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Applications of Wastewater Treatment Methods in IDP & Refugee Camps

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ABSTRACT- Wastewater treatment is essential before untreated wastewater can be reused or discharged into the environment. Treatment technologies such as constructed wetlands, activated sludge, trickling filters, water hyacinth systems, and extended aeration can be effectively implemented even with limitation of area, low-cost materials, and operational and maintenance requirement, to produce treated water that is environmentally safer.This article explores the wastewater treatment levels, challenges in managing it in IDPs/refugees camps and the environmental impacts, with a literature review of treatment technologies, their limitations, and the pursuit of more sustainable methods tailored to the needs of camps. Case studies from different camps are examined.

KEYWORDS- Sanitation, Wastewater treatment methods, IDPs Internally displaced persons, ABR Anaerobic baffled reactor, ANF Anaerobic filter, UASB Upstream Anaerobic Sludge Blanket Reactor, Sustainable Development Goals (SDGs)

I. INTRODUCTION

The rise of national and international conflicts alongside natural disasters has led to substantial populations of refugees and internally displaced persons. These groups often find themselves in expansive and rapidly changing camps situated in areas that frequently lack essential resources and face a growing population struggling to meet basic survival needs [1].In these crises, it is imperative that emergency responses tackle several pressing issues, including inadequate sanitation facilities, access to safe drinking water, health services, shelter, and food security. However, the urgency of the situation often constrains decision-makers, typically governmental bodies and non-governmental organizations (NGOs), to rely on conventional methods for wastewater management. This reliance frequently results in improper on-site sanitation systems that fail to meet the long-term needs of the population. Furthermore, during the initial disaster relief, time and resource limitations can lead to suboptimal sanitation practices. The World Health Organization (WHO) has established water quality standards for both surface and groundwater; however, these standards are often violated in emergency settings. Failure to manage wastewater properly can exacerbate health risks for vulnerable populations, making it crucial to implement effective treatment solutions [2].Various camps worldwide are implementing innovative approaches to wastewater treatment, demonstrating that it is possible to combine immediate relief efforts with sustainable practices. These initiatives not only improve sanitation and health outcomes but also pave the way for more resilient communities in the long term.

II. CHALLENGES AND IMPORTANCE OF WASTEWATER MANAGEMENT IN CAMPS

Refugees and Internally Displaced Persons (IDP) come from a variety of environments, including urban, rural, and peri urban. They are often forced to live in camps where sanitation is poor or absent, pushing the environment to degrade excessively. Treating wastewater in camps has become an important aspect because untreated wastewater results in contamination of surface and groundwater, deterioration of air and soil quality, spread of diseases, and intensified stress on local resources and ecosystems [3].In most camps, simple temporary sanitation systems are established, which can cause severe environmental health problems, especially because of poor maintenance. Noxious odors, flies, insects, and pathogenic microorganisms can result from overflowing and surface water draining from them. Therefore, wastewater treatment and safe disposal methods in camps are often criticized for being unmanageable, providing untreated waste effluents, and being harmful to environmentally sustainable approaches.During the intervention, camps present a special set of challenges for the implementation of wastewater treatment systems. Camps are frequently established in situations demanding immediate action, which require a swift and effective deployment of resources [4]. This makes available resources, policy and operational environment, which are further determined by location, time in crises, and other external factors, complicate the efforts of governmental, non-governmental organizations (NGOs) and other entities tasked with managing water, sanitation, and hygiene (WASH) initiatives in addition to fearing that the complexities of wastewater treatment could lead to delays in addressing urgent sanitation needs [5].Given the urgency of the circumstances, the ability to adapt existing policies and operational practices becomes increasingly crucial. Especially the design life of a camp proposed that will not exceed 10 to 15 years, and so infrastructure is designed for a short service life. However, in many cases can become permanent such as Al-Hol Camp in Syria originally established in 1991 for Iraqi refugees, which was later repurposed during the Syrian Crises to host internally displaced persons [6]. The camp has existed for decades and continues to be a long-term settlement. Another example of Dadaab Refugee Camp in Kenya established in 1991 to host Somali refugees fleeing civil war, Dadaab was initially intended for a smaller population but has evolved into a semi-permanent settlement. It is now one of the largest refugee camps globally, accommodating over 275,000 refugees. This makes camps residents in the near future have a similar requirement to those in urbanized locations but have limited resources and areas of land into which wastewater can be discharged. The intersection of emergency response and long-term settlement dynamics in camps highlight the necessity for tailored decentralized wastewater treatment solutions and a reevaluation of traditional WASH strategies, paving the way for more resilient and adaptive systems [7].Other challenges related to the implementation of effective wastewater management practices in camps include a significant lack of resources, particularly financial & human ones. The cost targets for delivering a specific level of service often influence the design decisions and scale of systems in humanitarian contexts. Consequently, this can lead to treatment processes falling short of accepted environmental standards. While this may be somewhat tolerable if the system is expected to be decommissioned shortly, however, it poses greater challenges for permanent camps. The prohibitive costs associated with advanced treatment technologies frequently obstruct the development of suitable treatment solutions within established budgets. Therefore, investments that have the potential for the most significant health benefits should be prioritized. To facilitate this, appropriate financing mechanisms must be established, which could involve models such as social impact investing, targeting financial stakeholders and recouping investments with returns from end-users or the government upon achieving results. Given these considerations, forming partnerships with local authorities and affected communities is advised to enhance the prospects for future investments in wastewater management within camps [8].Beyond the above-mentioned challenges, the lack of technical expertise for the implementation, requirement for operational and maintenance process, lack of area, lack of local standards and regulations are additional limitations must be considered for the adaptation of various treatment technologies in camps.

III. WASTEWATER TREATMENT TYPES

Wastewater treatment systems can be extensive (or natural) and intensive (or primarily mechanically driven) systems. In extensive systems, such as anaerobic and facultative lagoons, treatment rates are typically relatively slow, requiring large retention times and land requirements to achieve acceptable treatment levels. Intensive systems, such as aerated lagoons, are based on higher reaction rates, resulting in more compact reactor volumes and a smaller treatment plant footprint, but at the cost of engineering complexity, and thus typically requiring continual operational support, regular maintenance, and a continuous, reliable external source of energy [9]. According to a guide developed by World Bank Group there are 21 technologies for water treatment to be applied in small towns which are categorized into three treatment levels, each addressing different treatment needs based on complexity and local requirements:

i. **Primary Treatment**

Focuses on the removal of large solids and settleable matter through physical processes such as screening and sedimentation. This level is the most basic and serves as a foundation for further treatment. The primary treatment includes three methods, which are septic tank, biogas digester and Imhoff tank [9], [10].

ii. **Secondary Treatment**

Involves biological processes to break down organic matter and reduce the biochemical oxygen demand (BOD) and suspended solids in the wastewater. There are thirteen secondary methods such as Anaerobic baffled reactor, anaerobic filter, waste stabilization pond [9], [11].

iii. **Tertiary (Advanced) Treatment**

Provides additional refinement to remove nutrients (e.g., nitrogen and phosphorus), pathogens, and other contaminants that secondary treatment cannot fully address. The Tertiary techniques include filtration, chemical disinfection, and advanced biological or physical processes [12].

The results of the technical, environmental and financial evaluation conducted in the above-mentioned guide of the 21 methods classified under secondary treatment found that the ABR Anaerobic Baffled Reactor, ANF Anaerobic Filter and UASB Upstream Anaerobic Sludge Blanket scored highest overall. Most of the standards have been evaluated taking into account several criteria such as land requirement, energy use, operation and maintenance requirements, capital costs etc [9]. Since the criteria for these methods align closely with the primary challenges faced in camps—such as limited resources, high population density, temporary or semi-permanent infrastructure, and the need for cost-effective and easily maintainable solutions they are deemed more suitable for application in camp settings. These methods will be reviewed in more detail in the following section, providing an insightful analysis of their operational mechanisms, advantages, and potential applications in various contexts.

A. Anaerobic Baffled Reactor (ABR)

The Anaerobic Baffled Reactor (ABR) is a system designed to treat wastewater through a series of baffles that slow down water flow, allowing for sedimentation and biological treatment. ABR also affects the non-settleable and dissolved solids by contacting them with active bacterial mass that accumulates on the reactor walls. This interaction enhances the breakdown of contaminants, ensuring a higher quality effluent. Figure 1 illustrates the key components of this method [13].

This method is particularly effective in environments where land availability is constrained, and the energy supply is uncertain. It is applicable for groups of residential units or towns with a mixed wastewater flow is generated, making it applicable in camps as well. Additionally, it is resistant against organic and hydraulic shock loads. In terms of spatial requirements, the ABR is designed to occupy a moderate footprint and can be constructed underground, optimizing land use while maintaining efficiency. Operationally, the ABR is designed for minimal intervention. Regular maintenance primarily involves the removal of accumulated sludge and scum, which typically occurs every one to three years, depending on the system's loading and specific conditions [14].

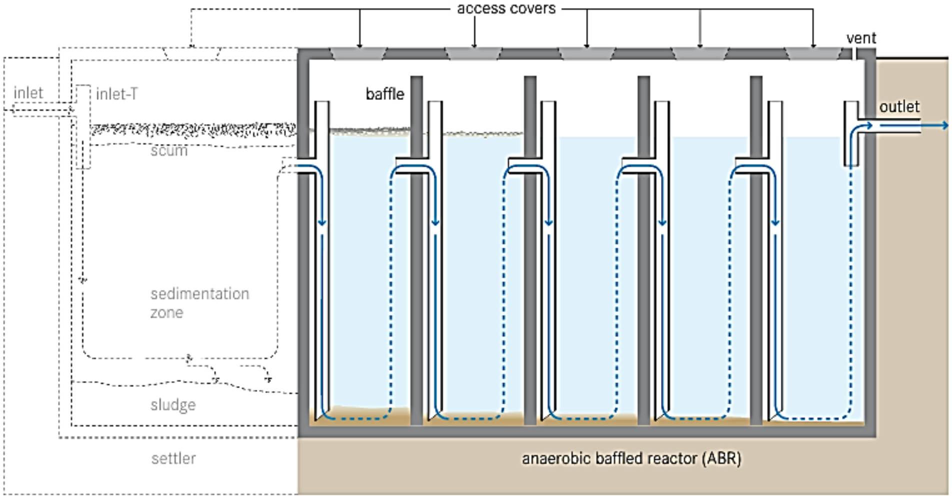

Figure 1: ABR Anaerobic baffled reactor

In Zaatari camp, a Syrian refugee camp in Jordan, an ABR system was implemented to treat the wastewater generated by more than 10,000 residents. The system was designed to handle fluctuations in wastewater quantity and quality. Over a six-month period, the results indicated a significant reduction in biochemical oxygen demand (BOD) and total suspended solids (TSS), demonstrating its effectiveness [15].

B. Anaerobic Filter (ANF)

ANF is an anaerobic filter, also known as fixed bed or fixed film reactor. As shown in figure 2, it consists of an anaerobic baffle reactor structure equipped with additional material that creates a filter conducive to bacterial growth. This design significantly increases the surface area available for wastewater interaction with active biomass, thereby enhancing treatment process. Non-settleable and dissolved solids are treated through their contact with surplus of active bacterial mass as the bacteria affix to solid particles and on the reactor walls. Filter materials, including gravel, stones, cinders, or specially designed plastic fragments, offer increased surface area conducive to the colonization of bacteria.This method, similar to ABR, is applicable for groups of residential units or town with a mixed wastewater flow is generated. The design requires moderate area and can be built underground. A critical parameter influencing the performance of this design is the hydraulic retention time, which directly affects filter efficiency. However, it is important to note that this method carries a risk of clogging which can happen as solids, grease, or biofilm accumulate on the media over time and impair treatment quality. To reduce the load on the filter media it is important to implement an effective pre-treatment stage (e.g., sedimentation or screening) to remove large particles, grease, and other debris before the wastewater enters the ANF [9].

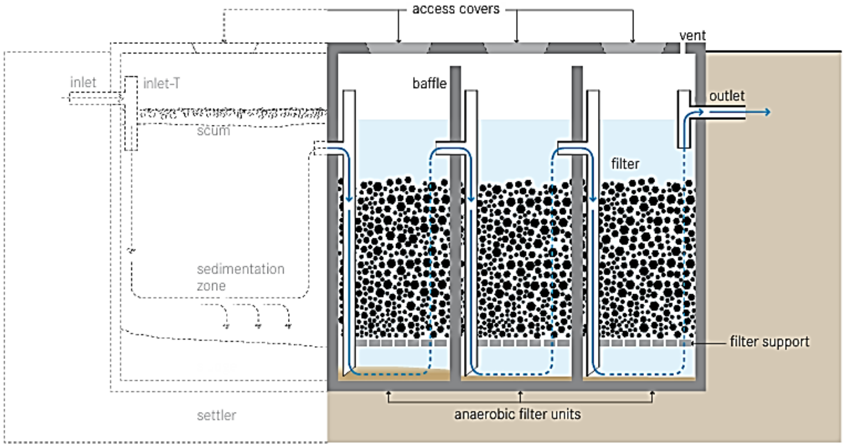

Figure 2: (ANF) Anaerobic Filter

In Nigeria, an ANF system was deployed in an IDPs camp to address the challenges of managing wastewater from a population of over 20,000. The system utilized locally available materials for the filter medium, which not only reduced costs but also engaged the community in its construction and maintenance. The ANF system achieved a notable reduction in pathogens, contributing to improved health outcomes in the camp.

C. Upstream Anaerobic Sludge Blanket Reactor (UASB)

The Upstream Anaerobic Sludge Blanket (UASB) reactor is designed as a tank wherein anaerobic digestion occurs under a layer known as the 'sludge blanket.' Wastewater is introduced uniformly across the base of the reactor, where it traverses through the sludge bed before entering the settling zone to allow further sedimentation of solids. The active sludge, suspended in the lower section of the digester, functions as an effective filtration medium. This granular sludge, populated by anaerobic bacteria, facilitates the treatment of wastewater as it flows through.

A distinctive feature of the UASB reactor is its phase separator, which took place at the top and divided the reactor into two distinct zones: the digestion zone below and the settling zone above. As wastewater flows into the settling area via openings in these phase separators. As shown in figure 3 a balance is formed between the velocity of the influent and the rate at which sludge settles, leading to a locally stable yet suspended layer of sludge. Over a period of several weeks, this process matures the granular sludge, which improves both physical stability and filtration efficiency within the blanket [11].

UASBs is suitable for camps with consistent water supply and energy access for the biogas reuse and it also effective for heavily loaded urban and industrial wastewater streams. Therefore, this method could be implemented in camps located near communities, with the potential to integrate it into a broader system as the population expands or the camp grows.

While this technology features straightforward design and construction processes, it requires several months for sufficient granular sludge to develop effective treatment. Primary sedimentation is unnecessary; if biogas recovery is not prioritized, reactors can be constructed underground to maximize space efficiency.

To sustain a stable sludge blanket, it is crucial to regulate flow rates according to variations in organic load. In smaller units, enhancing hydraulic retention time to stabilize processes may necessitate decreasing upstream velocity. The fully controlled UASB system is specifically applied to manage relatively strong industrial wastewater efficiently. Compared to septic tanks, UASB reactors have demonstrated an ability to yield higher quality effluent while occupying less volume and producing minimal amounts of sludge.

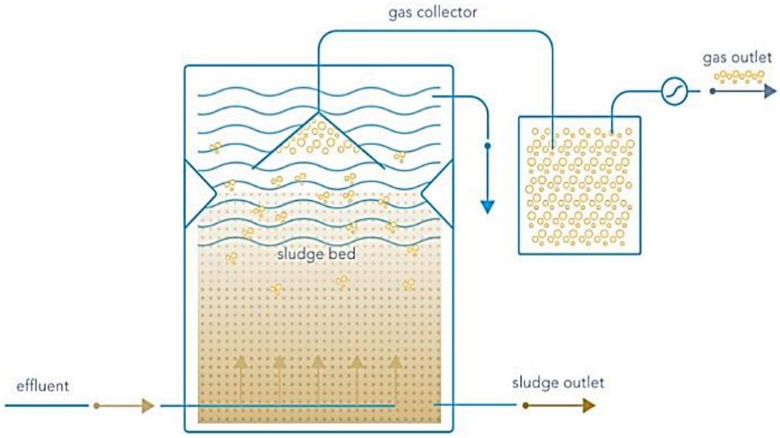

Figure 3: USAB Upstream Anaerobic Sludge Blanket reactor

An example of the use of UASB technology for wastewater treatment is in Kass camp, Sudan. In this camp, biogas technology, including anaerobic reactors like UASBs, has been introduced to address sanitation challenges and provide renewable energy. The technology has been used to treat high loads of organic waste effectively, making it a suitable solution for camps with limited infrastructure and expanding populations [13].

IV. OPTIMUM COMBINATION OF TREATMENT TECHNOLOGIES FOR WASTEWATER REUSE

The effluent produced by all the above-mentioned methods can be discharged in the ocean or a large river. However, for reuse purposes it requires additional treated steps.

The challenges of achieving the Sustainable Development Goals (SDGs), combined with water security, have driven countries to identify ways of deriving value from wastewater streams. Consequently, the potential for repurposing wastewater for agricultural, environmental, industrial, residential, or municipal applications has emerged as a crucial consideration in the design of wastewater treatment systems. Camps present unique opportunities for reuse in that there is a likely advantage for the treated wastewater to be generated closer to potential reuse sites. This is particularly true for agriculture.

Therefore, while the primary and secondary treatment technologies discussed are effective in eliminating rates suspended solids and organic material from wastewater, they often fall short in adequately addressing pathogenic microorganisms. Given the health risks associated with both direct and indirect utilization of treated wastewater, it is essential that pathogen removal and monitoring of control measures be integrated into the overall wastewater treatment process. Different combinations involving extensive and intensive treatment options can be used to achieve the desired effluent quality levels required for reuse such as the UASB method could be combined with ponds for disinfection, making the treated effluent is applicable to use for non-restrictive irrigation [16].

V. FACTORS TO CONIDER FOR WASTEWATER TREATMENT METHOD IN REFUGEES/IDPS CAMPS

There are essential criteria that present significant attributes, which must be considered when choosing a wastewater treatment system. These criteria underscore various factors that decision-makers are recommended to evaluate, including population dynamics, growth potential, local activities, and existing services and practices. First of all, the availability of services within the camp will significantly impact on the choice of wastewater treatment solutions. The density of residential units and the proximity between residences are critical considerations that affect the practicality of sewer-based sanitation compared to on-site alternatives, such as septic systems and pit latrines.

Water supply plays a key role in determining the viability of sewer systems. If the water supply is intermittent or households lack individual connections, a sewer-based sanitation solution may not be suitable or could be limited to specific areas of the camp. This is similarly true in cases where per capita water consumption is minimal, or where residents utilize most wastewater or graywater for irrigation such as vegetable plots resulting in negligible wastewater for sewer discharge. Typically, a factor of 0.8 of supplied water is employed; however, if a greater portion of water is allocated for irrigation, a factor of 0.6 may be more applicable [17].

In camps where both wastewater and stormwater are channeled together the sizing of wastewater treatment system must be adjusted accordingly. This, in turn, can affect both the capital and operational expenditures associated with the chosen method.

Improper management of solid waste in the camp can lead to excessive solid waste entering the sewer system and ultimately the treatment facility. Although solid waste arriving at the system can be processed, it may require additional pretreatment and operational maintenance. Ideally, solid waste should be collected at its source to prevent it from contaminating sewers, which typically demands more complex removal efforts.

Furthermore, the system capacity must accommodate future growth of the camp to prevent overloading, with design horizons typically set based on projected developments over a 15 to 20-year span. However, since camps often face uncertainties regarding their lifespan, shorter horizons might be considered as 10- 15 years. Generally, transient residents are factored in at 0.3 to 0.5 times the number of permanent residents.

In some scenarios, only segments of a camps may be serviced by the sewer system, while others continue with alternative sanitation methods. Political, geographical, urban development, and density considerations are vital in determining sewer project boundaries. Even when a project aims to serve the entire camp, distinctions between camp and surrounding zones may be ambiguous, which need justifications for including low-density or isolated areas while ensuring economic sustainability.

Additionally, according to the locations of the camp the regulations for wastewater treatment, effluent, and sludge discharge and reuse should be considered. Are there specific regulations governing the design of wastewater treatment plants, effluent discharge, sludge management, and emissions? Is reuse of treated water a concern? If so, what are the current regulations and what effluent quality standards must be met? How are these regulations enforced, if at all? Alternatively, are there water quality or environmental standards affecting reuse, even if not clearly regulated? In some instances, a lack of regulations may exist, requiring interveners to establish expectations and identify minimum quality standards for the design. Key parameters relevant to the design that should be enhanced against existing regulations include BOD5, COD, suspended solids, nitrogen, phosphorus, and indicators of fecal contamination, such as fecal coliforms (FC) [18].

As for the system location, it is important to select a site that is neither too central nor excessively surrounded by residential units of the camp to minimize complaints regarding odors, traffic, and noise. However, the chosen location should not be too remote to avoid high capital costs associated with pipe installation and high operational costs linked to necessary pumping. Elevated locations that require higher operating expenditures for pumping should be avoided.Site selection should also rely on the most current climate change data rather than solely on historical flood information. Additionally, the area should possess adequate geotechnical properties to support heavy construction, thereby minimizing foundation work expenses, and if possible, should allow for potential future expansion of treatment capacity or footprint. Eventually it is essential to confirm the availability of a dependable power supply at the proposed wastewater treatment system site if the selected method requires power and to consider sustainable energy sources such solar panels.

VI. CONCLUSION

The material in this article indicates that existing wastewater treatment methods may effectively eliminate both natural and emergent contaminants over varying durations and across different technical levels. Many of these technologies eliminate nearly 100% of biological contaminants in low-organic-loaded wastewater, enhance the stabilization period of the wastewater, reduce pathogen levels, and increase the potential for recovery and utilization of the treated wastewater. The technology employed will be contingent upon the refugee/IDPs population, duration of use, and the financial resources available from governments, NGOs, and other organizations for this initiative. To effectively handle wastewater concerns, it is crucial to formulate and execute comprehensive regulations and standards designed to meet the unique challenges encountered by camps. On the other hand, to mitigate the wastewater issue, it is important to consider reducing the number of camps worldwide which can be accomplished by promoting global peace, especially for those camps created as a result of wars and conflicts. The influence of climate change, shown through natural disasters, is also a critical component in the formation of camps, also emphasizing the necessity for sustainable solutions. In conclusion, all individuals, especially governors, policy and decision makers, play a key role in affecting change. Their active participation is crucial for the implementation of effective wastewater treatment systems, promoting environmental sustainability, and enhancing living circumstances in camps. This requires investments in sustainable infrastructure, community engagement, climate-resilient, and innovative technology. Customized policies, monitoring systems, and collaborations with stakeholders can further improve outcomes. Moreover, following instruction on wastewater management and the repurposing of treated water might enhance resource optimization.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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