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Water Recycle and Reuse – A Case Study of NMIMS University Campus

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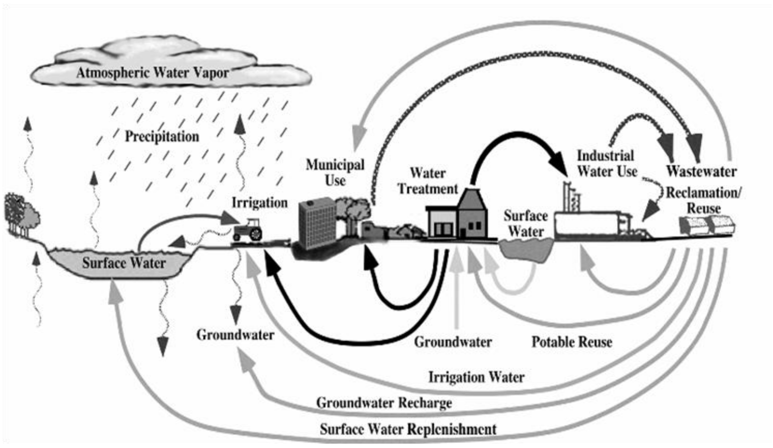
ABSTRACT: *A growing population worldwide and limited potable water resource is reducing the availability and quality of drinking water supplies. In technological term the water recycling, generally refers to projects that use technology to speed up the natural processes of recycling, which may be further characterized as "unplanned" or "planned". The earth is recycling and reusing water for millions of years through the natural water cycle. The treated wastewater may be reused to irrigate fields, recharge aquifers, flush toilets, and may also be also be used for potable purposes, however in such case a careful monitoring for pathogen removal is warranted. The wastewater treatment technologies, which make it reusable, include microfiltration (MF) and ultra filtration (UF) as pretreatment to reverse osmosis (RO) unit, natural systems such as wetlands, soil aquifer treatment and coagulation-adsorption systems. The disinfection is very important unit operation for ensuring the use of treated water from the view point of public safety. Overall, wastewater reclamation has found worldwide success.The natural interactions between water, soil, atmosphere, plants and microorganisms include physical, chemical and biological processes with decontaminating capacities. The natural or energy-saving wastewater treatment systems utilize these processes and thereby enable a sustainable management in the field of wastewater treatment, offering low investment and operation costs, little energy consumption, little and low-skill labor requirements, good landscape integration and excellent feasibility for small settlements, especially when remote from centralized sewer systems.The objective of this paper is to study the feasibility of the water recycle and its reuses for its effective application in Narsee Monjee Institute of Management Studies (NMIMS), which is located at the bank of Tapi River at village Babhulde, Taluka Shirpur, Dhule District, Maharashtra State of India. The present resources of water available for the campus are sufficient to fulfill the present water demand. However, to avoid the pollution of Tapi river which flows by the side of the campus the waste water is proposed to treat to the standard such that it can be reused for landscape irrigation and flushing of toilets and urinals.*

KEY WORDS:*Life Cycle Cost Analysis, Moving Bed Bio Reactor, Recycling of Waste Water, Sewage Treatment Plant, Waste Water Treatment*

I. INTRODUCTION

The term "wastewater" means, that the water that is no longer wanted i.e. no further benefits can be derived out of it. In waste water around 99 % by volume is liquid and only 1% is the solid wastes. An understanding of its potential for reuse to overcome shortage of freshwater existed in Minoan civilization in ancient Greece, i.e. 5000 years back, where the utilization of wastewater for agricultural irrigation was usual practice. The waste water farm practices have been recorded in Germany, UK, China and India since 16th and 18th centuries. However, planned reuse is gained importance only two or three decades ago, as the demands for water dramatically increased due to technological advancement, population growth, and urbanization, which put great stress on the natural water cycle. The several pioneering studies have provided the technological confidence for the safe beneficial reuse of reclaimed water. Although the initial emphasis was mainly on reuse for agricultural and non-potable uses at the tail end of sewerage system, whereas, the recent trends prove that there are opportunities for direct use to various applications closer to the point of generation. A general representation of the current practices of water usage in is shown in Figure 1, which presents the cycling of water from surface and groundwater resources to water treatment facilities, irrigation, municipal, and industrial applications, and to water reclamation and reuse facilities. The major pathways of water reuse include irrigation, industrial use, surface water replenishment, and groundwater recharge. The potential use of reclaimed water for a potable water source is also shown. The quantity of water that is transferred depends on the watershed characteristics, climatic and hydro geologic factors, the degree of water utilization for various purposes, and the degree of direct or indirect water reuse.

Figure – 1 : Recycling of Water Through Hydrologic Cycle



A combination of growing population and limited potable water resources is reducing the availability and quality of drinking water supplies. In addition, problems resulting from the disposal of wastewater continue to appear. Therefore, wastewater management practices that protect, conserve and fully utilize water resources are vital to the nation. Currently only 2 % of wastewater is being reused worldwide whereas according to various studies there is a great potential for the improvement of the current status. The recovery of wastewater means giving it a second life. Increasing the safe use of recycled water can greatly assist in meeting water requirements, enhance the environment, and benefit public health by preserving resources upon which public health protection is based. The water recycling may be termed as critical element because water conservation and water recycling fulfills the environmental needs and demand thus supporting the sustainable development and a viable economy. The value of wastewater is becoming increasingly understood in arid and semi-arid countries and many countries are now looking forward to ways of improving and expanding wastewater reuse practices. The research scientists in many of the countries are evaluating it as one of the options for realizing the future water demands.

II. LITERATURE REVIEW

The recycling can be defined as to recover useful materials from garbage or waste. It can further be termed as to extract and reuse. The water recycling is the reusing treated wastewater for beneficial purposes such as agricultural and landscape irrigation, industrial processes, toilet flushing, and ground water recharge. In current practices most of the time water is recycled and reused on site. A common type of recycled water is water that has been reclaimed from municipal waste water, or sewage. The term water recycling is generally used synonymously with water reclamation and water reuse.Despite a long history of wastewater reuse in many parts of the world, the question of safety of wastewater reuse still remains an enigma mainly because of the quality of reuse water. There always have been controversies regarding the quality of the recycled wastewater because the public health concern is the major issue in any type of reuse of wastewater, whether for irrigation or non-irrigation purpose, especially long term impact of reuse practices. The other issues include the socioeconomic considerations and hydro-geologic conditions. The socioeconomic considerations include community perceptions, and the costs of reuse systems. Wide community level surveys in various States of Australia during early 1990s indicated that in general, public is not averse to the concept of wastewater recycling within the community. In one of such surveys, less than 15% people readily agreed for potable reuse of treated waste water. While non-potable reuses options is a technically accepted option, although the concerns about possible health risks are frequently raised. However, appropriate treatment techniques with a good margin of factor of safety must be incorporated to eliminate, or at least minimize the potential risks of health hazard. The economic considerations are necessary because, when "first-hand" water is available at a cheaper price, it may not be worthwhile to reuse wastewater, unless there are special reasons. The due consideration of hydro-geologic conditions assists to compare the reuse water quality and the quality of alternative sources intended for the same kind of use. Almost all the guidelines and standards for wastewater reuse deal mainly with the reuse of wastewater for irrigation purpose. It is mainly because irrigation is the highest water consuming activity in entire world, and hence is the first option considered in any reuse planning.

III. BACKGROUND OF PROPOSAL

The Narsee Monjee Institute of Management Studies (NMIMS) is located at the left bank of Tapi River at village Babhulde, Taluka Shirpur, Dhule District, Maharashtra State India. The NMIMS is a residential campus developed in 48 acres of land and provides a state of art facilities to the students, faculty and staff. The present infrastructure of NMIMS includes main administrational building, the buildings for different departments, boys' and girls' hostels, buildings for some amenities such as gymkhana, banks and a small market and the quarters for faculties and staffs. At present the waste water system of the campus includes the conventional septic tanks designed as per requirement of individual building and the effluent from these tanks is disposed in the soak pits, which is a traditional practice in the area. In the rainy seasons, especially in the case of intense rainfall these soak pits pose problems by rejecting effluent due to rise in GWT and uncontrolled runoff. Again, the effluent characteristics from these septic tanks are quite poor and does not comply the desired standards for disposal and thus may contaminate the surface water of river Tapi, which flows by the side and is the main source of water for the campus. At the same time it is obligatory on the part of administration of NMIMS to treat the waste water up to the desired level as per norms and standard laid by the state pollution control board (SPCB) of Maharashtra state. Hence, Waste Water Treatment Plant (WWTP) with treatment units to treat the waste water as per requirement of SPCB of Maharashtra is proposed for campus. A complete study of the water demand pattern and waste water generation in the campus is done. The potential areas where the treated waste water can be reused along with the demand in those areas are also studied. The study resulted that the major demand of landscape irrigation of 25 acres of land can be satisfied by the treated waste water. The treated waste water may also be used to fulfill the evaporation losses of artificial lakes in the premises. The another potential area is the use for flushing the toilets and urinals in individual buildings, however this arrangement will require the laying and installation of separate pipe line, pumping system and storage.

IV. DATA COLLECTION

The present population of the campus is around 2100, residing in the campus hostels and staff quarters. The people are using the water for their day to day activities such as drinking, cooking, washing, flushing, bathing, housekeeping etc. The other water requirement in the campus is for swimming pools, water fountains and artificial lakes, cleaning of roads, floors of office buildings, some laboratories, public toilets and urinals and the landscape irrigation. According to the master plan, the facilities in the campus are planned for the population of 6000. The Tapi River is the source of raw water for the water treatment plant (WTP), which fulfills the demand including the demand for landscape irrigation. A WTP of 1.50 MLD (millions liters per day) is functioning in campus, out of which 1.0 MLD is used for residential and institutional sector, whereas 0.50 MLD is used for landscape irrigation and swimming pool. The water which is used for residential and institutional sectors are the main source for waste water generation. Hence, it is proposed to install a STP of 0.90 MLD.

V. WASTEWATER SAMPLING AND ANALYSIS

The purpose of sampling and analysis is to find out the constituents of the waste water and to plan and design the various unit operations required for treatment. The composite sampling of the waste water is done at various outlet locations. The collected samples are properly marked and tested in the chemistry and environmental engineering laboratory as per standard practice and procedure. The characteristics of waste water collected at different sources are shown in Table 1.

Table – 1 : Characteristics of Waste Water

Parameters	Unit	Admin. Bldg.	Civil Wing	Boys Hostel	Girls Hostel	Staff Quarters
pH		6.5	6.8	8.1	7.8	8.4
BOD_5	mg/L	260	255	310	322	318
COD	mg/L	485	481	520	510	498
Total Suspended Solids	mg/L	380	375	448	415	416
Total Kjeldahl Nitrogen	mg/L	48	45	42	38	35
Total Phosphorus	mg/L	7	6	5	5	6
Oil and Grease	mg/L	22	21	25	24	25
Sewage Temperature	^{O}C	28	26	30	29	28

After analyzing the characteristics of waste water samples collected at various places and the surrounding parameters, the design parameters of the waste water considered for designing wastewater treatment plant are mentioned in Table – 2.

Table -2 : Wastewater Characteristics for Design of WWTP

Parameters	Unit	Value
pH		6.5-8.5
BOD_5	mg/L	250-350
COD	mg/L	450-550
Total Suspended Solids	mg/L	350-450
Total Kjeldahl Nitrogen	mg/L	40-50
Total Phosphorus	mg/L	5-7
Oil and Grease	mg/L	20-30
Min. Sewage Temperature (Tmin)	^{O}C	25
Max. Sewage Temperature (Tmax)	^{O}C	30
Elevation above MSL	m	150
Min. Ambient Temperature	^{O}C	8
Max. Ambient Temperature	^{O}C	45

The expected characteristics of the effluent generated after treatment are listed in Table – 3.

Table - 3 : Expected Characteristics of Treated Wastewater (Effluent from WWTP)

Parameters	Unit	Value (Equal or less than)
pH		6.5-7.5
BOD_5	mg/L	20
COD	mg/L	50
Total Suspended Solids	mg/L	30
Ammonia Nitrogen	mg/L	1
Nitrate – N	mg/L	10
Total Phosphorus	mg/L	2
Oil and Grease	mg/L	10

The effluent from treatment must comply WHO recommended standards so that it can be reused. The values for various parameters are given in Table 4 for its reuse for landscape irrigation and flushing. These values are stringent than values given in Table 3 and therefore are considered as basis for the design of WWTP.

Table – 4 : Expected Quality of Treated Waste Water for Landscape Irrigation and Flushing

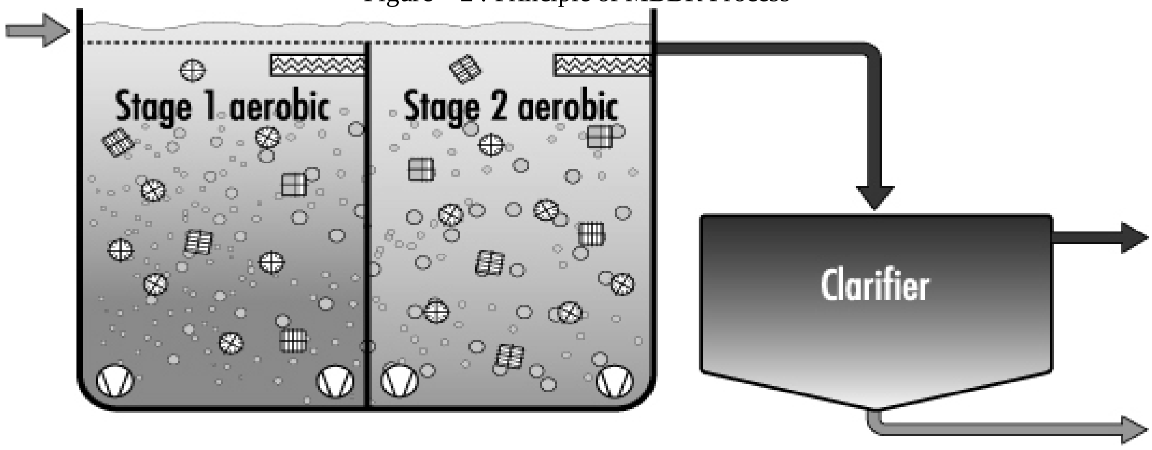
Parameters	**Unit**	**Value**
PH		6.9 – 7.1
BOD_5 at 20^0C	mg/L	≤ 10
COD	mg/L	≤ 50
Total Suspended Solids	mg/L	≤ 10
Ammonia – N	mg/L	≤ 1
Nitrate – N	mg/L	≤ 10
Oil and Grease	mg/L	≤ 10
Residual Chlorine	mg/L	≤ 1

TREATMENT METHOD - MOVING BED BIO REACTORS (MBBR)

The Moving Bed Bio Reactor (MBBR) is proposed and selected as treatment process. The MBBR is an integrated fixed film activated sludge process. The small cylindrical shaped carriers are added in the aeration tank to support the bio film growth. The bio film carriers are suspended in the activated sludge mixed liquor and thoroughly mixed using air agitation or mixers. The principle diagram of the MBBR process is shown in the Figure -2.

The MBBR does not require any return activated sludge flow or backwashing as in case of the traditional process. At the end clarifier is required to settle sloughed solids. The bio film carriers are retained in the reactor by the use of perforated plate at tank outlet. It provides an advantage for plant upgrading by reducing the solids loadings on existing clarifiers. With this technology it is possible to handle extremely high loading conditions without any problems of clogging, and treating the domestic wastewater on a relatively small footprint. The system mainly consists of a one or more stage system depending on the qualitative demand of raw waste water and effluent. The proposed WWTP includes the many essential units such as medium screens, oil and grease chamber, equalization tank, MBBR basin, Lamella clarifier, clarified water tank (CWT), pressure sand filter (PSF), activated carbon filter (ACF), treated water tank (TWT) and sludge dewatering equipments. The process flow diagram for treatment process is given in Figure – 3 (appended at end).

Figure – 2 : Principle of MBBR Process



VI. PROCESS DESCRIPTION

The raw sewage from NMIMS campus will be made available at the inlet of WWTP. The raw sewage will be passed through manually cleaned medium screen (6mm opening) by gravity to screen the floating materials, plastics, papers, etc, and the screened out materials will be collected manually at regular intervals and will be safely disposed off. Thereafter the wastewater will flow by gravity to oil and grease chamber, where oil and grease will be trapped and taken out by suitable mechanism. The preliminary treated wastewater from oil and grease tank will be collected in the equalization tank which will serve as balancing tank to store the excess flows during peak hours and to supply the wastewater during the lean period so as to allow constant flow rate at downstream units. The air will be supplied at the bottom of equalization tank to keep wastewater in mixed condition and also to maintain aerobic condition in the tank. The secondary treatment consists of MBBR basin and lamella clarifier. The MBBR basin will be oxygenated through diffused aeration process and will effectively bio-degrade the organic matter to the required BOD level of purity. The effluent from MBBR basin will be passed through lamella clarifier where sludge will be settled and supernatant will overflow to CWT where chlorine will be added for disinfection. The settled sludge will be stored in sludge holding tank. The air will be supplied in the sludge holding tank to maintain the aerobic condition of the sludge. The sludge will then be pumped to sludge dewatering equipment (filter press) where sludge will be dewatered to required sludge concentration. The supernatant from filter press will be recycled back to the inlet of STP. The sludge cake will be collected from outlet of filter press and sent for safe disposal. From CWT the wastewater will be pumped to pressure sand filter for further removal of suspended solids and then it will be passed through activated carbon filter for filtering residuals. The PSF and ACF will be regularly backwashed and backwashed water will be brought to inlet of STP. The treated wastewater will be disinfected with UV radiation and stored in TWT for supply the treated wastewater for reuse applications for landscape irrigation and flushing purpose.

VII. COST ANALYSIS

Selection of Treatment Process Using Life Cycle Cost (LCC) Analysis

The final selection of treatment process is done using life cycle cost (LCC) analysis. LCC is a tool to evaluate the best cost effective alternative among various alternatives to achieve the lowest long term cost of ownership. Basically, the LCC is the total cost of ownership of equipment, assets, including cost of land acquisition, operation and maintenance. A life cycle analysis of costs for wastewater treatment operations should consider capital as well as recurring costs, which are enlisted below :

- Project development costs, including initial site assessments and permits, process design, detail engineering, and site preparation.
- Capital costs, including equipment procurement, installation, construction, and commissioning costs.
- Operating costs, including labour, training, safety measures, reagents, consumables, power, maintenance, and waste disposal.
- Environmental liability costs, including recurring sludge management, and environmental bonding requirements that can tie up capital that could be otherwise deployed for new projects.
- Site closure costs, including site remediation measures and care and maintenance

In the LCC analysis, initial capital costs, periodic replacement costs (for items such as diffusers, membranes, pumps, blowers that must be replaced one or more times within the life cycle period of 30 years), and present value of O&M costs are estimated for each of the process i.e. Extended Aeration (EA), Sequencing Batch Reactor (SBR), Moving Bed Bio Reactors (MBBR), Submerged Aerobic Fixed Film Reactor (SAFF), Membrane Bio Reactor (MBR), on the basis of the following assumptions –

- Annual Inflation @ 6%.
- Annual Discount @ 6%.
- Replacement cost is included for major equipment such as pumps, air blowers, air diffusers, membranes as applicable.
- Frequency of replacement for diffusers, membranes is 7 years.
- Frequency of replacement for pumps, air blowers is 15 years.
- Land cost is Rs.1.0 million/Acre.
- Capital cost is taken from PWD DSR for the base year 2012.
- Analysis Period is for 30 years.
- O&M cost is inclusive of salaries on technical & non-technical human resources, cost of chemicals and energy cost etc. The O&M cost for MBBR, SBR, MBR and EA based plant is considered as Rs. 5.40/kL, Rs. 4.75/ kL, Rs. 9.40/kL and Rs. 6.00/kL respectively.

A summary of the LCC calculations of each the process considered for the treatment is tabulated in Table – 5.

Table – 5 : Economics for Selection of Waste Water Treatment Processes using LCC (in Million Rs.)

Process	**EA**	**SBR**	**MBBR**	**SAFF**	**MBR**
Capital Cost	28.75	35.70	26.21	26.61	38.90
Land Cost	0.33	0.22	0.25	0.25	0.20
Net Present Value (NPV) of O&M Cost	54.75	43.06	49.17	49.17	85.56
NPV of Replacement Cost	14.38	25.78	13.10	13.30	39.62
Total	**98.00**	**105.00**	**89.00**	**89.00**	**164.00**

Out of five processes the MBBR and SAFF has lowest LCC cost therefore either of this process can be selected as treatment process for proposed WWTP.

Cost Estimate

The cost estimate for proposed 0.9 MLD capacity WWTP is based on Maharashtra State PWD DSR for year 2011-12. The head wise abstract of estimate is given in Table – 6.

Table – 6 : Cost Estimate of Proposed WWTP – Capacity 0.90 MLD

Sr.No.	**Component**	**Capital cost (INR in Millions)**
(a)	MBBR plant	
1	Civil works	11.66
2	Mechanical works	9.72
3	Electrical works	0.90
4	I&C works	0.94
	Total	23.22
(b)	Cost for Tertiary treatment	1.34
(C)	Cost for erection, commissioning etc.	1.65
	Grand Total (a) + (b) + (c)	**26.21**

The scheme is designed for the 6000 number of users in the campus considering the forecasting period of 30 years.

Cost per user = $\frac{26210000}{6000}$ = Rs. 4368.33

VIII. CONCLUSIONS

Water recycling and reuse is a water resources management tool that can augment water resources, improve water quality, help maintain viable agricultural economies, and provide storage for drought mitigation purposes, aquifer replenishment, or stream flow maintenance. The recycled water can satisfy most water demands, as long as it is adequately to ensure water quality appropriate for intended use. Water recycling projects are useful to meet non-potable water demands. These projects are useful for recharging the ground water aquifers, augmenting surface water reservoirs with recycled water and meeting the other demand too. The following conclusions are drawn from the study –

- The Total Kjeldahl Nitrogen (TKN) in raw sewage is between 40-50 mg/L. As per CPCB Standards the limit is 50 mg/L. Therefore no specific treatment for removal of nitrogen is required.
- The total phosphorus in the raw sewage is between 5-7 mg/L. As per CPCB Standards the limit is 5 mg/L. Therefore no specific treatment for removal of phosphorus is required.
- Among the compact waste water treatment processes suitable for treating the small quantity of wastewater, the MBBR and SAFF are the economical process compared to other processes from the LCC analysis, out of which the MBBR is selected. The cost of the infrastructure for treatment is Rs.4368.33 per user.
- The effluent from the proposed WWTP based on MBBR process with tertiary treatment can be used for landscape irrigation and flushing purposes.

RECOMMENDATIONS

The following are the recommendations based on technical and financial analysis of the project.

- Application of treated wastewater for irrigation, fodder cultivation and for other reuse such as flushing and washing should be encouraged by the local authorities.
- Effluent from the waste water treatment process may contains a variety of pathogenic (infectious) agents thus while using the reclaimed water or sludge the public health must be protected.
- The reclaimed water if used for flushing purpose should be transported through the separate pipeline.
- Operators and end-users should require a basic knowledge functioning of recycled water supply works and the associated risks and controls, in maintaining a safe recycled water supply.
- The development of the Recycled Water Quality Management Plan (RWQMP) is an important tool for the ongoing implementation and management of the scheme in which performance evaluation and reviewing is done continuously. The RWQMP facilitates for the evaluation of the overall performance of the scheme must exists.
- 100% diesel generator backup should be provided to provide the power for running the plant in emergency during the power failure to prevent overflow of wastewater which is desirable from hygienic point of view.
- The dried sludge obtained may be used as manure for plants.
- Sample analysis at various points of the treatment plant must be done frequently to control the quality and efficient functioning of the plant.

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Figure – 3 : Process Flow Diagram of Treatment Process