APPLICATION OF THE TREATMENT SYSTEM BY STABILIZATION PONDS IN ARID AND SEMI-ARID REGIONS CASE STUDY: DESIGNING A TREATMENT PLANT FOR THE CITY OF SEBHA

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Abstract:

The establishment of a large number of urban drainage collection and treatment systems for the purpose of protecting public health and the environment and reusing the treated water to be a supplementary and sustainable water source has accompanied the urban growth processes in the Libyan regions during the past five decades. The urban wastewater treatment techniques as well as the performance levels of these systems varied greatly, but they all deteriorated and stopped completely after a short period of operation.

This paper aims to apply a wastewater treatment system in effective natural ways that do not rely much on technical skills to operate it in a manner that is characterized by simplicity of operation and maintenance. This system of treatment is known as the system of treatment by stabilization ponds (WSP). The stabilization pond treatment system is a natural and sustainable method for wastewater treatment that can be effective in arid and semi-arid regions. This system involves the use of ponds to treat wastewater through a combination of physical, chemical, and biological processes. The wastewater is first treated in anaerobic ponds, where microorganisms break down the organic matter in the absence of oxygen. Then, the wastewater is transferred to facultative ponds, where aerobic and anaerobic microorganisms further break down the remaining organic matter. Finally, the wastewater is treated in maturation ponds, where algae and other microorganisms remove the remaining nutrients. This system is low-cost and requires minimal energy inputs, making it an attractive option for areas with limited resources ،the application of this system in arid and semi-arid regions can help to address the challenges of water scarcity and wastewater management. Information was collect about the design of the treatment plant for Sebha city, which included the current and future population census of the city of Sebha, in addition to collecting wastewater samples to identify the characteristics of the existing wastewater.

Keywords: extension, maturation ponds, medullisation, waste stabilization ponds, wastewater.

الملخص

على مدى العقود الخمسة الماضية، صاحب النمو الحضري في المناطق الليبية إنشاء العديد من أنظمة جمع ومعالجة مياه الصرف الصحي. تهدف هذه الجهود إلى حماية الصحة العامة والبيئة، مع إعادة استخدام المياه المعالجة كمصدر مائي تكميلي ومستدام. ومع ذلك، على الرغم من هذه المبادرات، تدهورت العديد من أنظمة معالجة مياه الصرف الحضري وتوقفت عن العمل بعد فترة قصيرة من تشغيلها، وذلك إلى حد كبير بسبب التحديات التقنية وعدم كفاية الصيانة.

يقدم هذا البحث نظامًا طبيعيًا وفعالًا لمعالجة مياه الصرف الصحي يتميز بالبساطة في التشغيل والصيانة، مما يجعله متاحًا حتى للمجتمعات التي تمتلك مهارات تقنية محدودة. يُعرف هذا النظام بنظام البرك الاستنادية لمعالجة المياه(WSP) ، وهو مناسب بشكل خاص للمناطق الجافة وشبه الجافة.

يستخدم نظام البرك الاستنادية سلسلة من البرك اللاهوائية، والبرك الاختيارية، وبرك الإنضاج لمعالجة مياه الصرف من خلال مزيج من العمليات الفيزيائية، الكيميائية، والبيولوجية. في البرك اللاهوائية، تقوم الكائنات الدقيقة بتحليل المادة العضوية في غياب الأكسجين. يتم بعد ذلك نقل المياه العادمة المعالجة جزئيًا إلى البرك الاختيارية، حيث تواصل الكائنات الهوائية واللاهوائية تحلل الملوثات العضوية وأخيرًا، تستكمل برك الإنضاج المعالجة حيث تقوم الطحالب والكائنات الدقيقة الأخرى بإزالة المغذيات المتبقية. هذا النظام منخفض التكلفة وذو كفاءة في استهلاك الطاقة، مما يجعله خيارًا جذابًا للمناطق التي تعاني من نقص الموارد حيث تم جمع البيانات لدراسة حالة تصميم محطة معالجة لمدينة سبها، والتي تضمنت التعداد السكاني الحالي والمستقبلي، بالإضافة إلى جمع عينات مياه الصرف الصحي لتحديد خصائص المياه العادمة الحالية. إن تطبيق نظام البرك الاستنادية يمكن أن يوفر حلاً مستدامًا للتحديات الملحة المتعلقة بندرة المياه وإدارة مياه الصرف الصحي في مناطق مثل سبها.

الكلمات المفتاحية: البرك الاستنادية لمعالجة المياه، البرك اللاهوائية، البرك الاختيارية، برك الإنضاج، معالجة مياه الصرف الصحي، ندرة المياه.

Introduction:

The most effective wastewater treatment method is one that produces effluent meeting recommended microbiological and chemical quality guidelines while keeping costs low and minimizing operational and maintenance requirements (Arar, 1988). In developing countries, adopting a lower level of treatment is particularly desirable not only due to cost concerns but also because of the challenges of reliably operating complex systems. In many cases, it may be better to design the reuse system to accept lower-quality effluent rather than depend on advanced treatment processes that aim to continuously meet stringent quality standards.

1.1 Waste Stabilization Ponds (WSP):

Waste Stabilization Ponds (WSP) are now considered the method of choice for wastewater treatment in many parts of the world. For example, in Europe, WSP are widely used in small rural communities (serving populations of approximately up to 2,000, though larger systems exist in Mediterranean countries like France, Spain, and Portugal) (Boutin et al., 1987; Bucksteeg, 1987). In the United States, one-third of all wastewater treatment plants are WSP, typically serving populations of up to 5,000 people (EPA, 1983). In warmer climates such as the Middle East, Africa, Asia, and Latin America WSP are commonly used to treat wastewater for large populations, sometimes reaching up to 1 million people. In developing countries, particularly in tropical and equatorial regions, WSP systems are considered an ideal method that utilizes natural processes to improve sewage effluents.

1.2 Waste Stabilization Pond Systems:

Waste stabilization pond systems are designed to achieve different levels of treatment across up to three stages in series, depending on the organic strength of the wastewater and the effluent quality objectives. For ease of maintenance and flexibility in operation, most designs incorporate at least two parallel trains of ponds. Strong wastewater, with BOD5 concentrations exceeding 300 mg/l, is typically introduced into anaerobic ponds in the first stage, where a high volumetric removal rate is achieved (Mara, 2004). Weaker wastewater or stronger wastewater (with BOD5 up to 1000 mg/l), where anaerobic ponds are environmentally unacceptable, may be discharged directly into primary facultative ponds. Effluent from first-stage anaerobic ponds flows into secondary facultative ponds, which comprise the second stage of biological treatment. If further pathogen reduction is necessary after facultative ponds, maturation ponds are introduced to provide tertiary treatment (Mara & Pearson, 1998). Common pond system configurations are illustrated in Figure 1, though alternative combinations may also be used.

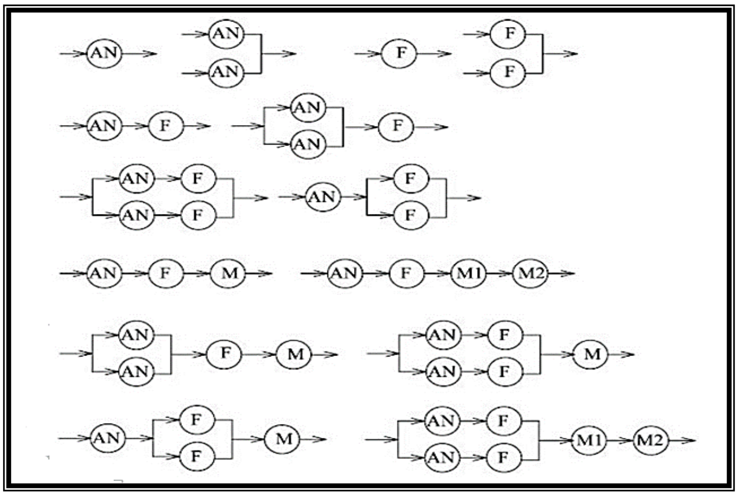

Figure (1): Stabilization Pond configuration: AN = anaerobic pond; F = facultative pond; M = maturation pond

Table 1 provides a comparison of the advantages and disadvantages of ponds with those of high-rate and low-rate biological wastewater treatment processes (note that Aerated Lagoon and WSP system are considered low-rate biological wastewater treatment processes). Stabilization ponds are the preferred wastewater treatment process in developing countries, where land is often available at reasonable opportunity cost and skilled labor is in short supply.

Table (1): Advantages and disadvantages of various sewage treatment systems (Arthur 1983)

	Criteria	Package Plant	Activated Sludge Plant	Biological Filter	Oxidation ditch	Aerated Lagoons	WSP system
Plant performance	BOD removal	Fair	Fair	Fair	Good	Good	Good
	SS removal	Fair	Good	Good	Good	Fair	Fair
	FC removal	Poor	Poor	Poor	Fair	Good	Good
	Helminth removal	Poor	Fair	Poor	Fair	Fair	Good
	Virus removal	Poor	Fair	Poor	Fair	Good	Good
Economic factors	Construction simplicity & cost	Poor	Poor	Poor	Fair	Fair	Good
	Land requirement	Good	Good	Good	Good	Fair	Poor
	Operational simplicity	Poor	Poor	Fair	Fair	Poor	Good
	Maintenance costs	Poor	Poor	Fair	Poor	Poor	Good
	Energy demand	Poor	Poor	Fair	Poor	Poor	Good
	Sludge removal costs	Poor	Fair	Fair	Poor	Fair	Good

BOD: Biological Oxygen Demand, FC: Faecal Coliform, SS: Suspended Solids, WSP: Wastewater Stabilization Ponds.

1.3 Types and Functions of Waste Stabilization Ponds:

Waste Stabilization Ponds (WSP) are classified based on the type of biological activity that takes place within them. There are three main types of ponds: anaerobic ponds, facultative ponds, and maturation ponds. Typically, a WSP system consists of a series of these ponds, either in a single sequence or in several parallel series. Before wastewater enters the pond system, it goes through preliminary treatment processes such as coarse screening, grit removal, and sometimes the shredding of large objects (Mara, 2004).

I. Anaerobic Ponds: Anaerobic ponds are deep ponds that treat wastewater by excluding oxygen, which promotes the growth of bacteria that break down organic matter in the absence of oxygen. These ponds function much like uncovered septic tanks. Anaerobic bacteria decompose the organic matter in the wastewater, producing gases such as methane and carbon dioxide as by-products (Pearson et al., 2009). Sludge settles at the bottom of the pond, while a crust forms on the surface, as shown in Fig. (2).

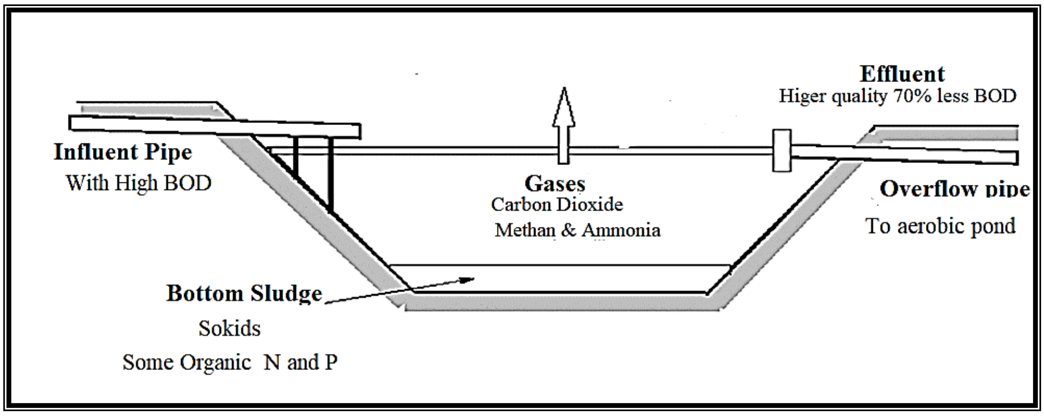

Figure (2): Operation of the Anaerobic Pond.

Anaerobic ponds are typically between 2 to 5 meters deep and handle a very high organic load, often exceeding 100 g of BOD per cubic meter (which is roughly equivalent to more than 3000 kg per hectare per day for a pond depth of 3 meters). Due to the high organic content relative to the limited oxygen available, these ponds maintain anaerobic (oxygen-free) conditions all the way to the surface. Interestingly, anaerobic ponds do not support algae growth, although you might sometimes notice a thin film of algae, primarily of the Chlamydomonas species, on the surface. These ponds perform particularly well in warm climates, achieving a Biological Oxygen Demand (BOD) removal efficiency of 60% to 85%. They also have relatively short retention times; for wastewater with a BOD of up to 300 mg/l, just one day of retention is sufficient when temperatures are above 20°C (Mara, 2004; Pearson et al., 2009).

II. **facultative ponds and secondary facultative ponds:** Primary facultative ponds receive raw wastewater, while secondary facultative ponds treat settled wastewater, typically the effluent from anaerobic ponds. These ponds are designed for BOD removal, using a lower surface loading (between 100 and 400 kg of BOD per hectare per day) at temperatures between 20°C and 25°C. The oxygen needed for the breakdown of organic matter by bacteria is primarily supplied through photosynthesis by algae. Because of the algae, facultative ponds are usually a dark green color, although they can occasionally appear red or pink, particularly when slightly overloaded. This color change is due to the presence of anaerobic, sulfur-oxidizing photosynthetic bacteria. The algae species that dominate in facultative ponds are generally motile, such as Chlamydomonas, Pyrobotrys, and Euglena, as their mobility allows them to adjust their position in the water column to optimize light and temperature conditions. Non-motile algae like Chlorella are also found in facultative ponds but are less dominant. In a healthy facultative pond, the concentration of algae typically ranges from 500 to 2000 micrograms of chlorophyll-a per liter, depending on the pond's organic load and temperature (Mara, 2004; Pearson et al., 2009).

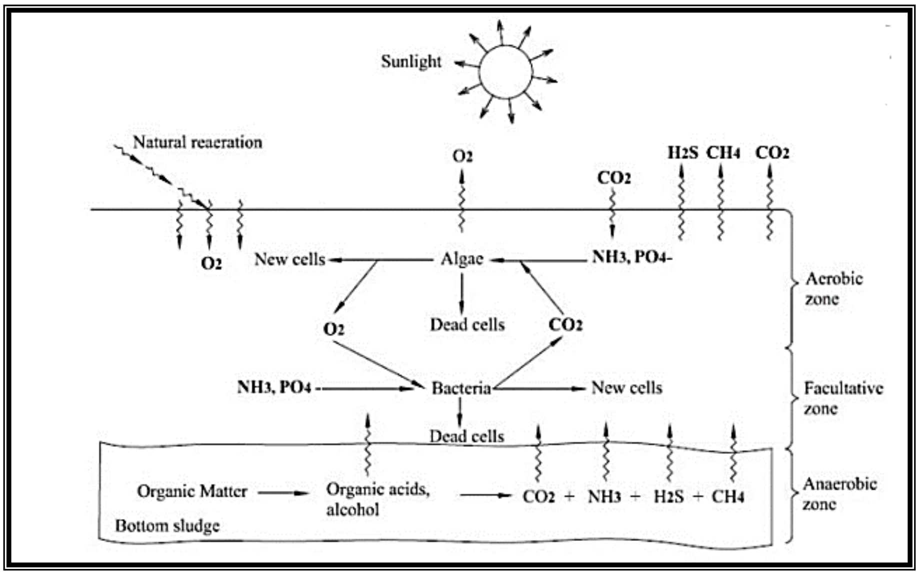

Figure (3): Schematic representation of Facultative Ponds

III. **Maturation or Polishing Ponds:** Maturation ponds are placed after facultative ponds for the purpose of pathogen reduction (Figure 4). These are usually 0.5–1.5 m deep with a retention time of between 15 and 20 days. These ponds serve to inactivate pathogenic bacteria and viruses through the action of UV radiation from sunlight and the greater algal activity in these shallow ponds, which raises the pH above 8.5. (pH is a measure of acidity and alkalinity. It has a scale from 0–14: pH 7 is neutral, less than 7 is acid and more than 7 is alkaline.) The long retention time in the maturation ponds also enhances the sedimentation of the eggs of intestinal parasitic worms. **Pena** and Mara (2004) indicated that maturation ponds receive the effluent from the facultative ponds and their size and number depends on the required bacteriological quality of the final effluent.

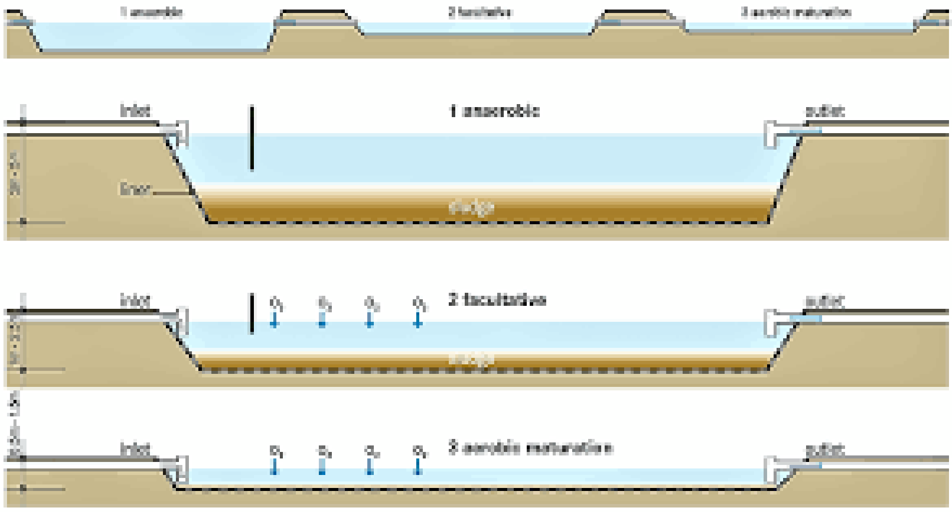

Figure (4): Maturation or Polishing Ponds.

2. Stabilization ponds are used to treat water in dry places like deserts and grasslands:

Stabilization ponds, commonly known as wastewater treatment lagoons, are vital for the treatment of waste in arid and semi-arid regions where water is scarce. The water in these ponds can use natural processes to remove contaminants through physical, biological and chemical treatment. (Mara, WHO 2004). In regions where water is limited, stabilization ponds are a form of low-cost, low-maintenance and environmentally friendly wastewater treatment. In these regions, wastewater disposal can be a significant challenge. However, stabilization ponds can provide an effective and viable solution. These systems use the high temperatures and sunlight common in dry regions that speed up the biological processes which degrade contaminants (WSP, 2007). Usually, in stabilization pond treatment systems, there are a series of ponds each having a specific purpose. The first pond is a primary settling pond where solids settle on the bottom. The facultative pond is the second pond that produces anaerobic and aerobic conditions for biological treatment. The maturation pond is the last pond. Algal growth takes place in maturation pond which absorbs excess nutrients and releases oxygen. Further treatment of wastewater is improved (Pearson et al., 2009). Use a wastewater treatment plant simulation for your thesis project. The treated effluent gets chlorinated or exposed to ultraviolet rays before it is released into the environment. This treated wastewater can then be recycled to irrigation and similar uses (non-potable uses) to conserve freshwater in the challenging conditions (Mara, 2004).One of the significant advantages of stabilization ponds is their low cost. They are relatively inexpensive to construct and maintain compared to more complex wastewater treatment options, such as activated sludge systems. Moreover, stabilization ponds require minimal energy input, as the natural biological processes generate the energy needed for treatment. This makes them particularly appealing for developing countries and rural communities, where financial resources may be limited (WSP, 2007). Overall, stabilization ponds represent an effective and sustainable method of wastewater treatment in arid and semi-arid regions. They not only provide a low-cost and low-maintenance solution for treating wastewater but also play a crucial role in conserving water resources for future generations (Pearson et al., 2009).

2.1 Limitations and Challenges of Stabilization Ponds in Wastewater Treatment:

While stabilization ponds provide a range of benefits for wastewater treatment, it is essential to recognize that they also come with certain disadvantages and limitations. One of the primary challenges is their significant land requirement. In densely populated urban areas or regions where land is scarce, finding enough space for these large ponds can be a substantial hurdle (Mara, 2004). Moreover, stabilization ponds thrive in warm, sunny climates with low rainfall, making them less effective in colder regions or areas with high precipitation. In such climates, the efficiency of the treatment process can be compromised (WSP, 2007). Another concern associated with stabilization ponds is the potential for unpleasant odors that can arise from the decomposition of organic matter. These odors can become a nuisance for nearby communities, affecting their quality of life (Pearson et al., 2009). Additionally, although stabilization ponds are effective at reducing organic matter and nutrients, they may not adequately remove pathogens, such as viruses and bacteria, from the wastewater. This limitation raises concerns about the safety of the treated effluent, especially if it is reused for irrigation or other purposes (Mara, 2004). The effluent discharged from stabilization ponds is often rich in nutrients, which, if not properly managed, can contribute to eutrophication in receiving water bodies. This situation can lead to harmful algal blooms and negatively impact aquatic ecosystems (Pearson et al., 2009). The treatment performance of stabilization ponds can also vary due to factors such as temperature, sunlight availability, and loading rates. This variability can result in inconsistent effluent quality, posing challenges for compliance with environmental regulations (WSP, 2007). Furthermore, regular maintenance is necessary for stabilization ponds, including tasks like sludge removal and vegetation management. While essential for effective operation, these maintenance activities can be labor-intensive and costly, potentially straining the resources of local communities (Mara, 2004). Overall, while stabilization ponds present a cost-effective and sustainable method for wastewater treatment, addressing these limitations is crucial to ensure their successful implementation and operation. By acknowledging and managing these challenges, communities can better leverage the advantages of stabilization ponds while mitigating their drawbacks.

2.2 Alleviating Odor Problems in Stabilization Ponds:

The Oduor problems in stabilization ponds are more difficult, since they affect the quality of life when affecting heap localities. Although, there are some tried and true methods that will help you overcome these fears. Floating covers or impermeable liners can be put over the ponds as one option. The gas capping stops gases releasing from the surface of the pond, which reduces odor emissions that will make a better living condition for people reside in the surrounding area (Mara 2004). Another effective method is aeration, which involves introducing air into the ponds. Aeration enhances the levels of dissolved oxygen thereby generating aerobic conditions which can inhibit the anaerobic processes that result in foul odors. This technique not only enhances the quality of water but also helps in maintaining a better ecosystem in the ponds (Pearson et al., 2009). In addition to these techniques, planting vegetation cover around the ponds can achieve several functions. For instance, it not only acts as a sponge absorbing the Oduors but also functions to separate the ponds from neighboring populations and thus increases the beauty and ecological value of the area (WSP, 2007). Odors can also be controlled with the aid of chemical treatment. Careful manipulation of the concentrations of chlorine or hydrogen peroxide can facilitate the oxidation of odorous compounds hence the stink is reduced. Another important practice is the frequent removal of sludge. Cleansing of congested sludge from the ponds on a regular basis reduces accumulation of the organic matter as well as odorous particles which correspondingly influences the odor in the environment (Mara, 2004). The construction of buffer zones around ponds and settlements is another method that can be used to enhance protection.

These zones function as barriers to the movements of odorous agents enabling removal of the Oduors before they reach the homes. There are two further important aspects, however, which are odor diagnosis and odor emissions monitoring. Regular assessments allow for the identification of potential odor issues, enabling prompt corrective actions to be taken before they become significant problems (Pearson et al., 2009).

2.3 The last resort to minimize the odor from the stabilization pond:

In general, the available measures aimed at solving the odor problems in stabilization ponds, can be quite different with regard to several conditions. Which include but are not limited to the quantity and the quality of the odorous compounds, their distribution within the volume of the pond, and the environmental aspects. In order to determine effective measures for the particular stabilization pond, the first considerations should begin with certain steps. The first step is to determine the areas of origin of the odors. Although, it may be in the need of doing a site survey and conducting odor detection to establish the sources of the odor in and outside the pond space. Following the studies by Mara (2004), for example, some specialists may have to take measurements of the concentration of some odorous compounds in the atmosphere and water. Next, the specific sources should be located, it should be remembered that some form of odor control has already been attempted for some sources. The evaluation of the achieved results can be carried out by the so-called before and after surveillance aimed at determining the changes in odor emissions after the application of these methods (Pearson et al., 2009). The next stage now targets the investigation of likely mitigation developments that are unique to the peculiar conditions of your stabilization pond. This might involve sourcing for literature, expert opinion, and case studies of other facilities that have undertaken and resolved similar odor problem issues (WSP, 2007). Once the alternative suggested strategies have been established, the next step is to perform a cost and a benefit analysis on their implementation. Assess the extent of the pond’s size and design, resources in location, and the probable environmental nuisance. Such area of deliberation would go a long way in ensuring that the selected alternative strategy will not only succeed but also remain relevant and viable for a long period of time. After you have approved the mitigation strategy, monitor its implementation on a regular basis. These types of monitoring would include, but not be limited to, premise Oduor and water quality monitoring and modification of the practice in line with the outcomes that will be recorded. One must remember that stabilization pond odor mitigation is a multi-dimensional and continual task. Several strategies are usually needed to achieve any satisfactory level of emissions reduction. Expert input of the highest regard and consistent evaluation will enhance the chances of suitable strategies being applied and sustained over time.

2.3 Stabilization Pond Treatment Plant Requirements in Arid and Semi-Arid Areas:

In dry and semi-arid areas, where water shortage is a major problem, stabilization ponds offer a workable and sustainable wastewater treatment solution. Stabilization ponds' efficacy and efficiency can provide much-needed relief in these situations where resources are scarce. A number of important factors are taken into consideration when designing these systems. Climate conditions are the most important factor to take into account. under many arid and semi-arid regions, stabilization ponds flourish under warm, sunny conditions with little precipitation. To guarantee that the ponds function at their best, it is crucial to comprehend the normal temperature and sun radiation levels throughout the year (WSP, 2007).

Land accessibility is still another crucial factor. Because stabilizing ponds require a large amount of land to construct, space may be limited in certain locations. Designers must consider both the potential for future expansion and the existing land resources to ensure that the system can adapt to changing requirements. The characteristics of the wastewater that needs to be treated are also crucial during the design stage. A thorough assessment of elements such as the organic and nutritional content is necessary to maximize the loading rates and retention periods in the ponds. With this careful evaluation, the required treatment efficiency must be achieved while also protecting the environment (Mara, 2004). Furthermore, the design of the ponds should Moreover, the design of the ponds should account for specific site conditions, such as slope, soil type, and groundwater table levels. Addressing these factors helps to ensure that the ponds function effectively and efficiently. Additionally, it’s important to incorporate measures that address potential odor issues, making the system more community-friendly (Pearson et al., 2009). Regular evaluation of treatment performance is essential to the success of stabilization ponds. Monitoring water quality parameters such as biological oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen, and total phosphorus provides valuable insights into the ponds’ effectiveness. These monitoring results should inform necessary adjustments to the design and operation of the ponds, ensuring they remain effective over time. Maintenance requirements are also a key consideration in the design phase. Regular removal of sludge and management of vegetation are essential for the ponds' longevity and performance. Designers should ensure that the ponds are easily accessible for maintenance and monitoring purposes. Finally, compliance with local, state, and federal regulations is a fundamental aspect of the design process. Meeting these regulatory requirements not only ensures legal compliance but also promotes community trust and environmental responsibility.

2.4 Analytical Methods for Monitoring Stabilization Ponds in Arid and Semi-Arid Regions:

In arid and semi-arid regions, where water scarcity and limited resources can complicate wastewater treatment processes, effective monitoring of stabilization ponds is crucial. Analytical methods play a key role in assessing the performance of these systems, ensuring they function optimally and contribute to environmental sustainability. One of the primary indicators of treatment performance is Biological Oxygen Demand (BOD). This measurement reflects the amount of oxygen consumed by microorganisms as they break down organic matter in wastewater. A high BOD value indicates a substantial organic load, while a low value suggests effective treatment. BOD can be measured using standard methods, such as the BOD5 test, which assesses the oxygen demand over a five-day period (APHA, 2017). Another critical measure is Chemical Oxygen Demand (COD), which evaluates the total oxygen required to chemically oxidize organic matter in wastewater. COD serves as a broader indicator of organic load than BOD and can highlight potential treatment deficiencies. Standard methods, such as the closed reflux titrimetric method, are commonly employed for its measurement (Standard Methods, 2017). Total nitrogen and total phosphorus are also vital parameters to monitor, as their excess in receiving water bodies can lead to eutrophication, causing harmful algal blooms and other ecological disturbances. The Kjeldahl method is typically used for measuring nitrogen, while the ascorbic acid method is frequently employed for phosphorus analysis (EPA, 2000). Additional parameters such as pH, temperature, and dissolved oxygen significantly impact the treatment efficiency of stabilization ponds. Regular pH measurements using a pH meter, along with temperature readings from a thermometer and dissolved oxygen assessments from a dissolved oxygen meter, are essential to ensure optimal conditions for biological processes (Wang et al., 2020). Microbiological analysis offers further insights into the microbial communities within stabilization ponds and the treatment processes taking place. Common microbiological methods include heterotrophic plate counts, as well as tests for fecal coliforms and Escherichia coli, which are critical for evaluating the effectiveness of pathogen removal (Baker et al., 2019).

2.5 Discussion on Stabilization Ponds in Arid and Semi-Arid Regions:

Stabilization ponds emerge as a promising solution for wastewater treatment in arid and semi-arid regions, where water scarcity and limited resources often render other treatment methods less viable. Various studies highlight the effectiveness of these ponds in achieving high treatment efficiencies for diverse wastewater types. For instance, research conducted in Saudi Arabia explored the performance of a stabilization pond system designed to treat municipal wastewater characterized by high salinity and low organic content. This study revealed that the system not only effectively removed organic matter, nitrogen, and phosphorus but also significantly reduced the salinity of the wastewater. Remarkably, it maintained stable treatment performance across varying operating conditions, including fluctuations in temperature and hydraulic retention time (Al-Gheethi et al., 2020). Such findings underscore the adaptability of stabilization ponds to challenging conditions typical of arid environments. Similarly, a study in Tunisia assessed the performance of stabilization ponds treating olive mill wastewater, known for its high organic content and low pH. The results demonstrated that the system was capable of achieving high removal efficiencies for organic matter, nitrogen, and phosphorus while also ameliorating the acidity of the wastewater. Again, the study found that the system consistently performed well under different loading rates and hydraulic retention times, reinforcing the reliability of stabilization ponds in diverse operational contexts (Hamdi et al., 2021). Beyond their treatment capabilities, stabilization ponds also offer cost-effectiveness and sustainability, especially in rural areas. Research in Egypt compared stabilization ponds with other wastewater treatment technologies and determined that they emerged as the most economical option for small-scale applications. This study indicated that stabilization ponds require significantly less energy and fewer resources than alternative treatment methods, marking them as a more sustainable choice in water-scarce regions (Yasien et al., 2020).

2.6 . Improving the performance of stabilization ponds:

Improving the performance of stabilization ponds is vital to achieving high levels of treatment efficiency while ensuring sustainability in wastewater management. One of the key aspects to consider is the loading rate of the ponds. It is crucial to tailor the loading rates to the characteristics of the wastewater and the specific treatment goals. When loading rates are too high, the treatment efficiency can decline, but if they are set too low, the pond's capacity may not be fully utilized. Therefore, regular monitoring becomes essential for adjusting these rates effectively (Bashir et al., 2021).Another important factor is the hydraulic retention time (HRT), which refers to the length of time that wastewater remains in the pond. Optimizing the HRT based on wastewater characteristics can enhance treatment efficiency. While longer HRTs may improve performance, they can also lead to increased land requirements and operating costs, necessitating a careful balance based on monitoring results (Ghosh & Prakash, 2020). Aeration is another technique that can significantly enhance treatment efficiency. By providing necessary oxygen to the microorganisms within the pond, aeration promotes aerobic conditions that facilitate the breakdown of organic matter. The type and amount of aeration should be customized according to the treatment goals and the specific characteristics of the wastewater (Patterson et al., 2019). Maintaining the right pH level is also essential. The pH of the pond water should be kept within a suitable range to support the growth of microorganisms responsible for effective wastewater treatment (Hussain et al., 2020). Similarly, managing algae growth is crucial since excessive algae can compete with beneficial microorganisms, ultimately reducing treatment efficiency. Therefore, implementing strategies for algae control, such as shading or chemical treatments, should be considered based on the unique conditions of each pond (Khan et al., 2018). Proper sludge management cannot be overlooked, as accumulated sludge can decrease the effective volume of the pond and hinder treatment performance. Regular removal of sludge is necessary to maintain optimal conditions (Ghosh & Prakash, 2020). Additionally, controlling odors is important to minimize their impact on surrounding communities. Measures for odor control, such as covering the pond, applying chemicals, or planting vegetation, should be adapted to the specific circumstances of the pond (Jenkins et al., 2019). By addressing and optimizing these factors, stabilization ponds can achieve impressive treatment efficiencies while functioning sustainably. Continuous monitoring and timely adjustments based on the monitoring results are crucial to ensuring the long-term effectiveness of these systems (Mara & Horan, 2017).

2.7 Monitoring the performance of installation pools:

Monitoring the performance of stabilization ponds is a critical aspect of ensuring they operate efficiently and effectively. The frequency of monitoring can vary based on several factors, including the size and complexity of the pond, the characteristics of the wastewater being treated, and the specific regulatory requirements that may apply. To maintain optimal performance, it is advisable to establish a regular monitoring schedule. Water quality parameters such as Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), total nitrogen, and total phosphorus are essential indicators of the pond's performance. These parameters should ideally be monitored at least once a month, or even more frequently if there are concerns about the pond's efficiency. Regular assessments of these indicators help in identifying potential issues before they escalate (Khan et al., 2018). In addition to water quality, monitoring algae and other microorganisms is crucial. Algae growth can significantly impact the treatment efficiency of stabilization ponds, so observing their levels at least monthly is recommended. Should any unusual spikes in algae growth occur, more frequent monitoring may be necessary to implement effective control measures (Hussain et al., 2020). Sludge accumulation within the pond is another important aspect to consider. Regular observations should be conducted to assess the sludge levels, with removal operations initiated once the accumulation reaches a certain threshold—typically between 30% to 50% of the pond depth (Bashir et al., 2021). Moreover, monitoring for odor emissions is essential for minimizing their impact on surrounding communities. Regular checks should be performed, and odor control measures must be adjusted based on the findings to ensure that residents are not adversely affected (Jenkins et al., 2019).

2.8 Common Problems and Solutions in Stabilization Ponds:

Stabilization ponds are often seen as a reliable solution for wastewater treatment, but they can encounter several challenges that may affect their performance. One of the most common issues is odor emissions. These unpleasant smells can be particularly distressing for nearby communities and are typically caused by gases like hydrogen sulfide and ammonia or from the breakdown of organic matter. To address this, several odor control measures can be employed. For instance, covering the pond, using specific chemicals, or planting vegetation can significantly reduce the unpleasant smells, making the area more tolerable for those living nearby (Jenkins, Richard, & McKinney, 2019). Another frequent problem is excessive algae growth, which can lead to competition with the microorganisms responsible for treating wastewater. High nutrient levels or insufficient aeration often contribute to this overgrowth. It’s essential to implement effective control strategies, such as shading the pond with trees, applying chemical treatments, or even mechanical removal, to keep algae levels in check (Khan, Waseem, & Rahman, 2018). Sludge accumulation is also a significant concern, as it can reduce the effective volume of the pond and hinder treatment efficiency. To maintain optimal performance, regular sludge removal is crucial. Moreover, the hydraulic retention time (HRT) of the pond is a critical factor that influences treatment efficiency. Changes in flow rate or loading can lead to HRT issues, potentially resulting in lower efficiency and increased operational costs. Monitoring and managing HRT is vital to ensure a balanced operation of the pond. pH levels are another critical aspect to consider. Both high and low pH values can inhibit the growth of the microorganisms essential for effective wastewater treatment. Fluctuations in influent pH or changes in the pond’s characteristics can lead to pH-related issues (Hussain, Saleem, & Usman, 2020). Additionally, poor water quality may arise from excessive organic matter and inadequate aeration, affecting treatment efficiency and possibly causing environmental harm. To effectively tackle these challenges, stabilization ponds require regular monitoring and maintenance. Routine checks on water quality parameters, algae levels, sludge accumulation, and odor emissions are essential for identifying potential problems early. Generally, it's advisable to conduct these assessments at least once a month and make necessary adjustments based on specific conditions and regulatory requirements. When it comes to controlling algae growth, a combination of physical, chemical, and biological methods can be effective. For example, shading the pond can limit sunlight, thereby slowing algae growth. Aeration can boost dissolved oxygen levels, promoting the growth of beneficial microorganisms that compete with algae for nutrients. Chemical treatments, such as copper sulfate, may also help manage algae, although they can have side effects on other pond inhabitants (Khan et al., 2018). Biological methods, such as introducing organisms that compete with algae, and mechanical removal techniques can also be useful. Stabilization ponds may host various types of algae, including green algae, blue-green algae (cyanobacteria), diatoms, euglenoids, and dinoflagellates. The specific types present often depend on nutrient levels and environmental conditions. Therefore, monitoring and identifying the dominant algae species is crucial for developing effective control strategies and ensuring the pond's overall health (Khan et al., 2018). Managing algae brings about several benefits, such as improved treatment performance and reduced odors. However, it's important to recognize that controlling algae can lead to changes in water quality, which may impact the pond and its surrounding environment. Careful consideration is essential when selecting control methods, as some may harm other organisms (Hussain et al., 2020).

3. METHODS:

Estimation of the design population and the wastewater flow:

Design population: Using the following for forecasting future population for the city of Sebha:

$$P_n = P_o (1 + r)^n$$

Where, P_n = population (predicted) after 'n' number of decades,

P_o = last known population

r = the rate of population growth.

n = number of decades between Po and Pn.

Influent wastewater flow: The flow was estimated as follows:

$$Q = 10^{-3} K.q.P_d + I + E$$

Where, Q= Design flow within the treatment system (m3/d).

K = liquid effluent access factor to the treatment system (0.8 - 0.9).

q = average per capita water consumption (100-300 litters /person /day).

P_d = Design Population.

I = Groundwater filtration income for piping system (m3/day).

E = Industrial wastewater flow (m3/day).

Temperature (OC)	Volumetric Loading (g/m3.d)	BOD removal (%)
<10	100	40
10-20	20T-100	2T+20
20-25	10T +100	2T+20
>25	350	70

Design equations for the pond system:

The following equations were used for the design of each pond. The equations are based on Mara and Pearson (1986) and Marais (1974) for the sizing of each of the ponds. They are as follows:

1. Anaerobic pond:

The anaerobic ponds are designed on the basis of volumetric BOD loading B_v:

$$B_v = L_i \times Q/V_1$$

Where, L_i is influent BOD (mg/L), Q is flowrate (m^3/d) and V_1 is anaerobic pond volume (m^3).

The first step is to select Bv (Mara and Pearson, 1986) and Mara et al. (1998) recommend the safely design values as shown in Table (1).

Table (1) Design values for anaerobic ponds (Mara and Pearson 1986)

The hydraulic retention time is calculated from the equation below:

$$t_1 = V_1 / Q \text{ (days)}$$

The mid- depth area:

$$A_1 = V_1 / d_1$$

Where, d1 is the assumed pond depth.

The minimum design retention time is one day in anaerobic ponds, four days in facultative ponds, and three days in maturation ponds.

2. Design of the facultative pond:

Facultative ponds are designed on the basis of surface loading Bs:

$$B_S = 10\, L_i \; Q / A_2$$

However, according to the Mara (1987) equation, the surface loading is based on temperature and is according to the equation below:

$$B_S = 20T - 120\ (kg / ha.\ day)$$

The total BOD load, Li Q_2 = BOD removal (%) × $L_i\ Q\ \ (kg / day)$

The mid- area:

$$A_2 = L_i\ .Q_2 / B_s\ (m^2)$$

Pond volume, $V_2 = A_2 \times d_2\ \ (m^3)$

Were, d_2 *the* assumed pond depth (m).

Hydraulic Retention time:

$$t_2 = V_2 / Q\ \ \ (days)$$

3. Design of The Maturation Ponds for Faecal Coliform Removal:

The method used is that of Marais (1974) for design of a pond series for Faecal coli form removal. This assumes that Faecal coli form removal can be reasonably well represented by a first-order kinetic model in a completely-mixed reactor. The resulting equation for a single pond is given by:

$$N_e = N_i\ / (1 + K_T\, t_3)\ FC /100\ \ \ ml$$

Where Ne and Ni are the number of Faecal coli form/100 in the effluent and influent, KT is the first-order rate constant for Faecal coli form removal (day^{-1}), and t3 is a retention time (day).

The value of K_T, (day^{-1}) is highly temperature-dependent. Marais (1974) found that:

$$K_T = 2.6\ (1.19)^{T-20}$$

The hydraulic retention time t3 is assumed although Marais (1974) recommended that a value of 3 for temperatures above 20 ˚C.

4. RESULTS AND DISCUSSION

Determination of the design flow

1. Design population: The project's target year is 2053:

The forecast for Sebha city in 2018 gives a total population of 210,000. Growth rate 2.86% and With Population density of 42.77 inh/ha.

(UN-Habitat City Profile of Sebha, LIBYA 2018)

Present population 2023 P2023 = 210,000 (1+-0286)5 =241798

Project target population 2053 P2053 = 241798 (1+0.0286)3 = 263144

Influent wastewater flow:

$$Q = 10^{-3} \times 0.85 \times 180 \times 263144 + 0 + 0 = 40261 \text{ m3/d} \quad \text{say } 50000 \text{ m3/d}$$

2 . Anaerobic Ponds Design:

Estimate influent BOD_5 (L_i); Assume BOD_5 per person = 54 g/c. d.

$W = L_i \times Q$ Where, W= organic loading rate (kg/d)

$$54 \text{ g/c. d} \times \frac{1000\ mg}{g} = L_i \times 50000 \frac{m^3}{d} \times \frac{1000\ l}{m^3} \quad \text{find } L_i(BOD_5) = 284.2 \text{ mg/L}$$

Volumetric BOD loading B_v: $B_v = L_i \times Q/V_1$

According to the Table (1) : Prevailing temperature in the study area > 25 OC , Volumetric Loading Bv =350 (g/m3.d). The total volume of anaerobic ponds = 40600 m3

Area of the anaerobic ponds, A1: A1 = V1 / d1 , Where, d1 is the assumed pond depth = 3.5m (Kayombo et.al 1998) and it is an average value based on the range of values given in the literature(2-5m). A1=40600/3.5 =11600 m^2. Assume two ponds used area of each one = 5800 m^2.

Assume the pond configuration is rectangular: Dimensions of the pond, A= L× W

Assume L= 4W, 5800 = 4 W^2 → W = 38 m say 40 m, L = 160 m

BOD removal = $2T + 20$, T=25 ^{O}C , Percent BOD removal = 2× 25 + 20 = 70 %

Anaerobic pond effluent (BOD_5) = (1- 0.70) × 284.2 mg/L = 85.26 mg/L

Retention time for the pond T_1: $T_1 = V_1/Q$ → T_1 = 1.62 day OK (minimum 1 day)

3. Facultative Ponds Design:

Facultative ponds were designed on the basis of surface BOD loading (Bs, kg/ha d) according to the equation below:

$$B_s = 10 L_i Q / A_2$$

Effluent BOD_5 o anaerobic pond is considered as influent BOD5 of the facultative pond = 85.26 mg/L. However, according to the Mara (1987) equation, the surface loading is based on temperature and is according to the equation below:

$$B_s = 20T - 120\ (kg / ha.\ day)$$

B_s = 20 × 25 -120 = 380 mg/L

Find the area of facultative ponds A_2: $B_s = 10 L_i Q / A_2$

380 = 10 ×85.26 × 50 × 10^3 / A_2 → A_2 = 121800 m^2 , consider two facultative ponds, area of each pond = 60900 m^2 say 60 hectares.

Assumed pond depth = 1.5m (Kayombo et.al 1998)

Volume of facultative ponds V_2 = 60000 m^2 × 1.5 m = 90000 m^3

Retention time for facultative ponds T_2: $T_2 = V_2/Q$ → T_2 = 3.66 days → 4 days

Assuming a length: breadth ratio of 2:1 to avoid sludge banks forming at the inlet.

A= L× W → 60000 m^2 = 2 W^2 → W = 173 m → L = 346 m.

According to the Mara (1987), the percentage removal of BOD5 of facultative pond range between (75% - 85%), select 75% removal efficiency.

BOD_5 in effluent = 85.26 mg/L (1- 0.75) = 21.32 mg/L.

4 . Maturation Ponds:

The method used is that of Marais (1974) for design of a pond series for Faecal coliform removal. This assumes that Faecal coliform removal can be reasonably well represented by a first-order kinetic model in a completely-mixed reactor. The resulting equation for a single pond is given by:

$$N_e = N_i / (1 + K_T t_3) FC / 100 \ ml$$

Where Ne and Ni are the number of Faecal coli form/100 ml in the effluent and influent, K_T is the first-order rate constant for Faecal coli form removal (d^{-1}), and t_3 is a retention time (day). The recommended hydraulic retention time for maturation ponds is 20 days for complete decomposition. (WSP, 2007)

The value of K_T, (day^{-1}) is highly temperature-dependent. Marais (1974) found that:

$$K_T = 2.6(1.19)^{T-20}, \ K_T = 2.6(1.19)^{25-20} = \ 6.2 \text{ days}$$

Marais (1974) suggests a value of 3 days for θ^{min}, Where θ^{min} is the minimum retention time to prevent algal washout and minimize hydraulic short-circuiting.

Use two maturation ponds. The volume of each one:

$$V = Q \times T = 25000\ m^3/d \times 3\ d = 75000\ m^3$$

Use depth 1 meter. Area of the pond = 75000/1 = 75000 m^2 equivalent to 7.5 ha.

Assume pond configuration is rectangular and Length = 2 wide L = 2W

$$A = L \times W,\ 75000 = 2W^2 \rightarrow W = 194\ m,\ L = 388\ m$$

5. CONCLUSION:

1. According to the specific objectives of the study, all the ponds have been clearly designed with all the specific dimensions.
2. The anaerobic pond has an area of 5800 m2 and a retention time of 1.62 days with the influent BOD at 284.2 mg/l.
3. The facultative pond has an area of 60900m2 and a retention time of 4 days. The effluent BOD is 21.32 mg/l, which is less than the standard of 50 mg/l so the pond is effective.
4. The maturation pond has an area of 75000 m2 and a retention period of 3 days. The number of Faecal E. coli in the influent is 12039333FC/100ml and the number in the effluent is 1052FC/100ml. This meets the standard value, which is less than 10,000FC/100ml.
5. Based on this study, the results obtained can be presented, which can be summarized in the following points:
6. The treatment system using stabilization ponds is considered one of the appropriate technologies that have been used in the treatment in many areas of science for various types of wastewaters.

It can be operated in many ways, and the operating method can be changed in the event of increasing hydraulic and organic loads without the need to add new units. This is done by using one or more of the systems used in one treatment plant: anaerobic oxidation ponds (which work as a preliminary treatment for sewage), facultative oxidation ponds, aerobic oxidation ponds, maturation oxidation ponds.

This method can be used in the following cases: areas where there are large areas of land at a cheap price, lack of necessary funds for expensive traditional treatment methods, lack of experience and trained workers to operate other methods.

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