Design Conceptions of Integrated Treatment Plant

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Abstract— **The present research consists of design conceptions of Integrated Treatment Plant (ITP) and its applications from Civil Engineering point of view. ITP was an innovative concept for Irrigation Department which was yet to be established/recognised in Water Resource Engineering. As per the land consumption, the construction of Water Treatment Plant (WTP) for large scale supply demands huge sum of space/land and capital and if Waste Water Treatment Plant (WWTP) would be existing will supplement into it.**

The present consequence alarms the unavailability/scarcity of land with limited investment and this instigated to introduce a newfangled concept of ITP whose generalised objective was to serve the principle of both WTP and WWTP with respect to economy and improved efficiency to promote water and waste water management.

The design of the ITP was based on the case study of the village Harkhi Pipra, Bihar, India. The objective was to place several units of ITP along the bank of river Ganga in order to prevent the direct disposal of the wastes in to the river. As the concerned village, did not had such units for treatment of the water and wastewater, in order to overcome this challenge, the ITP was designed as a preliminary solution for cleaning Ganga.

Keywords— **Water Treatment Plant, Waste Water Treatment Plant, Integrated Treatment Plant, Ganga, Irrigation, Agriculture, Management, Water Resource.**

I. INTRODUCTION

More than 80% of the Indian population live in rural areas but only about 60% of them have some form of potable water supply, with only about 20% having water-piped supply.it has not been feasible to cover all the villages with potable supplies because of various constraints, such as (i) scattered and inaccessible nature of the village; (ii) non-availability of nearby water source; (iii) non-availability of adequate funds in view of these constraints, it becomes very difficult to supply piped potable water to the village through the full-fledged conventional water treatment plant. Since most of the Indian river are non-perennial with merge storages, and generally located far-off distances from rural villages, it has generally not been feasible to supply surface waters tot the scattered and isolated rural area.

The treatment of water for rural and small communities will largely depend upon the quality of available raw water and also upon the funds to meet the cost of technical personnel as well as capital and optimum cost of the treatment plant. Most of the Indian rural supplies are therefore, being derived from the wells and tubewells and are usually supplied after simple chlorination which ensures the elimination of the bacterial contamination present in the raw water [1].

Sewers have not been laid in large part of India. We still find the existence of unsewered trans-Yamuna colonies even in Delhi (capital city of India). During 2015, about 38791 million litres per day (MLD) of untreated sewage (62% of the total sewage) is discharged directly into nearby water bodies. The five states viz Maharashtra, Tamil Nadu, Uttar Pradesh, Delhi & Gujarat account for approximately 50% of the total sewage generated in the country. Maharashtra alone accounts for 13% of the total sewage generation in the country. No sewage treatment plant has been established in seven states/UTs viz. Arunachal Pradesh, Chhattisgarh, Daman Diu, Nagaland, Assam & Tripura. The capacity of Sewage Treatment Plant (STPs) installed in the two states viz. Himachal Pradesh & Sikkim is adequate to treat the total quality of sewage generated in these states. The 35 metropolitan cities (more than 10 Lakh Population) generate 15,644 MLD of sewage while treatment capacity is 51 %. Among the Metropolitan cities, Delhi has the maximum treatment capacity that is 2330 MLD (30% of the total treatment capacity of metropolitan cities). Next to Delhi, Mumbai has the capacity of 2130 MLD, which is 26% of total capacity in metropolitan cities. Delhi and Mumbai therefore in combination have 55% of treatment capacity of the metropolitan cities. Some cities such as Hyderabad, Vadodara, Chennai, Ludhiana and Ahemedabad treatment capacity meets the volume of generation. Cities like Delhi, Dhanbad have more than 50% capacity, rest of the cities have the capacity less than 50%. When the city of India having, large population living with conservancy system of sanitation, one can easily imagine the fate of town and village folks [2, 3].

II. PROBLEM STATEMENT

From the study, it was found that there was problem of inadequate water supply and poor water quality to satisfy the demand in domestic, agriculture, villages etc. the release of untreated or partially treated sewage into the environment was causing water pollution and deterioration of freshwater resources. Several villages in India were already water stressed. This was further curbing the freshwater resources resulting into the worsening of the situation. Constructing dam across river and creating it as reservoir for WTP on large scale supply to a city/town/district would not be every time/anywhere possible might be due to excessive requirement of land which may not be vacant at that period or due to huge investment of capital. Water and waste water management was still a challenge in villages. Here the delinquent lies in the fact that villages still did not have appropriate and well-organised water supply system or drainage facility or the structure that could be in the state to oblige the purpose of both WTP and WWTP in limited scale area [3].

III. THE IDEA OF ITP

In India, we had water treatment plants as well as sewage treatment plants, and both constructed separately having entirely different concept [1, 2,]. But what would happen if both the plants constructed at the same plot for small scale treatment, let it be for agricultural land?

The working of ITP was completely based upon the typical principles of WTP and WWTP that are mentioned in Indian Standard Specifications Codes of Environmental Engineering.

A. The difference lies in its flexibility to be get attuned with regular or usual dispensation of agricultural, industry, village area etc. and that too on limited area.

B. The other fact that needed to be taken into the account was the design and construction of such structures in the village thereby resolving the problem of water supply and the waste water treatment.

IV. UNITS INVOLVED IN ITP

ITP was designed to be the combination of WTP+WWTP such that units involved within both the plants were available at one site as shown in fig 1. The various units of ITP with respect to WTP and WWTP are explained below:

A. Water Treatment Plant [1,5]:

1) *Intake cum Sedimentation Tank*: it functioned to receive water from the sources like underground water, rain water, river, reservoir, ponds, lake and other water bodies.
2) *Filtration Tank*: As per the feasibility filters like Rapid Sand/Gravity Filter, pressure filter, Roughening filters, Diatomaceous Earth Filters etc. can be implanted.
3) *Disinfection cum Storage Tank*: Killing of the pathogens can be done by treatment of the water by excess lime, ozone, iodine, bromine, UV rays, potassium permanganate, silver and most popular chlorine etc.

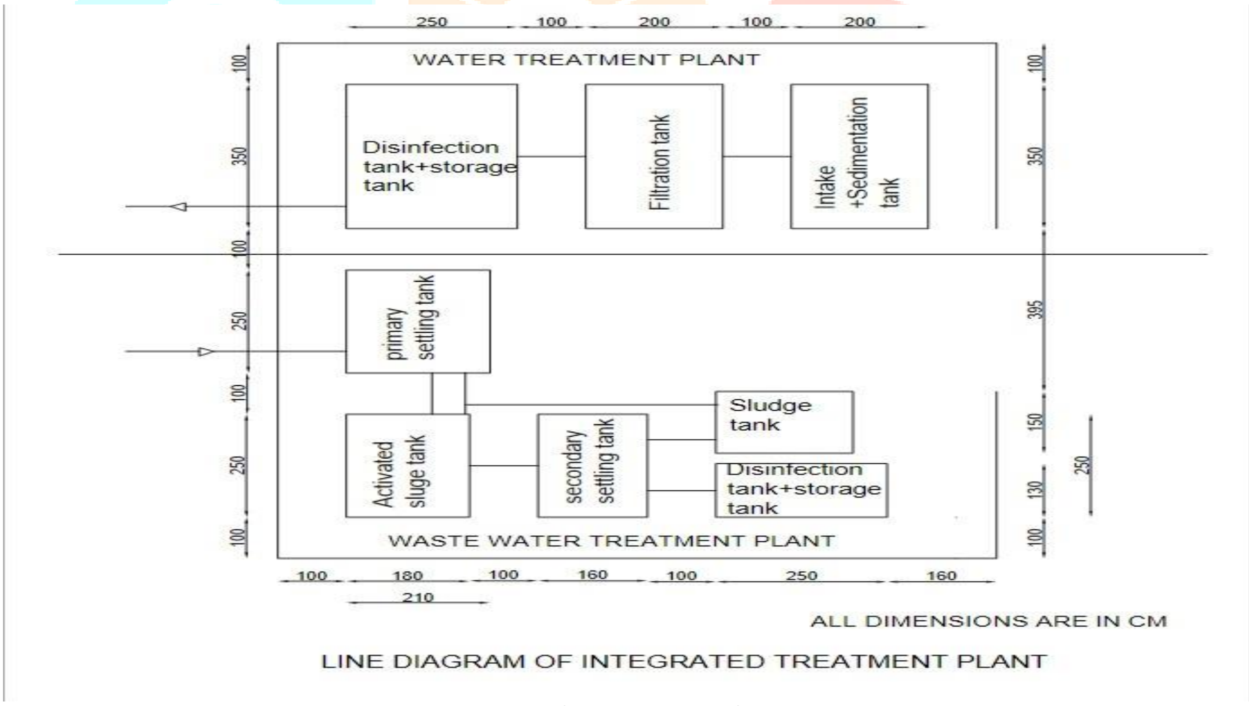

Fig. 1 Line-Plan of Proposed Design of Integrated Treatment Plant

B. Waste Water Treatment Plant [2,6]:

1) *Primary Settling Tank*: Received the waste generated and allowing primary settlement of solid content.
2) *Activated Sludge Tank*: Biological treatment of sludge with aerobic and anaerobic microbes takes place in this unit.
3) *Sludge Tank*: If the sludge obtained was organic and biodegradable could be the source of biogas or manure in the farms.
4) *Disinfection Tank*: The objective was to reduce the microbial content and transforming the sludge into less harmful state.

V. APPLICATION OF ITP

The design of the ITP proposed in this research can be found useful in the following applications:

A. Water management of ITP could be useful for the farmer as solid waste (organic and biodegradable in nature) which was acquired from waste water in ITP can be the manured for agricultural ranches and at the same time ITP would provide water for sprinkler and drip system.

B. Concept of ITP can be installed with Biogas Treatment Plant such that solid waste (organic and biodegradable in nature) which was obtained from waste water could serve the purpose of sources of biogas generation.

C. ITP can be constructed underground, above the ground or at basement of houses colonies etc. where ground water may be the source of water.

D. It can be merged with Rain Water Harvesting unit in residential or official buildings.

E. It could be the good idea to provide it in industry thereby serving dual purpose of drinking water supply and treatment of the waste generated.

F. The villages without systematic water supply or drainage can be installed with ITP making the scenario clean.

G. Water can be extracted from groundwater and ITP can be constructed below the ground can be found useful for the Military Camp or during the war the said purposes could serve the secret source for the supply.

H. Since the area requirement of the ITP was found limited (refer section VII), hence, the entire ITP can be constructed by maintaining significant distance between each other along the bank of the river (e.g. Ganga) exactly from where the untreated waste (polluted) water was directly discharged into the river [4].

VI. CASE STUDY

The village Harkhi Pipra, town Shahpur, district Bhojpur, state Bihar, India along the bank of river Ganga (as shown in Fig. 2) was taken for the study of design and working of ITP. According to the census 2011, population of the target village was found to be 3136. Population in the year 2001 was 1962. The village did not have WTP or WWTP for the piped-water supply or sewage treatment respectively. The domestic wastes, agricultural wastes etc. was directly discharged into the river Ganga [7].

Fig. 2 River Ganga in State Bihar, India

A. Design Calculations [1,2,5,6]*:*

The objective was to develop the design conception of the ITP with respect to the requirement of the village. The objective can be inferred from the Fig. 3 which shows the schematic representation of the entire plan of implanted ITP in the village. The map was created on the software AutoCad and hence, not to the scale.

Designing of ITP was based on serving the population of 100 persons with the discharge of 110 lpcd (litre per capits per day). The maximum daily demand and maximum hourly demand was assumed as 180% and 270% of average daily demand and fire demand was assumed to be 1 lpcd.

The target was to provide water supply as well as drainage to the locality of the village with the assumption to had the population of 100 persons per ITP installed.

B. Calculation of Diameter of Main Pipe

The diameter *(D)* of the main pipe required was obtained using an empirical relation given by: $D = 1.22\times Q^{(1/2)}$. Hence, by substituting the value of discharge for pumping out the water from the underground source we got:
$D = 1.22\times Q^{(1/2)} = 1.22\times (0.01944)^{(1/2)}$ = 0.17 metre = 17 centi-metre.

Thus, the designed diameter so obtained was 20 cm (approximately increased for safety purpose etc.) shown in Table IV.

As it can be inferred from Table I that maximum hourly demand was greater than the sum of maximum daily demand and fire demand. Hence, the distribution system for water supply would be based on the greater of the two i.e. maximum hourly demand.

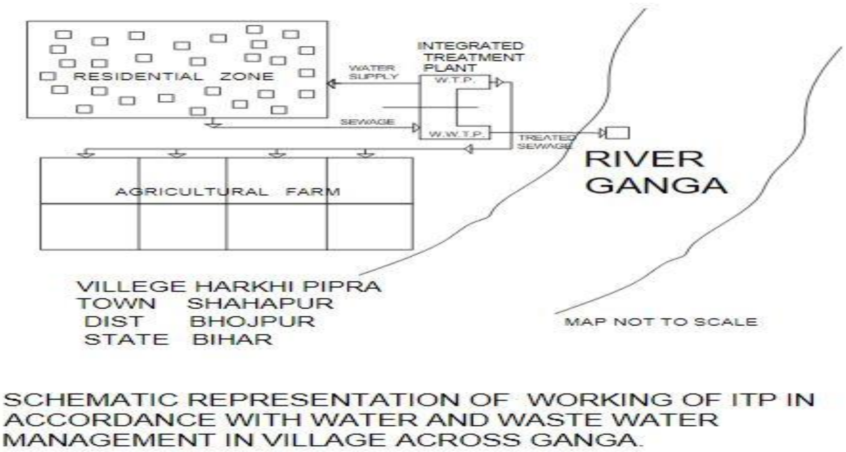

Fig. 3. Schematic Representation of the Case Study in District Bhojpur, Bihar, India

With the data obtained from the calculations shown in Table I and using the design formulae of treatment plants from the standard textbooks of Environmental Engineering [1,2], all the units involved in the water and wastewater tretment plant mentioned in section IV can be designed. The design values of the calculations are shown within Table II and III.

TABLE I
WATER DEMAND

S. No.	Specifications of ITP	Quantity
1	Population to be served	100
2	Water demand per day (assume	110 litre per capita per day (lpcd)
3	Average daily demand	100x110=11000 lpcd
4	Maximum daily demand	1.8x11000=19800 lpcd
5	Maximum hourly demand	2.7x11000=29700 lpcd
6	Fire demand	100x1 lpcd=100 lpcd
7	Coincident draft	19800+100=19900 lpcd

TABLE II
DESIGN OF WATER TREATMENT PLANT WITHIN ITP

S. No		Designed Dimensions

	Units of Water Treatment Plant in ITP	Volume (cubic metre)	Height + Free Board (metre)	Area (square metre)	Length (metre)	Wide (metre)
1.	Intake +sedimentation tank	21	2.5+0.5	7	3.5	2
2.	Rapid sand filter	22.4	2.5+0.7	7	3.5	2
3.	Disinfection tank	30.62	3+0.5	8.75	3.5	2.5

TABLE III
DESIGN OF WASTE WATER TREATMENT PLANT WITHN ITP

S No	Units of Waste Water Treatment Plant in ITP	Designed Dimensions				
		Volume (Cubic Metre)	Height + Freeboard (Metre)	Area (Square Metre)	Length (Metre)	Wide (Metre)
1	Primary sedimentation tank	10.5	1.5+0.5	5.25	2.5	2.1
2.	Activated sludge tank	9	1.5+0.5	4.5	2.5	1.8
3.	Secondary sedimentation tank	8	1.5+0.5	4	2.5	1.6
4.	Disinfection + storage	6.5	1.5+0.5	3.25	2.5	1.3
5.	Sludge tank	5.625	1.5+0.5	3.75	2.5	1.5

TABLE IV
CALCULATION FOR LIFTING PUMP

S. No.	Characteristics	Dimensions
1	Assumed Efficiency of pump	75%
2	Weight Density	9810 N//cubic metre
3	Suction head	0 metre (m)
4	Direct head	95 m
5	Head loss	0.056 m
6	Total head	95+0+.056=95.556 =96 m
7	Power required by pump	9810x.01944x96=24.90 horse power (HP)
8	Power required by motor	44.26 HP
9	Total power required	44.26x.0735=320536 kilo-watt

VII. RESULT ANALYSIS

The ITP designed had assumed to serve 100 persons of the village. The objective was to have distribution system via water supply, drainage system to receive the waste generated and the treatment of the sludge before its disposal into river Ganga. The following attributes can be analysed from Table I, II and III:

A. *Unit Demand Analysis*

1) Intake structure was based on maximum daily demand i.e. 19800 lpcd.
2) Rapid sand filter was designed on twice the average daily demand 22000 lpcd.
3) Disinfection cum storage tank had been designed on maximum hourly demand of the maximum day i.e. 29700 lpcd.
4) Waste water units were based on one-third of the design volume of the disinfection tank of WTP i.e. 10.2 cubic metre i.e. 10200 lpcd.

B. *Area-Wise Analysis*

As the source of water supply was underground water, therefore number of units in WTP had been reduced to 3. Whereas constructing WWTP adjacent to WTP helped in proper usage of the plot of land providing access to both the treatment unit and better control over the function of units. The area-wise analysis is as follows:

1) Area occupied by units of WTP = 22.75 square metre
2) Area of units of WWTP = 20.5 square metre

3)	Area occupied by entire ITP	= 43.25 square metre
4)	Area occupied by space and wall thickness	= 40 square metre (max)
5)	Total area of ITP	= 83.25 square metre

Hence, we could infer that the space required by ITP at small scale supply was only 83.25 square metre which was found effective on densely packed city where there would be scarcity of land.

C. Water Management

Area of units of WTP in ITP is found to be 22.75 square metre (about 30 square metre including space and wall thickness) could be implanted at the colony, agricultural land, at the basement of the houses etc. Water supply through actual large scale WTP from long distances in this village would be expensive. Hence, ITP served the same purpose paving the way for water supply and its management.

D. Wastes Water Management

Area of units of WWTP in ITP is found to be 20.5 square metre (about 25 square metre including space and wall thickness) could be implanted at the colony, agricultural land, at the basement of the houses etc. Hence, ITP served the same purpose paving the way for waste water treatment and its management.

VIII. CONCLUSION

Instead of constructing large scale Water Treatment Plant, small scale Integrated Treatment Plant (ITP) could be a strong alternative for serving both the rationale of water supply and sludge treatment in those areas where there was scarcity of the land. Decreasing serviceable portion of the land for any type of construction would be an apprehension for the Civil Engineers to design such a building that could substitute/replace such large area overwhelming structures.

The scope of the study can be extended by connecting the concept of ITP with biogas plant, rain water harvesting, drip and sprinkler system and involving it with agricultural meadow for the intension of providing manures from the sludge obtained in the treatment process. The design and calculation involved for developing the concept of ITP used in the research was fundamentally presented with the most elementary approach. There were still scope for the further improvement of this design.

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REFERENCES

[1] *Water Supply Engineering* by Garg S.K., Khanna Publisher, New Delhi, 13th edition, 2015.
[2] Sewage Disposal and Air Pollution Engineering by Garg S.K., Khanna pub, 29th edition, 2014, ISBN No. 978-81-7409-2304
[3] Report of water quality and treatment of sewage, Central Pollution Control Board (CPCB), 2016.
[4] DWAF *Integrated Water and Waste Management Planning*: Draft Operational Guideline, Department of Water Affairs and Forestry, Pretoria (2008).
[5] Palazzo del Congressi, Piazzale J. F. Kennedy 5 (EUR), the growing demand for land, Risks and Opportunities for Smallholder Farmers, Rome, Governing Council, 18-19 February 2009.
[6] Tchobanoglous, George; Burton, Franklin L.; Stensel, H. David; Metcalf & Eddy, Inc. (2003). *Wastewater Engineering*: Treatment and Reuse (4th edition). McGraw-Hill ISBN 0-07-112250-8.
[7] Information related to the river Ganga http://www.hindustantimes.com/ retrieved 14 may 2015.