2010.4.3 星期六

首 页 | 单位简介 | 新闻资讯 | 出国签证 | 出入境指南 | 审批事项
表格下载 | 政策法规 | 河北概况 | 各国概况 | 友好城市 | 学习园地

您的位置：首页 » 查询结果

优化加氯方式、保证管网水质

◆ 童祯恭鲁秀国
TONG Zhengong， LU Xiuguo

童祯恭，鲁秀国,华东交通大学土建学院

优化加氯方式、保证管网水质
Optimal Disinfection to Maintain Safe Water Quality in Water Distribution System

摘要：毒剂（液氯）传统的投加方式都是在净水出厂时投加，这样导致水厂附近管网水的余氯浓度较高，引起用户味觉及嗅觉的不适。同时在整个管网中，余氯浓度随时空的变化而波动较大。现提出管网中途加氯的方法以优化传统加氯方式，降低总加氯量，减少消毒副产物浓度；并对该技术的关键步骤——加氯选址及确定投加量提出数学模型，给出相应算法并以程序实现。最后以一算例从管网水质的安全性及经济性二方面对一次加氯和二次加氯技术作了全面的分析比较。
关键词：途加氯;覆盖水量矩阵;水质安全

Abstract Conventional practice adds disinfectant only at the treatment plant, which may cause taste and odor complaints by consumers who are close to the source and consequently receive higher disinfectant concentrations. Also, it leads to disinfection residual spatiotemporal concentration fluctuations all over the network. The best way to achieve minimum chlorine residual at all levels of branching in a network is to carry out booster chlorination. This will also assure more uniform spatiotemporal disinfectant residual, lowering the required total disinfection mass and less risk of DBP formation throughout the distribution system. This text proposes an algorithm to optimize the location of booster station and identify their dosage injection rates and makes program to reality it. At last, it gives us an example to make difference from the safety of the pipeline's water quality and the economy between the conventional chlorination and the booster chlorination.
Key Words booster chlorination; demand coverage matrix; water quality safety

1Introduction

With the further research of toxicological indicators and improvement of detection level, there are more than 2000 organics having been detected, some of which are carcinogen and dubious carcinogen. At present, the developed countries adopt many measures to decrease the subsidiary products of chlorination such as controlling chlorine usage, choose a better injection point or search substitutes.

The traditional chlorination is at the effluent of the water plant that will cause a high chlorine concentration in the network near the water plant and unfavorable taste and odor. Furthermore the chlorine residue concentration of every node fluctuates rapidly in the whole network. If area of the municipal water supply network is large and the water age is long, the chlorine residual concentrations of some network areas will not be enough. This problem can not be solved by adding more chlorine to the effluent for larger dosage will increase disinfection byproducts such as halogenated hydrocarbon. Furthermore, the chlorine addition to the effluent may cause long retention time of chlorine in the network that will increase DBP concentration. As a result it needs to find a better chlorine addition method and one effective method is booster chlorination.

2The meaning of booster chlorination

Booster chlorination is also named intermediate chlorination that is to add more chlorine at a certain node in the network such as the booster station or water storage tank station. When the delivery pipe is long, this method can not only ensure the disinfection effect, but also minimize the DBP value. There are mainly two reasons for decreasing the chlorine dosage. One is small dosage will cause small average concentration of chlorine in the network. The other is booster chlorination can give full use of the retention time and velocity of the water in the network that when the dosage falls the contact time will decrease and DBP formation will be reduced.

3The development at home and abroad

The research of secondly chlorination in networks started in the end of 90th in last century in developed countries. The research key is how to optimize the chlorine addition point and determine the dosage. The optimization is to make booster chlorination station as few as possible in a certain hydraulic cycle and minimize the total dosage based on a demand of water quality with a restraint condition that is making chlorine residue of monitoring node in a certain range. The research did not started early in developed countries, but developed rapidly. According to the recent investigation on 4 000 water companies, there are 15% water companies adopting booster chlorination method［1］.

At present, our country has begun to enter this field. Although some water companies adopt this chlorination method, the determination of the addition point and dosage is mostly based on experience.

4Optimization of chlorination locations in network

At the beginning of 90 th in 20th century, Professor Byoung H.Lee［2］ had proposed an idea of using a maximum water quantity node coverage method to optimize the selection of monitoring point. The method of this idea is to find out a downstream node which can reflect water quality of upstream node in the network in a certain condition while the sum of the upstream node water quantity is maximal. In a large degree, the optimization of booster station locations is same to that of water quality monitoring point. The difference between them is: the latter one is to find out a downstream node which can reflect the upstream node with maximum water quantity; the former one is to find out an upstream node which can reflect the downstream node with maximum water quantity［3］.

According to this idea and combining with the theory using water quantity node coverage to optimize water quality monitoring point, the mathematical model for the booster chlorination point can be deduced［4］, which supposes the decay of chlorine residue in water is first stage reaction. It is shown as follows:

Objective function：mix
∑mk=1（∑ni=1dkiyki(1)
Constraints：∑ni=1xi≤NS(2)
∑ni=1［R1(CC)i,j］xi-y1i≥0(3)
zi=∑nj=1d1(j,i)exp(-k′T1(j,i))z1j
∑nj=1d1(j,i)
+TC1i+xiTRChl(4)
Cmin≤z1i≤Cmax(5)
……………………
……………………

∑ni=1［Rm（CC）i，j］xi-ymi?0(6)
zi=∑nj=1dm(j,i)exp(-k′Tm(j,i))zmj
∑nj=1dm(j,i)
+TCmi+xiTRChl(7)
Cmin≤zmi≤Cmax(8)

i,j = 1,2, ……….,n
NS—maximum number of chlorine injection point；
di— flow of nodei；
n— number of node ；
R(CC)—demand coverage matrix；
k —number of various hydraulic conditions(1,……m)；

k'—decay coefficient of chlorine residual；

zi —chlorine residual concentration of nodei；

xi, yi—0-1 variations, xi =1 represents node i that is booster station location; yi =1 represents node i that is coverage point；

TRChl—booster chlorination concentration ；

Cmin ,Cmax—allowed upper and lower chlorine concentration bounds respectively

In this model, the key is to solve demand coverage matrix R(CC). It needs to notice there should be two indicators: one is water demand coverage criterion which is named Water Cri; the other is water age of two nodes that is named Time Cri. For example, when water quantity of the upstream node j excesses the Water Cri, the water will flow to node i and then the water age between the two nodes should larger than a certain standard value(T). Only when the two indicators are both satisfied, water quality of node j can reflect water quality condition of node i.

5Booster chlorination to optimize dosage

When the injection point of booster chlorination is determined, it then needs to optimize the chlorine usage.

The objectives of dynamically optimization of chlorine usage are shown as follows［5］:

(1)remain the chlorine residual of monitoring nodes in a certain range;

(2)minimize the total chlorine dosage.

When the locations of the booster stations are determined, nb is used to represent the number of the stations. Minimization of total chlorine dosage rate is realized by time continuation method. This objective function is considered as a method to minimize the quantity of DBP and chemical cost. For the decreasing quantity of DBP can not be quantized here, the kinetic factors affecting the formation of DBP can not be understood comprehensively. nm represents the number of monitoring point. The intermediate disinfectant mass injected can be expressed with time discrete optimization model.

Objective function： (minimize the chlorine injected mass in a certain period)

minulimK→∞

1K+1∑Kk=0

∑nbi=1uki•Δt（9）

Constraint：

Cmin≤Cmj(u)≤Cmax;j=1,…，nm；m=M，…，∞(10）

Cmj（u）=∑nbi=1

∑k≥0αkmij•uki(11)

Where:

uki（M/T）—subject to

kΔt≤t＜（k+1）Δt， the injected mass in injection point i；

u—vector expression for injected mass uki；

Δt(T)—injection time interval；

nb— number of chlorine injection station；

nm—number of monitoring point；

Cmj(u)—the chlorine concentration of monitoring point j at mΔtm（M/L3）；

Δmt—time interval for monitoring；

K—integer；

Cmax, Cmin—allowed upper and lower chlorine concentration bounds respectively；

akmij—coefficient of discrete kinetic response function；

Here, the key is how to obtain discrete coefficient aijkm. This coefficient can be calculated by the following formulation:

αkmij=?cmj/?uki［(M/L3)/(M/L)］（12）

This coefficient is used to reflect the impact on monitoring point j when the disinfectant mass of injection point i is uki at time mΔtm. When there are many injection points, the impact on point j can be obtained by linear superposition.

6Application example

6.1Network topological graph is illustrated as follow: Node 1 is water source.

Considering comprehensively, select NS=1 as a chlorine injection point except for water source point. Here, water Cri is 60% and time Cri 5. Then the chlorine residual decay can be expressed by the following generalized model:

dCdt=-(kbC+k3Cn)-kcC=-kC-k3Cn（13）

The result of the formulation through programming is maximal water demand coverage is at node 7 and then this node can be

The result of the formulation through programming is maximal water demand coverage is at node 7 and then this node can be selected as a booster chlorine injection point. The upper and lower bounds imposed on concentrations are respectively Cmax =4.0 mg/L and Cmin =0.2 mg/L. When there is one chlorine injection point calculated by the programming, in order to guarantee lower concentration bound Cmin ≥0.2 mg/L of each node in network, the chlorine injection mass of node 1 can be calculated as 1.0 mg/L. When there are two injection points, the chlorine injection mass of node 1 can be calculated as 0.3 mg/L and that of node 70.6 mg/L using the same method.

6.2Comparison between booster chlorination and traditional chlorination

Figure 2illustrates changes of chlorine residual concentration of each node in the network by one chlorine source or two sources.

Note：chlo1 represents the condition in one chlorine source and Aver1 is the average chlorine residual concentration in the network; chlo2 represents the condition in two chlorine source and Aver2 is the average chlorine residual concentration in the network.

6.2.1Analysis of water quality security

The above figure shows when there is only one chlorine source (chlorine injected at the water source), in order to maintain a concentration constraints Cmin≥0.2 mg/L for each node after in a stable network, the chlorine mass in node 1 must be 1.0 mg/L. When setting a booster station in the network that means to simultaneously inject chlorine at node1 and node 7, with the same concentration constraints, the chlorine mass in node 1 is calculated as 1.0 mg/L, that of node 7 is 0.6 mg/L and total chlorine mass is 0.9 mg/L which is lower than that in one chlorine source. Furthermore, in one chorine injection network maximal chlorine residual concentration of node is 1.0 mg/L, minimal concentration 0.2 mg/L and an average concentration 0.73 mg/L. This will cause large spatiotemporal concentration fluctuations. However, the fluctuations are lower in two chlorine sources with maximal chlorine residual concentration 0.6 mg/L, minimal concentration 0.2 mg/L and an average concentration 0.44 mg/L.

For chlorine residual concentration of each node is small with a booster chlorine station in network, the DBP is relatively low. Furthermore, this model will has balanced chlorine residual concentrations in the whole network. Those will contribute to water quality security largely.

From practical perspective, booster chlorine injection can effectively control regrowth of bacteria and reduce the formation of DBP. Furthermore, the complaints from residents about water taste and odor will decrease.

6.2.2Economical analysis

From the perspective of chlorine mass, booster chlorination can reduce 0.1 mg/L chlorine mass. If average water supply amount is 3 800 m3/d, this method can save 0.38 kg/d that is 10% of traditional chlorination. As a result, booster chlorination can get many economical benefits.

7Conclusion

Booster chlorination can reduce chlorine mass and chlorine residuals and simultaneously decrease spatiotemporal concentration fluctuations of chlorine residual concentrations. Optimization of chlorination can not only reduce harmful substances such as halogenated hydrocarbon in water, improve water quality and decrease chlorine consumption, but also scientifically control chlorination process which will bring many social and economical benefits.

Generally, by increasing the number of booster stations built in the network, total chlorine mass will be less and chlorine residual concentration of the whole network will be more homogeneous. As a result, the formation of DBP will be reduced and water quality security improved. However, booster chlorination is system engineering and needs to comprehensively consider social and economical factors. The locations for chlorination not only depend on shape, arrangement and flow of distribution network and water quality variation, but also depend on construction conditions, safety and O&M. As a result, water companies should make further research on applying this technology according to their own situations.

Reference：

［1］Dominic L.Boccelli, Michael E.Tryby, James G.Uber, et al. Optimal scheduling of booster disinfection in water distribution systems［J］.Water Resour Plng and Mgmt., 1998,124(2): 99111.

［2］Byoung H.Lee, Rolf A.Deininger, Robert M.Clark. Locating monitoring stations in water distribution systems［J］. AWWA, 1991,83(7):6066.

［3］Byoung H.Lee, Rolf A.Deininger. Optimal locations of monitoring stations in water distribution system.

J.Envir.Engrg [J] . 1992, 118(1):416.

[4] Arun Kumar, M.L.Kansal, Geeta Arora. Identification of monitoring stations in water distribution system. J.Envir.Engrg [J] . 1997, 123(8):746752.

[5] Harmant, A.Nace, L.Kiene. An algorithm to optimize booster chlorination in water distribution network.. ProceedingWater distribution systems analysis, Water Resources 2000.

【关闭窗口】 【回到首页】 【打 印】