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Comparison between Design of Water Treatment Plant Manually and by Using Software with Reference to Yavatmal City

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***Abstract:** Water treatment is the process of removing contaminants from raw water. It includes various physical, chemical, and biological processes to remove the impurities from raw water.*
The existing Chapdoh Water Treatment Plant is designed for 100 lpcd rate of supply to Yavatmal city. The water demand of Yavatmal city will increase with the development of the city.
The development leads to addition of industrial water demand and also there will be increase in living standards of people. Under these situations, the existing Chapdoh WTP will not be efficient. Hence, an attempt is made to design WTP by keeping the growth of Yavatmal city in near future with higher rate of supply.
The aim of present research work is to design WTP for Yavatmal city for design period of 30 years manually and using self-developed MS Excel program. After studying and comparing characteristics of raw water with Indian Standard Characteristics, design of various mechanical units of WTP along with chemical treatment processes like coagulation, water softening and disinfection are found to be essential.
The results obtained of WTP design manually are compared with MS Excel program design. MS Excel program developed for the complete design of WTP offers the function that, on entering design population, calculations are done automatically and complete WTP is designed. Also, the program minimizes the percentage of error that occurs in manual designing and it gives precise results in lesser time.
***Keywords**: Contaminants, Water Demand, Water Treatment Plant, Manual design, MS Excel program*

I. INTRODUCTION

A. Water Treatment Plant (WTP)

People like water to taste clear, look clear and smell clear; and it's the quality of the water source that will determine what kind of treatment it will need. Water treatment is the process of removing contaminants from raw water. It includes physical, chemical, and biological processes to remove physical, chemical and biological contaminants. A typical water treatment plant (WTP) comprises intake, pumping, pre-sedimentation (in some cases), coagulation, flocculation, clarification, adsorption, filtration, disinfection, storage, and pumping to treat water for consumption.
Generally, the water treatment design and planning process is driven by factors such as, water source availability and quality, sustainability assessments of treatment and source options that weigh financial, social and environmental parameters, legal regulatory requirements and the availability of land, skillsets and technology. In a conventional water treatment plant (WTP), raw water undergoes a series of processes which include the units below.

1) Intake and screening
2) Intake and screening
3) Flocculation
4) Clarification/sedimentation
5) Filtration
6) Chlorination/disinfection
7) Clear water reservoir

B. Existing WTP in Yavatmal City

Yavatmal is the city in Maharashtra state having elevation above sea level 451 m (1479 ft.).The area of the Town is 12 Sq.km. and rural area is 19 Sq.km. The population as per 2011 census record is 2,54,853. Present population is 2,66,000. The water supply to the city is provided from Chapdoh treatment plant situated at village Nilona. Chapdoh Water treatment plant has capacity 17.40 MLD. The main source of supply to water treatment plant is Chapdoh dam at a distance of 18.71 km which is built across Waghadi river, nearest village to dam is Chapdoh in Yavatmal District of Maharashtra. The dam is an Earth fill Dam. Catchment area is 12.266 thousand hectors. Maximum / Gross storage capacity is 13.127 MCM. Live storage is 7.65 MCM. Dead storage is 0.93 MCM. About 51% of total water supplied to the city is from this plant.

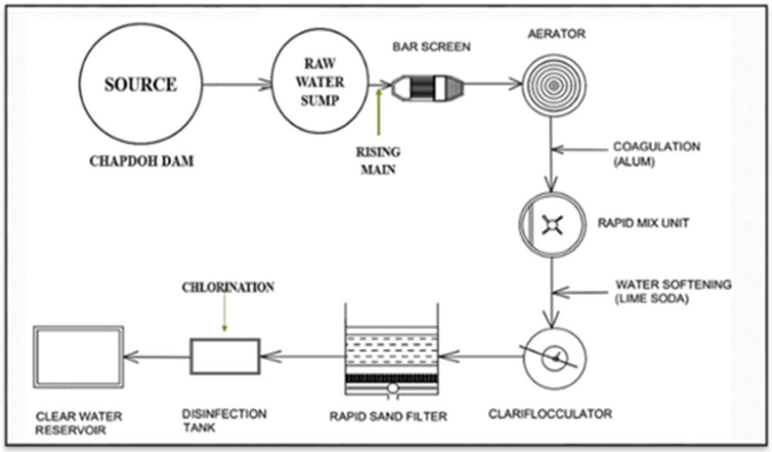

Fig. 1 Layout of Existing Chapdoh WTP

The plant operates for 22 hours and 17.40 MLD (725 m3/hr.) water is being treated and supplied to the city. Rate of water supply is 100 lpcd. The design and construction of the plant is conventional one and comprises of various units such as aerator, flash mixer, clariflocculator, rapid sand filters, chemical house, clear water sump and pump house.

C. MS Excel

Microsoft Excel is a spreadsheet program used to record and analyse numerical and statistical data. Microsoft Excel provides multiple features to perform various operations like calculations, pivot tables, graph tools, macro programming, etc. A Excel spreadsheet can be understood as a collection of columns and rows that form a table. Alphabetical letters are usually assigned to columns, and numbers are usually assigned to rows. The point where a column and a row meet is called a cell. The address of a cell is given by the letter representing the column and the number representing the row.

The main features of the MS Excel program in WTP design are as follows:

1) The software is completely user friendly.
2) Menu is displayed to select a particular unit for design.
3) Design procedures followed are according to BIS.
4) Permissible ranges of parameters are provided to guide user for entering the input data.
5) The software will not allow entering any data which is incompatible and prevents from obtaining erroneous results.

II. LITERATURE REVIEW

Darshanwad S.D. et al. (2013) "Comparison of the Design of Water Treatment Plant by Manual and by Software Method". In this study, an attempt to design conventional Water Treatment Plant of 100 MLD capacity by manual method and by using software. The physical and chemical Quality of drinking water does not exceed the limits as per Drinking Water Quality standards IS-10500 (1991). Conventional water treatment plant is designed using manual method and by using the software method. Manual design of Cascade Aerator, Flash-Mixer, Flocculator, Clarifier, Rapid Sand Filter, Parshall Flume, Chemical Storage Requirement and Chlorine and Underground Reservoir Requirement and its comparison with WTPSOFT02 Software was done. The manual method was lindy and tedious and on other hand the software method was easy and interesting. The time consumption for design by software method was less than the manual method. The errors in manual method were more than of software method.

Mujeeburahiaman P.S. and Murthy B.M. (2015) "Design of Conventional Water Treatment Plant for the Comprehensive Water Supply Scheme to Mukkam and Adjoining Villages in Kerala using WATPLANT Software" they designed a conventional water treatment plant for four rural panchayaths in Kozhikode district of Kerala state, India. Water treatment plant was designed using the WATPLANT software and it was proposed about 1.80 km away from the intake well location. The level of water supply was not adequate in different places coming under the existing water supply schemes. For the design of scheme, they studied the present population, population forecast for the three decades, daily water demand, and survey of the villages. Aerator, flash mixer, flocculator, clarifier, chemical house, chemical tanks, filter beds, wash water tank was designed using WATPLANT software.

III. OBJECTIVES

The specific objectives of the present study are:

A. To study the existing water treatment plant in Yavatmal city.
B. To design manually, the WTP for Yavatmal city for a design period of 30 years.
C. To develop a MS Excel program for any design population and using it for design of WTP for Yavatmal city.
D. To compare the WTP design obtained manually with self-developed MS Excel program design

IV. METHODOLOGY

A. Data Collection

For design WTP, the following data were obtained from Water Resource Department, Yavatmal

1) Details of existing WTP in Yavatmal city
2) Population records of past 3 decades
3) Raw water characteristics of Chapdoh reservoir

B. Population Projection

The total population of Yavatmal city as per 2011 Census is 131317. The design period considered is 30 years. 2011 is taken as base year and the population forecast for year 2051 have been worked out by 1) Arithmetic increase method 2) Geometric progression method 3) Incremental increase method. The census population for the census year 1991 to 2011 is considered. The values obtained from all three methods are nearly equal. The highest value is obtained by the method of Incremental increase i.e. 191633 and is taken as design population.

C. Raw Water Characteristics

The raw water characteristics of source i.e. Chapdoh reservoir is given in Table 1.

Table I
Raw Water Characteristics of Chapdoh Reservoir

Sr. No.	Test Parameters	Raw water	BIS Specification	
			Desirable Limits	Permissible Limits
1	Physical Observation	Turbid	-	-
2	Odour	Odourless	-	-
3	Turbidity (N.T.U.)	1.21	1	5
4	pH value	7.5	6.5 to 8.5	No relaxation
5	Chlorides (as Cl)	60	250	1000
6	Nitrates (as NO_3)	10.1	45	-
7	Total Hardness (as	140	200	600
8	Alkalinity (as $CaCo_3$)	20	200	600
9	Permanent Hardness	120	-	-
10	Iron (as Fe)	0.12	0.3	No relaxation
11	Fluoride (as F)	0.41	1	1.5
12	Total Dissolved Solids	272	500	2000

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D. Methods of Design of WTP

The design of WTP has been done manually and by using MS-Excel based program. Population of Yavatmal city for year 2051 is forecasted. The flow of water required is obtained by multiplying average daily water demand (135 lpcd.) with design population. The design flow is calculated by multiplying average flow required with peak factor. The raw water characteristics are compared with Indian Standards Characteristics for drinking water and the parameters such as turbidity, alkalinity, hardness, etc. which makes the raw water not suitable for drinking purpose are taken into account and treatment processes required are finalised accordingly.

All the necessary mechanical treatment units in advanced water treatment plant are designed along with chemical treatment processes to remove or lower the undesirable characteristics of raw water and make it safe and suitable for drinking purpose.

After studying and comparing characteristics of raw water, design of Intake well, Bar screen, Cascade aerator, Mechanical rapid mixer, Clariflocculator, Disinfection unit and Clear water reservoir along with chemical treatment processes like coagulation and water softening and disinfection were found to be essential and design for same is done manually as well as using Ms-Excel program.

V. RESULT AND DISCUSSION

From raw water characteristics, permanent hardness of 120 mg/L is objectionable and undesirable. It is required to be removed and hence, lime soda process of water softening is adopted. Similarly, for reducing turbidity and removing solids, coagulation with alum is adopted.

MS Excel program saves the time and manpower. The input parameters for each subprogram are to be entered in the input box during the design run. This program is very simple one and easy to understand. To get accurate result the design parameters has to be entered correctly. Design results are displayed in output box on the screen at the different phases of the design so that the designer can evaluate the design results of individual design phases and decide on their acceptability.

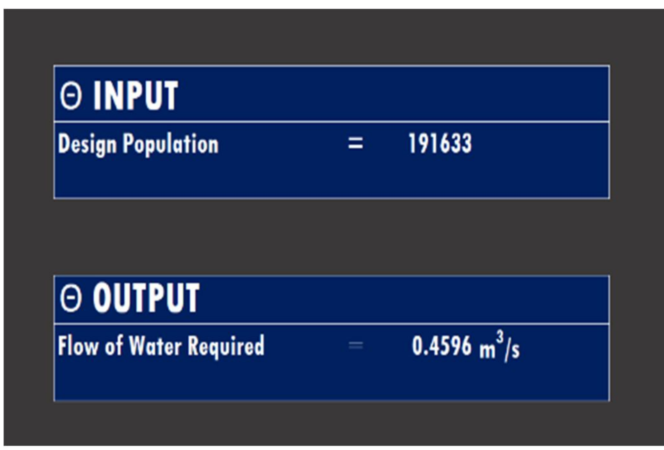

Fig. 2 Calculation of Design Flow

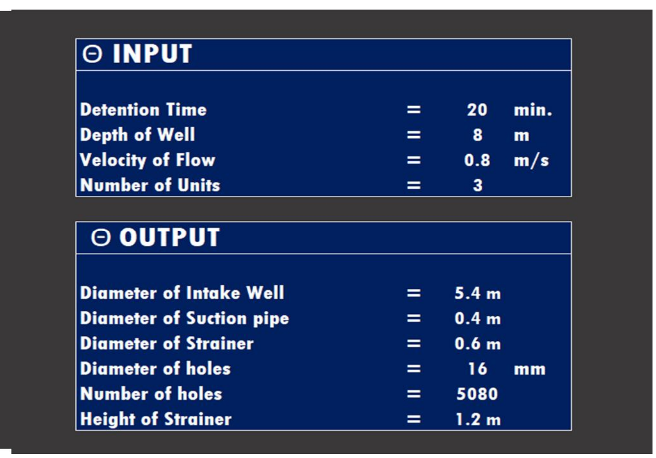

Fig. 3 Design of Intake Well

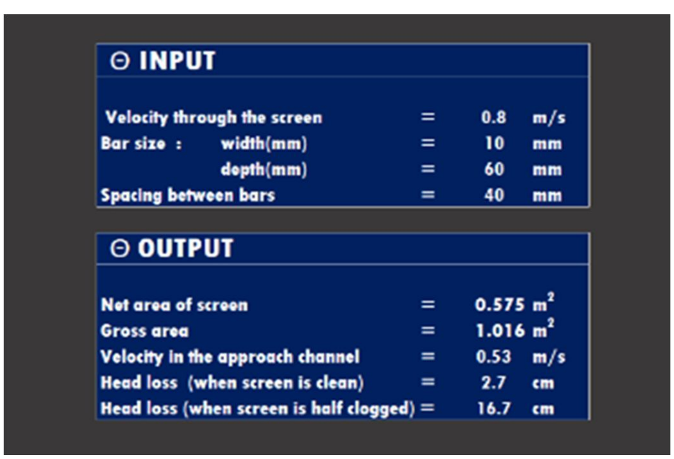

Fig. 4 Design of Bar Screen

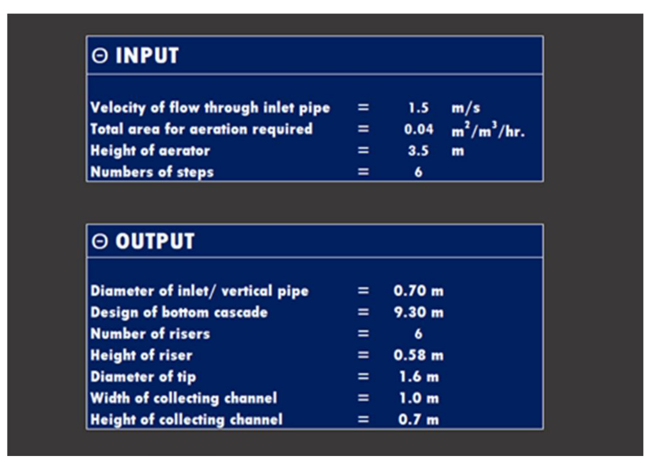

Fig. 5 Design of Cascade Aerator

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INPUT

Turbidity	=	1.2	NTU
Optimum dose of filtered alum	=	21	mg/L

OUTPUT

Quantity of alum required per day	=	833.847	kg
Quantity of alum required per year	=	304.354	Tonnes
Alkalinity required as $CaCO_3$	=	9.46	mg/L
Total wet volume of sludge	=	10.629	m^3/day
permanent hardness as $CaSO_4$	=	12.873	mg/L

Fig. 6 Coagulation with Alum

INPUT

Detention Time	=	30 sec.
Ratio of Tank Height to diameter	=	1 :1
Ratio of impeller dia. to tank dia.	=	0.3 :1
Impeller Speed	=	100 rpm
Velocity Gradient	=	400 sec^{-1}

OUTPUT

Detention Time	=	30 Sec.
Diameter of tank	=	3 rpm
Total height of Tank	=	2.80 m
Power Required per unit Vol.	=	162.00 KW
Number of Blade	=	4
Width of Blade	=	0.34 m
Length of Blade	=	0.07 m

Fig. 7 Design of Rapid Mix Unit

INPUT

pH	=	7.5	
Permanent hardness formed due to coagulation	=	12.87	mg/L
Permanent hardness present in water	=	120	mg/L
$CaSO_4$	=	50	mg/L
$CaCl_2$	=	10	mg/L
$MgSO_4$	=	50	mg/L
$MgCl_2$	=	10	mg/L

OUTPUT

Lime required	=	3373	kg/day
Soda required	=	4531	kg/day
Sludge produced	=	6351	kg/day
Volume of sludge	=	4.54	mg/L

Fig. 8 Water Softening

INPUT

Detention Time	=	30	min.
Depth of Tank	=	3.5	m
Velocity of Flow	=	1.2	m/s
Velocity Gradient (G)	=	20	sec^{-1}
peripheral velocities of blades	=	0.3	m/s
Velocity of the tip of blades (v)	=		sec.

OUTPUT

Diameter Of Influent Pipes	=	0.80 m
Depth of Tank	=	3.5 m
Diameter of Tank	=	17.70 m
No. of Paddles	=	8 nos.
Distance of Shaft from C.L. of Flocculator	=	4.2 m
Paddles Rotation (RPM)	=	4
Slope of Bottom (%)	=	8 %
Total Depth of Partition Wall	=	6.4 m
Diameter of Clariflocculator	=	45.1 m

Fig. 9 Design of Clariflocculator

INPUT

Rate Of Filteration	=	5000	lit./m^2/hr
Length (L) / Width (B) ratio	=	1.3	
Depth of sand	=	60	cm
Effective size Of Sand	=	0.5	mm
Overall Depth Of Filter unit including Free Board of 0.5m	=	2.5	m

OUTPUT

Number Of Units	=	8	
Size Of Unit (m)	=	(5.9 x 7.6) m	
Depth Of Gravel	=	50	cm
Diameter Of Perforation	=	13	mm
Diameter Of Central Manifold	=	0.68 m	
Spacing For Laterals	=	15 cm	
Number Of Laterals	=	102	
Diameter Of Laterals	=	50 mm	
Number Of Perforations	=	678	
Number Of Trough	=	5	
Size Of Trough (cm)	=	(20 x 44)	cm

Fig. 10: Design of Rapid Sand Filter

INPUT

Chlorine content	=	40	%
Chlorine demand	=	0.6	mg/L
Residual chlorine	=	0.2	mg/L
Detention period	=	30	min.
Number of units	=	3	
Depth of tank	=	4	m

OUTPUT

Total dose of chlorine required	=	0.8	mg/L
Amount of bleaching powder reqiuired	=	79.43	kg/day
Amount of bleaching powder reqiuired	=	28.99	T/year
Depth of tank	=	4	m
Length of tank	=	11.8	m
Width of tank	=	5.9	m
Velocity of flow in tank	=	0.007	m/s

Fig. 11: Design of Disinfection Unit

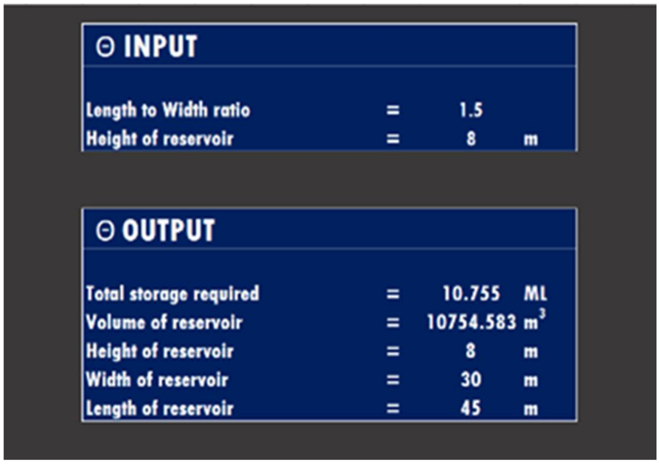

Fig. 12 Design of Clear Water Reservoir

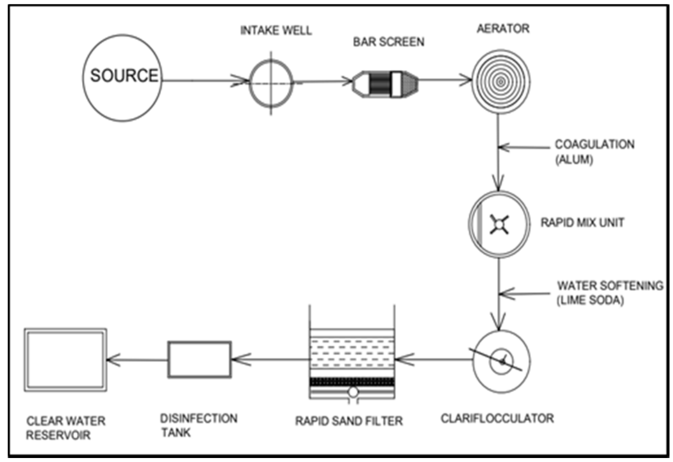

Fig. 13 Layout of Designed WTP

TABLE II
COMPARISON OF RESULTS

S.N.	Details of Unit	By Manual design	By software design
1	Water demand		
	Input		
	Design population	191633	191633
	Output		
	Flow of water required	0.4595 m^3/s	0.4596 m^3/s
2	Intake		
	Input		
	Detention Time	20 min	20 min
	Depth of Well	8 m	8 m
	Velocity of flow	0.8 m/s	0.8 m/s
	Number of Units	3	3
	Output		
	Diameter of Intake Well	5.4 m	5.4 m
	Diameter of Suction pipe	0.4 m	0.4 m
	Diameter of Strainer	0.6 m	0.6 m
	Diameter of holes	16 mm	16 mm
	Number of holes	5080	5080
	Height of Strainer	1.2 m	1.2 m
3	Bar Screen		
	Input		
	Velocity through the screen	0.8 m/s	0.8 m/s
	Bar size :	10 mm	10 mm
	depth(mm)	60 mm	60 mm
	Spacing between bars	40 mm	40 mm
	Output		
	Net area of screen	0.575 m^2	0.575 m^2
	Gross area	1.015 m^2	1.016 m^2
	Velocity in the approach channel	0.53 m/s	0.53 m/s

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	Head loss (when screen is clean)	2.7 cm	2.7 cm
	Head loss (when screen is half clogged)	16.7 cm	16.7 cm
4	Cascade aerator		
	Input		
	Velocity of flow through inlet pipe	1.5 m/s	1.5 m/s
	Total area for aeration required	0.04 $m^2/m^3/hr$	0.04 $m^2/m^3/hr$
	Height of aerator	3.5 m	3.5 m
	Numbers of steps	6	6
	Output		

	Diameter of inlet/ vertical pipe	0.7 m	0.7 m
	Design of bottom cascade	9.3 m	9.3 m
	Number of risers	6	6
	Height of riser	0.58 m	0.58 m
	Diameter of tip	1.6 m	1.6 m
	Width of collecting channel	1 m	1 m
	Height of collecting channel	0.7 m	0.7 m
5	Coagulation		
	Input		
	Turbidity	1.2 NTU	1.2 NTU
	Optimum dose of filtered alum	21 mg/L	21 mg/L
	Output		
	Quantity of alum required per day	833.846 kg	833.847 kg
	Quantity of alum required per year	304.35Tonnes	304.35Tonnes
	Alkalinity required as $CaCO_3$	9.46 mg/L	9.46 mg/L
	Total wet volume of sludge	10.629 m^3/day	10.629 m^3/day
	Permanent hardness as $CaSO_4$	12.873 mg/L	12.873 mg/L
6	Rapid mix unit		
	Input		
	Detention Time	30 sec	30 sec
	Ratio of Tank Height to diameter	1	1
	Ratio of impeller dia. to tank dia.	0.3	0.3
	Impeller Speed	100 rpm	100 rpm
	Velocity Gradient	400 sec^{-1}	400 sec^{-1}
	Output		
	Detention Time	30 sec	30 sec
	Diameter of tank	2.6 m	2.6 m
	Total height of Tank	2.8 m	2.8 m
	Power Required per unit Vol.	162 KW	162 KW
	Number of Blade	4	4
	Width of Blade	0.34 m	0.34 m
	Length of Blade	0.07 m	0.07 m

7	Water softening		
	output		
	Quantity of lime (Kg/day)	3373.189	3373.189
	Quantity of soda (Kg/day)	4530.926	4530.926
	Quantity of sludge (Kg/day)	6351.135	6351.135
	Volume of sludge (Kg/day)	4.537	4.537
8	Clariflocculator		
	Input		
	Detention Time	30 min	30 min
	Depth of Tank	3.5 m	3.5 m
	Velocity of Flow	1.2 m/s	1.2 m/s
	Velocity Gradient (G)	20 sec^{-1}	20 sec^{-1}
	Peripheral velocities of blades	0.3 m/s	0.3 m/s
	Velocity of the tip of blades	0.3 m/s	0.3 m/s
	Output		
	Diameter Of Influent Pipes	0.8 m	0.8 m
	Diameter of Tank	17.70 m	17.70 m
	No. of Paddles	8	8
	Distance of Shaft from C.L. of Flocculator	4.2 m	4.2 m
	Paddles Rotation (RPM)	4	4
	Slope of Bottom (%)	0.08	0.08
	Total Depth of Partition Wall	6.4 m	6.4 m
	Diameter of Clariflocculator	45.1 m	45.1 m
9	Rapid sand filter		
	Input		
	Rate Of Filtration	5000 lit./m^2/hr.	5000 lit./m^2/hr.
	Length (L) / Width (B) ratio	1.3	1.3
	Depth of sand	60 cm	60 cm
	Effective size Of Sand	0.5 mm	0.5 mm
	Overall Depth Of Filter unit	2.5 m	2.5 m
	Output		
	Number Of Units	8	8
	Size Of Unit (m)	(5.9 m x 7.6 m)	(5.9 m x 7.6 m)
	Depth Of Gravel	50 cm	50 cm
	Diameter Of Perforation	13 mm	13 mm
	Diameter Of Central Manifold	0.68 m	0.68 m
	Spacing For Laterals	15 cm	15 cm
	Number Of Laterals	102	102
	Diameter Of Laterals	50 mm	50 mm
	Number Of Perforations	678	678
	Number Of Trough	5	5
	Size Of Trough (cm)	(20 cm x 44 cm)	(20 cm x 44 cm)
10	Disinfection unit		
	Input		
	Chlorine content	0.4	0.4

	Chlorine demand	0.6 mg/L	0.6 mg/L
	Residual chlorine	0.2 mg/L	0.2 mg/L
	Detention period	30 min	30 min
	Number of units	3	3
	Depth of tank	4 m	4 m
	Output		
	Total dose of chlorine required	0.8 mg/L	0.8 mg/L
	Amount of bleaching powder required	79.43 kg/day	79.43 kg/day
	Amount of bleaching powder required	28.99 T/year	28.99 T/year
	Depth of tank	4 m	4 m
	Length of tank	11.8 m	11.8 m
	Width of tank	5.9 m	5.9 m
	Velocity of flow in tank	0.007 m/s	0.007 m/s
11	Clear water reservoir		
	Input		
	Length to Width ratio	1.5	1.5
	Height of reservoir	8 m	8 m
	Output		
	Total storage required	10.577 ML	10.577 ML
	Volume of reservoir	10754.582 m^3	10754.583 m^3
	Height of reservoir	8 m	8 m
	Width of reservoir	30 m	30 m
	Length of reservoir	45 m	45 m

VI. CONCLUSION

The MS Excel program developed offers the function that, on entering design population, calculations are automatically done and complete WTP is designed. This program reduces the percentage of error that occurs in manual designing and also software automates most of the task and thus, the amount of effort required is also reduced.

For WTP design it gave precise results without consuming time in lengthy calculations. The results obtained from MS Excel are accurate and approximately same as the results obtained from manual design.

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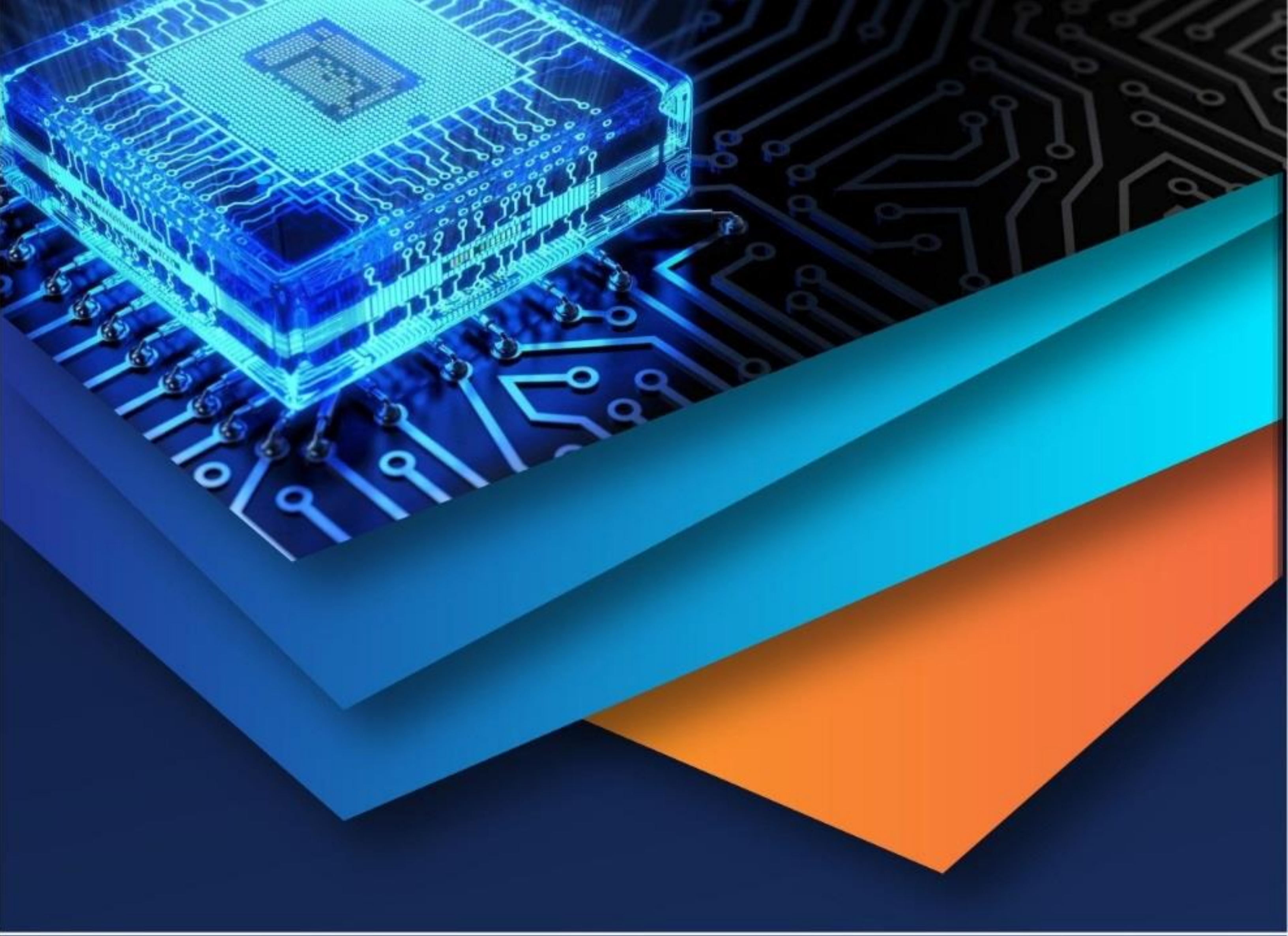

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