic and urban wastewaters; (ii) residual sludge from septic tanks and other similar installation for the treatment of sewage; (iii) residual sludge from sewage plants other than those referred in (i) and (ii)". All the EU Member States have transported the European limits of Directive 86/278/EEC for sludge use in agriculture into their own regulations. Since its adoption, several Member States have enacted and implemented stricter limit values for heavy metals. The directive seeks to encourage the use of sewage sludge in agriculture. At the same time, it regulates its use in such a way that any potential harmful effect on soil, vegetation, animals and human beings is prevented (Colón et al. 2017). In general, EU legislation on sewage sludge is based on the precautionary scheme, and the limits set for its agricultural use are in general stricter than EPA's. Legislations on sewage sludge management tends to incorporate issues related to the environmental protection, public health, climate change impacts and socio-economic benefits (Colón et al. 2017). Some MENA countries have established guidelines for sludge management, including maximum permissible limits for heavy metals and pathogens in biosolids, maximum concentrations in soil and maximum application rates that have to be fulfilled for biosolids application to be permitted. In 2002 Syrian Arab Organization for Standardization and Metrology (SASMO) issued Syrian National Standard (NSN No. 2002/2665) titled:" Allowable Application of Municipal Biosolids Products" (Dimashki et al. 2003). Egyptian Standards Directive 254/2003 was issued in 2003 for the bases and specification of the treatment, handling and safe reuse of sludge (Ghazy et al. 2009). The Jordanian standard (JS: 1145/1996) was issued in 1996 and updated in 2006 to regulate the production and reuse of biosolids for agriculture purposes, there still are no systematic data on the quality and quantity of biosolids generated (Suleiman et al. 2010). Table 1 summarizes some standards for maximum permissible limits of heavy metals (dry weight) mg/kg d.w. for land application from some countries. Table 2 shows classifications of biosolids according to their contents of heavy metals (mg/kg d.w.) according to SNS No. 2002/2665 class A for unrestricted use, B, C and D for three types of restricted use (Table 3).

Metal	86/278/EEC (range)	USA (part 503)	Syria(a) SNS No. 2002/2665	Egypt (b)	Oman (c)	Jordan (d)
Zn	2500-4000	7500	3000	2800	1000	7500
Cu	1000-1750	4300	1000	1500	1000	4300
Ni	300-400	420	200	420	200	420
Cd	20-40	85	20	39	30	85
Pb	750-1200	840	800	300	1000	840
Cr	-	3000	1000	1200	1000	3000
Hg	16-25	57	-	17	-	57
Mo	-	-	30	18	20	75
As	-	-	-	41	-	75
Co	-	-	-	-	100	-

a- SNS No. 2002/2665 b- Egyptian Standards Directive 254/2003 c- Regulations for wastewater re-use and discharge (1986) d-Jordanian standard JS: 1145/2006

Table 1: Maximum permissible limits of heavy metals for land application, EU, US and some MENA countries (mg/kg d.w.) (USEPA 1995a; Inglezakis et al.; Dimashki et al. 2003; Ghazy et al. 2009; Suleiman et al. 2010; Regulations for wastewater re-use and discharge 1986)

Metal	Category (mg/kg d.w.)			
	A	B	C	D
Zn	200	700	2500	2800
Cu	100	375	1500	1500
Ni	60	125	270	300
Cd	3	5	20	32
Pb	150	150	300	400
Cr	100	250	500	600
Hg	1	4	15	19
Se	5	8	50	90
As	20	20	20	30

Table 2: Classification of biosolids according to their contents of heavy metals (mg/kg d.w.) SNS No. 2002/2665 (Dimashki et al. 2003)

Category	Possible applications*	Degree of restriction
A	1-8	Unrestricted use
B	2-8	Restricted use I
C	4-8	Restricted use II
D	5-8	Restricted use III

*1- Home gardens, 2- Public gardens, 3- grasslands and landscapes, 4- Agriculture, 5- Forests, 6- Reclaimed soils and landfills, 7- sanitary landfill, 8- landfills within the premises of wastewater treatment plants

Table 3: Possible application of processed municipal sludge according to its classification of heavy metals content (Dimashki et al. 2003)

The preliminary estimates of sludge application for different types of land can be obtained from table 4.

Type of land	Frequency	Rates of application (tonnes/ha, d.w.)	
		Range	Average
Agricultural	Annual or twice annual	2-70	10
Afforested	Annually or at 3-5 years intervals	10-220	18
Reclamation sites	One time	7-450	112

Table 4: Preliminary estimates of sludge application (dry weight) for different types of land (USEPA 1995a)

In Jordan, only the As-Samara plant stabilizes the biosolids using anaerobic digestion. All other plants, sludge is thickened to different degrees and either dried in solar drying beds or hauled as liquid sludge for disposal. All dried biosolids are either sent to landfill or stored on site (Suleiman et al. 2010), biosolids are characterized in the Jordanian Standard JS: 1145/2006 as Types I, II and III. Table 5 shows heavy metals, physical and pathogenic concentration requirements for each type. Currently, there are no advanced sludge treatment techniques to produce Type I biosolids that have been certified as acceptable in Jordan.

Parameter	Unit	Concentration		
		Type I	Type II	Type III
AS	mg/kg d.w.	41	75	75
Cd	mg/kg d.w.	40	40	85
Cr	mg/kg d.w.	900	900	3,000
Cu	mg/kg d.w.	1,500	3,000	4,300
Hg	mg/kg d.w.	17	57	57
Mo	mg/kg d.w.	75	75	75
Ni	mg/kg d.w.	300	400	420
Se	mg/kg d.w.	100	100	100
Pb	mg/kg d.w.	300	840	840
Zn	mg/kg d.w.	2,800	4,000	7,500
Total Solids (TS)	%	90	10	3
Fecal Coliforms	MPN/g d.w.	<1,000	<2,000,000	NR
Salmonella	MPN/4g d.w.	<3	NR	NR
Intestinal Pathogenic Nematodes	Eggs/4g d.w.	<1	NR	NR
Enteric Viruses	PFU/4g d.w.	<1	NR	NR

NR: No Requirements

PFU: Plaque Forming Unit

Table 5: Requirements for biosolids Types in JS: 1145/2006 (Suleiman et al. 2010).

However, there are several issues associated with the reuse of municipal sludge in agriculture. The risk of contamination of soil and water, in addition to the risk of emission and transport of bioaerosols containing pathogens following land application of biosolids are among the main concerns (Colón et al. 2017). The characterization of an urban sewage sludge produced at the wastewater treatment plant of Korba, Tunisia showed that the heavy metals concentrations in the produced biosolids respect the Tunisian Standards for land application (NT 106.20, 2002). The C/N ratio was equal to 15 indicating that the nitrogen supplied by this sludge provides a good decomposition of the organic matter, which is an important indicator to improve the fertility of agriculture soils (Zoghlami et al. 2016). The municipal sludge is a potential source for the production of renewable energy in Morocco, and the process of anaerobic digestion presents a reliable solution for the treatment of municipal sludge, the produced sludge can be used for land application (Bellhadj et al. 2013).

Public health and Environmental Issues

Many wastewater treatment plants do not include sludge management within their treatment scheme, and until recently, sanitation projects have started to consider them as part of the overall program. In many cases, sludge is applied, disposed or discharged without any treatment and sometimes it is just air dried. In general, environmental cost is often seen as the fees that are paid for some ecological damages. In addition, some other factors are not considered when valuing the environmental cost of sludge management. Some of these factors include potential saving in the economic resources destined for public health, particularly to treat waterborne diseases; a decrease in the use of chemical fertilizers for crop production; and a reduction of land degradation (Jimenez et al.). US EPA conducted three comprehensive risk assessments for pollutants in biosolids that are land applied, surface disposed, or incineration. The risk assessments evaluated risks to human health through relevant exposure pathways for each of the use or disposal practices, as well as ecological risks to animals and plants for land application and surface disposal. Using appropriate parameters that represented relevant data and assumptions, the risk assessments quantitatively identified allowable concentration or application rates of pollutants in biosolids that are used or disposed to protect human health and the environment from reasonably anticipated adverse effects (USEPA 1995b).

Case studies in sludge management in some countries in MENA region

Syria: Syria has started in the early 1990s a huge program for constructing and operating wastewater treatment plants in urban and rural areas. Activated sludge is widely used in the major cities, while extended aeration is mostly used in the rural communities. Damascus wastewater treatment plant used activated sludge system and treated 200,000 to 300,000 m^3/d. The mixture of primary and secondary sludge is fed to the thickening of sludge tanks. The thickened sludge is about 2400 m^3/d pumped to anaerobic digesters. The retention time in these anaerobic digesters is 19 days at 36 ºC. This process produces stabilized sludge of approximately 43 g/L TSS and about 23,000-25,000 m^3 of biogas (70-75% CH_4, 20-25% CO_2 and some residual H_2S). Produced biogas is stored in a floating top of the collection tanks and is used for the generation of hot water and electricity. Then, the produced stabilized sludge is spread over 120 sun-drying beds, until it is completely dry and stayed there for about 6 months until complete stabilization of the sludge and elimination of pathogens. Fig. 1 shows flow diagrams for sludge treatment at Damascus wastewater treatment plant. Approximately between 70-100 m^3/d of dry sludge is produced and distributed to farmers (Dimashki et al. 2003). Conventional activated sludge is used in Homs wastewater treatment plant. A polyelectrolyte solution is added to the thickened sludge and then dewaters by a filter press to produce a sludge cake of 70-75% water content. Approximately, between 200-300 m^3/d of sludge, is produced by Homs wastewater treatment plant. In the original design of the plant, produced sludge should be spread at a shallow depth of 20 cm for 15 days and then pilled at heights of 3m for few months before distribution as a soil conditioner. However, due to certain restrictions which were imposed on the utilization of the sludge, produced sludge is stored in the sludge holding area before being transported to the dumping site located about 70 km east of Homs Fig.2. The quality of sewage sludge generated by Damascus, Homs, Aleppo and Salamiah wastewater treatment plants, in terms of heavy metals, meets the national and international standards (Table 5) and can be applied with safe margin on agricultural lands and used as a soil conditioner in land reclamation and on desert lands of poor soil quality (Dimashki et al. 2003). Conventional extended aeration represents a suitable method for small wastewater treatment plants in rural areas in Syria. It is a simple system eliminating primary wastewater treatment and sludge anaerobic digestion from the overall treatment system. Produced sludge is well stabilized. Fig. 3 illustrates sludge treatment method applied at small wastewater treatment plants, stabilized sludge is thickened in gravity thickeners and then dried in the drying bed.

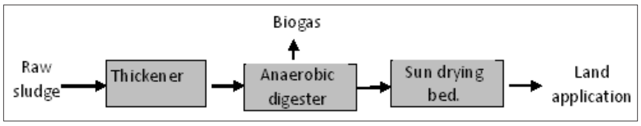

Figure 1: Sludge treatment at Damascus (Syria), wastewater treatment plants, used conventional activated sludge.

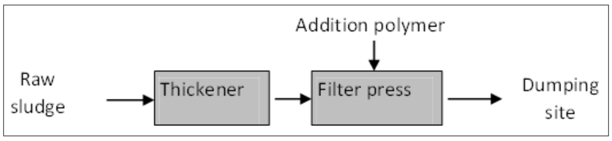

Figure 2: Sludge treatment at Homs (Syria) wastewater treatment plant used conventional activated sludge.

Metal	Damascus	Homs	Aleppo	Salamiah	standards
Zn	649	1091	1025	1123	3000
Cu	114	428	230	142.8	1000
Ni	13.5	44	78.4	45.3	200
Cd	1.1	4.1	2.3	3.57	20
Pb	122.8	106	71.6	45.5	800
Cr	36.6	17.3	29.5	87.3	1000

Table 6: Concentration of heavy metals in the sludge produced from some wastewater treatment plants in Syria (mg/kg d.w.) (Dimashki et al. 2003)

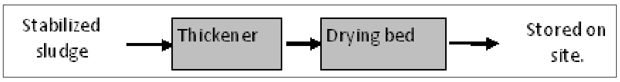

Figure 3: Sludge treatment at small wastewater treatment plants in Syria which used extended aeration treatment system.

Egypt: like in other MENA countries there are continuously increasing in sewage sludge production from wastewater treatment plants in Egypt. Therefore, and currently the main topic and needs in Egypt is to control using treaded municipal sludge in sustainable and safe in agriculture and to improve soil characters by improving sludge treatment process and its disposal methods. Sewage sludge treatment and disposal technologies implemented in Egypt since long time are very limited and old. As the main aim of sludge treatment was depending on natural drying in sludge drying bed without sludge quality control produced from this method. (Ghazy et al. 2009).

Recently, and under supervision from Holding company of water and wastewater in Cairo, there are several innovations technologies are applied in this field as new scenarios for sewage sludge treatment, which have been developed and improved in many wastewaters treatment plant in Egypt to improve sludge quality for reuse purposes in agriculture to include aerobic and anaerobic stabilization processes, and other treatment technologies. The most common scenario for sewage sludge treatment and disposal that is applied in most of existing WWTPs in Egypt is presented in Fig 4 where the primary and secondary sludge is pumped to thickening facilities, the solids are concentrated to 4-6% d.w. the thickened sludge is pumped to natural dewatering units (drying bed facilities) where it is drying to the concentration of 40-60% d.w The sludge characteristics and management in Egypt indicated that concentration of heavy metals (Zn, Cu, Pb, Cd, Cr, As, Hg, and Ni) in sludge vary widely. Generally, the sewage sludge produced from the Egyptian wastewater treatment plants did not have high heavy metals concentration except in few cases, which can be attributed to irregular contribution from industrial areas (Ghazy et al. 2009).

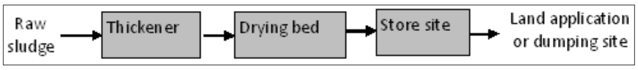

Figure 4: The most common sewage sludge treatment scenario applied in Egypt.

Stabilization process using anaerobic digestion has been applied in Gabel Asfer WWTP (Fig. 5) which is the biggest wastewater treatment plant in Egypt, the large portion of the produced biogas is used for the operation of hot water boilers, which are operated to heat the raw sludge in the primary digesters, the excess produced biogas is used to generate electricity in WWTP (Shareef .2019).

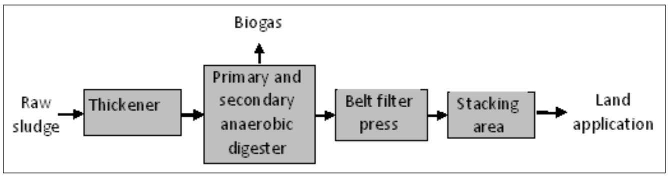

Figure 5: Sludge treatment WWTP- Asfar Egypt.

Stabilization process using windrow composting is recently applied as a pilot project in the Al Berka WWTP in Cairo. Fig. 6 shows the general flow diagram of the sludge treatment and disposal using windrow composting in Al Berka WWTP. A mixture of dried sludge produces at Al Berka WWTP drying beds, and rice straw are composted in long parallel rows (stacking).

According to the Egyptian conditions (dry and warm weather most of the year), good bacteriological results were achieved in the produced compost as evaluated by several laboratory analysis (Ghazy et al. 2009).

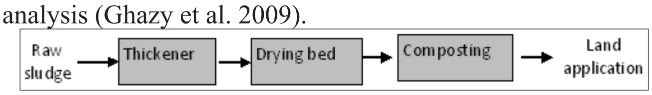

Figure 6: Sludge treatment using windrow composting in Al Berka WWTP in Egypt

The aerobic biological treatment-stabilization for sewage sludge in Egypt showed higher negative impact for the environment, this was indicated by the environmental assessment of sewage sludge treatment processes. While anaerobic biological digestion showed a positive enhancement in all environmental categories impacts considering the effect of avoided emissions resulting from the avoided electric energy generation. The environmental impacts of mechanical dewatering facility using belt filter press (BFP) dewatering process were significantly higher in the toxicological risk on human health and ecosystem. The application of windrow composting process using the rice straw as a bulking agent has a positive effect on the global warming potential, the depletion of abiotic resources and the photochemical oxidation (Ghazy et al. 2011).

Jordan: In Jordan 85% of the population are being served by WWTPs use activated sludge or trickling filters, most of the wastewater treated at two newly constructed activated sludge plants in Aqaba (South Jordan) and As-Samra (Jordan center). As-Samra facility is the largest plant in Jordan and serves about 3.0 million habitants. The sludge is treated by mesophilic anaerobic digestion for 17-20 days, utilizing most of the generated biogas for energy production and generating class B biosolids as per the USEPA Rule 503 requirements, or Type II according to the JS: 1145/2006. Sludge is dewatered using belt filter press and drying beds as Fig.7 shows, then stored on site for future reuse for land application. All other wastewater treatment plants use thickening of sludge to different degrees and either drying in solar drying beds or hauling as liquid sludge for disposal, Fig. 8 shows flow diagrams for sludge treatment for Jerash Ramtha and Kufranjeh Cities. Drying is usually practiced in the summer months between May and September. The drying technique becomes a challenge during the rainy and cold winter months from October to April. All dried biosolids are either sent to landfills (dumping ground) or stored on site (Suleiman et al. 2010).

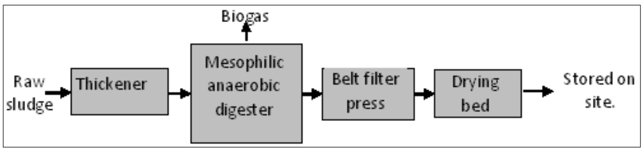

Figure 7: Sludge treatment at As-Samra (Jordan), wastewater treatment plants, used conventional activated sludge.

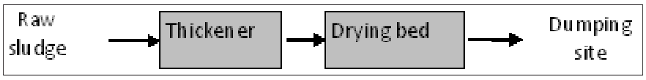

Figure 8: Sludge treatment at Jerash (Jordan) WWTP used conventional activated sludge.

Trends in sludge management

Increasing the sludge amount which is produced by wastewater treatment plants by more implementation of more wastewater treatment plants and the revolution in the Industrial sector in many countries. This increasing in wastewater sludge ad municipal and industrial make the sludge management more complex. Therefore, more stringent regulations are needed to control the sludge disposal methods. This needs to improve the biological treatment stage to improve sludge quality which be enforced to minimize adverse sanitary also to protect the environment and its impacts. Recently and for sludge disposal many countries acknowledged that sludge is a value and organic and phosphorus recovery is an important subject worldwide. Since the phosphorus resources are limited in nature. In other hand, landfill disposal is not a sustainable practice, according to the economic reasons as transportation cost and land availability are an important issue in many countries. Therefore, recycling offers are the best future prospective worldwide because it is the most economical and environmentally adequate alternative (Andreoli et al. 2010). Sludge type produces from municipal and Industrial wastewater treatment process in wastewater treatment plants especially in biological treatment process should be improved in every treatment plant to meet the requested sludge quality. Then all management methods will be ecologically and economically justified. Different processes using thermal hydrolysis (neutral, acid, alkaline) or chemical oxidation (H_2O_2, O_2, O_3) have been applied to improve sludge dewatering and facilitate the ultimate disposal (Neyens et al. 2004). A group of scientists and operators from different countries developed an integrated system for sustainable management of sludge. The system consists of three main steps: anaerobic sludge treatment or anaerobic digestion which leads to produce gases and then energy to use it in the operation of the wastewater treatment plants and to recover more energy needs. This will reduce the treatment and disposal cost and to use it in the second step of sludge dewatering and drying where sludge is treated to obtain the characteristics necessary for subsequent thermal treatment by Pyrolysis/Gasification, where useful materials are obtained and/or energy is recovered (Spinosa et al. 2011). The system can be adapted to different local situations. On the other hand, it was agreed that land application of biosolids is the most sustainable alternative. This requires treatment, particularly disinfection and strict regulations, concerning the quality of biosolids to be used.

Conclusion

Sustainable sludge management is an important issue in MENA countries, where the treatment technologies have to be adapted to local conditions based on sociocultural, technological, economic, environmental and geographical restrictions. The evaluation of alternatives for municipal sludge treatment and final disposal is usually complicated and expensive. Also, the final sludge disposal is often neglected in the conception and design of wastewater treatment plants. The crucial issues in municipal sludge treatment and disposal include:

1. Municipal sludge reuse for biogas production, co-incineration, biosolids production and compost production.
2. The construction of facilities for treatment and disposal of sludge, control of treated sludge quality and decrease of its risk also monitoring the sludge environmental risk assessment.
3. Implementation of new and innovative sludge treatment process and sludge disposal technologies. This is to meet the reuse requirements and regulations.

Main methods for sludge treatment in MENA countries include thickening, natural drying, and either dumping or land application. More attention to improve sludge management may include expanding in the use of mechanical dewatering equipment and polymers, the use of stabilization processing of biological treatment to improve sludge quality and increasing the reuse in agriculture or for land applications.

Application of treated sludge to land provides essential nutrients for plant growth and reduces environmental and economic considerations that limit the disposal in landfills or incineration. However, a careful assessment of the characteristics of soil and biosolids is required. Application of treated sludge to land provides essential nutrients for plant growth and reduces environmental and economic considerations that limit the disposal in landfills or incineration. However, a careful assessment of the characteristics of soil and biosolids is required before land application as well as minimizes the potential adverse impact of long-term biosolids land application. Legislations related to sludge treatment and disposal is achieved by intensive studies that range from sludge characterization to demonstration projects would provide valuable information that will help support regulations, and if applicable, adopt or adapt the appropriate foreign limits. Regulations should consider both the quality of the sludge and the application procedures that guarantee the safe reuse of this product. Also, adequate monitoring and enforcement policies are essential for future sludge management programs.

Recommendation

Future trends on municipal sludge treatment and management depend on local conditions and economic evaluation, in addition to assessment of environmental and social impacts. Climate change policy and renewable energy will also influence sludge management. One of the most interesting topics in selecting sludge treatment and disposal alternatives is the application of cost-benefit analysis, environmental impact assessment, or life cycle assessment. Future of the wastewater treatment and disposal worldwide is an important topic and must take in account the developments process and implementation of innovation technologies also the same for sludge treatment and sludge disposal business also there are many technologies for sludge treatment and disposal are already applied in the MENA region but this still individual applications or pilot projects which cannot meet the market requirements.

Technologies transfer from several countries with good experience in sludge management are needed for the MENA region as there a lake in experience in this field. German experience in sludge management can be a good lessen learn. New techniques in sludge treatment and disposal, for phosphorus recovery from sewage sludge and incineration ash, are in application and development and must become the most common sludge treatment technologies established in Germany and other European countries the next few years. The sewage sludge and waste management chain should be adapted and adjusted to changing costs of treatment and disposal accordingly. Also using treaded and good sludge quality as fertilizer for plants also to improve the agriculture soil is an important topic for reuse of sludge and recycle the nutrients in the nature.

The German Agency of environment announced to avoid using industrial sludge as fertilizer in the long term as the future option is to recover phosphorus from industrial and municipal sludge ash. It also provides an overview of the current situation and developments as well as of the future options in sewage sludge treatment and disposal in Germany to be guide sludge management experts.

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