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OptimizationStrategyforDecentralizedWaterTransport SystembasedonSpecificPollutantsControl

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Abstract

At present, in the research of water resources dispatching technology, while the quality impact of raw water on treatment process as well as pipeline network is usually neglected. In this paper, taking the source wells with poor quality on the upper and middle reaches of the Yellow River as the research object, the dispatching technology of quantity and quality combined optimization based on specific pollutant control is studied. Firstly, according to water quality characteristics of shallow groundwater around Yellow River, plant influent-source water coupling model of specific pollutants is established by combining the Fourier Transform with the Artificial Neural Network (ANN) method. On this basis, an optimization model of decentralized water transport system is constructed considering water quality, supply safety and economy. The optimization strategy is applied to Z city in the middle and upper reaches of the Yellow River, the effectiveness and practicability of decentralized water transport system based on specific pollutants control are verified in the mean while.

Keywords:*Dispatching Optimization, Plant Influent-Source Water Coupling Model, Decentralized Water Transport System, Specific Pollutants Control, Middle and Upper Reaches of the Yellow River*

1.Introduction

AsanessentialwatersourceofChina,groundwaterplays anoteworthyroleindrinkingwatersupply,socialeconomydevelopmentandeco-environmentbalance.Additionally,groundwaterisanimportantguaranteeofwell-balancedwatercycling.However,thepollutionproblemsofgroundwaterarelackofconcernforalongtime,duetotheelusivecharacteristicandsystemiccomplexity.Withtheincreasingattentiontothesafetyofwatersourceandtransportsystem,thereisgreatsignificancetostudyoptimizationofgroundwatertransportsystemandcontaminantscontrol.

Inrecentyears,withtheincreasingshortageofwaterresourcesandtheincreasingawarenessofenvironmentalprotection,scholarshavecarriedoutalotofresearchontheoptimaldispatchingofwaterresourcesathomeandabroad.ZhangYanlan(2014)setupamulti-sourcejointdispatchingmodelforBeijingundertheconditionofSouth-to-NorthWaterTransfer,aimingatensuringtheminimumyieldofwatersupplyanddiscard.YuBing(2015)tookthesocialbenefitandsupplycostofwatersupplysystemasthedispatchingobjective,constructedthethree-layerwatersupplynetworkstructureof"watersource-waterplant-userindifferentareas",andestablishedtheoptimaldispatchingmodelofmulti-sourcesupply.DanielW.(2014)studiedtheapplicationofmulti-objectiveoptimizationmodelforwaterresourcessustainability.Obviously,scholarsathom

TEST Engineering & Management

July-August 2020
ISSN: 0193-4120 Page No. 3672 - 3680

eandabroadhavepaidgreatattentiontowaterallocationresearchformulti-sourcedispatchingatpresent.Manyinvestigationshavebeencarriedoutprimarilywiththepurposeofwaterresourcessecurityassuranceandwatersupplycostreduction.Nevertheless,therearefewstudiesonqualityassuranceandpollutantcontrolintheprocessofwaterresourcesdispatchingrelatively,andtheresearchresultsarenotyetmature.

Inthispaper,thesourcewellswithpoorqualityontheupperandmiddlereachesoftheYellowRiveraretakenastheresearchobject,therelationshipofparticularpollutantsatwaterworksandnetworkdepartmentisresearched.Then,theoptimaloperationmodelofsourcewaterisestablishedbasedonthecomprehensiveconsiderationofparticularpollutantscontrolandoperationenergyreduction.TheresearchwillprovidetheoreticalguidanceforwaterqualityguaranteeandscientificmanagementofgroundwaterdistributionsystemontheupperandmiddlereachesoftheYellowRiver.

2.PlantInfluent-SourceWaterCouplingModelofSpecificPollutants

Itisquitecommontofetchwaterfromthewellsbesidethemainstreambeachof YellowRiver,becausethegroundwaterlevelismuchhigherthereduetoexcellentrechargingconditions.Watersamplesfromthesewellweretestedwhichindicatedhigherconcentrationsof As,Fe,Mnandsomeothercontaminants.On-lineinstrumentsarenotcommonlyinstalledfordecentralizedsourcewaterwellsduetoeconomicreasonsorlackofmaintenance.Asaresult,impactofwaterqualityvariationfromwellsontheinfluentofplantscouldnotbedetectedontime,whichbringsdifficultiestocontrolspecificpollutantsconcentrationallocatingsourcewater.

Thespecificpollutantsconcentrationofinfluentofplantsusuallycorrelateswiththatofwellswithinwatertransportsystems.However,thecorrelationcannotbesimplyexplainedbypolynomialsorlinearfunctions.Fortunately,non-mechanismwaterqualityanalysismethodsbecamemoreandmorepopular,whenstatisticmethodsandartificialintelligencealgorithmwasintroduced.Thisresearchmainlyfocusonsourcewaterwellsinthemiddle-lowerreachesofYellowRiver,andemploysFouriertransformandartificialneuralnetworks(ANN)tostudyPlantinfluent-Sourcewatercouplingmodelofspecificpollutants.

2.1FourierTransformofSpecificPollutants

FourierTransformisoneofthemostimportanttransformsformodernmathematics,whichhasbeencommonlyappliedindigitalsignalprocessing.Especiallyforthosecomplexandelusivefunction,Fouriertransformcouldtransformcomplextimedomainsignalsintomoreanalysisfriendlyfrequencydomainsignals.

Forarbitrarydiscretetimeseries $\{x_n\}$,withFouriertransformweget

$$y(\omega)=\sum_{-\infty}^{+\infty} x_n \exp(-i\omega k)\,, \qquad (1)$$

Relevantly,if $y(\omega)$ isapericodicfunctionwithperiodlength 2π,reverseFouriertransform

$$x_n=\frac{1}{2\pi}\int_{-\pi}^{\pi} y(\omega)\exp(i\omega k)d\omega\,, \qquad (2)$$

DigitalfilteringwasperformedviaFouriertransformtoremovedisturbanceofspecificpollutantsdataofplantinfluenceandsourcewaterwells.Thenthefrequencydomaindatawastreatedastheinputandmodeltrainingdataofartificialneuralnetwork.

2.2PlantInfluent-SourceWaterCouplingModelofSpecificPollutantsbasedonArtificialNeuralNetwork

Inordertoimprovethecalculationaccuracyoftheartificialneuralnetworkmodelandavoidtheinterferenceofnoisedataonthesimulationaccuracy,theFouriertransformwasusedtopretreatthespecificpollutantsmonitoringdataofplantinfluentandsourcewells.Afterremovingthenoisedata,theplantinfluent-sourcewellcouplingmodelofspecificpollutantsbasedontheartificialneuralnetworkwasestablishedbasedonthefrequencydomainsignal ,asshowninFigure1.

July-August 2020
ISSN: 0193-4120 Page No. 3672 - 3680

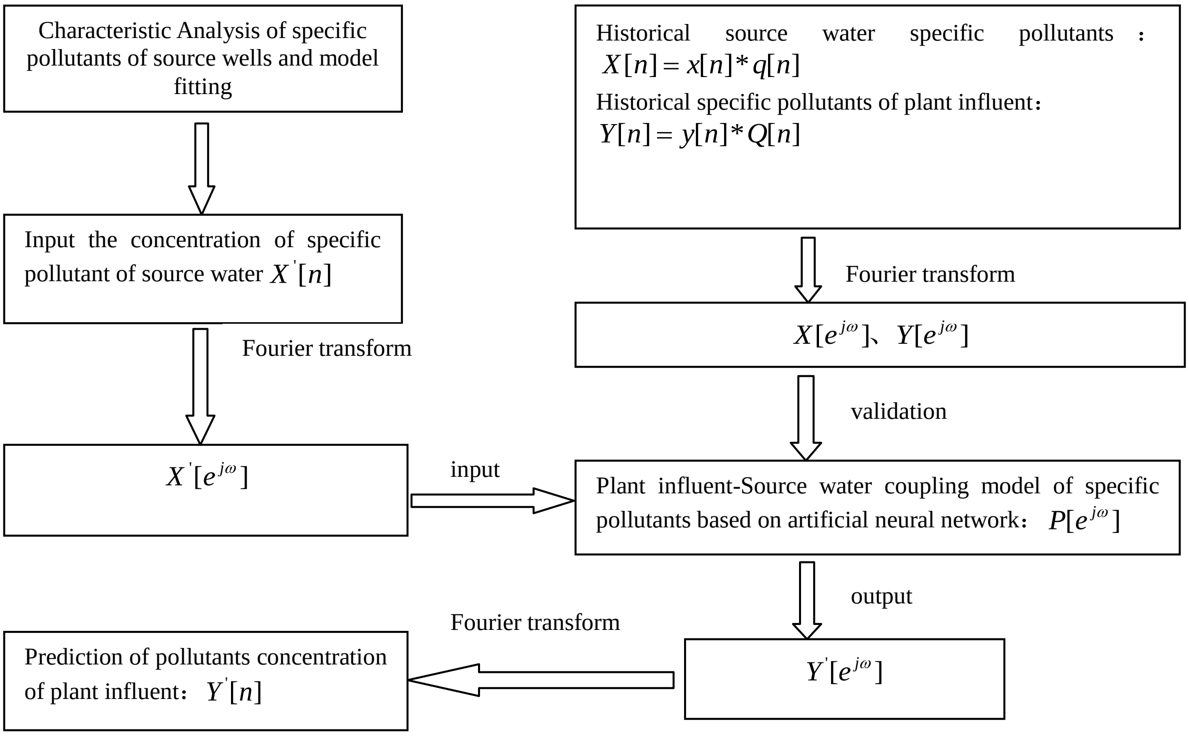

Fig.1.PlantInfluent-SourceWaterCouplingModelofSpecificPollutants

DuringtheconstructionofANNmodel,240sampleswith fourindexesoftheinfluentflow,specificpollutantsconcentration,wells'outletflow,andwells'specificpollutantsconcentrationwerefilteredbyFouriertransformanduse dastrainingparameters.ThemodelwastrainedbyLevenburg-Marquardtfunction.ABPnetworkmodelwasbuilt laterwithhiddenlayers,wherethefirsthiddenlayerhad14neuronsandthesecondhiddenlayercontains20neurons.Logsigfunctionisusedasthetransferfunctionbetween hiddenlayers.Meanwhile,inputlayerandhiddenlayerusedtan-sigmoidfunction,andhiddenlayertooutputlayera ppliedpurelinlinearfunction.

3.ConstructionofWaterTransportOptimizationModel

Inordertoguaranteewatersafetyandsatisfywaterrequirementaswellasreduceenergyconsumption,awatertransportoptimizationmodelwasbuiltwithconsiderationofreducespecificpollutantsconcentrationofplantinfluent. Thedecisionvariablesofthemodelaresourcewaterwell numbers(anddecidewhichwellsaresuitabletoprovidewateratcertaintime),flow,andpumpingtimelength.

3.1ObjectiveFunction

$$\min f\left(F_1,F_2,F_3\right), \tag{3}$$

3.1.1Waterqualitycouplingmodel F_1

$$F_1=f_1(x[n],q[n],y[n],Q[n],X^{'}[n],Y^{'}[n]), \tag{4}$$

Themethodstobuildspecificpollutantscouplingmodel hasalreadystatedinsection"PlantInfluent-SourceWaterCouplingModelofSpecificPollutantsbasedonArtificialNeuralNetwork".

3.1.2Energyconsumptionmodel

Energyismostlyusedforpumpingwaterfromsourcewellsofdecentralizedwatertransportsystem.

$$F_2=\sum_{i=1}^{I}\sum_{j=1}^{J}SP_{i,j}\frac{C\cdot NP_{i,j}\cdot QP_{i,j}\cdot HP_{i,j}}{\eta_{i,j}}, \tag{5}$$

Where, $SP_{i,j}$ --electricityfeeoftheithwellattimejth,CNY/kwh;

C--conversioncoefficient;

$NP_{i,j}$ --operationstatusoftheithwellattimejth.Ifthepumpofthiswellison,NP=1,otherwiseNP=0;

July-August 2020
ISSN: 0193-4120 Page No. 3672 - 3680

$QP_{i,j}$ --outletflowoftheithwellattimejth,m^3/h

$HP_{i,j}$ --pumpheadoftheithwellattimejth,m;

$\eta_{i,j}$
--pumpefficiencyoftheithwellattimejth,whichcouldbecalculatedfromthefittedpumpefficiencycurve;

I--totalnumbersofwells;

J--totalhours,whichisequalto24forthismodel.

3.1.3Watertransportsafetyguaranteemodel

Sourcewellsusuallyapplysubmergedpumpswithconstantspeed,whichhavesmallerscopeforflowandheadadjustment,comparedwithsecondarypressurepumpstation.Moreover,thereisgapsbetweenoutletflowofwellsandtherequiredflowofthetransportsystemundercertainconditions.Ifflowexceedrequirement,itnotonlywastewaterbutalsoresultsinhigheroperationcost.Ifwaterflowcannotthantherequirement,thewatertransportsystemcannotberegardedasareliablesystem.Therefore,scientificsolutionisnecessarytoallocatewellpumpswithdifferentratedflowandheadoptimally.

Theoretically,waterquantitybalancesabsolutely,whichisdenotedas $\sum_{i=1}^{I} Q_{i,j} = QF_j$ .However,inordertoguaranteethefeasibilityofoptimizationcalculation,therestrictioncouldbereduced.Asaresult,amodeltoguaranteewatertransportsafetyisbuiltasbelow.

$$F_3 = \sum_{j=1}^{J} \left| \sum_{i=1}^{I} Q_{i,j} - QF_j \right|, \tag{6}$$

Where, QF_j
--totalwaterrequirementattimejth(predictedviawaterconsumptionmodel),m^3/h;

$Q_{i,j}$ --waterflowoftheithpumpstationattimejth,m^3/h.

3.2Restrictions

3.2.1Hydraulicconditions

Watertransportsystemshouldsatisfyheadlossequation(Darcy–Weisbachequation)andcontinuityequation.

HeadLossequation:

$$h = SQ^n \tag{7}$$

Continuityequation:

$$A\overline{Q} = \overline{q}, \tag{8}$$

3.2.2Watersupplycapacityofeachwell

$$\sum_{j=1}^{J} Q_{i,j} \le Q_{\max i}, \tag{9}$$

Where, $Q_{i,j}$ --outletflowoftheithwellattimejth,m^3/s;

$Q_{\max i}$ --maximumoutletflowoftheithwell,m^3/s.

3.2.3Runningtimelengthofeachpump

Overloadriskalwaysexitsifacertainpumphascontinuouslyrunfortoolongtime.Onthecontrast,pumpswillgetoutoforderiftheyhavestayedofffortoolongperiod.Therefore,therunningtimelengthofeachpumpshouldbetakenintoconsideration.

$$DUR_{\min i} \le DUR_i \le DUR_{\max i}, \tag{10}$$

Where, DUR_i --runninglengthoftheithpump,h;

$DUR_{\min i}$, $DUR_{\max i}$
--minimumandmaximumrunninglengthoftheithpump.

3.3OptimalSolution

Thesolutionofwatertransportoptimizationmodelisatypicalmulti-objectiveoptimizationproblem.Therefore,howtofindtheoptimalsolutionbetweenparallelobjectivefunctionsandmultipleconstraintsisanimportantproblemtobesolved.Theinherentparallelismofhybridmulti-objectiveevolutionaryalgorithm(HMOEA)makesitpossibletofindmultipleParetooptimalsolutionsinsimulation.Comparedwithtraditionaloptimizationalgorithm,itcandealwithdiscontinuity,non-differentiabilityandnon-convexityofParetofrontierbetter.Therefore,themodelinthispaperissolvedbyHMOEA,andtheimplementationprocessisshowninFigure2.

July-August 2020
ISSN: 0193-4120 Page No. 3672 - 3680

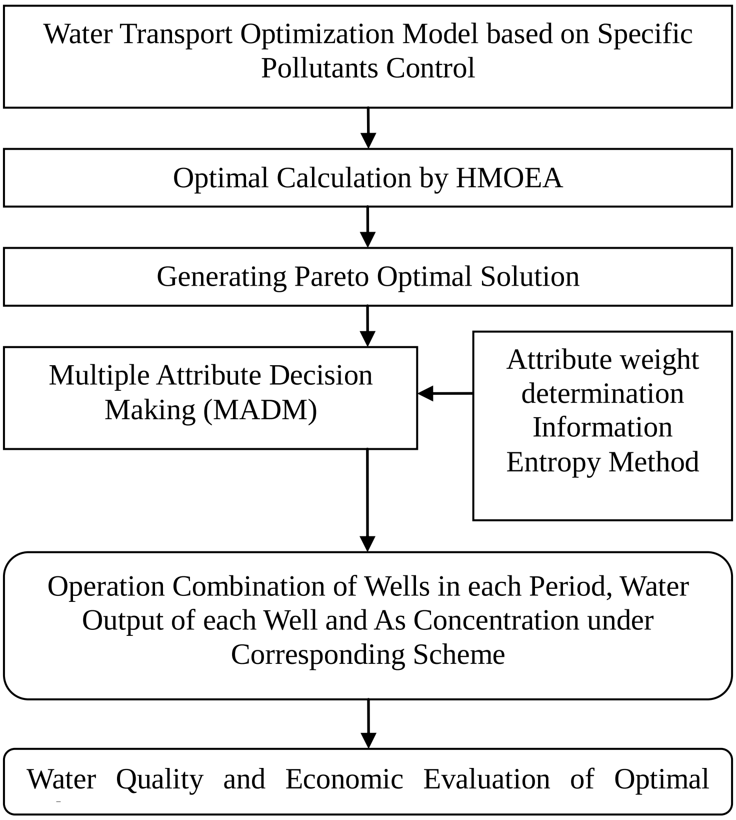

Fig2.WaterTransportOptimizationModelCalculationProcess

4.ApplicationandPractice

4.1ProjectBrief

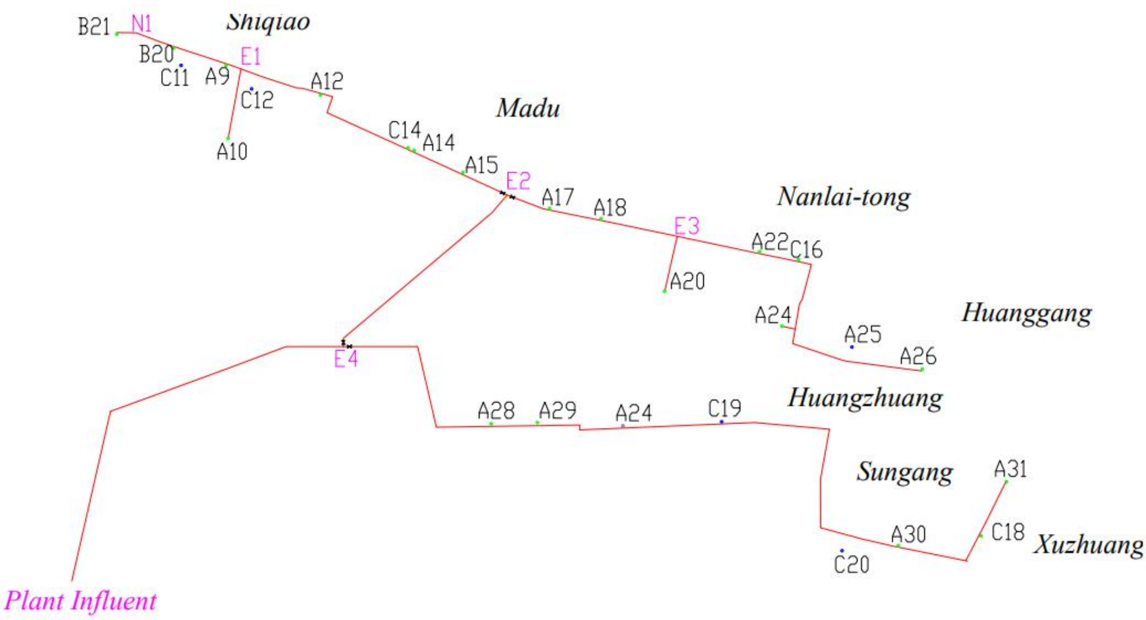

Fig.3.TopologyRelationofSourceWaterWellsandTransportNetworks

July-August 2020
ISSN: 0193-4120 Page No. 3672 - 3680

Asisdemonstratepreviously,supplyingwaterfromwellsalongthebeachofYellowRiverisquitecommoninthemiddle-upperreachesofYellowRiver.Groundwaterrechargedfromyellowriverconstitute30%watersupplyofthecityZinthemiddle-upperreachesofYellowRiver.However,specificpollutantsuchasarsenic,iron,manganeseandammoniumofgroundwateralongtheshoreofYellowRiverexceednationalstandardsquitecommon.Forinstance,arsenicconcentrationofgroundwaterin“95Tan”achieves0.06mg/L,andironandmanganeseconcentrationismuchhigheraswell.Thereare26groundwaterwellsintheeasternwatersourceareaofZcity,amongwhich19wellsareshallowwellsand7wellsaremiddle-deepwells.Thetopologyrelationofwellsandwatertransportnetworkscanbefoundin Figure3.Inthispaper,16wellsareselectedfordispatchingoptimization.

4.2PlantInfluent-SourceWaterCouplingModelValidation

20samplescorrespondingtodifferentoperationstatuswasselectedtovalidatethecouplingmodelofplantinfluent-sourcewaterspecificpollutants.Thedataofoutletflowofwells,fittedarsenicconcentrationofwells,andplantinfluentflowareinputtothemodelafterFouriertransform.Predictedarsenicconcentrationofplantinfluentwastheoutputofthemodel.Predictedvaluesandmeasuredinfluentarsenicvaluesarecomparedtovalidatethemodel.

Table1.PredictionAccuracyValidationResultsof10RunningConditions

	Operation status	Influent flow(m^3/h)	Predicted As (μg/l)	Measured As (μg/l)	Relative error (%)
1	0010110111110011	2591	19.36	20.01	3.36
2	0011100111011111	2722	19.14	19.48	1.78
3	0011111111110110	2887	20.76	20.39	1.78
4	0100011111111001	2578	20.55	20.14	2.00
5	0111101101111111	3076	19.83	20.33	2.52
6	0111101111111111	3301	19.77	20.25	2.43
7	1111110011111011	2437	19.39	18.72	3.46
8	1001101111011100	2625	20.32	19.93	1.92
9	1001111111111011	3112	21.28	20.68	2.82
10	1011101100111011	2790	19.83	19.55	1.41

PartialresultsareshowninTable1,themaximumrelativeerroramong20typesofoperationstatusisequalto3.46%,whiletheaveragepredictionaccuracyachieved97.75%,whichishighenoughtoprovidedatatosupportwatertransportallocatestrategybasedonspecificpollutantscontrol.

4.3OptimalDispatchingandEconomicTechnicalAnalysis

Adaptiveintelligentcombinedalgorithmwasappliedtopredictedtherequiredwaterflowbasedonon-linedataon14thJuly2017.PartialresultsareshowninTable2.

July-August 2020
ISSN: 0193-4120 Page No. 3672 - 3680

Table2.HourlyWaterUsagePredictionoftheSelectedAreaon14thJuly2017

Time	0	1	2	3	4	5	6	7
Predictedflow(m^3/h)	3145	3059	2982	2966	2955	2930	2918	2908
Measuredflow(m^3/h)	3025	2994	3001	2950	2955	2862	2901	2884
Time	8	9	10	11	12	13	14	15
Predictedflow(m^3/h)	2889	2888	2824	2805	2799	2773	2639	2588
Measuredflow(m^3/h)	2929	2862	2889	2915	2888	2794	2780	2612

SourcewatertransportfromcertaingroupsofwellsisperformedaccordingtothewatertransportoptimizationmodelmentionedinSection “ConstructionofWaterTransportOptimizationModel ” ,basedonthepredictedwaterflow.ThentheproblemissolvedbyHMOEA,inwhichthepopulationpartperiodis200,thecrossoverprobabilityis0.85,andtheprobabilityofvariationis0.02.Thecrossoverprobabilityisofoff-linewatertransportresultsaswellasthecorrespondingevaluatingvariablesareshowninTable3.Generally,theaverageenergyconsumptionof24hoursofthisoptimizationstrategyis344.74kw,meanwhileaveragearsenicconcentrationoftheplantinfluentis16.91μg/l.

Table3.SimulatedWaterTransportOptimizationResultsoftheSelectedAreaon14thJuly2017

Time	Optimized operation	As (μg/l)	Energy consumption (kw)
0	1100101110111111	16.73	378.83
4	1100101110111111	15.86	380.69
8	1100101110111111	17.74	380.15
12	1100101110111011	17.79	353.64
16	1100101110111011	16.82	349.23
20	1100101110111011	16.09	322.81
23	1100101110111111	15.08	349.38

Totesttheeffectivenessoftheproposedstrategy,aperiodofdata(January-July,2017)wasemployedtoperformtechnologyandeconomicanalysis.14thJuly2017,partialresultsoftherealwatertransportstrategybasedonmanualexperienceisalsomeasuredasisshowninTable4.Theaverageenergyconsumptionofthisstrategyis372.85kw,whilearsenicconcentrationoftheplantinfluentis18.27μg/l.

Table4.MeasuredWaterTransportResultsbasedonExperienceoftheSelectedAreaon14thJuly2017

Time	Optimizedoperation	As (μg/l)	Energyconsumption (kw)
0	1100011110111111	18.17	401.29
4	1100011110111111	18.38	403.56
8	1100011110111101	17.60	385.93
12	1100011110111101	17.8	386.30

July-August 2020
ISSN: 0193-4120 Page No. 3672 - 3680

		1	
16	1100011110111101	17.47	381.35
20	1100011110111111	18.33	390.92
23	1100011110111111	18.08	394.74

Table3andTable4showsthatoptimizedwatertransportstrategycouldreduceenergyconsumptionandarsenicconcentrationoftheplantinfluentsignificantlyon14thJuly2017.

TechnologyandeconomicanalysiswasperformedtocomparetheoptimizedwatertransportstrategyandempiricalstrategybasedthedataduringJanuarytoJuly2017.Asaresult,iftheoptimizationstrategyproposedaboveisadopted,energyconsumptioncouldbereducedby850~1000kwpermonth,whiletheaveragearsenicconcentrationoftheplantinfluentcouldbereducedby1.5~2.3μg/l.What's more,theoptimizationstrategycouldcontrolthearsenic concentrationalwaysbelow20μg/l,whichprovideguaranteeofwatersafety.

5.Conclusions

(1)Intheprocessofsourcewateroptimaldispatching,Fouriertransformandartificialneuralnetwork(ANN)areusedtoexplaintherelationbetweenspecificpollutantsconcentrationofgroundwaterandoutletflow.Plantinfluent-Sourcewatercouplingmodelofspecificpollutantsisbuiltwhichbringswatersafetyintoconsiderationforwatertransform.FouriertransformisemployedtoprovidefrequencydomaininputtoANNmodel,whichavoidsnegativeinfluencefromdisturbanceandimprovesthepredictionaccuracy.

(2)Withthetargetofminimizingspecificpollutantsofinfluent,aswellassatisfyingwaterquantityrequirementandreducingenergyconsumption,thewaterdispatchingoptimizationmodelisbuilt,inwhichtheoperationcombination(decidewhichwellsaresuitabletoprovidewateratcertaintime),flow,andpumpingtimelengtharetakenasdecisionvariables.Themodelconsidersthewaterquality,securityandeconomyofwatersupplycomprehensively,andrealizesthewaterquality-waterquantityjointdispatchingoptimizationtechnology.

(3)TheproposedmodelisappliedtooptimizewatertransportinthecityofZ.Thepredictionaccuracyofthespecificpollutantscouplingmodelachieves97.75%,whichprovideaccuratedatasupportforwatertransportoptimization.Comparedwithmanualexperiencestrategy,theproposedoptimizationsolutioncouldreducespecificpollutantsconcentrationoftheplantinfluentsignificantlyaswellasreducingtheenergyconsumption,andthenguaranteedthesafetyandeconomyofwatertransportsystem.

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References

1. Athanasia-Tatiana,SandPeter,R.(2018)'ParetoOptimizationofWaterResourcesUsingtheNexusApproach',WaterResourcesManagement,Vol.15, pp.505-5065.
2. Berglund,E.Z.(2015)'UsingAgent-BasedModelingforWaterResourcesPlanningandManagement',JournalofWaterResourcesPlanningandManagement,Vol.11,pp.1-17.
3. Chen,NandLi,Y.(2006)'Optimaldeploymentof waterresourcesbasedonMulti-ObjectiveGenetic Algorithm',JournalofHydraulicEngineering,Vol.3,pp.308-313.
4. Conglin,ZandYu,L.(2015)'AnempiricalstudyonthespatialdistributionofthepopulationeconomyandwaterresourcesinNortheastChina',PhysicsandChemistryoftheEarth,Vol.78-82,pp.93-99.
5. DanielWandRohman,F.(2014)'WaterResources Sustainability:DevelopmentofaMultiobjectiveOptimizationModel',JournalofWaterResourcesPlanningandManagement,Vol.140,pp.1-9.
6. Fikret,K.(1999)'ReviewofGroundwaterPollutionandProtectioninKarstAreas',WaterAirandSoil Pollution,Vol.113,pp.337-356.

7. Frederico,KandLuisa,F.(2012)‘HybridWaterDemandForecastingModelAssociatingArtificialNeuralNetworkwithFourierSeries’,JournalofWaterResourcesPlanningandManagement,Vol.3,pp.245-256.
8. Istvan,SandJozsef,G.(2012)‘Optimal(short-term)pumpscheduledetectionforwaterdistributionsystemsbyneutralevolutionarysearch’,AppliedSoftComputing,Vol.8,pp.233-2351.
9. Jawad,AandJafar,Y.(2017)‘Reservoiroperationusingarobustevolutionaryoptimizationalgorithm’,JournalofEnvironmentalManagement,Vol.197,pp.275-286.
10. Khalil,BandSt-Hilaire,A.(2011)‘EstimationofWaterQualityCharacteristicsatUngaugedSitesusingArtificialNeuralNetworksandCanonicalCorrelationAnalysis’,JournalofHydrology,Vol.3-4,pp.277-287.
11. Li,XandWei,J.(2014)‘Aparalleldynamicprogrammingalgorithmformulti-reservoirsystemoptimization’,AdvancesinWaterResources,Vol.67,pp.1-15.
12. Liu,BandChen,X.(2009)‘Waterresourcesdeploymentmodelforriverbasinbasedonsynergetictheory’,JournalofHydraulicEngineering,Vol.40,pp.60-66.
13. Markos,P.(1985)‘OptimalMultireservoirNetworkControlbytheDiscreteMaximumPrinciple’,WaterResourcesResearch,Vol.21,pp.1824-1830.
14. McClymont,KandKeedwell,E.(2015)‘Ananalysisoftheinterfacebetweenevolutionaryalgorithmoperatorsandproblemfeaturesforwaterresourcesproblems,Acasestudyinwaterdistributionnetworkdesign’,EnvironmentalModellingandSoftware,Vol.69,pp.414-424.
15. Moravej,MandHossseini-Moghari,S.(2016)‘LargeScaleReservoirsSystemOperationOptimizatio n:theInteriorSearchAlgorithm(ISA)Approach’, WaterResourcesManagement,Vol.10,pp.3389-3407.
16. Shahbaz,KandDharma,D.(2010)‘AnAdaptiveLearningFrameworkforForecastingSeasonalWaterAllocationsinIrrigatedCatchments’,NaturalResourceModeling,Vol.3,pp.324-353.
17. Song,GandShen,B.(2012)‘Anecology-basedwaterquantityandqualitycombinedoperationmodelforurbanrivers’,JournalofHohaiUniversity(NaturalSciences),Vol.40,pp.258-263.
18. Sun,XandLuo,J.(2018)‘Multi-ObjectiveOptimizationforReservoirOperationConsideringWaterDiversionandPowerGenerationObjectives’,Water,Vol.10,pp.1-15.
19. Sung,EandWon,S.(2014)‘ArtificialNeuralNetworkensemblemodelingwithconjunctivedataclusteringforwaterqualitypredictioninrivers’,JournalofHydro-environmentResearch,Vol.3,pp.325-339.
20. Suo,MandWu,P.(2017)‘AnIntegratedMethodforIntervalMult-ObjectivePlanningofaWaterResourceSystemintheEasternPartofHandan’,WaterResources,Vol.7,pp.1-17.
21. Tu,MandHsu,H.S.(2008)‘OptimizationofHedgingRulesforReservoirOperations’,JournalofWaterResourcesPlanningandManagement,Vol.1,pp.3-13.
22. Windsor,J.(1973)‘OptimizationModelforReservoirFloodControl’,ResourcesRes,Vol.9,pp.1219-1226.
23. Yu,BandLiang,G.(2015)‘Modelingofjointoperationforurbanwater-supplysystemwithmulti-watersourcesanditsapplication’,AdvancesinWaterScience,Vol.26,pp.874-884.
24. Zhang,YandTian,F.(2014)‘JointoperationmodelofmultiplewatersourcesinBeijing’,JournalofHydraulicEngineering,Vol.45,pp.844-849.
25. Zhu,JandWang,S.(2011)‘ModelingandSimulationofWaterAllocationSystemBasedonSimulatedAnnealingHybridGeneticAlgorithm’inICICIS2011:InternationalConferenceonIntelligentComputingandInformationScience,Zhengzhou,CHINA,pp.104-109.