Evaluation of Water Quality and Efficiency to Treat WaterPollution Problem in Two Types of Supply WaterDistribution System: Loopand,Treein Iraq:By UsingWaterGEMSSoftware

Comment [N1]: The title have to be Rearranged

Abstract. There are a lot of Iraqi cities in Iraq that used a tree supply water distribution system, it is also an old supplywater network, which produces poor water quality in this network. This paper has studied water quality in two systemloops and a tree net in two of Iraqi's cities requires Water GEMS. This document's goal is to review the effect of themajor types of supply water distribution system on its pollution and characteristic in Iraq. The results of the analysis oftwo water systems show the efficiency of the loop distribution system of supply water networks compared to the treedistribution system ones in preventing water pressure drop, preserving water type, and preventing pollution. Where thedeadendsin the tree network cause the deposition ofpollutants,whichincreasesthe possibility of an increase inorganic pollutants, unlike the loop distribution system ones, which makes the water in constant movement,whichpreventstheoccurrenceofpollutionand giveswaterpressurestability.

These results are confirmed by laboratory tests for water in both cases loop and tree distribution systems ofsupplywater networks, in addition to QWI which showed thatthe loopsystem canmaintain the quality ofwater andreducethe causes of pollution through the absence of this system from dead ends and the continuous movement of water.Although the water quality in the two networks was very poor because the network is old and the treatment system isineffective.

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Keywords.drinkwater,supplywaterdistribution,waterqualityindex,WaterGEMS.

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INTRODUCTION

The main goal of the supply water distribution network is to deliver safe drinking water to consumers.evaluation of the water distribution system is very important to improve quality and quantity for this vital part of ourlife.Thesepurposesdependedonmanyfactorslikepipetype,ageofthispipe,andrepairandtreatmentoperationsin a network [1,2]. The companies' water supply needs to exercise control over the operating conditions of watersupply networks has contributed to the development of several methods for their diagnosis. The evaluation anddiagnostics of technical infrastructureare considered a constantly developingfield. The studies present, the review& division of the previously used methods of Evaluation & diagnosing the operating conditions of supply waternetworks. Some of the studies take also assessed & classified the usefulness of the methods of evaluation &diagnosis in specific operating conditions. The review shows that: there is a need for research on the detection ofoperating conditions ofsupplywaternetworksundertheoperatingconditionsofrealsystems [3,4].

Nowadays; Water operators in a water supply distribution company aspire to achieve access in the mostefficient way and to achieve this goal they are required to take multiple actions simultaneously, and significantimprovements in working conditions can be achieved by using programming systems to solve the problems. of watersupply distribution networks by connecting some Water supply networks with model programs [5,6]. They diagnoseconditions of supply water distribution network systems depending on many random and deterministicfactors [7].To solve the problem of thesupply watersystem comprehensively,weneedan analysisof theshape of theparameters of the water network operating conditions like pressure & flow rate, during abnormal water intake, &underspecificoperatingconditionsofpressuremanagement,forcedthedevelopmentofappropriatemethodsand

mathematicalprocedures[8,9].Todeterminetheoperatingconditionsof asupplywaternetworksystem;itmustbeconsidered bothoperationally&technically[10].

The processes affecting the achieved values of the operating condition parameters of the supply waternetwork are complex; their diagnosis is a multifaceted issue. Moreover; the cyclicity observed in the time series of(pressure and flowrate) makes this information nonstationary [11]. Proper determination of unitary supply waterdemand and diurnal distribution of water consumption as supply water consumption histogram that provides thedimensioning, basis for designing, & all analyses of supply water networks system. It is important to make a case formathematical modeling of flows in a water supply network, especially while determining the requirements forliquefied water in the context of a network simulation [12,13]. The main deferent between supply water distributiontypes loop and tree, is the dead end which can appear more often in the second type compare to the first one.In loopsystem: minimized head loss and minimization of water age retention time in a network, also its effect on water flowrate. Water age is considered a major factor in water efficiency and quality of supply water network because of itseffectonthephysicalandchemicalwatersupplycharacteristic[14].

MATERIALSANDMETHODS

To achieve the objectives of this research, several software programs and techniques were used, includingCivil3D and WaterGEMS,itis considered one of thelatestspecialized engineering programsfor the design,operation, and simulation of liquefaction networks. The specific area has been studied and comparing them, as theywere close in areas (≈ 1.4 km2) and a similar population density (≈3*104 cap./km2). Figure (1) represents the studyarea where the tree distribution networks in Kirkuk city and the loop distribution networks were in Erbil city. Region.The topography of the area was studied through aerial survey and engineering programs software as Civil3D and theproduction of topographic and contour maps for the specific area. Maps have also been drawn for the mentionedarea, including streets and buildings, in addition to studying the type of population from an economic point of viewand theamountandtypeoftheiruse ofsupplywater.

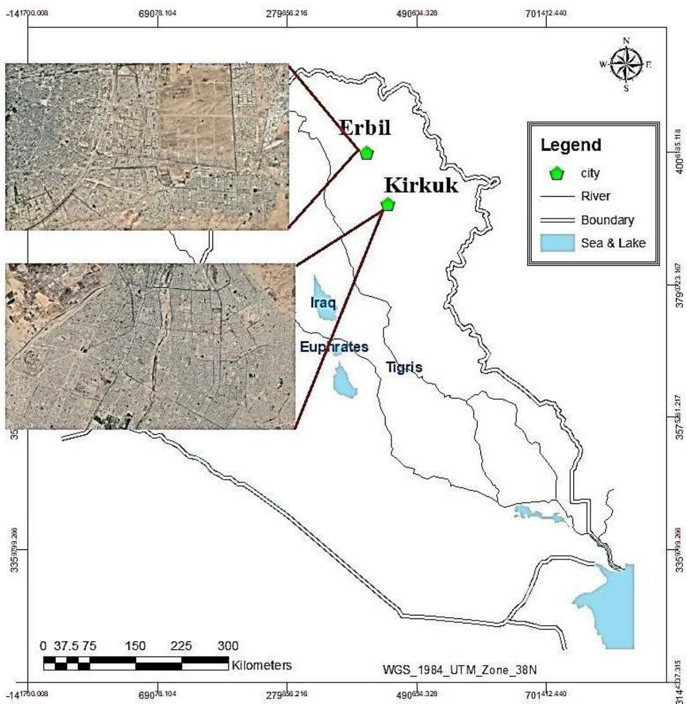

FIGURE1. AreaStudyMap–Iraq

The supply water network was mapped, the processing hours were water demands through the engineeringsoftware programs: Civil3D &WaterGMES, the water supply network was operated through the WaterGMESprogram, and the pumping hours and pressures were evaluated. 200 sample of supply water samples were collectedand the necessary tests (13 chemical tests) were conducted. Emphasis was placed on the points that are the ends ofthe tree water supply network because of theirimportancein determining the quality of water. 100 samples ofsupply water in the loop distribution system were collected to perform a lab test. In addition, 100 samples werecollected from the tree distribution network, and most of them were from dead ends. The water pressure for bothnetworks loop and tree were measured for 24 hours in two cases: 1- the normal state of the network. 2- A scenariowas made for the network and turned into a contrary, and the water pressure reaching the consumer was measured.Where theschematics showinblacklines the pipes thatcontain water with a pressure of 1.5 bar and above, whilethe pipes in which the pressure drops below 1.5 bar are drawn in the white line. This is illustrated by the diagrams inTables3&4.

RESULTS

The evaluation and diagnostics of technical infrastructure like supply water distribution networks is a youngand constantly developing field. However, detection of working conditions of supply water networks, and watersupply projects are vital projects, and it is necessary to evaluate them and develop solutions to problems due to theseriousnessofwaterpollutioninthis network.

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TheChemicalTest

The tests conducted included many physical and chemical properties of drinking water to assess its qualityof the water .The decrease in dissolved and insoluble pollutants is observed in Loop distribution relative to treedistribution, with minimum and maximum values for 200 samples in both types of distribution in the tables loop andtree system. 100 samples were collected from the tree distribution network, most of them were from dead ends, and100samplesofsupplywaterintheloopdistributionsystemwerecollectedtoperformlabtests.

ThePowerorPotentialofHydrogen-pH

The obtained values for pH were within a small range (7.2-8.35) in the loop distribution system and (6.8-7.95)inthetree distributionsystemand thisisthe normalrangefordrinking water,asshown in figure (2).

Turbidity

Turbidityisoneoftheimportanttestsdueto itsdirecteffectonthe qualityofthemicroparticlesinwater. The turbidity values ranged between - NTU (8-42) in the loop distribution system and (9.6-59.36) in the treedistribution system, as shown in tables No. (1&2) and figure (3). It was noted that a was outside the determinants ofthe Iraqi standard specifications, which specified the turbidity values with NTU (10) This is due to the inefficiencyof the plant in water treatment, due to the deterioration in the quality of the alum used, in addition to the increaseddemand for water consumption, which leads to a lack of contact time. Sufficient to perform the coagulation processwith inefficientfilters due totheold age ofthe drinking watertreatmentplantand thelack ofcontinuousmaintenance.

Totaldissolvedsolids-TDS&Totalsuspendedsolids-TSS

The concentrations of total dissolved solids (TDS) for the models ranged within the range (530-920) mg/Lin the loop distribution system and (651.9-1132) mg/L in the tree distribution system as shown in tables No. (1&2)and figure (4), according to the Iraqi standard specifications for drinking water. Which determined the upper limit ofTDS > (1000 mg/L), total suspended solids TSS value for the all samples did not exceed the upper limit according tothe Iraqistandard specificationsfordrinking water,asshownintableNo.(1&2)and figure(5).

Total dissolvedoxygen-DO

The concentrations of total dissolved oxygen (DO) for the models ranged within the range (5-10) mg/L inthe loop distribution system and (4.1-8.9) mg/L in the tree distribution system as shown in table No. (1&2) andfigure(6),accordingtotheIraqistandardspecificationsfor drinkingwater.Whichdeterminedtheupper limitofDO >(5mg/L),andbasedonthesespecifications,themeasuredconcentrationsareconsideredsuitablefordrinkingpurposes.

Electricalconductivity-EC

Electricalconductivityexpressesthevalueofdissolvedsaltsinwateranditsincreasecausestheunpleasanttaste of drinking water. When it exceeds the permissible limits (1000 cm/µS), results shown in the table (1&2) andfigure (7) indicate that the values did not exceed µS/cm (800) for the loop distribution system and (850) for a treedistribution system. It is thus within the permissible limits for the drink and these results are less than what wasobtained for drinking water these differences in values are due to the difference in the quality of the raw waterpermitted forliquefactionstations [15].

Chlorine-Cl

Itisoneoftheimportantcriteriafordeterminingthequalityofwater, becausehighconcentrationsmeanthepresenceofpollutionofnutritiousrawwatersourcestoliquefactionstations, andrendersitunfitfordrinkingandwatering livestock [16,17]. It is noted from the above table that the highest concentration of (15.2-15.58 mg/l) inboth types of network respectively as shown in figure (8), which is much less than the permissible limits for thedrink,and studiesindicate ahighconcentration inIraqiwater,towardstothe southasa resultofthedischarge of civil, industrial and agricultural wastes into the rivers, which will affect its concentration in the waters of the riversdrinking;As[18]indicated,theconcentrationofchlorideionsfordrinkingwaterinthecityofBasrawas590mg/l.

Sulfateions-SO4

SulfateionsSO4arepresentinwaterindifferentconcentrationsthatdependonthegeologicalformationsthat these waters passed through and on excesses in the dumping of all civil, industrial, and agricultural waste intothe waters of rivers, which is reflected in its concentration in the waters of the rivers [10]. Wich is reflected in itsconcentration in supply water, and that its high concentration causes liquefaction and bitter taste and itsconcentration in the studied drinking water does not exceed (90.8) mg/l in both networks as shown in table No.(1&2) and figure (9), which is within the permissible limits of the drink 250 mg/l according to the Iraqispecifications [19].

Sodium-Na

The concentrations of Na for the samples ranged within the range (16.1-22.5) mg/L in the loop distributionsystem and (17.2-24.1) mg/L in the tree distribution system as shown in table No. (1&2) and figure (10), accordingtotheIraqistandardspecificationsfordrinkingwater.WhichdeterminedtheupperlimitofNa>(20mg/L)[20].

Calcium-Ca,Magnesium-Mg,Potassium-K

The concentrations of (Ca, Mg, K) for the all samples did not exceed the upper limit according to the Iraqistandard specifications for drinking water, as shown in table No. (1&2) and figures (11, 12, 13), and based on thesespecifications,the measured concentrationsareconsidered suitablefordrinking purposes[21].

WaterQualityIndex-WQI

After calculating the water quality index using the weighted mathematical index using thirteen drinkingwaterstandardstodetermineitsqualityanditsvaliditytothedrinkcomparedtotherecommendedstandardlimitsasshown in table 3, it is noted from the table that the value of the WQI of chemical and physical examinationsamounted to 217.9 for loop distribution system (200~300 very poor water), Which is less than water quality indexfor supply water in the tree distribution system (247), and thus, the quality of drinking water is classified as WaterPooraccording towaterqualityclassificationbased onthe valueofthe WaterQualityIndex WQI shown inthetable(1 & 2). This deterioration in quality is due mainly to bacteriological contamination; The value of the water qualityindex for the bacteriological test (total plate count TPC) was very large compared to the rest of the criteria studied(asshownintableNo.(1&2)and figure(14))[15,20,22].

TABLE1. ChemicaltestandWQIforsupplywaterfromloop distributionsystemnetwork

	pH	Turbidity	DO	TDS	TSS	Cl	mg	Na	K	Ca	SO_4	TPC	EC
			mg/l										μS/cm
Max. result	8.35	42.4	9.4	855	33.2	15.2	30.7	22.6	4.2	50.1	90	126	735
Min. result	7.2	12	5	530	17	13	15.5	16	3.5	43	36	16	350
Average result	7.8	30.2	7.6	690.4	25.2	14.1	24.5	19.4	3.9	47	66.6	78.5	569.6
IraqiStan 2006-	6 8.5		n.5	1000							250	10	Max. 1000
WQI							217.9						

TABLE2. Chemicaltestand WQIforsupply waterfromtreedistribution systemnetwork

	pH	Turbidity	DO	TDS	TSS	Cl	mg	Na	K	Ca	SO_4	TPC	EC
			mg/l										μS/cm
Max. result	7.95	59.36	850	1132	45	15.48	32.34	24.12	4.383	52.61	90.18	15	850
Min. result	6.8	9.6	385	651.9	21.3	13.2	16.9	17.2	3.5	44.7	51.8	0.8	385
Average result	7.4	36.7	632.4	842.1	31.5	14.4	24.3	20.0	4.0	48.8	75.5	10.4	632.4
IraqiStandard 2006-	6.5~ 8.5	10	Max. 1000	Max. 1000	25	250	150	20	12	200	250	10	Max. 1000
WQI							247						

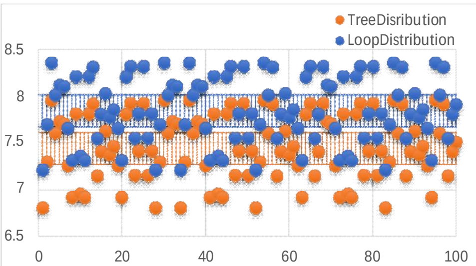

FIGURE2.pH.

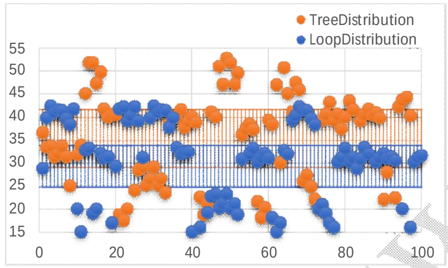

FIGURE3. Turbidity-NTU

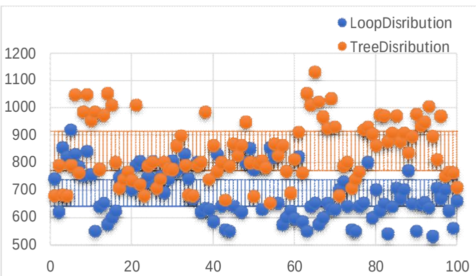

FIGURE4.TDS(mg/l).

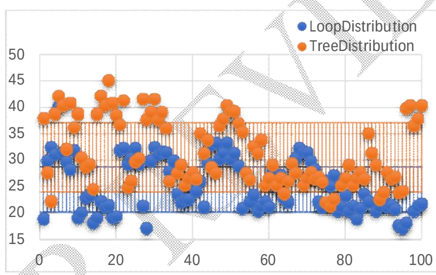

FIGURE5.TSS(mg/l)

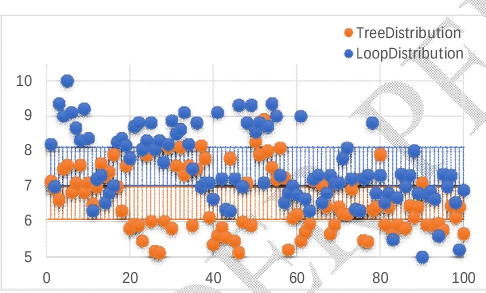

FIGURE6.DO(mg/l)

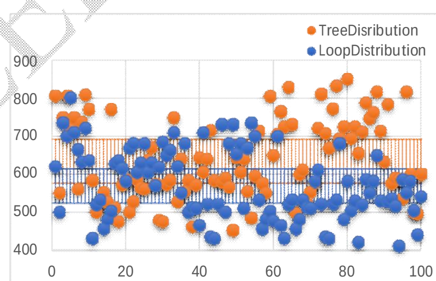

FIGURE7.EC(µS/cm)

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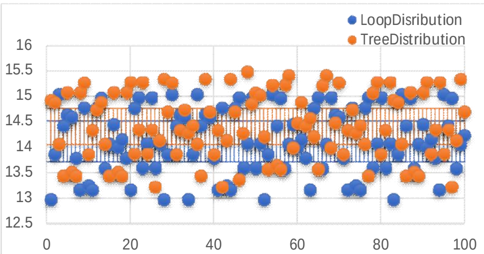

FIGURE8.CL(mg/l).

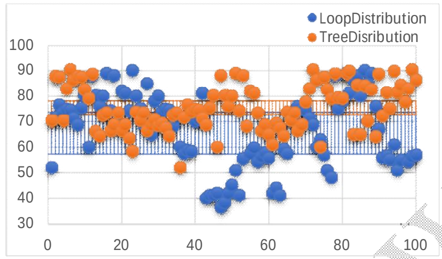

FIGURE9.SO_2(mg/l).

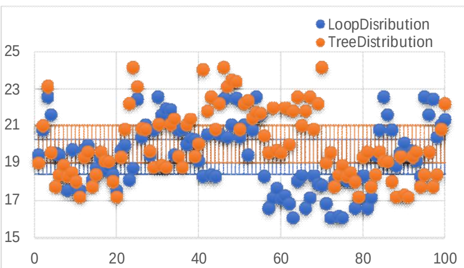

FIGURE10. Na(mg/l).

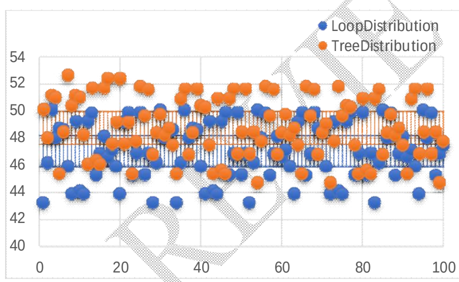

FIGURE11. Ca(mg/l)

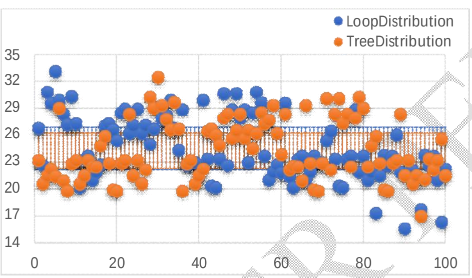

FIGURE12. Mg (mg/l).

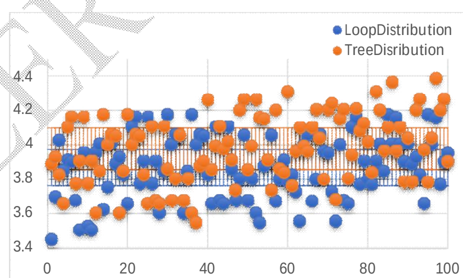

FIGURE13. K(mg/l).

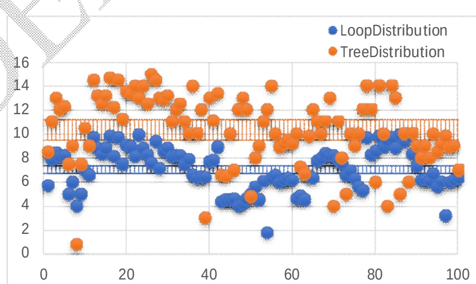

FIGURE14. TPC(cell/ml).

* All figure results for 100 samples of supply water in the loop distribution system and 100 samples of supply water in the t reedistributionsystem.

WATERGEMSSOFTWAREANALYSIS

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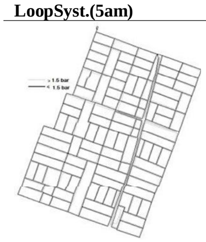
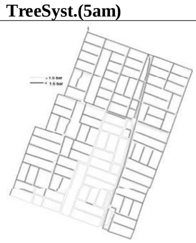
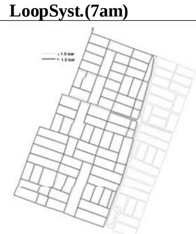
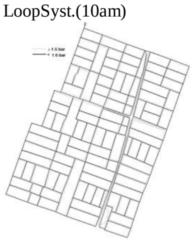
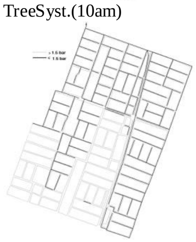
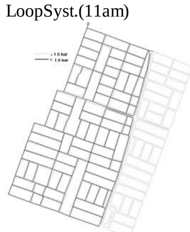
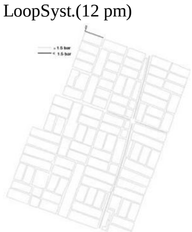
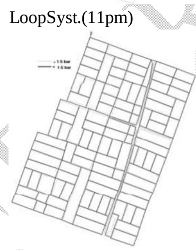
To analyze the results using WaterGEMS software, a scenario was made for the two networks to comparethe value of water pressure (water demand), flow, head loss, pressure loss, and velocity in the two cases: Thescenario includes a change in the type of connection in the network from the loop distribution system to treedistribution system; Where the presence of pipes in a black line indicates a rise in water pressure to more than 1.5bar, as shown in Table (3): while pipes in which the pressure drops below 1.5 bar are marked in white. A decrease inwater pressure was observed in a large part of the tree-type network (first scenario: convert loop type to tree type)compared to the loop type during the time from (5 am to 12 pm), which also shows a rise in pressure losses and headloss in tree type compare to loop type. During the period between (12 pm to 11 pm) the supply of water wasinterrupted in the two networks, and a significant increase in pressure losses and head loss as a result of the highrequirement and the inability of the two networks to meet the amount of water, as shown in figure (15), and figure(16), where figure (16) has been drawn for the scenario of converting a loop distribution network consisting of 301pipes into a tree distribution to compare the effect of distribution and connection methods on the network in terms ofwater pressure, flow, velocity, head loss. Each line in this figure has a different color and represents one of thenetwork pipes (more than 300 pipes in each study network) and the conduction of supply water in it as the water'svelocity, flow, head loss, and pressure with the time. Thus, the increase in the water requirement of the populationcan be observed during the daytime hours, especially the noon hours, and this leads to an increase in the waterpumping and flow rate, as the speed increases with it, and thus the water pressure in each pipe increases. Also, thelocation of each pipe in both networks gives a different effect, thus, the pipes near the pumping station have a moreuniform flow of water and its velocity with low pressure, unlike distant pipes, where pressure losses increase andwaterquantitiesdecrease,especiallywiththeincreased risksofdamagetopipes andjunction.

The tree distribution system in the supply water network was also analyzed using WaterGEMS software. A secondscenario for the network was made to compare the efficiency of this network in the two cases. The scenario includesa change in the type of connection in the network from a tree distribution system in the supply water network to aloop distribution system. When converting a supply water network type from tree distribution to loop distributionusing WaterGEMS software: a relative rise in water pressure was observed in most of the studied networks of thesame network in the loop system compared to the tree system; thus, a satisfactory quantity of water reaches theconsumer in most of the loop distribution system of supply water network from the hour (5 am) to (11 am) as shownin Table (4). Figure (17) and (18) also shows a rise in water pressure and flow with a decrease in head loss andpressure loss, in addition to the change in the water requirement with the hours of the day and the effect of thelocation of each pipe in the network. Table (4) also shows the water interruption in both networks from (12 pm to 11pm), and a significant increase in head loss as a result of the high-water requirement and the inability of bothnetworks to meet the quantity of demand water, as shown in figure (17) and figure (18), where figure (15) showresult for various factors 345 pipes in the tree distribution system, whereas figure (16) represents the scenario ofconverting a tree distribution network system into a loop distribution network system to compare the effect ofdistribution and connection methods on the network in terms of pressure. This difference in the laboratory andapplied results is due to the dead ends in the tree distribution system in contrast to the loop distribution system andthe separate connection of thenetwork,whichlimits thecontinuity of watermovementand the dynamics ofdistributioninadditionto sedimentation inthese endsandthe occurrence ofpollution insupplywater[15,23].

TABLE 3. Comparison of water pressure for 24-hour (in the loop distribution system and tree distribution system) first Scenariomodelingsimulationforsupplywaternetworkoperation byusingWaterGEMSsoftware.

LoopSyst.(5am)	**TreeSyst.(5am)**	**LoopSyst.(7am)**	**TreeSyst.(7am)**
			
LoopSyst.(10am)	TreeSyst.(10am)	LoopSyst.(11am)	TreeSyst.(11am)
			
LoopSyst.(12 pm)	TreeSyst.(12pm)	LoopSyst.(11pm)	TreeSyst.(11pm)
			

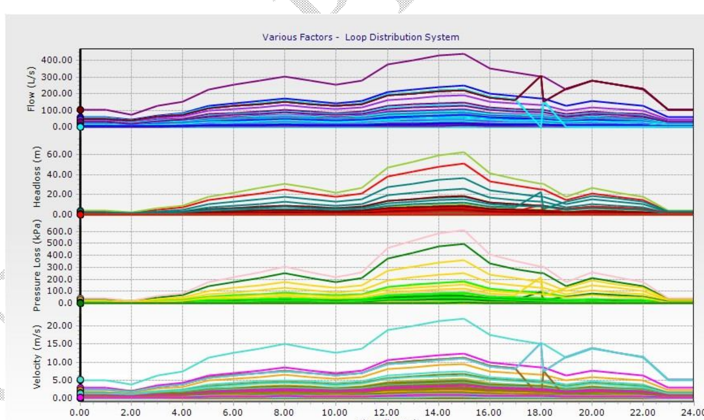


FIGURE15. Variousfactorsfor301 pipes withthetime– Loopdistributionsystem

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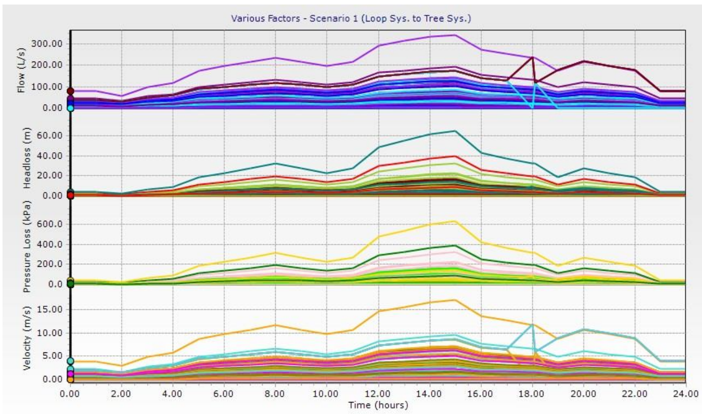
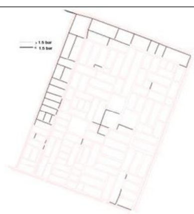
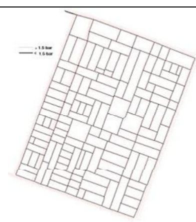
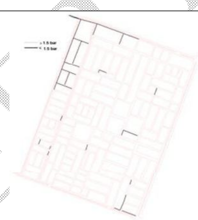
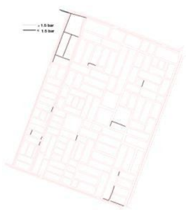
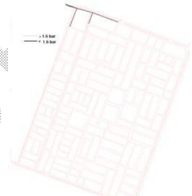
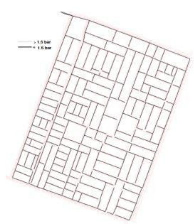
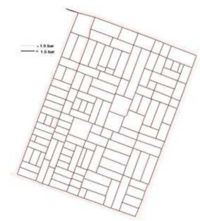


FIGURE16. Variousfactors301pipes – LoopdistributionsystemtoTreedistributionsystem

TABLE4. Comparison ofwaterpressurefor24-hour(intheloopdistributionsystemandtreedistributionsystem)secondScenariomodelingsimulationforsupplywaternetworkoperation byusing WaterGEMSsoftware.

TreeSyst.(5 am)	**LoopSyst.(5am)**	**TreeSyst.(6am)**	**LoopSyst.(6am)**
			
TreeSyst.(11am)	LoopSyst. (11am)	TreeSyst.(11pm)	LoopSyst.(11pm)
			

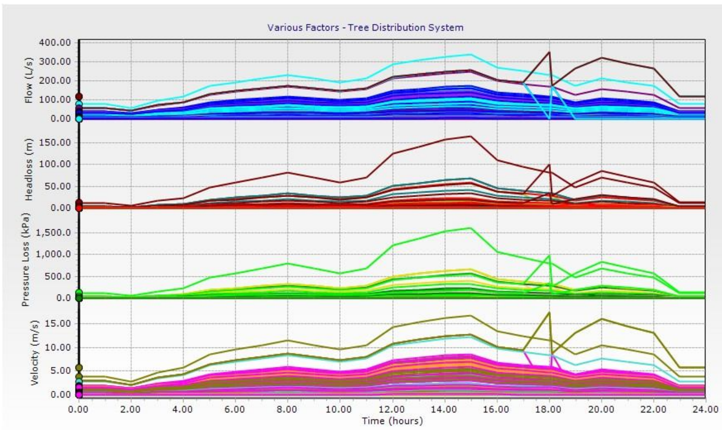


FIGURE17.Variousfactors345pipes – Treedistributionsystem

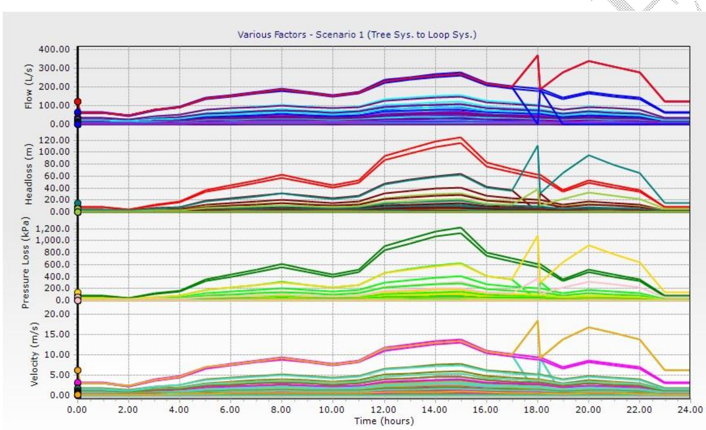


FIGURE18. Variousfactors345pipes–TreedistributionsystemtoLoopdistributionsystem

CONCLUSION

The use of engineering programs in design and analysis gives greater possibility and accuracy for designingand evaluating and operating the project, especially huge projects such as supply water network projects. The resultsof the analysis of two water systems show the efficiency of the loop distribution system of supply water networkscomparedtothetreedistributionsystem onesinpreventingwaterpressuredrop,preservingwatertype,andpreventing pollution. Where the dead ends in the tree network cause the deposition of pollutants, which increases thepossibility of an increase in organic pollutants, unlike the loop distribution system ones, which makes the water inconstantmovement,whichpreventstheoccurrenceofpollution.

These results are confirmed by laboratory tests for water in both cases loop and tree distribution systems ofsupply water networks; In addition to QWI which showed that the loop system can maintain the quality of water andreducethecausesofpollutionthroughtheabsenceofthissystemfromdeadendsandthecontinuousmovementof water. Although the water quality in the two networks was very poor because the network is old and the treatmentsystem is ineffective. This difference in the laboratory and applied results is due to the dead ends in the treedistribution system in contrast to the loop distribution system and the separate connection of the network, whichlimits the continuity of water movement and the dynamics of distribution in addition to sedimentation in these endsand theoccurrenceofpollutioninthesupplywater.

Due to the size of the large infrastructure networks, which include a large number of pipes and nodes andthe complexities of their operation, especially the supply water network, it has become necessary to resort tospecialized engineering programs in the design, analysis and operation of these networks. The most important andlatest of these programs is WaterGEMS, which gives a clear idea of the method of water disposal in each pipe of thenetwork over time. It also takes into account the location and type of pipes in the network. This increases the speedof this program in determining the location and type of problems, which contributes to the development of quicksolutions to them, which is important given the importance of this type of project and its close connection with thepopulation. Themain objective of this paperis to compare the types ofsupply water networks to choose the bestones for a good amount of water and to preserve the quality of water from pollution, and this goal applies to the loopdistributionnetworksystem.

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