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Clean Water: Design of an efficient and feasible water treatment plant for rural South-Bengal

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Abstract - *Waste water treatment is an important issue because of lessening water resources. The primary reason for waste water treatment process is to expel the different constituents of the polluting load: solids, natural carbon, supplements, inorganic salts, metals, pathogens and so on. In this paper, mainly de-centralized method is considered as a solution. A new rural wastewater treatment process is introduced with proper planning and designing by using empirical equations. This paper exhibits the waste water treatment technologies present in Bangladesh, to expel contaminants from wastewater, for example, halogenated hydrocarbon mixes, overwhelming metals, colors, pesticides, and herbicides, which speak to the fundamental toxins in waste water. This research shows that the proposed decentralized system is more feasible economically and environmentally (about 75% BOD removal), since the centralized system needs modern machineries and high initial investment. To design a sustainable wastewater treatment system for developing area, further assessment on environmental, health, social and institutional aspects are recommended.*

Keywords *– water, waste water, Water treatment plant, Design of treatment plant, South Bengal, Bangladesh.*

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1. Introduction

Municipal wastewater is the conveyed wastes from homes, business offices or modern industries, notwithstanding any groundwater, surface water and tempest water that might be available. Untreated wastewater for the most part contains elevated amounts of natural material, various pathogenic micro-organisms, and in addition supplements and dangerous mixes. It along these lines involves ecological dangers and thus should promptly be passed on far from its sources and treated properly before definite transfer. An objective of wastewater treatment is the security of the earth in a way comparable with general wellbeing and financial concerns [1].

Because of increased population, water will end up plainly one of the scarcest assets in the 21st century [2].In the year 2015; about 27 megacities were with a population over 10 million each, 17 of which were of developing standard [3]. Fundamental to the urbanization wonders are the issues related with giving civil administrations and water segment foundation, including the arrangement of both clear water assets and sanitation administrations. Right now, giving lodging, medicinal services, social administrations, and access to essential human needs framework, for example, clean water and the transfer of gushing, presents real difficulties to designers, organizers and lawmakers [4, 5]. As population is increasing; more prominent strains will be set on accessible assets and stance considerably more noteworthy risk to ecological sources. A report by the Secretary General of the United Nations Commission on Sustainable Development reasoned that there is no supportability in the flow employments of new water, and around the world water use has been developing at more than three times the total increased population, thusly prompting far reaching general medical issues, restricting financial and horticultural advancement and unfavorably influencing an extensive variety of biological communities [4]. A great part of the human used after products enter water bodies through the release of waste from household, point and non-point sources conveying undesirable and unrecoverable substances [6]. In spite of the fact that the accumulation of wastewater goes back to old circumstances, its treatment is a moderately late advancement dating from the late 1800s and mid-1900s [7]. Current learning of the requirement for sanitation and treatment of wastewater in any case, began with the often referred to instance of John Snow in 1855, in which he demonstrated that a cholera episode in London was because of sewage water got from the Thames River [8]. In developed nations, treatment and release methods can forcefully contrast amongst nations and amongst provincial and urban clients, as for urban high salary and urban low-pay people [9]. The most well-known wastewater treatment strategies in created nations are brought together by modern wastewater treatment plants and tidal ponds for both local and mechanical wastewater.

Bangladesh is one of those developing countries, where water treatment and sanitation are currently facing challenges. Bangladesh has developed in water accessibility and arsenic reduction from potable water although having various internal problems. Awareness about sanitation and hygiene has been improved considerably in recent times. A number of local and international organizations are trying to mitigate the water related issues. Many initiatives have been taken to install tube wells for safe water sources. But the quality of water from those tube wells has noticed to be contaminated. Around 11% of death by diarrhea has been associated with the use of untreated ground water [10].Contamination is more severe in areas with silt and clay layers. In addition, improper placement of latrines and discharge of untreated effluent in the surface water are causing more severe contamination.

In Bangladesh, underground water layer depletion is one of the most significant issues. A research of 2011 shows, in Bangladesh depletion of ground water was round 0.01-0.05 m/year. Over the last 50 years, the increment of extraction of ground water was 20-260 km3/year [11]. Water extraction for irrigation by deep tube wells are the main sector of ground water contamination.

The condition of water contamination is quite different in urban and rural areas. Water scarcity is a serious issue in urban areas; as on-ground water is contaminated by toxic effluent discharge. In rural areas relatively more people have accessibility to water sources. In the past few years arsenic was a major issue. Somehow, this condition has been overcome by taking significant efforts to minimize this problem. Rural areas still lag in treatment facilities of wastewater. Village inhabitants discharge wastewater almost untreated to the nearest water bodies although there is a huge potential of this waste water to be reused in agricultural fields. Such initiative will not only reduce ground water demand, but can also serve for a better environment, if proper treatment is provided.

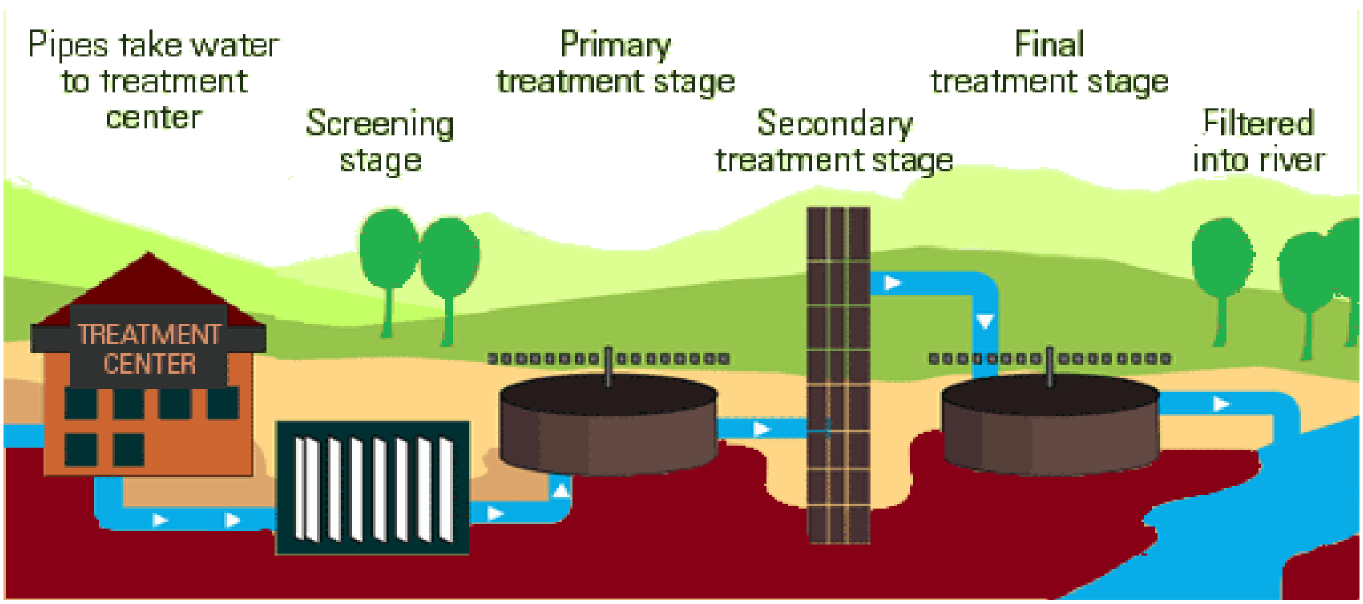

Figure 1. Schematic of typical waste water treatment process

Waste water from home has to be treated in an environment friendly manner to reuse it. In the system screening is the very first process where wastewater is cleaned (removal of course particles i.e. sanitary items, cotton buds, face wipes, glass particles and etc.); though heavy machinery is not used here. Then the primary treatment is applied, where organic/solid materials are separated. It is done by putting the screened water into settlement tanks for the solids to sink the bottom of the tank. The rest of the process is termed secondary treatment; high removal of BOD, COD and toxic materials are done in this stage. Primary treated water is stored in rectangular shaped tanks (Aeration Lane) and air is pumped inside to meet the DO. Lastly sludge is again filtered and scrapped by sand filter bed resulting in edible water to be reused. Then the clean water is released into nature for reusing. Figure 1 shows the outline of the proposed system.

In the last few decades several works have been done for treating waste water. Chen et al. showed different electrochemical techniques for treating waste water. Though all the systems were effective but all of them had very high initial cost and there were a huge chance of chemical exposure [12]. Liu et al. worked on three types of chemical system to purify industrial wastewater and did a development plant to produce electricity in the meantime of purification by using single microbial fuel cell. The researchers mainly focused to produce electricity and systems had low effectiveness of treatment process [13]. Crini et al. Reviewed 4 types of treatment system and researched on absorbent based biological treatment process. The system was only applicable for industries and high scale treatment process; cost is moderate but high risk of contamination via absorbents [14]. Le-Clech et al. did a research on membrane utilized treatment system via bio-reactor; used osmosis and reverse osmosis process to treat waste water. Bio-reactors are very tough to settle and only applicable for non-tropical region [15]. Du et al. did a compact review on treating water using microbial fuel cells along with electricity generation, showed various drawbacks of this process. It has higher efficiency, but it hampers the normal living of micro-organisms of pond [16]. Rozendal et al. did a research on wastewater treatment by using bio-electrochemical systems and implemented a successful use on treating industrial waste water along with electricity generation. The method was only applicable for Industries, can't be used in natural treatment process [17]. Kampschreur et al. conducted a research project on water treatment plants and determined the adverse effects of different centralized treatment processes. The system was effective but huge amount of NOx was produced while implementing [18].Fu et al. reviewed various treatment process and found zero-valence iron to be an effective treatment effluent. Only natural treatment processes can use zero-valence iron. High risk of iron ion contamination in ground water was the major deficiency of the plant [19]. Seto et al. did a case study on centralized treatment process on San Francisco and found that centralized systems has higher possibility on micro-organism contamination [20]. Yuan et al. did a research on urban areas on Waste Water Treatment Processes using decentralized technique. This process is also applicable for urban areas where underwater level is good enough [21].

All the above electrochemical processes are very much costly and the other processes were invented for industrial and urban waste water treatment and a large population. These plants are not very much effective while Bangladesh is a poor country and most of the people lives under the poverty line. For Khulna district of Bangladesh it is necessary to find or invent a method which would be efficient and can be implemented at low cost. In paper a new technique is designed and discussed for decentralized waste water treatment with primary and secondary treatment processes which has high efficiency and plant initial and running cost is low. This plant is very much effective for a big family or three-four small families.

2. Quality of drinking water in Bangladesh

According to Bangladesh national drinking water survey 2009, "22 million people are still drinking water that does not meet the standard level for arsenic of 0.05 mg/l and 5.6 million are in high risk of having water with more than 0.2 mg/L arsenic" [22].

Table 1 shows the standard values of different elements in water according to Department of Public Health Engineering and World Health Organization. Some common elements have been selected in this table. From recent few years, Arsenic was a very big issue of concern for Bangladesh. BOD, COD, Nitrate, Phosphate and chloride are very important elements for drinking water. Excessive amount of these elements can cause health hazard. Drinking water should contain the following elements according to the standard stated in Table 1.

Table 1. Water quality parameters [23]

Elements	Bangladesh Standards (mg/L)	WHO Standards (mg/L)
BOD_5	0.20	0.16
Arsenic	.05	0.01
COD	4.00	4.50
Aluminum	0.01	0.2
Cadmium	0.003	0.002
Iron	0.3-1.0	0.2-0.3
Chloride	150-600	-
Nitrate (NO_3^-)	10	50
Fluoride	3.5-4.0	1.5
Phosphate	6.0	-

The survey also stated that, "*98% of the tested samples meet the Bangladesh standard of 600 mg/L for chloride concentration*" [22]. Fluoride concentration was not so high according to this survey. Six samples (1%) exceeded the Bangladesh standard of 1.1-1.5 mg/L. But, Iron concentration seems to be a little bit concerning in the edible water. Throughout the country, only 60% of the tested samples meet the national standard of 1 mg/L iron. The other 40% is below the standard. The amount of phosphorus in almost 93% of the sample meet the standard value 1.96 mg/L, which is equivalent to 6 mg/L phosphate [22].

In Dhaka city, normally water is pumped from deep aquifers. However, the quality does not remain similar to the consumers. Along its transport through the pipe net-work a number of sources cause contamination of the water. Negative pressure of pump, leakage in the pipes, service installation networks under septic tanks etc. are reasons behind water contamination in the pipe network [24].

Bangladesh government has introduced rules and regulations to protect their water and environment. Different governmental organizations as well as NGOs work for implementing regulations. The Department of Environment (DoE) is a government organization, it works on that basis. This organization has created mobile court in order to implement action against environment conservation violator under the ECA Act, 2010. "Polluters pay principal" is mentioned in the ECA, 1995 [25].

Table 2 represents guidelines for different parameters in surface water. Surface water used by different activity should maintain concentration of various parameters according to the table below.

Table 2. Standard for surface water [26, 27]

Water Use	BOD (mg/L)	DO (mg/L)	pH	Total Bacteria (number per thousands)
Recreational	5-8	<3	>5	<200
Food Storages	6.5-9	<9	>6	<500
Fisheries Sector	7-8	7-10	>5	-
Agricultural	6.5	<10	<12	<900

The National Environment Management Action Plan (NEMAP), 1995 includes identification of major environmental issues and action to minimize environmental degradation improving natural environment by conserving biodiversity. Different international organization also helps financially by providing fund for implementing environmental regulations in Bangladesh namely DANIDA, SIDA, USAID, CIDA etc. [25, 27and 28].

3. Present Treatment of drinking water of Bangladesh

3.1 Urban treatment process

In urban areas, DWASA is responsible for treating potable water for the community, in the capital city Dhaka. DWASA is currently running one large and three small water treatment plants with financial assistance from different funding organizations.

According to the department of public health and engineering of Bangladesh, most of the treatment facilities include filtration, flocculation, sedimentation and disinfection. Some also include ion exchange and filtration depending on the quality of collected water. A ground water rule is developing to specify the appropriate use of disinfection to assure public health protection.

However, to meet the fastest growing water demand and reduce ground water extraction, DWASA planned to build four large surface water treatment plants until 2021. They are "Saidabad Phase II", "Saidabad Phase III", "Padma/Pagla", and "Khilkhet". These plants havebeen proposed to draw water from less polluted surface water even though they are distant sources such as rivers. The four plants are expected to have a combined capacity of 1.63 mil-lion cubic meters surface water per day, whereas in 2010 the supply of ground water was 2.11 million cubic meters per day [28-30].

3.2 Rural treatment process

Easy availability and no content of pathogenic microorganisms make ground water so popular that most of the rural population is now dependent on low-cost tube wells. Studies stated that Bangladesh achieved a remarkable success providing 97% of the rural population with bacteriologically safe tube well water. In some regions where tube well water is not trust worthy, people usually boil water for purification.

Arsenic contamination is one of the major challenges in the shallow aquifers and many parts of the country have made shallow tube well water unsafe for drinking. Different strategies have been developed to mitigate the arsenic problem. Those are classified as chemical and non-chemical treatment. Pond sand filters dug and ring well, chulli water purifiers (CWP) are some nonchemical solution for arsenic contamination. Chulli water purifier is a special type of clay oven with metal coil. Water is passing through the coil and gets purified from arsenic by heat [31]. Chemical options include different types of filters such as SIDKO, SONO, READ F, and AIKAN [26, 30].

4. Materials and Method

The research is mainly focused on wastewater treatment. In this paper, a new economical wastewater treatment for the urban side oftheSouth-Bengal (Khulna Division) site has been designed and proposed. The process is mainly a de-centralized one. Decentralized wastewater treatment does not mean one specific plant for the whole population of a defined area but it rather defines more than one or an assortment of technologies [32]. This system is mainly designed for a low to moderate population and small scale treatment [33]. Decentralized wastewater systems are appropriate especially for semi urban and rural communities, where population density is comparatively low and scattered. For treating water septic tank and anaerobic pond can be a better concept. First a village is selected from the area. Different parameters for designing the tank and pond are first collected and evaluated. Then considering all this parameters a design calculation for the septic tank and anaerobic pond is done. Only a primary treatment is not enough to make the effluent in quality of an accepted level. For secondary treatment facilitative pond is chosen. The design method includes empirical equations. Area requirement for various onsite treatment options has been calculated. Also nitrogen and phosphorus removal with these systems has been discussed. For designing this section different parameters were taken from different experimental values done by different researchers and organization.

4.1 Design of a wastewater treatment process

To evaluate the recommended decentralized treatment option in rural areas of Bangladesh, a typical village in the middle part of the country has been selected as a case to make a design of the proposed treatment process, which is decentralized wastewater treatment.

4.2 Area selected for design

The village named "Sundermahal" is situated in Surkhali union, Batiyaghata Upazila, Khulna District and Khulna division. The area is mostly flat and the climate is tropical. Average temperature for this area is about 29.9°C and the total annual precipitation is about 1812 mm. Precipitation/Rainfall is the lowest in December, with an average of 6 mm; most of the precipitation here falls in July, averaging 357 mm [34]. In 1988, 1992, 1994, 1997, 2005 and 2011 a number of flood damages were recorded [35].

According to Population Census 2011, the total population of this village is 1233 with 236 households [36]. Agriculture is the main occupation in this area. Tube wells are the main sources of drinking water. Almost 93% of the population use tube wells for potable water collection. Also ponds and other surface water sources are available for collecting water. In this area almost 36% of the households use sanitary latrines and 58% has non sanitary latrines. Almost 6% has no latrines at all [37]. So it indicates that, this area has a deficiency in sanitation. No information of wastewater treatment facility was found for this area. Figure 2 gives an overview of Southern Bangladesh (South-Bengal).

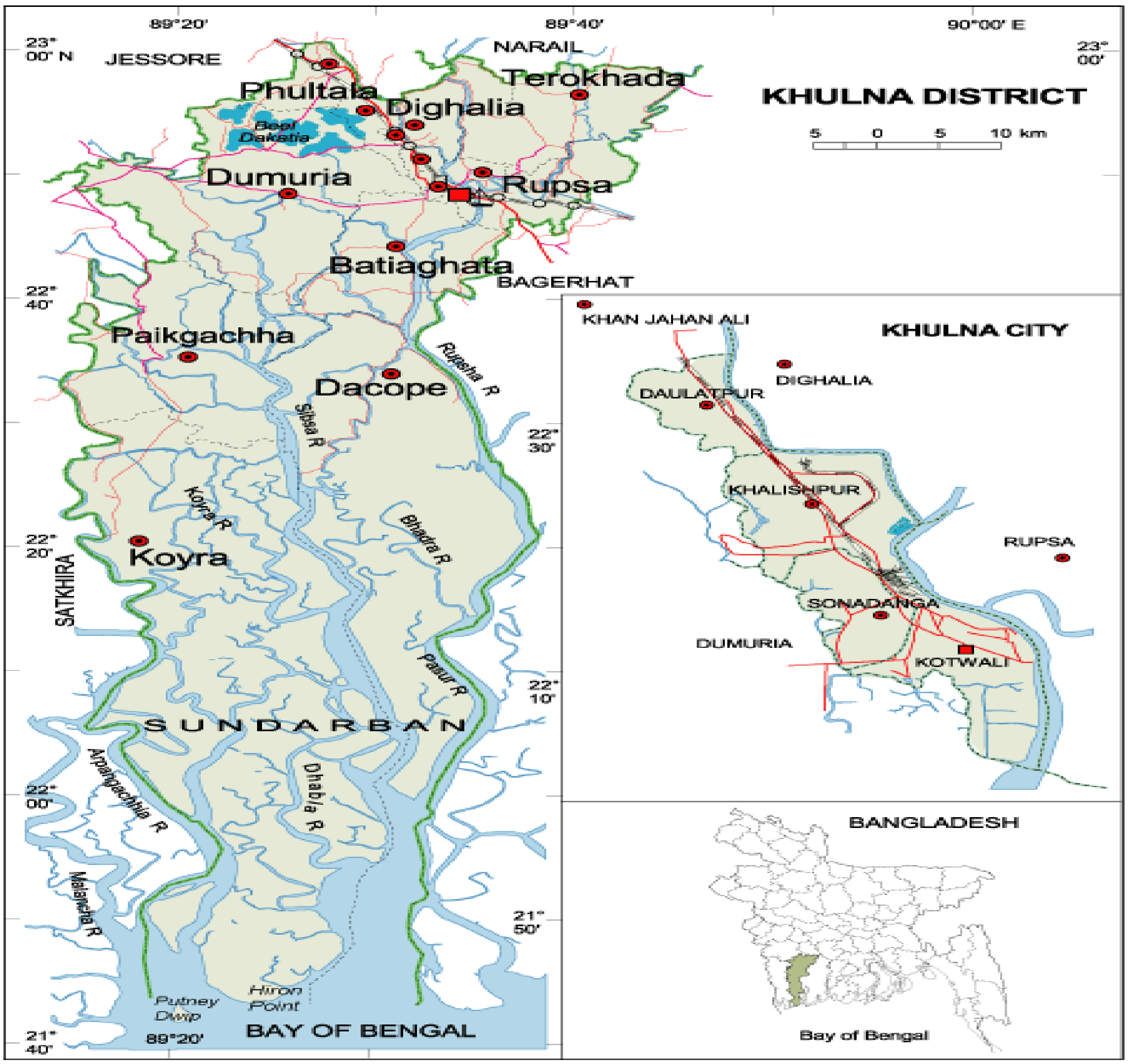

Figure 2. Location of the selected area (Collected from: Maps of Bangladesh)

In the data source used, 30 km2areas were given for the total area of the upazila including 15 other villages [36, 37]. To make the calculation simple, it has been assumed that all the villages are similar in size. Then the area of the selected village has been found about 2 km2.The condition presented is a typical condition for most of the villages in Bangladesh. There is a significant improvement potential in latrine use and reduction of open defecation but still people are in risk without any proper waste water management. Only use of latrines cannot be a single solution, also appropriate wastewater treatment is needed to complete the process and make a healthy environment.

4.3 Estimation of water flow and BOD_5

Before designing the process, some basic parameters have been collected from various sources. Among them average water consumption in rural areas of Bangladesh was found to be 83.17 liter /person/ day [38]. It is a bit lower than the urban water consumption. This could be due to less water availability or poor economic condition.

Average daily water consumption Q = 83.17 liter/person/day = 0.083 m3 /person/day (Appendix-1) will result in an average daily waste water flow QD = 87.17 m3/day, where, wastewater flow is assumed to be 85% of daily water consumption.

Table 3 includes BOD, TN, N as NH4+ and TP in the daily wastewater flow. It also includes required amount of BOD, N and P in the effluent for water usable in irrigation. Average BOD5 in the influent is calculated in Appendix. The required BOD value in the effluent is found from Table 2. The required values for Nitrogen and Phosphorus in the effluent are found from a report named Water Quality for Agriculture. Average amount of TN, N and TP in the influent is estimated as typical content in municipal wastewater with minor industrial contribution. Calculations are found in Appendix-1.Table 3 shows concentration in effluents and influents.

Table 3. Concentration of various parameters in influent and effluent

Parameter	Concentration (Influent) mg/L	Concentration (Effluent) mg/L
Nitrate component	28	10
Ammonium component	20	<5
Phosphates	6-10	<2
BOD_5	<500	15

BOD in the influent is calculated from an empirical equation (Appendix-1), for influent BOD, C0 =1000 B/QD, BOD contribution per day (B) is assumed to 40 g/capita/day for medium sized communities [39].

4.4 Pre-treatment facility

A primary treatment is needed to make the whole treatment process more efficient and to reduce the organic load in the secondary treatment. A septic tank is one of a common type of primary treatment. Also anaerobic ponds can also act as a primary treatment tools. Septic tank can be installed in each household or one anaerobic pond can be used for the whole community.

5. Results and discussion

5.1 Design of septic tank

An Indian standard code will be used for the design of the septic tank in 'Sundermahal' village.

Figure 3 represents recommended size of septic tanks according to the number of users (Bureau of Indian standards, 1993).

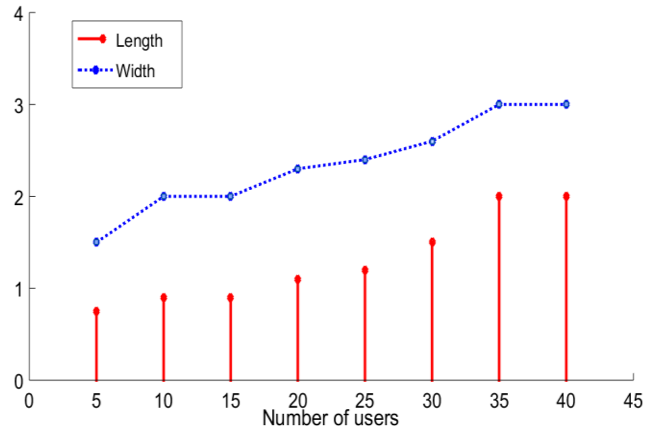

Figure 3. Length and width of septic tank according to the number of users

If 5 persons in each house are assumed for the selected village, then from Figure 3 the size of a septic tank can be found to be of 1.5 m long and 0.75 m wide. The depth is assumed 1.3 m including 1 m depth from the outlet pipe to the bottom of the tank and 0.3 m distance from roof to liquid. So a 1.13 m2 septic tank is recommended for each household in this village.

V (volume of septic tank) = (1.5*0.75*1.3) = 1.46 m3 (approximately)

This septic tank can store 1460 L liquid and each of the houses will need septic tank of approximately 1.46 m3.

Several requirements are stated for installing a septic tank. It should be 60 m away from any community well, 9 m away from any buried water storage tank and 15 m from any source of potable water or natural water body [40-42].

A septic tank can remove BOD, TSS, oil and grease. Typically a septic tank can remove 30 to 50% BOD and 60 to 80% TSS [43].

5.2 Design of anaerobic pond

Design of an anaerobic pond below has been done using Waste stabilization pond and Constructed Wetland Design Manual,

Volume of anaerobic pond, $V_A = C_0 Q_D/\lambda_v$ (1) [41]

Hydraulic retention time, $t_{AN} = V_A/Q_D$ (2)

From equation (1), VA = 141 m^3 (**Appendix 2**)

Depth of anaerobic pond is considered to be 3 m and the area would then be almost 37 m^2.

Hydraulic retention time, t_{AN} = 1.6 days (approx.) (**Appendix 2**)

The minimum value of retention time is recommended to be one day. With the designed anaerobic pond almost 70% BOD removal is possible in the temperature above 25°C [42, 42].

5.3 Secondary treatment

Only a primary treatment is not enough to make the effluent in quality of an accepted level. With the above design of septic tank and anaerobic pond 30 to 70% of BOD removal is expected. For secondary treatment different options can be chosen, such as wetland, facultative pond or sand filters. Depending on the geography, landscape and weather condition various options can be adopted.

5.4 Design of Facultative pond

Area of facultative pond, $A_F = 10C_0Q_D/\lambda_s$ (3)

In Bangladesh, average temperature is assumed to be more than 25°C. Here in the calculation 28°C have been used. In this design a primary treatment has already been suggested. In primary treatment, for septic tank almost 30% BOD is removed. So in further secondary treatment design a reduced BOD in the secondary influent is assumed.

From equation (3), AF = 784.692 m^2(**Appendix 3**)

Retention time,

$T_F = A_F D / Q_M$ (4)

Where, D is the depth of the pond (1.5 m usually) and QM is mean flow, QI is influent flow, QE is effluent flow and 'e' is evaporation rate.

Evaporation rate for Bangladesh is found from a historical data study and the values vary with temperature during the year. An average monthly evaporation value of 120 mm for 28°C is considered in this calculation [44]. From this a daily evaporation rate can be calculated.

Average daily evaporation rate (e) = 120 /30 = 4 mm/day

$Q_M = (Q_I + Q_E)/2$ (5)

$Q_E = Q_M - 0.001\ A_F.e$ (6)

From equation (6) and (5),

Q_E= 84 m^3/day

Q_M= 85.67 m^3/ day = 86 m^3/day

Then, putting values of Q_M and Q_E in equation (4),

T_F= 14 days (approx.) (**Appendix 3**)

Again, if an anaerobic pond is considered as primary treatment, from the above equation the area for facultative pond becomes 260 m^{2}and the retention time found 6 days. This variation is because of the high BOD removal in the anaerobic pond, with almost 70% BOD removal in an anaerobic pond.

5.5 Design of wetland

Area of reed bed of wetland,

$A = K.Q_D(\ln C_0 - \ln C_t)$ (7)

K is a rate constant, the value found for BOD removal K20 = 180 m /year = 0.5 m/day for subsurface wetland and θ is constant and the value is 1.1. [6-9]

$K_T = K_{20}\theta^{(T-20)}$ (8)

$K_{28} = (0.5)\ (1.1)^{28-20}$ = 1.08 m/day (for 28°C)

Using values of K in equation (7),

A = 346.386 m^2(approx.) (**Appendix-4**)

This area for subsurface wetland is calculated with 30% BOD reduction from septic tank. The value varies if an anaerobic pond is used as pretreatment. Then the area needed will be 209 m^2. The depth of the wetland designed above is considered to be 0.6 m. Equation 7 and 8 have been collected from reference no [41] and [42].

5.6 Design of sand filter

Using a guideline from Washington State Department of Health (2012) an intermitted sand filter is designed below.

The surface area of filter bed

$A_S = Q_D$/ Loading rate (9)

The maximum loading rate is 2 to 5 gal/day/square feet recommended in the EPA design manual; the depth of media is 46-91 cm [45]. Design loading rate is considered 4 gal/day/square feet.

A_S = 534.785 m^2(approx.) (**Appendix 5**)

420 m^{2}sand filters are found to be suitable for loading rate 4 gal/day/square feet.

6. Design summary

The above design shows an overview of the total decentralized system for a typical village. The area of the village is about 2 km2 (assumed). Primary treatment facilities show, occupying a small area of about 37 m2 for the anaerobic pond. For secondary treatment, the area of a wet-land found was almost half of the facultative pond. To implement a facultative pond of 784.926 m2 in this small area will not be suitable.

In the above design several systems are discussed with an example size of treatment facility. Also a comparison between options has been done to evaluate suitable options according to the situation.

To make the effluent reusable, required BOD value has been calculated according to the requirements given by the government in Table 3. As nutrient concentration is important for reusing the effluent water in irrigation, nitrogen and phosphorus removal has been discussed. With a facultative pond the effluent fulfils requirement given in Table 2. But for the other two systems N and P concentration was higher than requirement.

7. Design advantages and limitation

The new waste water treatment plant is discussed and designed in this paper which is very much cost effective. The plant is easy to make and it treats the water by removing waste from it specially BOD, Nitrogen and phosphorus. It can be implemented in not only rural areas but also in semi urban areas. It does not need any modern machinery rather it can be build using very low initial investment comparing to other centralized and de-centralized methods. Any big family or small two to four families can easily use one plant for water treatment. In the above design, some assumptions have been done for various parameters for calculation. In some cases, assumptions may not be similar to reality. Also temperature has been considered as 28° C, which may be a bit lower than real situation. This is considered to make the calculation simple. Chosen area is considered as a typical village, but there are areas with different topography than the designed one. So this design may not be appropriate for hilly or coastal regions in the southern and southwest part of Bangladesh. Nitrogen and phosphorus removal for the designed system has been calculated with a rough estimation. The efficiency could be different in practical case. This design is an example and a model of the recommended solution. When implementing this solution in reality, some changes according to necessity could be done. Such as for places with a high ground water table, depth of anaerobic pond or septic tank could be adjusted. In addition, some specific value of the area of this village has not been found. Therefore, an estimation and assumption have been done.

8. Conclusion

Water pollution is one of the major concerns of Bangladesh, especially in rural areas. Many people die every year due to polluted drinking water. The proposed plant is very much efficient and feasible for implementing in southern site of Bangladesh. If some modification in the plant is done considering weather, size and pollution rate, then this plant can also be used in other locations of Bangladesh, which may be a future research consideration. Finally, this paper would help researchers for further development of the system and finding more feasible and efficient treatment plant for Bangladesh.

References

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

[2] Day, D. (1996). How Australian social policy neglects environments. Australian Journal of Soil and Water Conservation, 9: 3-9.

[3] Population Division, Department of Economic and Social Affairs of the United Nations. Data is from the 2014 World Urbanization Prospects report released July 10th, 2015.

[4] United Nations Commission on Sustainable Development (1997). Comprehensive assessment of the fresh water resources of the world: A report of the Secretary-General. Retrieved from: www.un.org/dpcsd/dsd/freshwat.html

[5] Giles, H. and B. Brown (1997). And not a drop to drink. Water and sanitation services in the developing world. Geography, 82: 97-109

[6] Welch, E.B. (1992). Ecological effects of wastewater: applied limnology and pollutant effects. Chapman and Hall, New York

[7] Chow, V.T., R. Eliason and R.K. Linsley (1972).Development and trends in wastewater Engineering.In Wastewater Engineering. McGraw-Hill Book Company. New York, St. Louis, Dusseldorf, Johannesburg, Kuala Lumpur, London, Mexico, Montreal, New Delhi, Panama, Rio de Janeiro, Singapore, Sydney, Toronto. pp. 1-11

[8] Cooper, P.F. (2001). Historical aspects of wastewater treatment. In Decentralized sanitation and reuse concepts, systems and Implementation. Eds., Lens P., Zeeman G., and G. Lettinga.IWA Publishing. London. pp. 11-38

[9] Doorn, M.R.J., S. Towprayoon, S. Maria, M. Vieira, W. Irving, C. Palmer, R. Pipatti and C.Wang, (2006).Wastewater treatment and discharge.In 2006 IPCC Guidelines for National Greenhouse Gas Inventories. WMO, UNEP. pp. 5: 1-6

[10] Knappett, P.S., McKay, L.D., Layton, A., Williams, D.E., Alam, M.J., Mailloux, B.J., Ferguson, A.S., Culligan, P.J., Serre, M.L., Emch, M. and Ahmed, K.M., (2012). Unsealed tube wells lead to increased fecal contamination of drinking water. Journal of water and health, 10(4), pp.565-578.

[11] Shamsudduha, M., Taylor, R.G., Ahmed, K.M. and Zahid, A., (2011). The impact of intensive groundwater abstraction on recharge to a shallow regional aquifer system: evidence from Bangladesh. Hydrogeology Journal, 19(4), pp.901-916.

[12] Chen, Guohua. "Electrochemical technologies in wastewater treatment." Separation and purification Technology 38.1 (2004): 11-41.

[13] Liu, Hong, RamanathanRamnarayanan, and Bruce E. Logan. "Production of electricity during wastewater treatment using a single chamber microbial fuel cell." Environmental science & technology 38.7 (2004): 2281-2285.

[14] Crini, Grégorio. "Recent developments in polysaccharide-based materials used as adsorbents in wastewater treatment." Progress in polymer science 30.1 (2005): 38-70.

[15] Le-Clech, Pierre, Vicki Chen, and Tony AG Fane. "Fouling in membrane bioreactors used in wastewater treatment." Journal of membrane science 284.1 (2006): 17-53.

[16] Du, Zhuwei, Haoran Li, and TingyueGu. "A state of the art review on microbial fuel cells: a promising technology for wastewater treatment and bioenergy." Biotechnology advances 25.5 (2007): 464-482.

[17] Rozendal, Rene A., et al. "Towards practical implementation of bio-electrochemical wastewater treatment." Trends in biotechnology 26.8 (2008): 450-459.

[18] Kampschreur, Marlies J., et al. "Nitrous oxide emission during wastewater treatment." Water research 43.17 (2009): 4093-4103.

[19] Fu, Fenglian, Dionysios D. Dionysiou, and Hong Liu. "The use of zero-valent iron for groundwater remediation and wastewater treatment: a review." Journal of hazardous materials 267 (2014): 194-205.

[20] Seto, Edmund Y., et al. "A quantitative microbial risk assessment of wastewater treatment plant blending: case study in San Francisco Bay." Environmental Science: Water Research & Technology 2.1 (2016): 134-145.

[21] Yuan, J., Dong, W., Sun, F., Li, P., & Zhao, K. (2016). An ecological vegetation-activated sludge process (V-ASP) for decentralized wastewater treatment: system development, treatment performance, and mathematical modeling. Environmental Science and Pollution Research, 23(10), 10234-10246.

[22] Bangladesh national drinking water quality survey 2009, 2011

[23] UNICEF, 2011; Department of Public Health Engineer-ing Bangladesh, 2016

[24] Dhaka Water Supply and Sanitation Project (World Bank). Retrieved from: http://documents.worldbank.org/curated/en/319831484319690176/ICR-Main-Document-P093988-2016-12-21-19-34-01102017.docx

[25] Rahman, MdSaifur, and Lukas Giessen. "The power of public bureaucracies: forest-related climate change policies in Bangladesh (1992–2014)." Climate Policy 17.7 (2017): 915-935.

[26] Water Quality Parameters Bangladesh Standards & WHO Guide Lines. (Public Works Dept., Peoples Republic of Bangladesh) Retrieved from: http://dphe.gov.bd/index.php?option=com_content&view=article&id=125&Itemid=1

[27] Bangladesh National Drinking Water Quality Survey. (UNISEF) Retrieved from: https://www.unicef.org/bangladesh/BNDWQS_2009_web.pdf
[28] Hossain, MdMoazzem, et al. "Corporate social and environmental reporting practices: A case of listed companies in Bangladesh." Sustainability Accounting, Management and Policy Journal 8.2 (2017): 138-165.
[29] Sharma, Manoj. "The Dhaka Water Services Turnaround." (2017).
[30] Farok, GM G. "Non-Revenue Water (NRW) is a challenge for Global Water Supply System Management: A case study of Dhaka Water Supply System Management." Journal of Mechanical Engineering 46.1 (2017): 28-35.
[31] Johnston, R. B. "Death by heat: the Chulli treatment system." Water, sanitation and hygiene: sustainable development and multisectoral approaches. Proceedings of the 34th WEDC International Conference, United Nations Conference Centre, Addis Ababa, Ethiopia, 18-22 May 2009. Water, Engineering and Development Centre (WEDC) Loughborough University of Technology, 2009.
[32] Iribarnegaray, Martín Alejandro, et al. "Management challenges for a more decentralized treatment and reuse of domestic wastewater in metropolitan areas." Journal of Water Sanitation and Hygiene for Development (2017): washdev2017092.
[33] Libralato, Giovanni, AnnamariaVolpiGhirardini, and Francesco Avezzù. "To centralise or to decentralise: an overview of the most recent trends in wastewater treatment management." Journal of Environmental Management 94.1 (2012): 61-68.
[34] Climate report and data. Retrieved from: https://en.climate-data.org/location/3943
[35] Hofer, Thomas, and Bruno Messerli. "Floods in Bangladesh." History, dynamics and rethinking the role (2006).
[36] Population cencus Bangladesh, 2016. Retrieved from: http://203.112.218.65:8008/WebTestApplication/userfiles/Image/PopCenZilz2011/Zila-Khulna.pdf
[37] Climate change and natural disaster report. (Bangladesh Bureu of Statistics) Retrieved from: http://203.112.218.65:8008/WebTestApplication/userfiles/Image/National%20Account%20Wing/Disaster_Climate/Disaster_Climate_Statistics%2015.pdf
[38] Al-Amin, M., et al. "Domestic water consumption patterns in a village in Bangladesh." 4th Annual Paper Meet and 1st Civil Engineering Congress, Dhaka, Bangladesh. 2011.
[39] De Vries, J. "Soil filtration of wastewater effluent and the mechanism of pore clogging." Journal (Water Pollution Control Federation) (1972): 565-573.
[40] Stenstrom, Michael K., and R. Gary Gilbert. "Effects of alpha, beta and theta factor upon the design, specification and operation of aeration systems." Water Research 15.6 (1981): 643-654.
[41] McGhee, Terence J., and Ernest William Steel. Water supply and sewerage. Vol. 6. New York: McGraw-Hill, 1991.
[42] Kadlec, Robert H., and Scott Wallace. Treatment wetlands. CRC press, 2008.
[43] Gilbert Gedeon, P. E. "Wastewater Treatment System Performance Requirements."
[44] Rajib, M. A., M. M. Rahman, and E. A. McBean. "Validation of Observed Evaporation-Temperature Trend Models with GCM Projections for Bangladesh." proceedings of the 5th International Water Association Young Water Professionals Conference. Vol. 5. No. 7. 2010.
[45] EPA manual, 2000. (US Environ. Pro. Asso.) Retrieved from: https://www.epa.gov/sites/production/files/2015-06/documents/types_of_filter.pdf

Nomenclature

Sign	Meaning
BOD	Bio-chemical Oxygen Demand
COD	Chemical Oxygen Demand
WHO	World Health Organization
BOD_5	5-day Bio-chemical Oxygen Demand
ECA	Environment Conservation Amendment
DO	Demand of Oxygen
DWASA	Dhaka Water Supply & Sewerage Authority
TSS	Toxic Shock Syndrome
A_S	Surface Area
N	Nitrogen
P	Phosphorus
EPA	Environmental Protection Agency

Appendix

Appendix 1
Calculation of water flow and BOD

Avg. water consumption/day, Q = 83.17 L/person/day =0.083 m^3/person/day

Waste water flow is assumed 85% with respect to total consumption.

Avg. waste water flow/day, Q_D = 0.85 Q = 87.17 m^3/day (for 1233 persons)

BOD contribution/day, B = 40 g/capita (for medium sized community)

BOD_5 of the influent, $C_0 = B/Q_D$ = 0.5658 g/L = 565.8 g/m^3

Appendix 2
Calculation for anaerobic pond volume

Volume of anaerobic pond, $V_A = C_0 Q_D/\lambda_v$ (1)

Volumetric loading of BOD to the pond = λ_v

For a temperature greater than 25^0C, λ_v is assumed to be 350 g/m^3/day [9]

So, V_A = (565.8) (87.17)/350 = 140.92 m^3 =141 m^3 (approx.)

Hydraulic retention time, $t_{AN} = V_A/Q_D$ = 141/87.17 = 1.6 days (approx.) (2)

Appendix 3
Calculation for facultative pond

Area of facultative pond, $A_F = 10 C_0 Q_D/\lambda_s$ (3)

Surface loading,λ_v = 20T – 120 = 20.(28) – 120 = 440 kg/ha.day

Let assume 30% BOD removal in the primary treatment, thus

BOD of influent = $0.7C_0$
So, A_F = (10) (0.7) (565.8) (87.17)/440 = 784.926 m^2 (approx.)
Time for retention, $T_F = A_F D/Q_M$ (4)
Here, Depth of the pond, D = 1.5 m (assumed)
Now,
Mean flow, $Q_M = (Q_I+Q_E)/2$ (5)
Effluent Flow, $Q_E = Q_M - 0.001A_F.e$ (6)
From eqn3, eqn5 and eqn6,
Q_E = 87.17 - (0.001) (784.926) (4) = 84.03 m^3/day = 84 m^3/day
Q_M = 85.67 m^3/ day = 86 m^3/day
Putting the values of Q_M and Q_E in eqn3,
T_F = (784.926) (1.5)/85.67 days= 13.74 days = 14 days (approx.)

Appendix 4
Calculations for Wetland

Area of reed bed of wetland, $A = KQ_D (\ln C_0 - \ln C_T)$ (7)
Here, K is a rate constant. The value found for BOD removal, K_{20} = 0.5 m/day (For sub-surface wetland)
Now,
$K_T = K_{20}.\theta^{(T-20)}$ (8)
$K_{28} = (0.5)\ (1.1)^{28-20}$ = 1.08 m/day (for 28°C)
Using the value of K in eqn7,
A = (1.08) (87.17) (ln ((0.7) (566)) - ln10) = 346.386 m^2 (approx.)

Appendix 5
Calculations for Sand Filter

Surface area of filter bed, $A_S = Q_D$/Loading Rate
From, EPA-Design Manual 1999;
Depth of media = 46-91 cm; Maximum Loading Rate = 2-5 gal/day/sq. feet
Let, Load Rating = 4 gal/day/sq. feet
A_S = 87170/163 = 534.785 m^2 (approx.)