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Role of Aerators in the Treatment of Waste Water

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Abstract

Different types of Aerators were studied by author which plays very important role in the treatment of waste water. The Efficiency of Aspirating as well as Mechanical Aerators was compared and it was found that aspirating type aerators were more efficient. Among Aspirating type Aerators Sudden expansion is more efficient than Venturi. Future scope of work is also suggested in the study which may be proved very useful in accelerated developing country like India.

Keywords: Aerators, sudden expansion, venturi, mechanical aerator, two film theory, dissolve oxygen.

Introduction

About 70% of this globe is covered with water it is the reason the earth seems blue in colour. This water can be either in the form of ice or saline. Only approx. 2.5 % water is available as fresh water (potable). Not only India but also world is facing scarcity of potable water. This water directly cannot be taken for use neither from ice (frozen) nor saline (sea water), but it should be processed by some suitable means. In India we treat dirty water and use to cater the domestic as well as industrial needs. In Middle East this requirement is overcome by treating saline water to meet domestic and industrial requirements. Aeration techniques of water treatments are used in USA, UK, Germeny, Russia, Japan and many other countries.

In the water treatment process, there is a unit which is known as aeration which plays very significant role in the treatment of waste water/sewage. Hence, I conducted study of different aeration units which are classified as following: Aspirating type aeration, sudden expansion, venturi, surface aeration (mechanical aerator)

We are aware of problems of environment as noise pollutions, air pollution, sewage disposal, depletion of ozone layer etc. Water pollution is the most important problem of environment. Aeration plays a significant role in the waste quality management. "The principal object of aeration is to remove or add gases or volatile substances to water. In this process the waste brought into contact with a high concentration of micro-organism in the presence of dissolved oxygen. In the biological process aeration transfers the required oxygen and induce sufficient mixing[3].

The aim of this study is to develop the most efficient system of aeration. In order to achieve this Sudden expansion, Venturi and Surface aerators have been compared in respect of Oxygenation Efficiency.

Significance of Aeration

The process which brings air in the intimate contact with water, waste water or sewage for improving its quality is known as aeration. It is the most significant units and gets valuable place in the treatment of waste water or sewage[1].

Following methods of oxygenation are used in the liquid waste treatments. Diffusion of compressed air – Units used in large plants. Mechanical surface entrainment aerators used at smaller plants. Diffused air with submerged turbine dispersers. Air aspirators like venturi and sudden expansion are repeated to have high oxygen transfer efficiency.

Objective

Aspirating type aerators consists of venturi and sudden expansion type aerators with throat size 0.795 cm and expansion ratio (sudden expansion) or convergence and divergence ratio (venturi) is 1.5, manufactured in the workshop .

But in case of surface aerators it is gear reducing type mechanically operated aerators with varying depth of submergence and having 3- phase input supply to the motor which is on the fixed platform, purchased from suppliers. These experiments were done on the non-steady –state condition.

Aeration Theory

In an aerobic treatment process the supply of oxygen is then most important for treating effluents. A number of factors come to play in transferring the required oxygen into the desired system.

When mass transfer takes place in a turbulence fluid, molecular diffusion is supplemented by eddy transfer. Two film theory by Whitman and Lewis is applicable to this system[2].

$$\frac{dc}{dt} = F\,(P_g) = F\,(C_s - C)$$

$$\frac{dc}{dt} = \text{Rate of mass transfer}$$

Where notations are: F = Constant, (Pg) = Partial pressure of gas, (Cs - C) = Concentration gradient, where Cs is saturation concentration. For minor soluble gases, such as O_2 and CO_2, as in the case of most waste –treatment processes, in which liquid phase controls transfer of mass. Concentration gradient (Cs-C) is therefore, important. Hence

Mass transfer per unit time = KLa (Cs-C).

Where: KL = Liquid film coefficient, a = interfacial area for transfer per unit volume

Determination of Oxygenation Efficiency: The main task of a good aeration system is to supply oxygen to take the biomass in response to its rate of dissolved oxygen in the aeration tank. Also, the function of creating enough mixing of the contents in the aeration tank is achieved by aeration.

In this process DO (dissolved oxygen) was measured and found that quality of water gets improved after passing through aspirating type aerators. In this study one sudden expansion, one venturi, one mechanical aerator has been tested. First two aerators are tested when they are sucking air from atmosphere and third (mechanical) with gear reducing type aerator.

Sudden Expansion Aerator 0.795cm x1.5: Throat size = 0.795 cm, Expansion Ratio = 1.5, Volume of Water in the Tank = 0.5151 m^3, A = Cross section area across which the solute is diffusing, Sucking Atmospheric air only

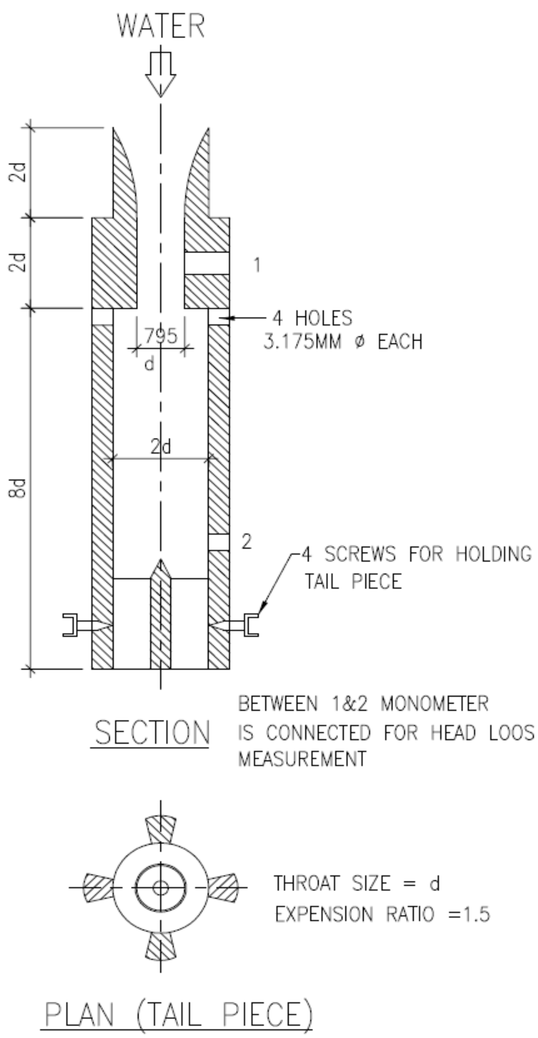

Figure-1
Sudden Expansion Aerator

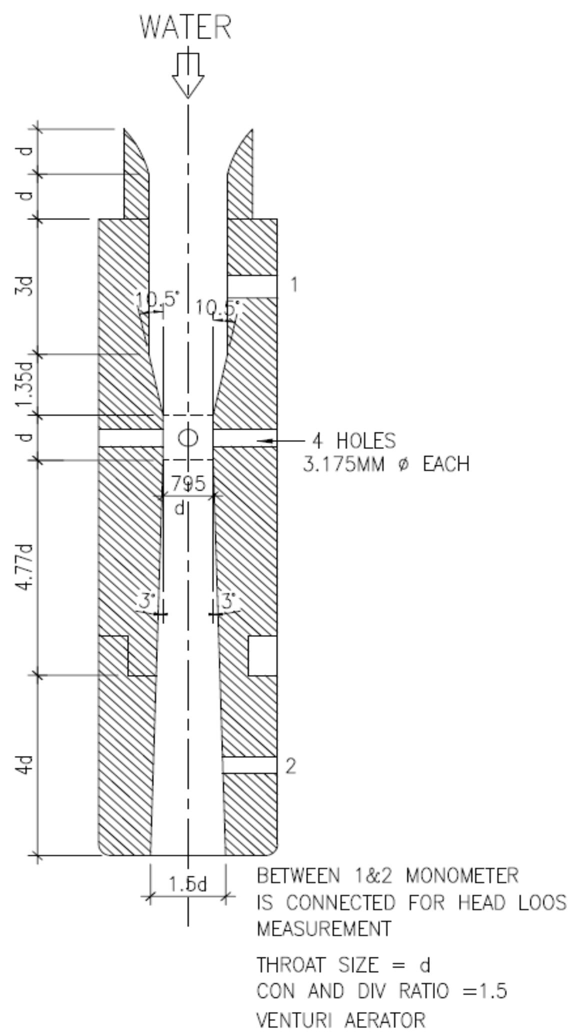

Figure-2
Venturi Aerator

Figure-3
Testing of Sudden Expansion Aerator

Table-1A
Data and Results

Sr. No.	Temp. ^{0}C	Time Min.	C_0	C_t	C_s	(KLA)t ^{0}C	(KLA) 20 ^{0}C	W (kg/hr)	Discharge lps
1	16	10	1.9	2.6	9.76	0.288	0.3166	2.9033X10-^{3}	0.16
2	16	10	2.6	4.0	9.76	0.6717	0.7385	6.772X10-^{3}	0.21
3	16	10.5	2.5	4.7	9.76	1.0614	1.1671	0.0107	0.258
4	16	10	4.7	5.6	9.76	0.6046	0.6648	6.096X10-^{3}	0.258
5	15	10	2.2	4.1	9.96	0.8670	0.9761	8.95X10-^{3}	0.275
6	15	10	2.2	4.3	9.96	0.9742	1.0968	0.0101	0.290
7	16.5	10	3.1	4.8	9.655	0.9268	1.0070	9.235X10-^{3}	0.305
8	15.5	10	5.6	6.9	9.860	1.124	1.2210	0.0112	0.335
9	17	10	2.7	4.8	9.55	1.1302	1.214	0.0111	0.340
10	16	5	5.8	6.7	9.76	1.5919	1.7503	0.0161	0.415

Table-1B
Data and Results

Velocity m/sec	Head Loss (m)	Horse Power (Hp)	Efficiency Kg/Hp.hr	Reynold Number (R_e)	Friction Factor (f)	Chezy Constant (' C)	Manning Constant (n)	Weber Number (W)	Mach Number (M)
3.223	0.4767	1.017X10-^{3}	2.855	25623	0.024	56.74	0.0063	1131	0.0022
4.231	0.9270	2.696X10-^{3}	2.609	33637	0.023	58.59	0.0061	1950	0.0029
5.198	1.4049	4.84X10-^{3}	2.211	41324	0.022	59.98	0.0059	2943	0.0036
5.198	1.4049	4.84X10-^{3}	1.258	41324	0.022	59.98	0.0059	2943	0.0036
5.540	1.5587	5.715X10-^{3}	1.566	44043	0.0214	60.43	0.00587	3343	0.0039
5.842	1.8752	7.251X10-^{3}	1.387	46444	0.0212	60.78	0.00583	3717	0.0041
6.144	2.2250	9.048X10-^{3}	1.021	48845	0.0210	61.13	0.0058	4111	0.0043
6.749	2.4725	0.0111	1.014	53655	0.0206	61.78	0.00574	4961	0.0047
6.849	2.517	0.0114	0.975	54453	0.0205	61.87	0.0057	5109	0.0048
8.360	3.510	0.0194	0.827	66462	0.0196	63.24	0.0056	7611	0.0058

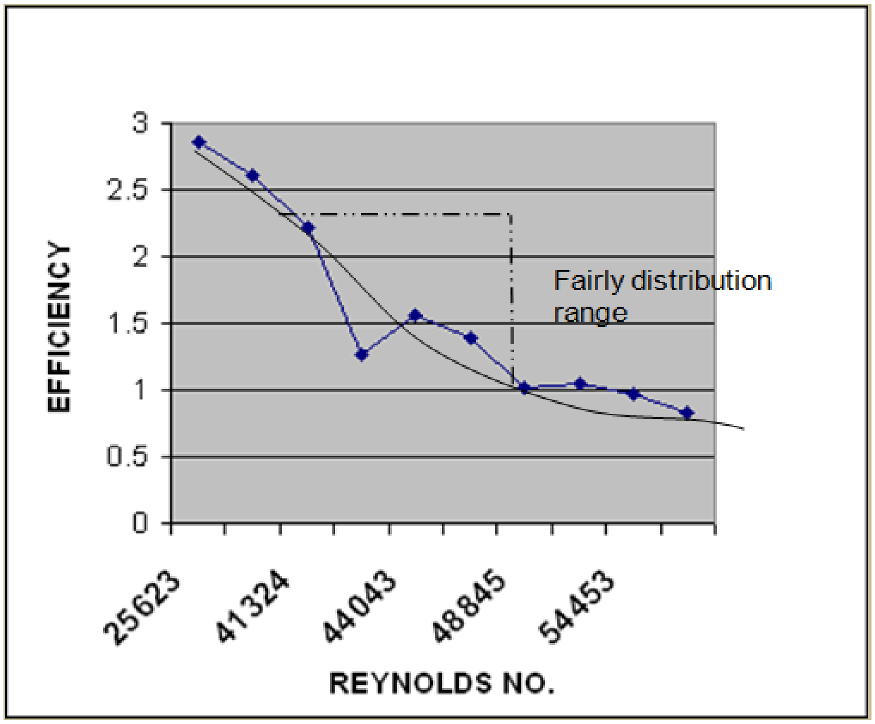

Figure-4
Efficiency v.s Reynolds, Number Curve

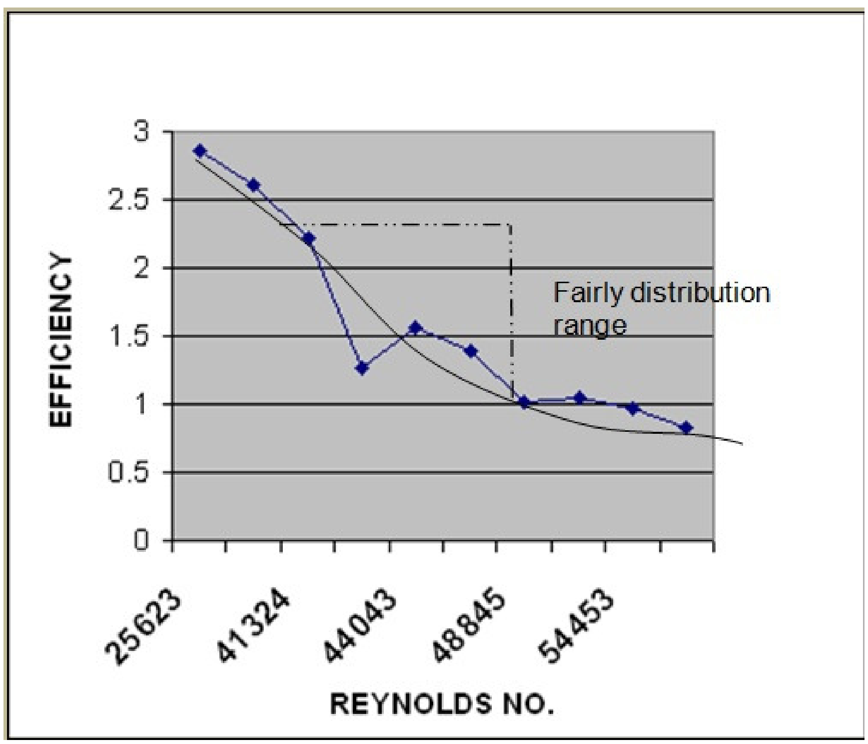

Figure-5
Efficiency v.s Weber Number Curve

Venturi Aerator 0.795cm , Con. and Div Ratio 1.5: Throat size = 0.795 cm, Conversion and Diversion Ratio = 1.5, Volume of Water in the Tank = 0.5151 m^3, A = Cross section area across which the solute is diffusing, Sucking Atmospheric air only

Figure-6
Testing of Venturi Aerator

Table-2A
Data and results are presented in the table as below

1	2	3	4	5	6	7	8	9	10
Sr.No.	**Temp.^{0}C**	**Time min.**	**C_0**	**C_t**	**C_s**	**(KLA)t ^{0}C**	**(KLA) 20 ^{0}C**	**W (kg/hr)**	**Discharge lps**
1	16	10	1.9	2.7	9.76	0.3314	0.3644	3.3411X10-^{3}	0.142
2	16	10	1.9	3.0	9.76	0.4654	0.5117	4.693X10-^{3}	0.164
3	16	10	2.2	3.4	9.76	0.5336	0.5867	5.379 X10-^{3}	0.185
4	16.5	10	2.0	3.2	9.655	0.5264	0.5719	5.245X10-^{3}	0.196
5	16.5	7	4.5	5.1	9.655	0.5457	0.5930	5.437X10-^{3}	0.220
6	16.5	10	2.3	3.6	9.655	0.6004	0.6524	5.982 X10-^{3}	0.250
7	16.5	10	3.2	4.5	9.655	0.6943	0.7543	6.982X10-^{3}	0.280
8	16	10	2.7	4.2	9.760	0.7374	0.8107	7.434 X10-^{3}	0.310

Table-2b

11	12	13	14	15	16	17	18	19	20
Velocity m/sec	**Head Loss (m)**	**Horse Power (Hp)**	**Efficiency Kg/Hp.hr**	**Reynold Number (R_e)**	**Friction Factor (f)**	**Chezy Constant (‘ C)**	**Manning Constant (n)**	**Weber Number (W)**	**Mach Number (M)**
2.861	0.6175	1.169X10-^{3}	2.8578	22745	0.0251	55.94	0.00634	892	0.0020
3.304	0.7975	1.7446X10-^{3}	2.6901	26267	0.0242	56.91	0.00623	1189	0.0023
3.727	1.122	2.768X10-^{3}	1.9439	29629	0.02355	57.72	0.00614	1512	0.0026
3.949	1.267	3.311X10-^{3}	1.5840	31395	0.02323	58.12	0.00610	1698	0.0027
4.432	1.5152	4.444X10-^{3}	1.223	35235	0.0226	58.90	0.0060	2139	0.0031
5.036	1.8814	6.271X10-^{3}	0.9539	40036	0.0219	59.78	0.0059	2762	0.0035
5.641	2.4477	9.138X10-^{3}	0.7570	44846	0.0214	60.54	0.0058	3466	0.0039
6.245	2.623	10.84	0.6857	49648	0.0209	61.25	0.0058	4247	0.0043

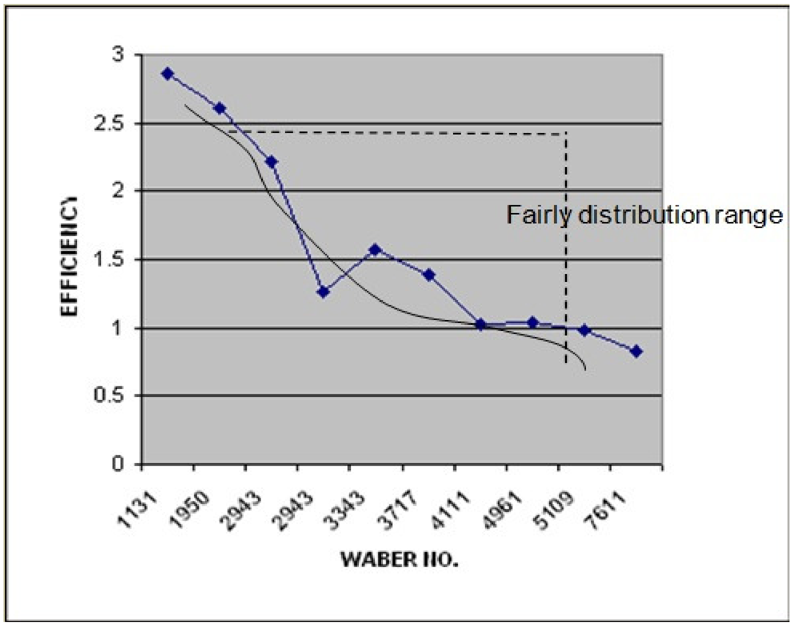

Figure-7
Efficiency v.s Reynolds, Number Curve

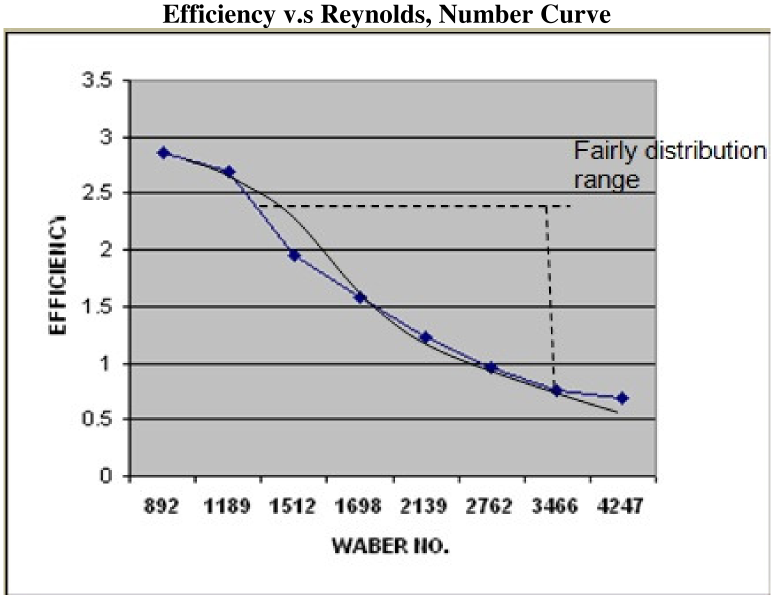

Figure-8
Efficiency v.s Weber Number Curve

Conclusion

Our objective was the "Comparison of Oxygenation Efficiencies of Surface and Aspirating type Aerators", when aspirators were sucking atmospheric air.

For sudden expansion aerator (throat size 0.795 cms and expansion ratio 1.5) though the Reynold's Number is ranging from 25623 to 66462 and Oxygenation efficiency between 2.855 to 0.8265 kg/(hp.hr). But from the fair distribution curve of Oxygenation efficiency v.s Reynold Number, the range of Reynolds Number is 40,000 to 48,500 and Oxygenation efficiency from 2.28 to 1.0 kg/hp.hr. Within this range (2.28 to 1.0) of Oxygenation efficiency for any given value of Reynolds Number the value of oxygenation efficiency can be worked out.

For Venturi aerator (throat size 0.795 cms and conv. to diver. ratio 1.5), the range of Reynolds Number is 22745 to 49648 and Oxygenation efficiency 2.8578 to 0.6857 kg/hp.hr. But from the fair distribution curve (Oxygenation efficiency v.s Reynolds Number) from 27500 to 48000 and Oxygenation efficiency from 2.43 to 0.62 kg/hp.hr shows better range. For the range of Oxygenation efficiency (2.43 to 0.62), the given value of Reynolds Number can be worked out.

Figure-9
Testing of Surface Aerator (Mechanical Aerator)

For the sudden expansion aerator though the range of Weber Number is 1131 to 7611 and oxygenation efficiency 2.855 to 0.8265 kg/hp.hr. But fair distribution curve ranges are from 2600 to 5120 and 2.34 to 0.98 respectively. Hence within this range (2.34 to 0.98 of oxygenation efficiency, knowing the Weber Number, efficiency can be worked out from the distribution curve.

In case of venturi aspirator though Weber Number and efficiency ranges are 892 to 4247 and 2.8578 to 0.6857 kg/hp.hr, but from fairly variation curve these ranges are 1280 to 3800 and 2.38 to 0.68 kg/hp.hr respectively. For the range (2.38 to 0.68 kg/hp.hr) of oxygenation efficiency for a particular Weber Number corresponding efficiency can be worked out from the fairly variation curve.

For the same throat size and discharge the values of oxygenation efficiencies were compared and found that the sudden expansion aspirators are 5% to 48 % more efficient than venturi aspirators.

At lower discharges the oxygenation efficiency is higher and is of the order of 2.8 kg/hp.hr for aspirtors. But as the discharge increases the oxygenation efficiency decreases and is of the order of 0.6kg/hp.hr.

Mach Number for the both aspirators calculated but this values was of the range of 0.0020 to 0.0058 , which is very less. To study the effective of Mach Number of the study the should be more than 0.4 which is the recommended for the study.

Though the efficiency of surface aerator (Mechanical Aerator) has been reported in the literature of order of 1.6kg/hp.hr, but as per tests performed the efficiency was worked out to be in the range of 0.5 to 0.6 kg/hp.hr. This very low value could be attributed to improper setting of rotor shaft or cone and other such manufacturing defects.

Future scope of work: As from the Table of both sudden expansion and venturi aerators, it is clear that the higher oxygenation efficiency can be obtained at low flow in order to cater higher flow rates of sewage. The flow could be divided into number of channels and passed through aerators. This will provide more dissolved oxygen in the water. In other words we can say that aerators connected in parallel shall be able to oxygenate greater volumes of water.

In this study air was sucked from air which contains of 21% oxygen and that oxygen gets dissolved and measured as dissolved oxygen in the tank.

Hence, instead of air supply, artificially prepared oxygen, which will provide more oxygen content in the water, may prove to be more efficient. It is hoped that two suggestions improve aeration of waste waters.

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