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Design Guidelines of Establishing Modified Integrated Pond Arrangement System (Mipas) for Effective Treatment of Wastewater in Katni District of M.P.

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Abstract

The present work done was concerned with the study and checking of the suitability of establishing waste stabilization ponds (WSPs) for treating wastewater in Katni Dist, of M.P. where the proper options of municipal wastewater treatment facilities does not exist. The work comprised of setting up pilot scale Modified Ponds in a manner to facilitate the treatment process in lesser time with better treatment efficiency.

Experimental work had two cases depending on many considerations such as economical and specification of final effluent. A conventional model of three ponds in series was used as first case of experimental work. Then in the second case the first pond was changed from conventional to modified pond – High Rate Anaerobic Pond (HRAP) with a plastic screen. At last, a settling pond was used to polish the final effluent by removing the solids. The whole system was named as Modified Integrated Pond Arrangement System (MIPAS).

The three ponds settled up had different surface area with different depths, where it was 1.5m for anaerobic pond, 0.5m for facultative pond and 0.25m for aerobic pond. From the tests taken for the two cases which included analysis of pH, Total solids, Total Suspended Solids, Biochemical Oxygen Demand and Faecal coliform concentration, the results obtained for the second case was much better when compared with first case. Settling pond (basin) contributed in improving final effluent by decreasing total suspended solid (TSS) also in increasing removal efficiency of biochemical oxygen demand (BOD). At the end, the results of this work could be taken as an invitation to establish and use waste stabilization pond for wastewater treatment in rural areas or even small communities but it may need more examinations to get best results.

Keywords: Waste stabilization ponds, wastewater treatment, MIPAS.

Introduction

Several techniques are used to treat domestic wastewater. These can be classified into two groups: conventional and non-conventional treatment plants. The former has high-energy requirements. The later is solely dependent on natural purification processes. Among all the technologies, the widely recommended ones for developing countries are the WSPs.

Waste stabilization ponds, have become one of the worlds most used methods of treating wastewater in areas where there is sufficient space for their construction. In addition, they are one of the most economical and environmentally friendly ways of treating wastewater and producing a highly purified effluent. They create a natural environment and utilize natural processes to treat a wide range of wastewater contaminants and can include systems such as constructed wetlands, septic tanks, lagoons and others.

Types of Stabilization Ponds with their functioning

There are three main types of stabilization ponds: anaerobic, facultative and maturation. This section will outline the mechanisms involved in the three main types of ponds with their considerations.

Anaerobic Ponds

Anaerobic ponds, which are lacking oxygen except at a thin layer at the surface, rely totally on anaerobic digestion to achieve organic removal. Anaerobic digestion is a two stage process. The first stage is putrefaction, and the second stage is methanogenesis. Putrefaction is the bacterial degradation of organic matter into organic acids and new bacterial cells. In methanogenesis, methanogenic

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bacteria break down the products of putrefaction into methane, carbon dioxide, water, ammonia and new bacterial cells. Anaerobic ponds operate under heavy organic loading rates (usually greater than 100g BOD/m3.d). The main mechanism of BOD removal in anaerobic ponds is by sedimentation of settleable solids, and subsequent anaerobic digestion in the resulting sludge layer. The process of anaerobic digestion is more intense at temperatures of or above 15ºC.

Facultative Ponds

Facultative ponds take their name from the facultative bacteria that populate them. Facultative bacteria are capable of adaptive response to aerobic and/or anaerobic conditions. Facultative ponds degrade organic matter through different processes depending on the depth layer considered. Facultative ponds (FPs) are characterized by having an upper aerobic and lower anaerobic zone, with active purification occurring in both. Facultative pond designed for BOD removal and sized on the basis of volumetric BOD loading (g BOD/m2.d). Facultative ponds are often categorized as either primary or secondary ponds, treating raw or settled wastewaters respectively. As organic matter enters the basin, the settable and flocculated colloidal matter settles to the bottom to form a sludge layer where organic matter is decomposed anaerobically. the biochemical oxygen demand generated from living organisms such as algae is not necessarily detrimental to the environment.

Maturation Ponds

Maturation ponds are placed last in the pond treatment system, if they are used at all. They are very shallow, and generally occupy very large surface areas. Their main function is the reduction of pathogenic organisms. Maturation ponds are also known to remove some algae and some nutrients, but this is not their principal function. The processes by which the pathogens are removed are multiple, and include sedimentation, lack of food and nutrients, solar ultra-violet radiation, high temperatures and pH, natural predators, toxins and natural die-off. Pena and Mara (2004) indicated that maturation ponds receive the effluent from the facultative ponds and their size and number depends on the required bacteriological quality of the final effluent. They are shallower than facultative ponds with a depth in the range 1−1.5 m, with 1 m being optimal (depths of less than 1 m encourages rooted macrophytes to grow in the pond and so permits mosquitoes to breed). These ponds are also reportedly being studied and practices for the efficient removal of nutrient contents of nitrogen and phosphorous from wastewater.

WSP in India

Waste stabilization ponds are not a new technology in India. The then Central Public Health Engineering Research Institute organized a Symposium on WSP over 30 years ago, and published a WSP guidance manual over 20 years ago. Nevertheless, and certainly in recent years, little work on WSP in India has been published, as evidenced by the contents lists of such journals as the *Indian Journal of Environmental Health*. Many of the existing WSP systems in India are old, often poorly maintained and overloaded, and sometimes abandoned. They generally did not include anaerobic ponds. One State where WSP are favored is West Bengal. Four modern WSP systems have been installed in the Calcutta region (three within the metropolitan area, at Titagarh, Panihati and Ballay North Howrah, and one just outside, at Nabadwip).

Materials and methods

Before raising the design proposal pilot scale pond setups were laid and the efficiency of the modified system of WSP was checked by analyzing the physio chemical parameters of the two systems, but before to it the following considerations were made –

1. Location of work place- Ram Niwas Singh Ward - Katni District.
2. Temperature (T) - Average temperature of the town was selected to be 25 ^{o} C from 8 ^{o} C minimum to 42 ^{o} C maximum. T = 25 ^{o} C
3. Volume of wastewater treated per day (V) = 50 liters
4. Wastewater contribution of per person per day, Wwc = 100 Liters/capita/day
5. BOD contribution of each person in a day, BOD = 45 gm/capita/day
6. Number of each pond and other unit for conventional system – Anaerobic pond – 1, Facultative pond – 1, Maturation pond – 1, Settling Pond- 1; and HRAP – 1.
7. Detention periods for various ponds –
   a. Anaerobic pond – 1 day
   b. Facultative pond – 2 days
   c. Maturation pond – 2 days
   d. HRAP – ½ day
8. All the factors such as wind action, public safety, leakage, seepage,

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Work plan

After laying the considerations the two separate setups in which the first being conventional system (CS) having 1 anaerobic, 1 facultative and 1 maturation ponds connected in series and the second being modified system – MIPAS having a change of a HRAP instead of conventional anaerobic pond, 1 facultative, 1 maturation along with an settling pond for accumulation of the dead algal cells along with other suspended solids also connected in series were laid as shown in figure - 1 and the treatment process was analyzed by treating the waste water for the removal of TS (Total Solids), TSS (Total Suspended Solids), BOD (Biochemical Oxygen Demand) and Faecal coliforms from the same wastewater. Also the pH value examination of the effluent is done for checking the decline rate of faecal coliform bacteria.

Figure 1 – Pilot scale setup of CS (Top) and MIPAS(Bottom)

The efficiencies of the two systems were checked and compared after determining the above mentioned parameters for the two separate systems in two different time periods – April 2013 (For the Conventional System) and April 2014 (For the MIPAS system) of same climatic conditions having a temperature of 27 ^{0}C in average.

The schematic diagram of the proposed pond system is given in figure – 2 where the conventional anaerobic pond was replaced by an HRAP (High Rate Anaerobic Pond) for getting up to 80 % BOD removal efficiency from the system along with significant reduction in the total solids, total dissolved solids and faecal coliforms present in the wastewater.

Parameters Tested

After laying the pilot scale pond setups the wastewater was treated in them in two separate time periods. The common month of April was selected for the years 2013 and 2014 with intervals in the dates 1,6, 12, 17, 22 and 28 and the following physio - chemical and bacteriological parameters were tested for separate wastewaters entering and leaving the treatment facilities –

a. pH
b. Total Solids
c. Total Suspended Solids
d. Biochemical Oxygen Demand
e. Faecal Coliform content

Result and discussion

The results of all the physio- chemical analysis of the two separate systems are computed and given in Table 1 and represented in figure 2 as –

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Table No.1 Physio chemical analysis of wastewater

Results obtained of influent and effluents parameters tested prior to and post treatment of wastewater from CS (conventional System – upper row) and MIPAS (Modified Integrated Pond Arrangement System - bottom row)

Properties	pH		BOD		TS		TS	
Dates in Apr 2013 /2014 ↓	Influent pH	Effluent pH	Influent BOD	Effluent BOD	Influent TS	Effluent TS	Influent TSS	Effluent TSS
1	6.7	8.2	452	21.69	855	684	198	59.4
	7.7	8.7	455	13.19	859	214.75	193	38.6
6	6.8	8.3	449	24.24	850	680	195	58.5
	7.9	8.9	459	10.09	865	216.25	195	39
12	7.2	8.6	449	27.83	865	692	197	59.1
	8.4	9.1	465	11.16	868	217	193	38.6
17	6.8	7.9	456	24.63	852	681.6	199	59.7
	8.5	9.2	468	11.7	860	215	195	38.2
22	7.6	8.3	459	26.62	845	676	200	60
	8.6	9	462	8.77	856	214	189	37.8
28	7.7	8.8	449	25.59	850	680	196	58.8
	8.3	8.9	465	9.76	862	215.5	194	38.8

Faecal coliform analysis of the wastewater was performed by performing the MPN test for the two separate systems and the results obtained along with its representation can be given in table 2 and figure number 3 as

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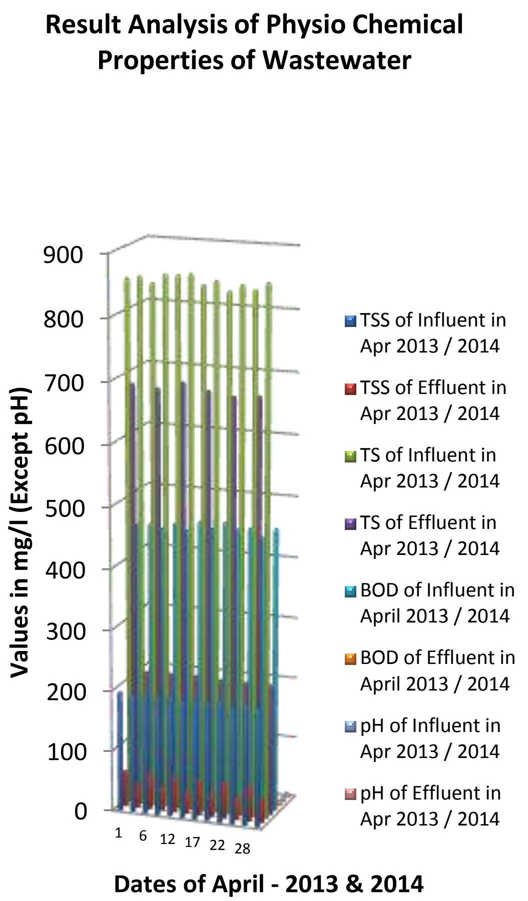

Figure No. – 2 – Graphical representation of results obtained from physio – chemical analysis of wastewater

Table No 2 – Result analysis of Faecal coliform bacteria present in wastewater

DATE	**Feacal Coliform Content**	
	INFLUENT	EFFLUENT
12. 4. 13	1 x $10^{8.1}$	825
12. 4. 14	1 x $10^{8.5}$	810

The value of $10^{8.1}$ and $10^{8.5}$ was taken in a scale of 1810 and 1850 for the representation of the results thus obtained for the faecal coliform content of the wastewater pre and post its treatment which is represented in figure 3 as –

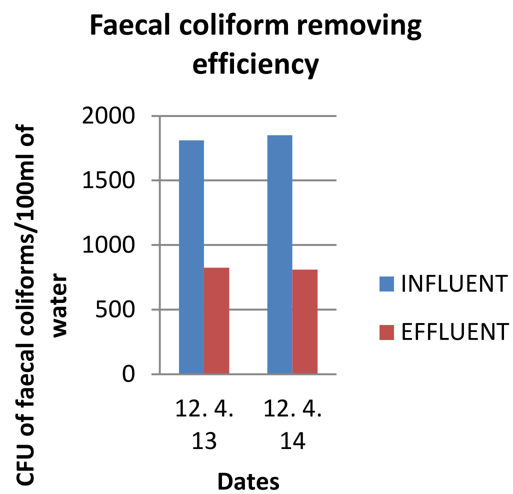

Figure No. – 3 Comparison of Faecal coliform removing efficiencies of two systems

The advantage of the MIPAS systems over CS by analyzing the BOD removing efficiencies by the conventional anaerobic pond of the first and the High Rate Anaerobic Pond of the MIPAS system is computed in table number 3 and represented in figure 4 as –

Table No. 3 – Comparative values of BOD obtained after treatment from the anaerobic ponds of CS and MIPAS

Dates of April 2013 /2014	VALUE OF BOD IN mg/L	
	EFFLUENT from Anaerobic Pond of CS	EFFLUENT from HRAP of MIPAS
1	137.408	96.46
6	144.578	102.357
12	139.639	95.325
17	140.448	98.748
22	145.044	93.324
28	136.047	95.79

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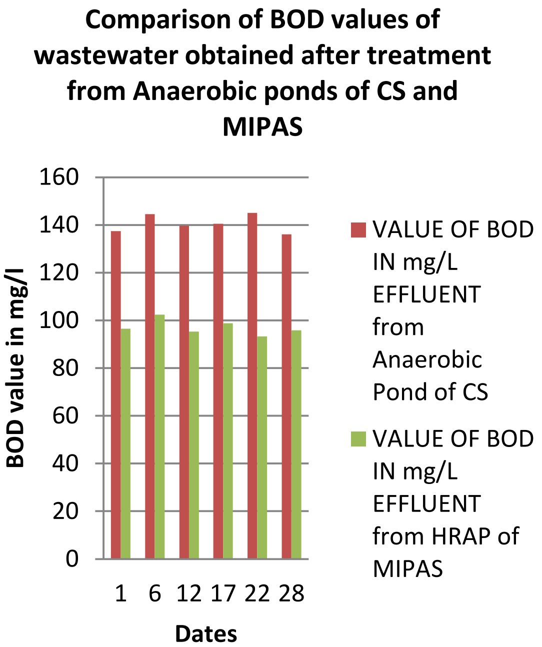

Figure No. 4 – Comparison of BOD values obtained from wastewaters of anaerobic ponds of CS and MIPAS

Proposed Design guidelines

Since the results obtained above clearly showed the advantages of MIPAS over CS the proposed design guidelines of the pond setup can be raised for the city with bigger dimensions can specifications. The considerations which have to keep in check can be summarized as –

1. Proposed location of work place- Near Katayghat area of Katni District with coordinates as- 23.48°N 80.12°E in M.P. state of India.
2. Temperature (T) - Average temperature of the town was selected to be 25 ^{o} C from 8 ^{o} C minimum to 42 ^{o}C maximum. T = 25 ^{o}C
3. Population considered, Pe = 80000
4. Wastewater contribution of per person per day, Wwc = 100 Liters/capita/day
5. BOD contribution of each person in a day, BOD = 45 gm/capita/day
6. Total load of organics, (B) = 3600 Kgs/ day
7. The Influent BOD concentration Li = 3600 / 100 x 80000 = 0.00045 Kg/L = 450 mg/L
8. Volumetric Loading, λ v = [300 (25 – 12)/ 18] + 100 = 316.66 gm/m^3/day
9. Influent Bacterial Concentration, Bi = 1 x 10^8 faecal coliforms/ 100 mL of wastewater.
10. Number of each pond and other unit for the conventional system – Anaerobic pond – 1, Facultative pond – 1, Maturation pond – 2, Settling Pond- 1.
11. Number of each pond and other unit for the MIPAS system – Anaerobic pond – 1, Facultative pond – 1, Maturation pond – 2, Settling Pond- 1.

Factors to be considered

- Adequate protection of public health (removal of pathogens)
- Level of operator skills available,
- Minimization of operating costs,
- Maximization of the use of local resources (labor, materials, equipments, land)
- Depth (which needs to suit the operating conditions for the pond);
- Shape and layout arrangement (length to width and inlet / outlet orientation) which dictate plug flow treatment to avoid short circuiting)
- Wastewater characteristics
- Sludge accumulation (period between cleanout)
- Environmental factors (temperature, sunlight, rainfall and wind velocity)
- Geotechnical considerations like the properties of prevailing soil
- Net flow rate of the wastewater which at all the times should be greater than the net evaporation and rate of seepage.
- Wind action, surface runoff, geology of the area and,
- Location of the water supply units

Design Specifications of Systems

The design specifications of the two separate systems can be calculated from the guidelines given by many engineers and research scholars who have developed several guidelines for the laying out of these treatment ponds. In the present work the design guidelines were taken from the manuals developed by Dr. D.D. Mara, manuals developed by CPCB of India, and the design sheet from EPA. The calculations for the specifications of the ponds were then made and are given cumulatively in table 4 showing the advantages of the MIPAS system in the accordance with area and the detention time which in themselves are important for the efficient treatment of wastewater easily and economically.
The proposed layout of MIPAS setup is given in figure 5. The possible proposed design setup can be modified or enhanced as an option for future advancements in the process of treatment of wastewaters. Area of the city where this facility can be constructed is shown in figure 6 where the stabilization pond system can be set

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replacing the sewer taking majority of the wastewater to the river katni which can be seen in the same figure.

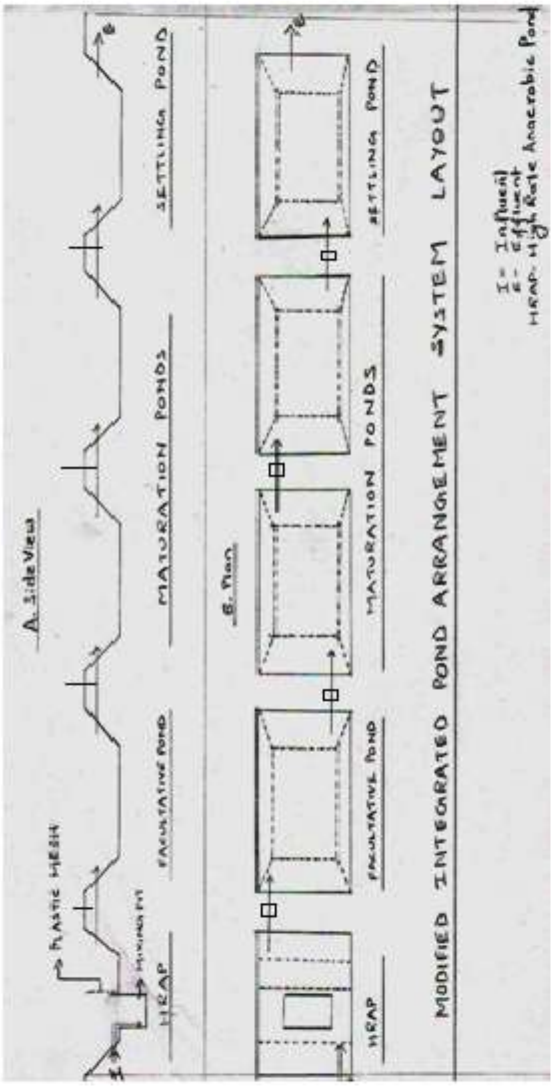

Figure No. – 5 Proposed outlined setup of MIPAS

Table No.4 - Comparative Sheet of the parameters of the two systems

Type of Pond	Parameter	CS	MIPAS
Anaerobic Pond	Volume	11368.66 m3	11368.66 m3
	Detention Time	1 day	12 hours
	Depth	3 meter	3 meter
	Area	3789.53 m2	2273.73 m2
Facultative Pond	Volume	32727 m3	32727 m3
	Detention Time	4 days	4 days
	Depth	1 meter	1 meter
	Area	32727 m2	32727 m2
Maturation Pond	Volume	32000 m3	32000 m3
	Detention Time	4 days	4 days
	Depth	1 meter	1 meter
	Area	64000 m2	64000 m2
Total of parameters in individual systems --	Volume	76095.66 m3	76095.66 m3
	Detention Time	9 to 10 days	≈ 8.5 days
	Area	99916.53 m2	99000.73 m2

Conclusion

The work done was intended to propose a simple yet effective treatment option for the wastewater generated from various sources of the city Katni and hence to reuse the treated water for various purposes among which the option of river revival was primarily focused as the prime river of the city receives loads of wastewater and remains heavily polluted throughout the year. The main sewer collects all the wastewaters generated from the domestic as well as commercial sources and dumps the same to the river thus creating a lot of havoc and anxiety for the inhabitants especially them who live on the banks of the river. The conditions get worst during the hotter months where the clean water is hard to be found in the river and the whole river span is filled with wastewater brought by many sewers. The work done is also can be regarded as a wake up call for the authorities who are not at all taking a single step towards the river protection. The WSP system till date is regarded as the cheapest and easiest method of wastewater treatment and the same working principles of these WSP's were taken into considerations during the entire work. The WSP system had been developed many years ago but still is not bought in regular practice not only in the area discussed but throughout the country. There are many design models developed already by many engineers and researchers which are every now and then are brought into use across many places globally.

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Figure No. – 6 - Proposed location for setup of MIPAS

The present work compares the working efficiencies of the two systems mentioned above. Out of the results obtained after the physio chemical and bacteriological examination of wastewater entering and leaving the treatment facilities the conclusions were made that the modified setup i.e. MIPAS is far more beneficial and effective than the conventional WSP system of treating wastewaters. The advantages of the modified system in comparison to rest of the systems are summarized in table number 5

Table No.5 - Advantages of MIPAS over other treatment options (G-Good;F-Fair;P-Poor;SS-Suspended Solids)

	Criteria	Package plant	Activated sludge plant	Extended aeration activated sludge	Biological filter	Oxidation ditch	Aerated lagoon	MIPAS (Waste Stabilization Pond System)
Plant performance	BOD removal	F	F	F	F	G	G	G
	FC removal	P	P	F	P	F	G	G
	SS removal	F	G	G	G	G	F	G
	Helminth removal	P	F	P	P	F	F	G
	Virus removal	P	F	P	P	F	G	G
Economic factors	Simple and cheap construction	P	P	P	P	F	F	G
	Simple operation	P	P	P	F	F	P	G
	Land requirement	G	G	G	G	G	F	P
	Maintenance costs	P	P	P	F	P	P	G
	Energy demand	P	P	P	F	P	P	G
	Sludge removal costs	P	F	F	F	P	F	G

The usage of these modified ponds should not only be taken into practice by the authorities but also by the companies, communities even the peoples who show concerns on reducing the pollution of water

Thus from the results obtained and the advantages shown above the MIPAS system can prove to be a almost undisputed best solution (only except for the

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land requirement/ availability) for the treatment of wastewater generated from various sources, and should be brought into usage as early and as effectively as possible.

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