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Recent Technologies Adopted for Upgradation of Existing Sewage Treatment Plants and for Sewage Reuse and Recycle in Surat, India

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Abstract
This paper describes the technical details about upgradation by using advance technologies like Sequencing Batch Reactor (SBR) and Integrated Fixed Film Activated Sludge (IFAS) carried out for various existing sewage treatment plants at Surat constructed on different technologies like Upflow Anaerobic Sludge Blanket (UASB), Conventional Activated Sludge Process (CASP) and Moving Bed Biofilm Reactor (MBBR). The paper also describes details of tertiary sewage treatment plant at Surat based on SBR followed by Dual media filteration for reuse as gardening purpose and tertiary sewage treatment plantbased on UF-RO unitsfor reuse of water for industrial application.

Keywords:*Sewage, CASP, MBBR, SBR,IFAS,UF& RO, Reuse and Recycle.*

1. Introduction

India is facing two major challenges presently with respect to water management. One is upgradation of existing Sewage Treatment Plants for increase in capacity of plant and also to meet revised treated sewage disposal standards as per statutory requirement. The other challenge is to look at alternative and unconventional sources of water like sewage reuse and recycle considering acute water scarcity in some parts of the country.

This paper discusses the examples of few plants designed with the aim of upgradation of the existing STPs as well as sewage reuse to meet the increased capacity of STPs and the latest sewage discharge standards.

2. Upgradation of Existing Plant to Meet requirements of increased capacity of the plant and revised Treated Sewage Disposal Standards

The sewage treatment facilities in India adopted till date is in line with the treated sewage disposal standards specified against various Environmental Protection Acts and implemented/modified from time to time. The first environmental protection initiative in India was the enactment of the Water (Prevention and Control of Pollution) Act (Water Act) in 1974. This act was modified during the year 1986 to take stringent measures to protect and preserve the environment. The Environmental (Protection) Act (EP Act) which is an umbrella law was legalized in 1986 [1]. Subsequent to this the treated sewage standards were further made stringent as per the draft notification dated 24.11.2015 issued by the Ministry of Environment, Forest & Climate Change (MoEF& CC). The treated sewage discharge standards as per above Acts/notification are described in Tables 1, 2, and 3respectively.

Table 1: Discharge Standards for Disposal into Surface Waters as per Water Act, 1974

Sr. No.	Parameters	Unit	Parameter Limits
1	BOD_5	mg/L	100
2	COD	mg/L	250
3	TSS	mg/L	100

Table 2: Discharge Standards for Disposal into Surface Waters as per EP Act, 1986

S. No.	Parameters	Unit	Parameter Limits
1	BOD_5	mg/ L	20
2	TSS	mg/L	30

Table 3: Environmental (Protection) Draft Amendment Rules, 2015

S. No.	Parameters	Unit	Parameters Limit
1	PH	--	6.5 – 9.0
2	BOD_5	mg/L	10
3	COD	mg/L	50
4	TSS	mg/L	20
5	NH_4-N	mg/L	5
6	Total N	mg/L	10
7	Dissolved P	mg/L	< 2
8	Fecal Coliform	(MPN/100ml)	< 100

The sewage treatment plants in the country installed periodically to meet the capacity requirements with respect to population growth and of treated sewage standards applicable at the time of construction of the plants by various towns and cities on different technologies mainly covering Upflow Anaerobic Sludge Blanket (UASB), Extended Aeration (EA), Conventional Activated Sludge (CAS) process and Advanced technologies like Sequencing Batch Reactor (SBR), Moving Bed Biofilm Reactor (MBBR), Integrated Fixed film Activated Sludge (IFAS) Process, A_2O etc.

The SMC has also installed various STPs right from 1995 till date based on various technologies to meet the treated sewage discharge standards as specified by State Pollution Control Boards (SPCBs). The plants installed at Surat includes the technologies like UASB, CASP, UASB followed by EA, MBBR, A_2O process, SBR etc. Subsequently all these plants are upgraded with respect to increased capacity and/or to meet the revised treated sewage discharge standards as per Acts/ notifications as above. The examples are given below describing the capacity, designed criteria and technology adopted for existing STPs. The following existing plants are covered including details of their augmentation/modification with respect to capacity and/or quality.

1. UASB with quality upgradation
2. CASP with quality/capacity upgradation
3. MBBR with quality/capacity upgradation.

2.1 100 MLD Sewage Treatment Plant Upgradation, Bamroli, Surat

PHASE I

The STP with UASB followed by Extended Aeration (EA) was set up in the year 2008 consisting of screening, grit removal and anaerobic biological treatment through UASB units followed by EAas 2nd Stage Biological Treatment with sludge dewatering facilities. The plant was designed to meet the sewage discharge standards as per Table 2.

The raw and treated sewage characteristics considered for design in Phase – I (UASB + EA Plant) are presented in Table 4**.**

Table 4 Phase – I Characteristics of Raw and Treated Sewage

Sr. No.	Parameter	Unit	Raw Sewage	Treated Sewage
1	pH		7-8	7-8
2	BOD	mg/L	100	<20
3	COD	mg/L	250	<100
4	TSS	mg/L	100	<30
5	Residual Chlorine	mg/L	-	0.5

The Figure 1 shows the phase I flow scheme of 100 MLD capacity STP at Bamroli, Surat.

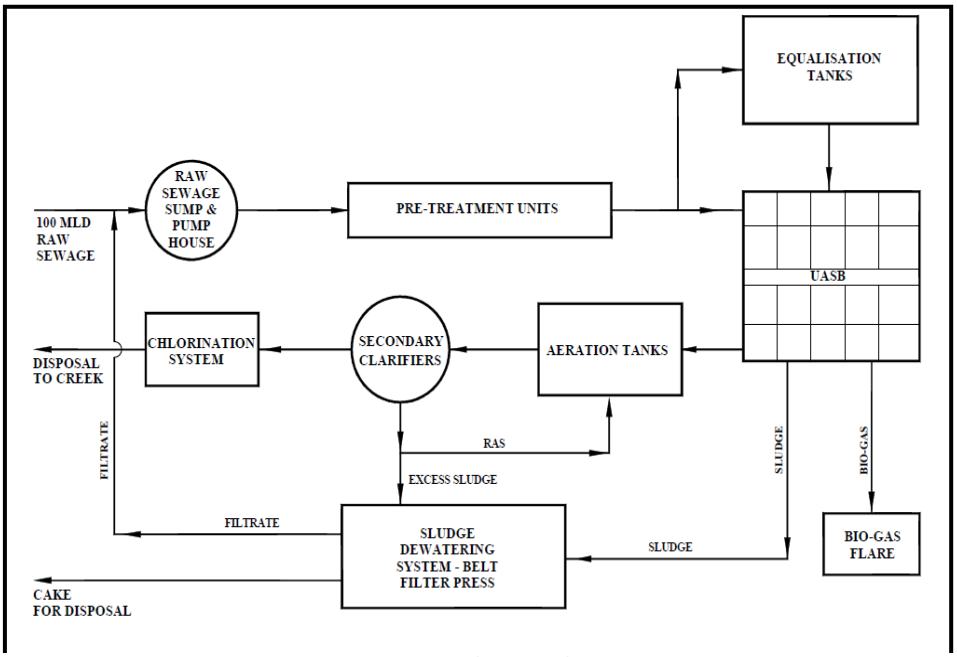

Fig. 1 Flow scheme of phase I of 100 MLD capacity STP, Bamroli

The Figure2 shows the photograph of phase I of 100 MLD capacity STP at Bamroli.

Fig. 2 UASB + EA based 100 MLD capacity STP (phase I), Bamroli

PHASE II

The Bamroli STP is unique in India with respect to quality upgradation. The 100 MLD UASB followed by EA process was set up in the year 2008 with respect to treated sewage discharge quality as BOD = 20 mg/L and SS = 30 mg/L. However, subsequent to this there was growth of Industrial Estates namely Udhna, Pandesara and Sachin Industrial Estates covering the upstream network area of sewerage system from where the 100 MLD sewage is received at Bamroli STP. It seems due to unauthorized, untreated industrial waste discharge in domestic sewerage system, the quality of raw sewage drastically deteriorated and the parameters like BOD, COD and SS were almost observed double the original design values of the plant shown in Table 4. Moreover, the MoEF Draft notification was introduced during the year 2015 and treated sewage discharge standards were made stringent as shown in Table 6. This made the SMC to upgrade the 100 MLD STP (UASB + EA based plant) with Integrated Fixed Film Activated Sludge process as shown in Figure3

The new characteristics of raw sewage are presented in Table 5.

Table 5 Characteristics of Raw Sewage

Sr. No.	Parameter	Unit	Raw Sewage (90%tile)	Raw Sewage (Average)
1	pH	-	6.5 – 7.5	6.5 – 7.5
2	BOD5	mg/l	450	370
3	COD	mg/l	900	700
4	Total Suspended Solids	mg/l	500	350
5	Total Nitrogen as N	mg/l	23	20
6	Total phosphorus	mg/l	13	10

Later, the equalization tanks of the existing STP was upgraded to IFAS system to achieve the treated quality as per requirement is presented in Table 6. The upgraded/augmented 100 MLD STP is in operation since May 2019.

Table 6 Treated Sewage Quality

Sr.No.	Parameters	Value	Unit
1	PH	7.0 – 8.5	-
2	BOD5	≤ 10	mg/l
3	COD	≤ 50	mg/l
4	Total Nitrogen	≤ 10	mg/l
5	Total Phosphrous	≤ 7	mg/l
6	Suspended Solids	≤ 20	mg/l
7	Residual Chlorine	0.5	mg/l
8	Fecal Coliform Count	≤ 230	MPN/100 ml

The Figure 3 shows the phase II flow scheme of 100 MLD capacity STP at Bamroli, Surat.

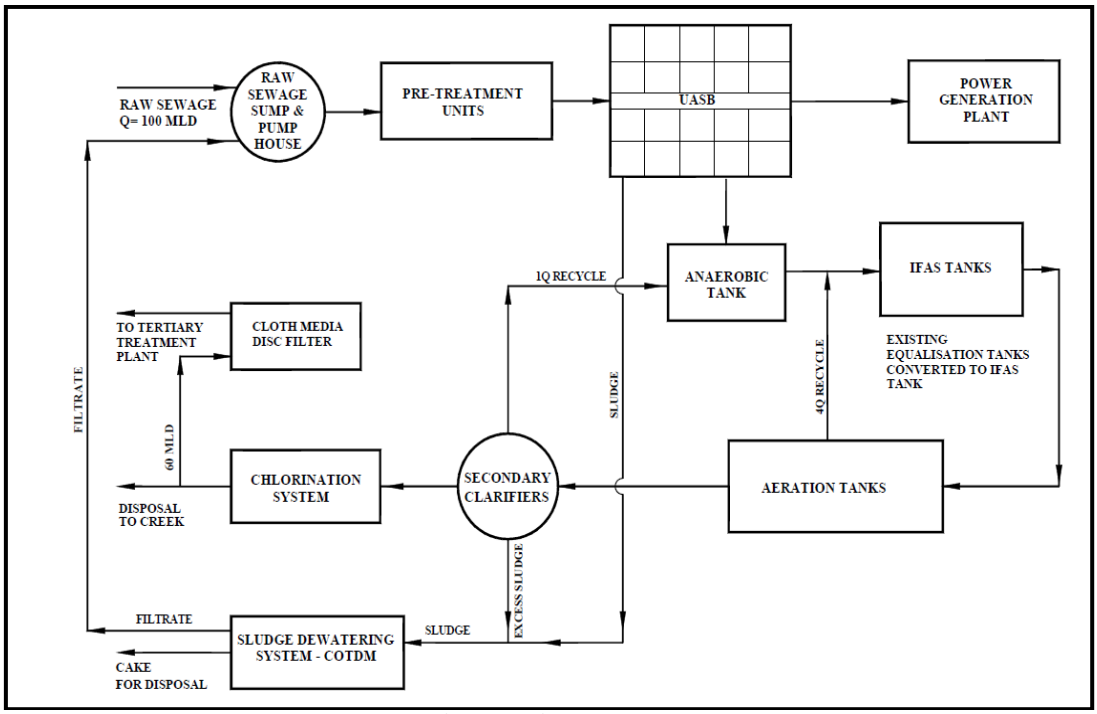

Fig.3 Flow scheme of phase II of 100 MLD capacity STP, Bamroli

The Figure 4 shows the photograph of phase II of 100 MLD capacity STP with augmentation from equalization tank to IFAS system at Bamroli, Surat.

Fig. 4 Equalisation tank of 100 MLD STP, Bamroli modified to IFAS system

2.2 167 MLD STP, Dindoli with upgradation of CAS based plant from 66 MLD to 167 MLD capacity

PHASE I

The 66 MLD capacity plant was installed during the year 2008 by SMC at Dindoli consisting of pretreatment for screen, grit removal and biological system based on CAS process including sludge digestion and dewatering facilities.

The raw and treated sewage characteristics are presented in Table 7.

Table 7 Characteristics of Raw and Treated Sewage

Sr. No.	Parameter	Unit	Raw Sewage	Treated Sewage
1	pH	-	6.5-8.5	7-8.5
2	BOD	mg/l	250	20
3	COD	mg/l	500	100
4	TSS	mg/l	350	30
5	Residual Chlorine	mg/l	-	0.5
6	Faecal Coliform Count	MPN/100 ml	-	1000-10000

The Figure 5 shows the phase I flow scheme of 66 MLD capacity STP at Dindoli, Surat.

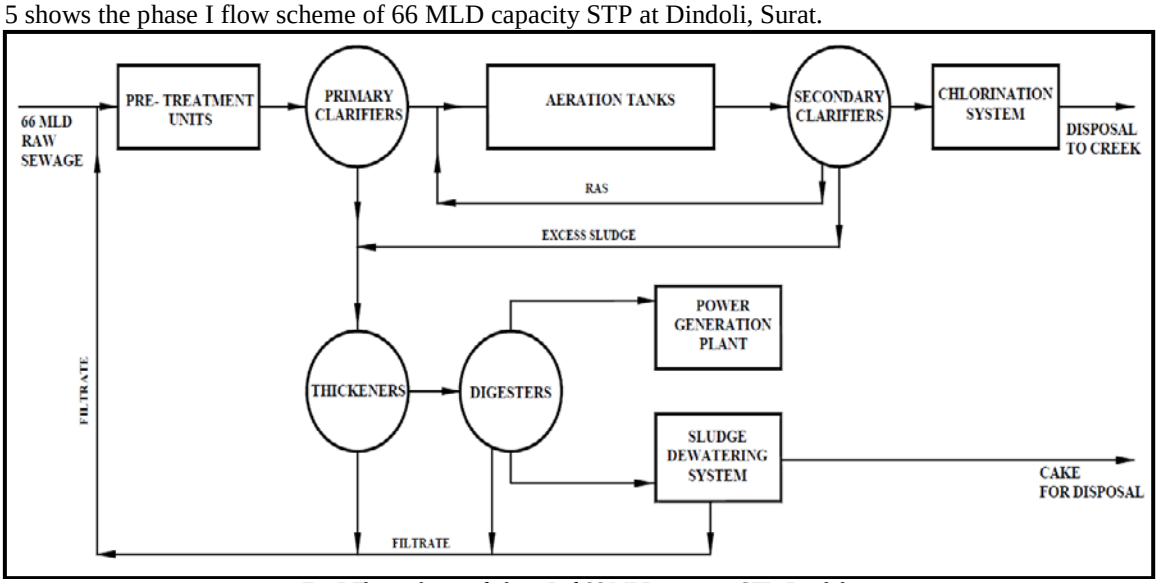

Fig.5 Flow scheme of phase I of 66 MLD capacity STP, Dindoli

PHASE II

The 66 MLD CAS plant is further modified with IFAS and SBR technology to achieve the new discharge standards introduced in the year 2015 and to meet the capacity requirement of 167 MLD. The upgraded and augmented plant is completed during November 2019.

The plant design was carried out in such a way that all the units of the existing 66 MLD plant could be utilized. The anaerobic tank followed by Integrated Fixed Film Activated Sludge process was introduced with necessary return activated sludge in the place of aeration tanks for 45 MLD capacity and the new SBR plant of 122 MLD capacity was constructed balancing the biological process to make the total plant capacity of 167 MLD as shown in Figure 6 – Flow scheme of the plant. The treated sewage of 61 MLD from SBR plant is further passed through disc filter for reducing particularly SS < 5 mg/l as per design requirement of further 40 MLD net output TSTP with UF-RO membrane system. The tertiary treated product water of 40 MLD plant will be further conveyed to Pandesara Industrial Estate for process water application whereas, the 106 MLD total sewage will be discharged into the creek.

The raw and treated sewage characteristics are presented in Table 8.

Table 8 Characteristics of Raw and Treated Sewage

Sr. No.	Parameter	Unit	Raw Sewage	Secondary treated sewage
1	pH	-	6.5 –7.5	7 –8.5
2	BOD5	mg/l	250	≤ 10
3	COD	mg/l	600	≤ 50
4	TSS	mg/l	300	≤ 10
5	TKN	mg/l	40	-
6	Ammonical Nitrogen	mg/l	25	-
7	Total Nitrogen as N	mg/l	42	≤ 10
8	Total phosphorus	mg/l	7	≤ 2 (as dissolved -P)
9	Fecal Coliform Count	MPN/100 ml	1 x10^5	<100

The Figure 6 shows the phase II flow scheme of augmented 167 MLD capacity STP at Dindoli, Surat.

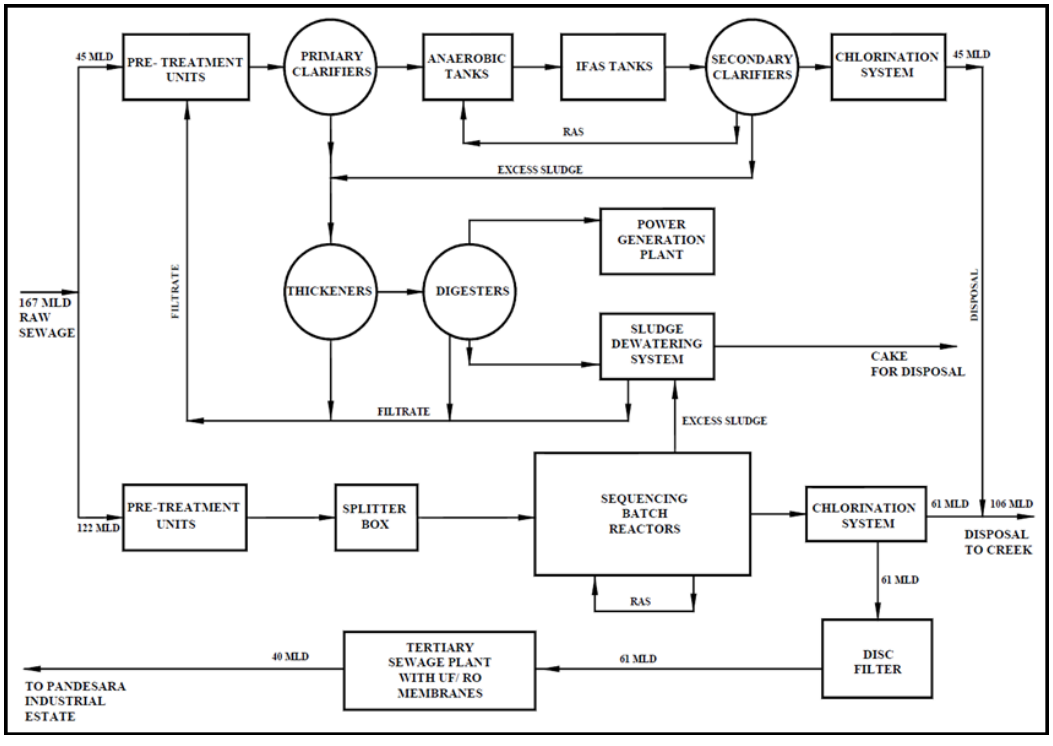

Fig. 6 Flow scheme of phase II of 167 MLD capacity STP, Dindoli

2.3 55 MLD STP, Khajod with upgradation of MBBR based plant from 25 MLD to 55 MLD Capacity

The 25 MLD capacity STP based on MBBR technology at Khajod was completed in 2010 and now the work of augmentation of plant up to 55 MLD capacity with revised treated sewage quality standards is in progress. The technology adopted for the upgradation of plant includes attached growth process (MBBR + IFAS) and suspended growth process (SBR).

PHASE I
The 25 MLD capacity plant consists of pre-treatment units, MBBR units, secondary clarifiers, chlorine contact tank and aerobic sludge digester with belt filter press unit for sludge digestion and dewatering.

The raw and treated sewage characteristics are presented in Table 9.

Table 9 Characteristics of Raw and Treated Sewage

Sr. No.	Parameters	Units	Inlet	Outlet
1	pH		6.5 -8.5	7.0 – 8.5
2	SS	mg/L	350	30
3	BOD	mg/L	250	20
4	COD	mg/L	600	100
5	Fecal Coliform	MPN/100ml	-	1000–10000

The Figure 7 shows the phase I flow scheme of 25 MLD capacity STP at Khajod, Surat

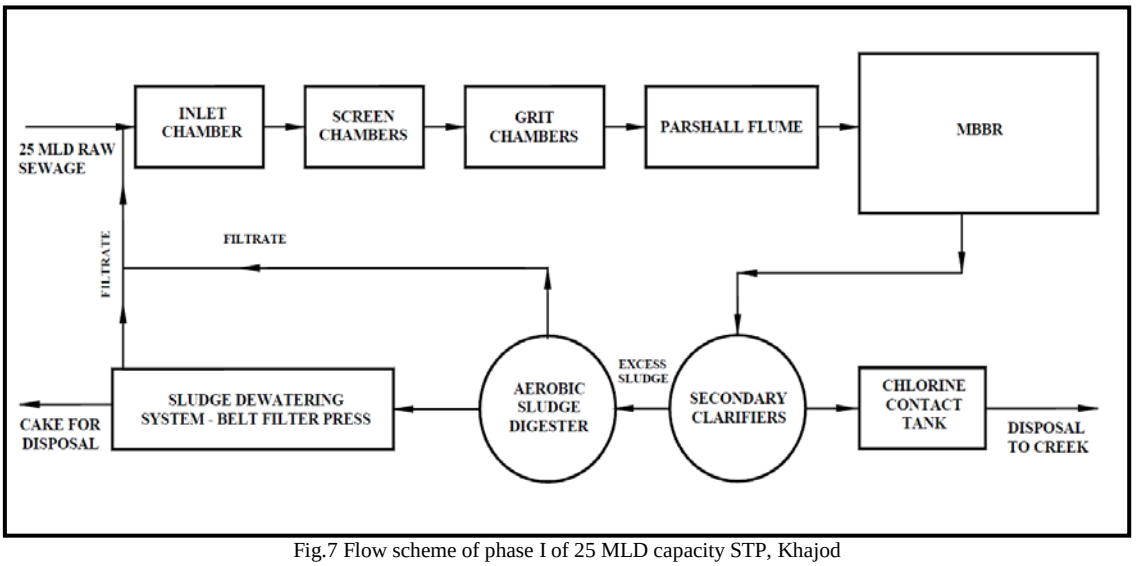

Fig.7 Flow scheme of phase I of 25 MLD capacity STP, Khajod

PHASE II
The upgradation of existing plant of 25 MLD up to 55 MLD capacity with the treated sewage standards as described in Table 10 is in progress and the technology adopted for upgradation is based on the use of entire existing plant units with minimum modifications by converting existing part of MBBR tanks into anaerobic and anoxic zones followed by MBBR unit. The existing aerobic digester is converted to aeration unit with IFAS to treat 15 MLD of raw sewage. The SBR system is adopted to treat 40 MLD of raw sewage thus, making total 55 MLD. The selection of two independent streams of 15 MLD and 40 MLD as above is most techno-commercially viable solution adopted for upgradation.

The raw and treated sewage characteristics considered for design are presented in Table 10 and the proposed flow scheme for 55 MLD treatment plant is indicated in Figure 8.

Table 10 Characteristics of Raw and Treated Sewage

Sr. No.	Parameter	Unit	Raw Sewage	Treated Sewage
1	pH	-	7.5	6.5-9
2	BOD5	mg/l	225	≤ 10
3	COD	mg/l	450	≤ 50
4	TSS	mg/l	310	≤ 10
5	TKN	mg/l	30	-
6	Ammonical Nitrogen	mg/l	15	≤ 5
7	Total Nitrogen as N	mg/l	32	≤ 10
8	Total phosphorus	mg/l	7	<2 (as dissolved P)
9	Faecal Coliform Count	MPN/100 ml	1×10^5	≤ 100

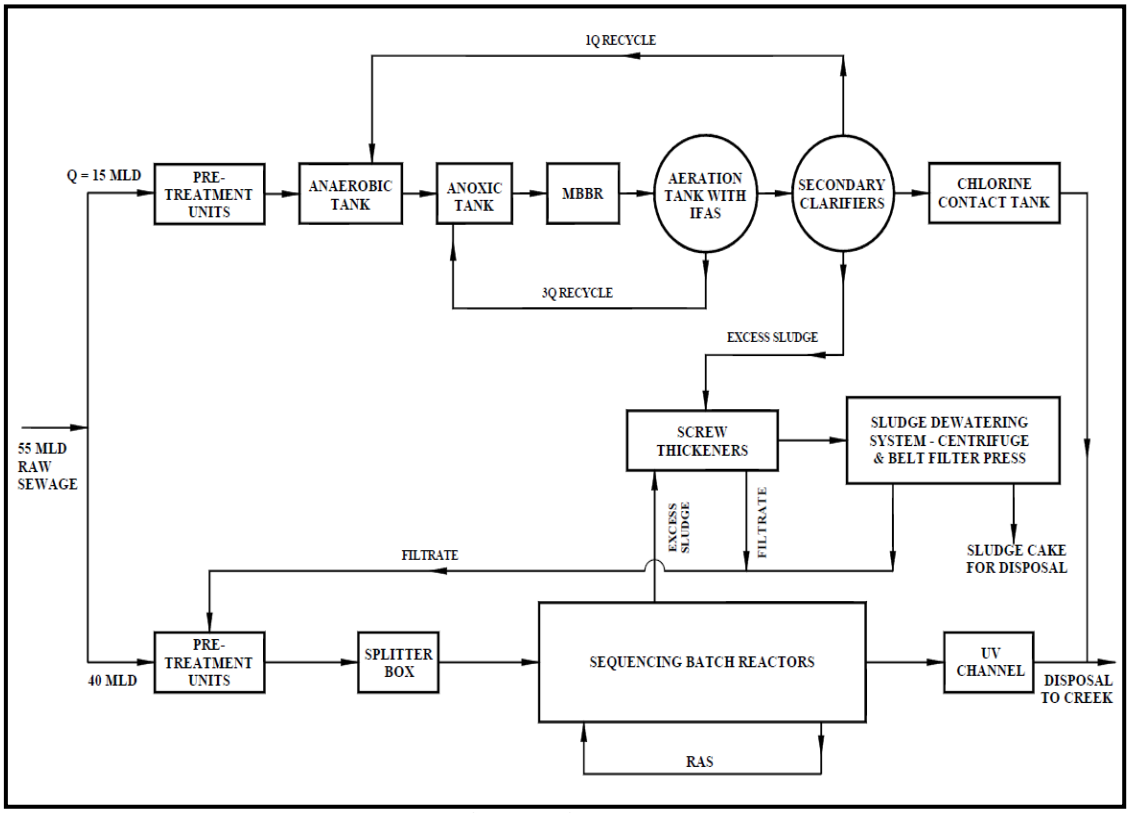

Fig.8 Flow scheme of phase II of 55 MLD capacity STP, Khajod

3. Sewage Reuse & Recycle

Water is the lifeline of all living beings. Even though two third of earth is covered with water, only a small fraction of total water is actually usable by mankind. According to the report of World Population Prospects 2019 published by United Nations (UN 2019) based on medium-variant projection, the world population is expected to rise to 9.7 billion and 10.9 billion by the years of 2050 and 2100 respectively [2].

To tackle the water problem, in addition to various water saving measures, we should also look at alternative and unconventional sources of water. Among them, sewage is one of the best source of water. Quantity of sewage generated from urban areas is around 62,000 MLD[3]. This is a huge quantity available as alternate source of water if treated properly.

With increase in population the demand for freshwater has skyrocketed presenting a threat of impending water crisis[3]. In this scenario sewage reuse presents an attractive alternative. Recycled water is most commonly used for non-potable (not for drinking) purposes, such as agriculture, gardening, and golf course irrigation. Other non-potable applications include cooling water for power plants and oil refineries, industrial process water for such facilities as paper mills and carpet dyers, toilet flushing, dust control, construction activities, concrete mixing, and artificial lakes [4]. Few examples of TSTPs in operation at Surat are described below:

(a) Sequencing Batch Reactor (SBR) based plant for use in gardening
(b) Tertiary Treatment Plant (TTP) with Ultrafiltration (UF) and Reverse Osmosis (RO)membrane systems for use as process water in industries.

3.1 Sewage Reuse for Cooling Water Make up/ Gardening/ Irrigation/Non process industrial use

In India, the chemical treatment and filtration after the secondary sewage treatment is commonly used for reuse of water as cooling water make up/ gardening/ irrigation/ non process industrial use. 130 MLD capacity STP in Nagpur is constructed by Koradi Thermal Power Station (KTPS) based on SBR followed by Sand Filteration and final product water is used for cooling tower saving the freshwater requirements[5].

One such SBR based plant with nutrient removal followed by dual media filters constructed by SMC for reuse of treated sewage for gardening/ non process industrial use is described below:

3.1.153 MLD STP, Gavier, Surat with SBR followed by Dual Media Filtration

In this plant, initially the sewage is subjected to pre-treatment which includesremoval of floating material through screen and grits with the help of grit removal Mechanism. After grit removal, the sewage passes through Parshall flume for flow measurement. After pre-treatment the sewage is taken to the SBRbasins for biological treatment with internal recirculation arrangement to remove BOD, COD, Suspended Solids. The treated effluent flows through the chlorination units for disinfection. After chlorination, the sewage is passed through the Dual Media filters for further removal of organic matter and suspended solids.

The plant is in operation sinceFebruary2017.

Quality Parameters: The raw and treated sewage characteristics considered for design are presented in Table 11.

Table 11 Characteristics of Raw and Treated Sewage

Parameters	Units	Inlet	Outlet
pH		6.5 -8.5	6.5 -8.5
SS	mg/L	300	≤ 5
BOD	mg/L	250	≤ 5
COD	mg/L	550	≤ 100
Total Nitrogen	mg/L	38	≤ 8
Fecal Coliform	MPN/100ml	-	≤ 100

The Figure 9 shows the flow scheme of 53 MLD capacity STP at Gavier, Surat

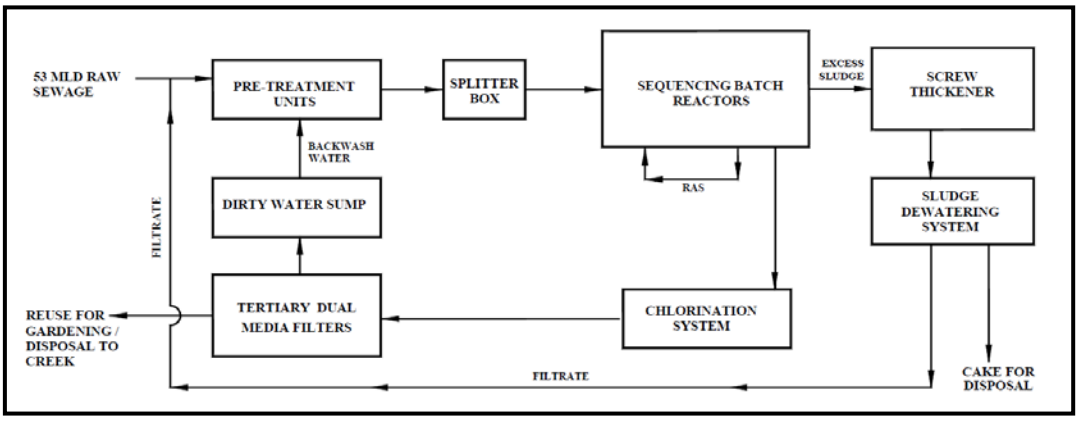

Fig. 9 Flow scheme of 53 MLD capacity STP, Gavier

3.2 Tertiary Treatment Plants for Reuse as Process Water in Industries

Industries have a huge requirement of water for their various processes and with the depleting water sources, it is difficult to meet their ever increasing demands. The best alternative is to reuse the wastewater after tertiary treatment. The policy launched by the Government of Gujarat in 2018 states that all the industries in the state must make use of recycled wastewater for their industrial purposes [4].

SMC has taken lead to installTTPof capacity 40 MLD at Bamroli in Surat in 2012to supply product water to textile units of Pandesara Industrial Estate to meet their requirement of 100 MLD fresh water. The project was a trend-setterfor the sector and its success points to an optimistic future for reuse of treated sewage effluent in Indian industry [6]. The plant was based on UF and RO membrane technology. After its successful operation for a period of more than 6 years, another TSTP of capacity 35 MLD is now completed at Bamroli similar to the design criteria adopted for 40 MLD TSTP as above which will supply the product water to chemical units at Sachin Industrial Estate. One more TSTP of 40 MLD with UF- RO is in final stage of completion at Dindoli STP site which will supply treated sewage to textile units at Pandesara Industrial Estate and will help in meeting the 100 MLD water requirements of Pandesara Industrial Estate. The detailed description of 35 MLD TSTP is given below.

3.2.1 35 MLD TSTP, Bamroli, Surat

The secondary treated domestic sewage after filtration through Disc Filters is supplied to the TTP consisting of UF and RO systems to provide a net output of 35 MLD industrial grade water.The UF system removes sub-micron particles including bacteria, large colloids and other suspended solids from the treated effluent to improve the performance of the downstream RO process by reducing fouling and minimizing the chemical cleaning requirements. Cartridge filters are provided at the upstream of the RO system.RO permeate is passed through degasser to remove gases from RO permeate. The product water then will be sent to the industries.

Quality Parameters: The raw and treated sewage characteristics considered for design are presented in Table 12**.**

Table 12 Characteristics of Raw and Treated Sewage

Sr. No.	Parameter	Unit	Raw Sewage (90%tile)	Secondary Treated sewage	Tertiary TreatedIndustrial GradeWater
1	True Colour	Hazen Units	90	50	< 5
2	Turbidity	NTU	-	-	< 5
3	pH	-	6.5 –7.5	7 –8.5	6.0 –7.5
4	Total Hardness as CaCO3	mg/l	900	-	< 300
5	Iron as Fe	mg/l	0.72	-	< 0.25
6	Manganese as Mn.	mg/l	0.4	-	< 0.10
7	TDS	mg/l	1400	1400	< 500
8	BOD5	mg/l	250	≤ 10	< 5
9	COD	mg/l	400	≤ 50	< 50
10	TSS	mg/l	250	≤ 10	< 2
13	Total N	mg/l	40	≤ 10	< 10
14	Total P	mg/l	8	≤ 6	6-10
15	Fecal Coliform Count	MPN/100 ml	1 x10^5	<100	-

The Figure 10 shows the flow scheme of 35 MLD capacity TTP at Bamroli, Surat.

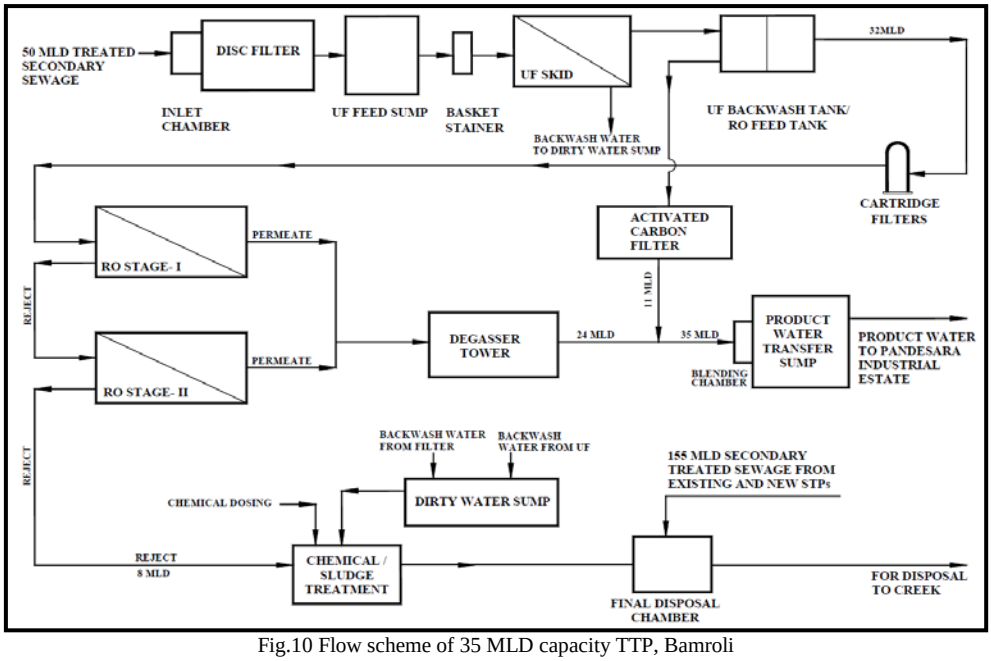

Fig.10 Flow scheme of 35 MLD capacity TTP, Bamroli

The Figures 11 and 12 show the photographs of UF and RO Membrane Modules at 35 MLD capacity TTP at Bamroli, Surat respectively


Fig.11 UF Membrane Modules at 35 MLD capacity TTP, Bamroli


Fig. 12 RO Membrane Modules at 35 MLD capacity TTP, Bamroli

4. Conclusions

The Upgradation / Augmentation of existing Sewage Treatment Plants has become necessary to treat the increased capacity as well as to meet the revised stringent treated sewage standards as per MoEF, Govt. of India notification. This paper discusses upgradation of two existing Sewage Treatment Plants constructed on CASP and MBBR Technology at Dindoli and Khajod, Surat respectively. The further upgradation of these plants with IFAS and SBR system to meet the increased flow and revised treated sewage standards is found to be technically suitable as this involves utilization of existing units with minimum modification and less requirement of additional space.

The upgradation of existing UASB followed by EA based 100 MLD Plant at Bamroli carried out due to change in Raw Sewage quality due to industrial ingress doubling BOD / COD / SS and also to meet revised treated sewage quality by introducing IFAS System within the existing Units.

The rapid industrialization around Surat city is putting more stress on available water sources. To meet the process water requirement of various industrial estates near Surat particularly Textile and Chemical units, the 35 MLD Tertiary Sewage Treatment Plant with UF / RO installed at Bamroli after successful operation for more than 6 years of one similar India's first largest 40 MLD TSTP at Bamroli. The TSTP with UF/RO treatment seem to be more effective and economical to generate product water for Textile and Chemical industries around Surat.

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