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Design of Sewer Collection Network System

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Abstract: *Urban areas are characterized with dynamic change in terms of demography, land use, living standards of inhabitants, increase in per capita water demand and consequently in the waste water that is discharged from households and industries. The study designed hydraulic sewer collection network system in some selected areas of Maiduguri, Borno State Nigeria using PVC pipes with varying diameters ranging from 150mm - 600mm depending on the expected flow rates for the areas. Population Forecast for 10 years design period was adopted and Geometric Progression Population Forecasting Method was used for the prediction of the population growth pattern. The study observed highest flows rate of 46.4, 36.64 and 80.14 litres per second at pipe P1, P4 and P9 respectively. This is due to proximity of pipes from the wastewater source. However, lowest flow rates of 0.50, 1.57 and 7.26 litres were recorded from pipes P13, P12 and P3 respectively. Because of the distance from the source. Furthermore, lowest demands were also observed from junction J3 and J4 with a demand of 10LPS*

Key words: *Design, Network, Hydraulic, and Sewer*

Introduction

A sewerage system is a system that contains pipes of several lengths and diameters, which are very important to convey the wastewater, including domestic, residential, industrial and commercial treatment services (Ansari et al., 2013). Sewerage system plays a critical role in that it supports public health and environmental protection. Normally, the wastewater flow in the sewerage system is directly related to human usage for all kind of activities. A sewerage system is composed of various sewer lines terminating at the junction of a large sewer line. The large sewer line also terminates at the junction of a still larger sewer line. Finally, the main sewer line terminates at the outfall. Thus, a sewerage system can be viewed as a set of sewer lines collecting discharges at their nodal points and emptying into another set of sewer lines. In this paper attention is focused on the optimal design of a sewer line, which is a basic unit of a sewerage system. The problem consists of minimization of a nonlinear cost function subjected to nonlinear constraints.

In developing countries the sewage disposal is not given proper priority so treatment and disposal of sewage is still area of major concern. Untreated sewage from cities and towns is the biggest source of pollution of water bodies in third world countries (CPCB Highlights, 2001). In India there are 211 Sewage Treatment Plants (STPs) in 112 of the 414 Class I cities and 31 STPs in 22 of the Class II towns (CPCB Highlights, 2005). Besides, 27 STPs are in 26 other smaller towns. In all there are 267 STPs, Including 231 operational and 38 are under construction. There remain 302 Class I cities and Class II towns together generate an estimated 29129 ml/day sewage (Nadeem et al., 2008). Against this, installed sewage treatment capacity is only 6190 ml/day. There remains a gap of 22939 ml/d between sewage generation and installed capacity. In percentage this gap is 78.7%. Another 1742.6 ml/day capacity is under planning or construction stage. If this is also added to existing capacity, even then there is gap of 21196 ml/day (equal to 72.2%) in total sewage treatment capacity.

Camp (1946) was the first to emphasize the need for hydraulic design of sewers, which was neglected in the technical literature at that time as well as by the sewage works engineers. Since then a large number of research workers contributed to this subject. These approaches employed heuristic methodologies, which can be adapted on a microcomputer (Liebman 1967; Cook and Lockwood 1977; Mays 1978; Lorine 1982: Dasher and Davis 1986; Miles and Heaney 1988; Charalambous and Elimam 1990). Using dynamic programming, Argaman et al. (1973), Merritt and Bogan (1973), and Walsh and Brown (1973) affected the design. Using piecewise linearization, the problem was solved by linear programming by Dajani et al. (1972), Dajani and Hasit (1974), and Elimam et al. (1989). On the other hand, Jain (1987) and Tyagi (1989) used a sequential linear programming method to find the sewer diameters. Gupta et al. (1976) used Powell's method of conjugate directions to search the optima of the cost function.

All these approaches use the Manning equation or Hazen- Williams's equation for resistance description. The Manning equation is applicable for a limited bandwidth, 0.004–0.04, of relative roughness (Christensen 1984). ASCE (1963) has disapproved the Manning equation and recommended the use of the Darcy-Weisbach equation for open-channel resistance. On the other hand, in a detailed study Liou (1998) strongly discouraged the use of the Hazen-Williams equation.

Sewerage networks are an important part of the infrastructure of any society. The main purpose of providing the sewer network is to carry away sanitary waste from a municipal area in such a way that it does not cause any public health related problems. It is known that urban sewerage system provide one of the basic infrastructure facilities to transport sanitary waste to sewage treatment plant. Sewerage network infrastructure conveys wastewater used by individuals, commercial and industrial establishments to wastewater treatment facilities, ultimately to be returned to the natural environment. A sewerage network is just a reverse action of water supply network. The cost of laying a sewerage system is appreciably high compared to the water supply system. It involves a large cost with need for daily maintenance, and the operational coast is one of the major expenditures (Katti et al, 2015).

Sewer systems are important for a modern city, but are often overlooked because of difficulty of maintenance, monitoring, and rehabilitation caused by underground burial.

However, sewages are apt to get cracks and defects due to corrosive wastewater inside and complex surroundings outside.

Serious cracks and leaks may result in the inflow to sewer treatment plants exceeding the design rate due to infiltration of rainfall or underground water. Also, the leakage of sewerage from failed pipes may cause a health hazard with the possible contamination of groundwater and soil. Negligence concerning these failures increases maintenance and rehabilitation costs significantly. In order to prevent worse failures and continue to provide designed functions, regular rehabilitation of sewages is necessary (Hernebring et al., 1998). Pipe rehabilitation can reduce either water infiltration into or leakage of sewage and increase the efficiency of treatment facilities and wastewater reuse opportunities (Wirahadikusumah et al., 1998; Bakir, 2001; Gupta et al., 2001). In addition to the construction of new municipal infrastructure, to appropriately allot limited budget on rehabilitation of the present infrastructure is another important job (Abraham et al., 1998; Sægrov et al., 1999; Gokhale and Hastak, 2000; Gupta et al., 2001; Ariaratnam and MacLeod, 2002). Generally, sewage authorities adopt a simple rehabilitation strategy that allots rehabilitation capital to "critical sewers", which are those pipes where collapse repair costs could be expected to be the highest (Fenner, 2000). In Taiwan, city governments used to fix all failed pipes (both critical and non-critical pipes) to keep the sewage system in good condition. However, when financial support runs into a limit, an optimization model to find the best sewerage rehabilitation plans becomes a valuable tool. Many researchers indicate that both rehabilitation method and substitution material affect rehabilitation cost and service life when sewage rehabilitation is executed (Ouellette and Schrock, 1981; Reyna, 1993; Gupta *et al.,* 2001).

Decentralized sewage treatment system (DTS)

DTS is the system in which instead of collecting whole sewer of town at one place and treating it, it provides small treatment units on site at many places. DTS provides treatment of waste water flows from 120 to 1200kl/d (kilo litre per day) or even more from domestic sources (CPHEEO, 1987). It is based on principal of anaerobic fermentation. The selection of which has been determined by its reliability, longevity, easy control and least maintenance. Actually in DTS the partial treatment is given to the sewage water as it can be utilized in urban agriculture irrigation purpose with drip or sprinkle irrigation technique instead of disposing it in to the streams (BORDA, 1998). So this small scale treatment plant can give real benefits in terms of money without polishing sewage with advance treatment like Activated Sludge Process etc. In this system a balance between the advantages of large scale treatment in terms of Economics of scale and individual Responsibility for domestic waste water treatment can be obtained by providing colony wise/sector wise treatment system. Demonstration plants using onsite DTS should be promoted throughout the developing nations for which not only Government Agencies and Non-Governmental Organizations (NGOs) but also progressive builders and resident welfare association may show the way.

Methodology

Population Forecast for 10 years design period was adopted.

Geometric progression population forecasting method (equation 3.1) was used due to the nature of rapid population growth pattern of the city.

$$P_{t} = P_{o}\left(1-\frac{r}{100}\right)t \quad (3.1)$$

Table 3.1: Population forecasting

Zone(Maiduguri)	Population for design	
	Present Population	Future population in 10 years
Umarari	65,000	105879
Ngarannam	52,000	84,702
Total		190581

EPANET Software was used to determine the following:

- Pipe properties (roughness, diameter, length)
- Nodal properties (demand, elevation)
- Reservoirs, Tanks (location, elevation, operating levels, shape, volume)
- Pumps (operational/efficiency profile, scheduling)
- Patterns (diurnal demand profiles)

The key outputs from a network simulation include the spatial and temporal variation of:

- Nodal pressure/head
- Pipe flow
- Tank levels
- Energy consumption (pumping)
- Water quality (including age and chemical concentrations)

EPANET Hydraulic Pipe Layout and Analysis

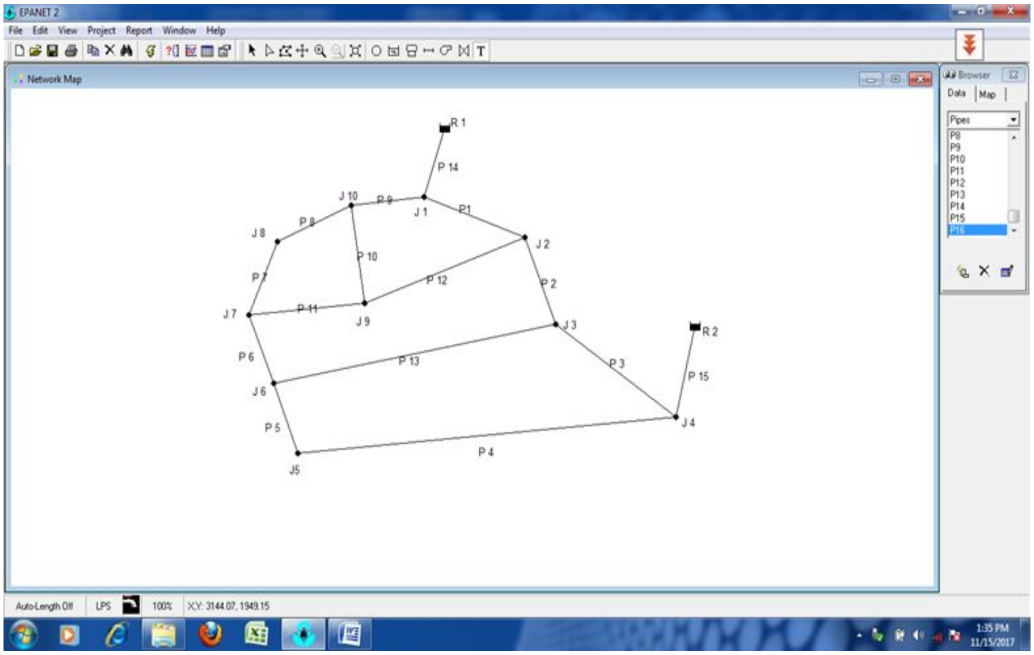

Figure 3.1: EPANET Runner Network Analysis

Designed Data for the sewer system

Table 3.2 Design Data for sewer Sanitary Pipe Sizing

Item	Value
Total population	190581
Expected water consumption per design	150 Litres per day
Total amount of water consumed	150 ×190581 = 2858710l/d
Wastewater produced (85% of water consumed becomes wastewater)	0.85 × 190581 = 161993.85
Adopted Peaking Factor, P.F	3.0
Discharge Q = wastewater produce × P.F	161993.85 × 3.0 = 485982 l/d
Assuming 80% of the population contributes to the wastewater generated	485982× 0.8 = 388785 l/d

Table 3.2: Time Range expressed in Percentage Wastewater Generated

7:00am – 8:00am	15% of 388785 = 58,317 l/d
8:00am – 5:00pm	5% of 388785 = 194,39 l/d
5:00pm – 6:30pm	20% of 388785 = 777.57 l/d
6:30pm – 7:00am	60% of 388785 – 233,27l/d

Where
P_t=Expected Population
P_0 = Base years' population (i.e. 2006 census figure)
r =population annual growth rate which is estimated as 5% for urban area.
t = number of year from base years

The projected population is shown in Table 3.1 as computed from equation 3.1

Table 4.1: Flow and velocity of network links

Link ID	Length (m)	Diameter (mm)	Flow (Litres/Sec)	Velocity (m/s)	Unit Head Loss(m/k)
Pipe P1	1760	300	-46.41	0.12	0.10
Pipe P2	518	300	-12.06	0.13	0.09
Pipe P3	1340	300	-7.26	0.30	0.29
Pipe P4	2280	300	-36.64	0.58	1.00
Pipe P5	450	300	10.36	0.16	0.08
Pipe P6	466	300	16.28	0.27	0.22
Pipe P7	1890	300	-10.73	0.70	1.19
Pipe P8	1200	350	0.50	0.33	0.30
Pipe P9	692	300	80.14	0.59	1.24
PipeP10	1480	300	-30.27	0.02	0.01
PipeP11	623	300	-1.57	0.53	0.66
PipeP12	1650	300	-45.43	1.22	3.14
PipeP13	1680	300	-25.62	0.02	0.01
PipeP14	712	600	130.05	0.24	1.42
PipeP15	250	600	101.20	0.60	0.11

The pipes that have higher rate of flows reflect the proximity of these pipes to the pipes closed to source of supply. It can be observed that the pipes having the highest flows are P1, P4 and P9, the pipes having flows of 46.41, 36.64 and 80.14 litres per second respectively.

Table 4.2: water requirement and pressure heads at nodes.

I.D.	Demand(LPS)	Head (m)	Elevation	Pressure (m)
Junction J1	32.00	350.59	325.70	24.89
Junction J2	20.00	350.69	325.50	25.19
Junction J3	10.00	350.88	323.00	27.88
Junction J4	10.00	351.39	331.80	19.59
Junction J5	20.00	351.30	333.60	17.70
Junction J6	15.00	353.15	332.40	20.75
Junction J7	45.00	352.03	333.30	18.73
Junction J8	25.00	356.01	336.00	20.01
Junction J9	35.00	350.47	335.50	14.97
Junction J10	45.00	350.47	334.00	16.47
Reservoir1	93.50	354.00	330.00	24.00
Reservoir2	76.20	344.30	320.30	24.00

The demand was distributed to all junction depend on demand of each junction, for J3 and J4 with the lowest demand of 10LPS each due their less demand from the nodes. The highest demand was given to junction 7 and 10 with flows of 45LPS and 45LPS each respectively.

Conclusion

The study design hydraulic sewer collection network system in some selected areas using PVC pipes with varying diameters ranging from 150mm - 600mm depending on the expected flow rates for the areas. Based on the design, the following conclusions were drawn:

i. The study observed highest flows rate of 46.41, 36.64 and 80.14 litres per second at pipe P1, P4 and P9 respectively. This is due to proximity of pipes from the wastewater source.
ii. Lowest flow rates of 0.50, 1.57 and 7.26 litres were recorded from pipes P13, P12 and P3 respectively. Because of the distance from the source.
iii. Lowest demands were also observed from junction J3 and J4 with a demand of 10LPS.

References

Argaman, Y., Shamir, U., and Spivak, E. (1973). ‘‘Design of optimal sewerage system.’’ J. Envir. Engrg. Div., ASCE, 99(5), 703–716. ASCE Task Force on Friction Factors in Open

Camp, T. R. (1946). ‘‘Design of sewers to facilitate flow.’’ Sewage Works J., 18(1), 3–16.

Central Pollution Control Board, (CPCB) Highlights (2005). Parivesh NewsLetter.

Central Pollution Control Board, India (2001). Decentralized Sewage treatment System, Concept and approach, October.

Charalambous, C., and Elimam, A. A. (1990). ‘‘Heuristic design of sewer networks.’’ J. Envir. Engrg., ASCE, 116(6), 1181–1199.

Christensen, B. A. (1984). ‘‘Discussion of ‘Flow velocities in pipelines, ‘by Richard R. Pomeroy.’’ J. Hydr. Engrg., ASCE, 110(10), 1510–1512.

Cook, L. A., and Lockwood, B. (1977). ‘‘The investigation of sewer network by computer.’’ J. Inst. of Civ. Engrs., Part 2, 63(2), 481–494.

Dajani, J. S., and Hasit, Y. (1974). ‘‘Capital cost minimization of drainage networks.’’ J. Envir. Engrg. Div., ASCE, 100(2), 325–337.

Dasher, D. P., and Davis, P. K. (1986). ‘‘Designing sanitary sewers with microcomputers.’’ J. Envir. Engrg., ASCE, 112(6), 993–1007.

Elimam, A. A., Charalombus, C., and Ghobrial, F. H. (1989). ‘‘Optimal design of large sewer networks.’’ J. Envir. Engrg., ASCE, 115(6), 1171–1189.

Gupta, J. M., Agarwal, S. K., and Khanna, P. (1976). ‘‘Optimal design of wastewater collection system.’’ J. Envir. Engrg. Div., ASCE, 102(5), 1029–1041.

Hernebring, C., Mark, O., & Magnusson, P. (1998). Optimisation and control of the inflow to a wastewater treatment plant using integrated modelling tools. *Water science and technology*, *37*(1), 347-354.

Jain, R. K. (1987). ''Optimal design of a sewer line.'' ME dissertation, University of Roorkee, Roorkee, Uttaranchal, India.

Katti, M., Krishna, B. M., & Kumar, M. (2015). Design of Sanitary Sewer Network using Sewer GEMS V8i Software. *Int. J. Sci. Technol. Eng*, *2*, 254-258.

Liebman, J. C. (1967). ''A heuristic aid for the design of sewer networks.'' J. Sanit. Engrg. Div., ASCE, 93(4), 81–90.

Liou, C. P. (1998). ''Limitations and proper use of the Hazen-Williams equation.'' J. Hydr. Engrg., ASCE, 124(9), 951–954.

Lorine, J. M. (1982). ''Sanitary sewer design.'' Civ. Engrg., ASCE, 52(6), 66–67.

Mays, L. W. (1978). ''Sewer network scheme for digital computations.'' J. Envir. Engrg. Div., ASCE, 104(3), 535–539.

Merritt, L. B., and Bogan, R. H. (1973). ''Computer-based optimal design of sewer systems.'' J. Envir. Engrg. Div., ASCE, 99(1), 35–53.

Miles, S. W., and Heaney, J. P. (1988). ''Better than 'optimal' method for designing drainage systems.'' J. Water Resour. Plng. and Mgmt., ASCE, 114(5), 477–499.

Nadeem K, Rajiv S, Raghav AK, Mittal AK (2008). UASB technology for sewage treatment in India, Twelfth International Water Technology Conference, IWTC12, Alexandria, Egypt, p. 1411.

Tyagi, A. (1989). ''Optimal sewer line design.'' ME dissertation, University of Roorkee, Roorkee, Uttaranchal, India.

Walsh, S., and Brown, L. C. (1973). ''Least cost method for sewer designs.'' J. Envir. Engrg. Div., ASCE, 99(3), 333–345.