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Research on the Method of Human Health Risk Assessment for Reclaimed Water

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Abstract

In order to reveal the influence of harmful substances in reclaimed water quality on human health, this paper carries out the research from the perspective of risk assessment. Firstly, according to reclaimed water reuse applications and water quality requirements, the characteristics of its safety evaluation were analyzed and summarized. Then deducing risk scenario and analyzing the consequences to determine the risk transfer path of reclaimed water reuse, and the framework of water safety evaluation index system was put forward based on the result. Finally, by combining the traditional risk assessment theory and the USEPA's four-step method with the characteristics of human health risk for reclaimed water, the procedure and model of human health risk assessment for reclaimed water were established.

Keywords: reclaimed water, risk assessment, risk transfer path, human health

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INTRODUCTION

Reclaimed water has certain using function which is urban sewage after proper regeneration treatment technology, but it may also contains some hazardous and noxious substances (Qiu and Wang 2003). With the increasing mature of regeneration treatment technology, reclaimed water has been widely used and it has become important supplement of water resources. Reclaimed water reuse has some characteristics such as low pollutant content, wide range, higher contact probability with human, long duration and so on. And its reuse directions can be simply attributed to the following aspects: agricultural irrigation, industrial water, municipal construction, recreational water, the maintenance of lake and scenery water, groundwater recharge and acted as comprehensive water resources indirectly (Chen et al. 2003).

When the city reclaimed water was used for flushing, washing the car, greening of living areas, irrigation, scenery water and other locations that have larger human exposure and frequent contact, hazardous and noxious chemicals, bacteria, virus and other pathogenic microorganisms in water can cause harm to human health (Yin et al. 2008). On the other hand, it may accumulate in the soil and be absorbed and transferred by crops, and ultimately affect human health through the food chain (Duan 2012, Wang et al. 2007, Wu et al. 2013). Li An studied the distribution characteristics of antibiotic residues in reclaimed water: Ma X.F., Wang Z.J., Liu X.Y. et al. studied on biological toxicity monitoring of reclaimed water (Li 2015, Liu 2013, Ma and Li 2016, Wang 2014).

Therefore, it's urgently necessary to use safety assessment technology to assess potential hazards to public health, so as to ensure that the process of reclaimed water reuse will not harm human health. The human health risk assessment for reclaimed water did not only describe the harm caused by pollutants, but quantify the severity of pollutants and directly express their harm to human by risk degree. To evaluate the risk of reclaimed water can also guide the management, decision-making and ensure the smooth implementation of reusing.

ANALYSIS AND SUMMARY OF ASSESSMENT CHARACTERISTICS

All kinds of reclaimed water quality standards are the basic foundation for selecting treatment technology. At present, in order to control water pollution and ensure the safe use of reclaimed water, all countries and the related world organizations develop corresponding water quality standards according to the different reuse ways of reclaimed water. Due to the complexity and

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Table 1. Domestic reclaimed water quality standards

GB Standard	Standard Name	The Quantitative of Water Quality Indicators
GB/T 18919-2002	The Classification of urban Sewage Reclamation	sewage reclamation and reuse is divided into 5 uses
GB50335-2002	Standard of Sewage Reclamation and Reuse Engineering Design	
GB/T 18920-2002	The reuse of urban recycling water--Water quality standard for urban miscellaneous water consumption	13 control indicators
GB/T 18921-2002	The reuse of urban recycling water--Water quality standard for scenic environment use	14 basic control indicators,50 selected control programs
GB/T 19923-2005	The reuse of urban recycling water-Water quality standard for industrial uses	20 basic control indicators
GB/T 19772-2005	The reuse of urban recycling water-Water quality standard for groundwater recharge	21 basic control programs,52 selected control programs
GB 20922-2007	The reuse of urban recycling water - Quality of farmland irrigation water	19 basic control programs17 selected control programs

Table 2. Reclaimed water reuse applications and the possible hazards to human health

Reclaimed Water Reuse Applications	The Possible Hazards to Human Health
Agricultural water (irrigating food and non-food crops)	soil hardening after irrigating, polluting groundwater, the accumulation of toxins in crops
Industrial water (circulating water, cooling water, boiler make-up water)	pathogenic microorganisms harm human through winding and splashing, scaling, corrosion and plugging of equipment and pipe, the growth of microorganisms
urban miscellaneous water (greening, car wash, flushing)	Pathogenic bacteria harms human health by direct contact or aerosol transmission in the process of reclaimed water reuse
scenic environmental water (park, wetland, pond)	Bacteria and viruses harm eyes, nose, throat and other contact parts, eutrophication and algae bloom, be harmful to aquatic organisms
Supplemental water (groundwater recharge, the supplement of drinking and non-drinking water)	It can probably pollute underground aquifer as a source of drinking water, refractory organics and heavy metals affect underground water

variability of the situations that including reuse objects, types, use scene and final receiving waters, there are differences in water quality standards in different application areas. Until now domestic relevant departments have issued seven reclaimed water quality standards (Writing by 'Guidelines for urban reclaimed water series standard' Writing Group 2008), as shown in **Table 1**.

Due to the specialty of the reclaimed water, there are big differences between the human health risk assessment for reclaimed water and the traditional assessment method. Reclaimed water contains a lot of hazardous and noxious pollutants, so there are different hazards to human health according to how the reclaimed water may be used. Reclaimed water reuse applications and the possible hazards to human health are shown in **Table 2**.

According to the characteristic of reclaimed water, combining the basic theories with the method of traditional safety assessments, we find that the human health risk assessment for reclaimed water has following characteristics:

1) various reuse applications, complex use scene;
2) The water quality indicators are not unified, historical data are difficult to collect;
3) Treatment technology varies greatly, and the extent is difficult to control;
4) Many risk factors, the relationship is difficult to determine;
5) It's hard to unify the assessment standards and hard to define and describe the risk level.

THE CONSTRUCTION OF RISK TRANSFER PATH AND INDEX SYSTEM OF RECLAIMED WATER REUSE

The Construction of Risk Transfer Path

The human health risk caused by reclaimed water reuse has diversity. Hazardous and noxious substances can be reused through carrier in reclaimed water and cause hazards to human health. Human health risk assessment for reclaimed water in this paper refers to predictive risk assessment, and the risk transfer path is: hazardous and noxious pollutants in reclaimed water→the hazards of reclaimed water→reuse of reclaimed water→human body contact reclaimed water→carcinogenic and pathological hazards to human, the form from determinate reclaimed water hazards to human contact reclaimed water through different ways, and eventually it brings consequences of human health hazards. The risk transmission, from reclaimed water own hazards to human health, is accordant with the danger evolution in traditional safety assessment.

In this paper, traditional safety assessment method, is adopted to build risk transfer path of reclaimed water reuse. Firstly, taking the reason which brings about human health risk as top event, and constructing the path according to the transferring relationship of risk, then deducing risk scenario and analyzing the consequences which harms human health, finally, analyzing the possibility and severity of hazards by quantitative or semi-quantitative methods (Luo et al. 2005). The risk transfer path of reclaimed water reuse is shown in **Fig. 1**.

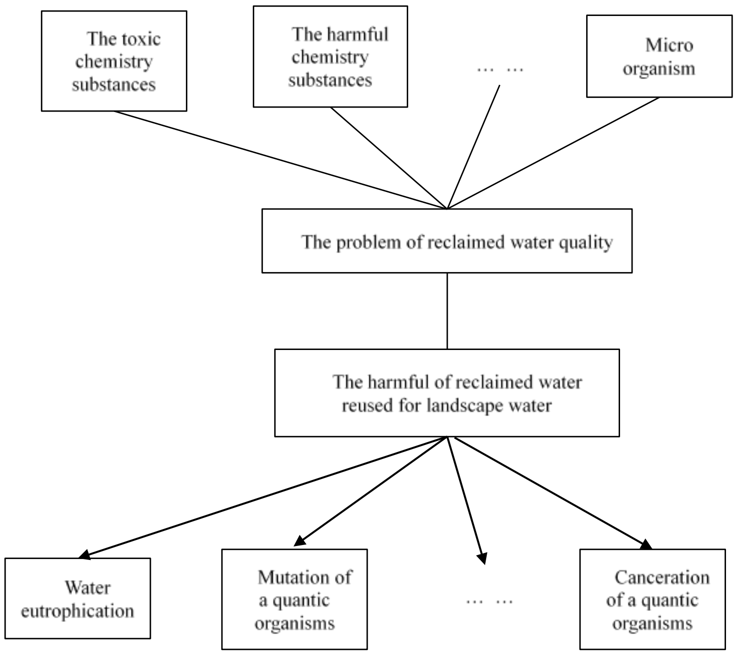

Fig. 1. The risk flow route of reclaimed water reuse

The Construction of Index System

The foundation for the selection of reclaimed water safety assessment index

According to the risk flow route of reclaimed water, analyzing existed pollutants and all kind of hazards to human health caused by them, and selecting pollutants which causing larger hazard to human health(such as pathogens, carcinogen, international banned substances and so on),then determining the pollutants that penetrated through skin or inhaled through air as primary noxious substances of reclaimed water, and putting forward some key indicators which can fully reflect the human health risk assessment of reclaimed water.

The important link of reclaimed water safety assessment for human health lies in selecting appropriate representative motoring index. We choose indexes based on a number of factors: 1) reclaimed water reuse applications, such as urban miscellaneous water consumption or farmland irrigation water, the selection of indexes vary with reuse applications; 2) the known pollutants existing in water environment which could be harmful to human and the primary pollutant indexes which were determined in reclaimed water both at home and overseas; 3) the source of sewerage for determined water and the treatment technology of reclaimed water, pollutants contained in reclaimed water vary with the source of sewerage and treatment technology; 4) the historical materials of primary pollutants contained in sewerage, e.g. the certain high concentration of Volatile Organic Compound must be selected as evaluation indicator; 5) laboratory facilities of research institute, hardware technology and other objective conditions. In general, while evaluating the risk of reclaimed water for human health, high concentration and extremely venomous parameters, harmful to environment, living creature and human beings, should be selected as evaluation indicator.

Human health risk assessment index for reclaimed water

The selected evaluation indicators for reclaimed water risk are mostly classified according to reclaimed water reuse applications. This paper classifies the index of human health risk by combining the above approach with the effect of reclaimed water reuse acts on human health, which is mainly divided as three types: conventional pollutants, carcinogenic chemicals and non-carcinogenic chemicals, pathogenic microorganisms. Such classification can facilitate definition of substances in reclaimed water which not only harmful to human beings but also have strong carcinogenicity, we should focus on this substances in the process of risk assessment. The index affecting human health in reclaimed water is shown in **Table 3**.

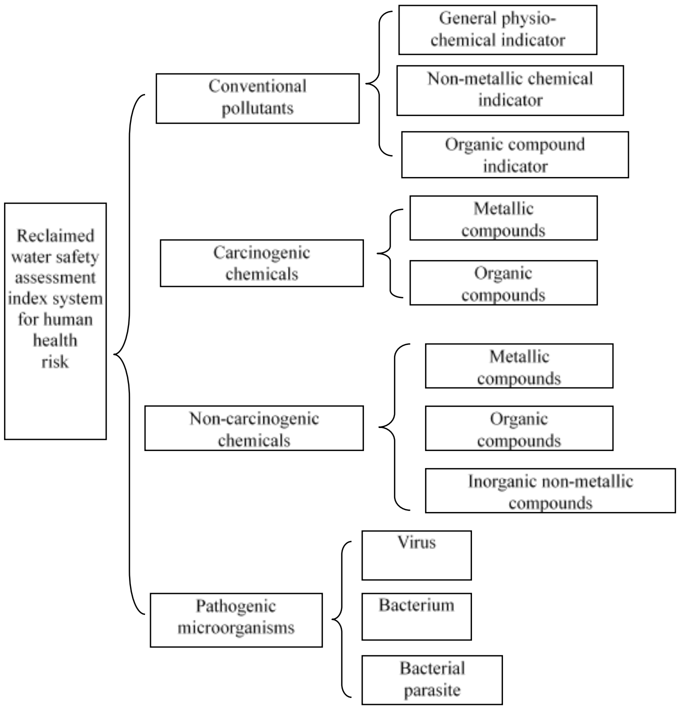

Fig. 2. Reclaimed water safety assessment index system for human health risk

Table 3. The index affecting human health in reclaimed water

The classification of index		The specific index
Conventional index	general indicator	pH,fume,turbidity,chromaticity, electric conductivity,total hardness, total dissolved solid,anionic surfactant
	non-metallic compounds	residual chlorine, ammonia nitrogen, alkalinity,total phosphorus,total nitrogen
	Organic compounds	BOD_5、 COD、 TOC、UV_{254}
chemicals	Carcinogenic chemicals	heavy metal(As,Cr,Cd,Pb,Ni.etc), micro organics(chloroform, carbon tetrachloride, trichloroethylene.etc)
	Non-carcinogenic chemicals	heavy metal(As,Cr,Cd,Cu,Pb,Ni,Zn,Hg.etc), Inorganic non-metallic Compounds(fluoride,nitrite.etc), micro organics(phenol,ethyl benzene,aromatic compounds.etc)
Pathogenic microorganisms	Bacterium	Escherichia Coli, dysenteriae,parasitic ovum, Salmonellae,Cryptosporidium
	Virus	HAV,coxsackievirus,echoviruses

Human health risk assessment index system for reclaimed water

Based on the principles of independence, availability, comparability and direction for indicators, screening a series of indicators as the index set of human health risk assessment, and constructing 3 levels of reclaimed water safety assessment index system for human health risk: the first level is target layer, human health risk assessment; the second level is element layer, including general index, carcinogenic chemicals index, non-carcinogenic chemicals index, pathogenic microorganisms index; the third level is index layer, which is basic assessment index, and it depicts element layer in detail. The human health risk assessment index system for reclaimed water is shown in **Fig. 2**.

THE METHOD OF HUMAN HEALTH RISK ASSESSMENT FOR RECLAIMED WATER

The Selection of Assessment Method

Risk refers to "the possibility of suffering damage and loss" (Aaron et al. 1986). Currently, it is generally acknowledged that the mathematical formulas used for risk assessment can be expressed as: $R=S\times P$ (Bai 2009), R represents the risk of certain effect or hazard, S represents the severity of effect or hazard, P represents the probability of effect or hazard, respectively.

Health Risk Assessment takes the degree of risk as assessment index, it connects environmental pollution with human health to depict the risk that pollution harms health by quantitative method (Han et al. 2006). At present, the most common method is the four-step mode of Environment Health Risk Assessment which proposed by America's National Academy of Sciences and the National Research Council in 1983, namely, Hazard Identification, Exposure Assessment, Dose-Response Analysis and Risk Characterization. The four-step mode has been widely applied to the health risk assessment of carcinogens, at the same time, the health risk assessment of non-carcinogens also follow these steps.

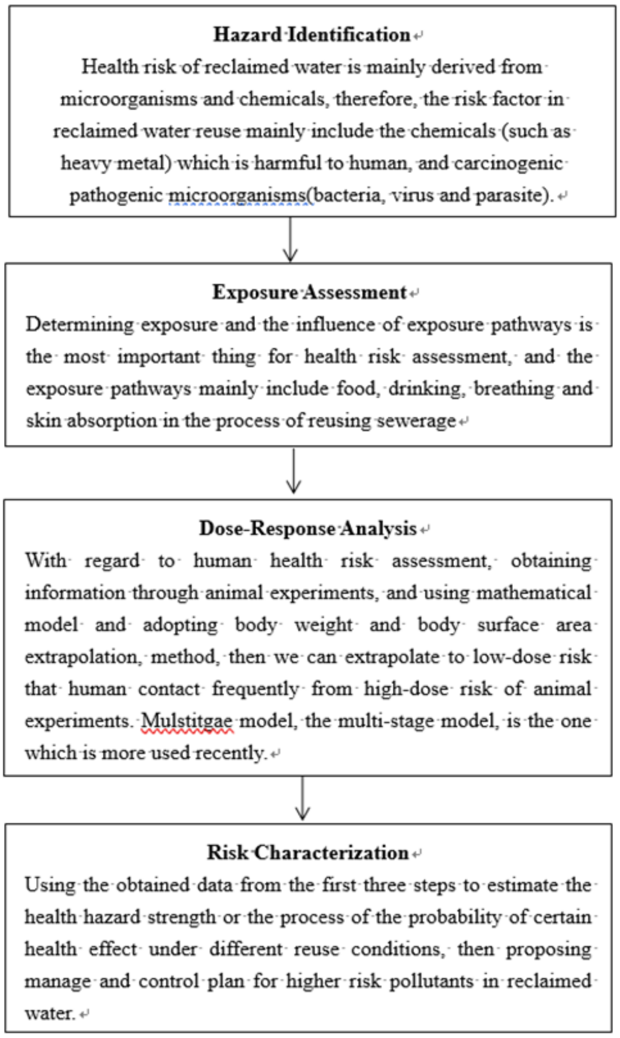

Fig. 3. The reclaimed water health assessment procedure

Assessment Procedure

The United States Environment Protect Agency (EPA) conducted comprehensive research on human health risk of chemicals and established the integrated risk information system. To one certain chemical substance which affect human health, the system presents qualitative description and quantitative assessment. To non-carcinogens, the system presents oral reference dose and inhalation reference dose; and with regard to carcinogens, the system presents carcinogenic strength classification and carcinogenic strength coefficient. So we can draw lessons from the health risk assessment method of EPA that evaluating chemicals in drinking water to assess human health risk for reclaimed water.

By the construction of index system, we can learn that human health risk of reclaimed water is mainly derived from a variety of substances which are harmful and noxious to human health, they are generally divided into two categories: chemicals and pathogenic microorganisms. The former can be divided into chemical carcinogens and chemical non-carcinogens. According to the pollutants which harm human health in the risk flow route of reclaimed water, as well as the theoretical method of health risk assessment, we can set up the risk assessment model that the effect of different types pollutants act on human health.

Based on the risk transfer path of reclaimed water, the construction of index system and the related theories of human health risk assessment, the procedure for health risk assessment of reclaimed water is shown below in **Fig. 3**.

Risk Assessment Model

Human health risk assessment for reclaimed water requires a large amount of data, calculation formulas and mathematical models, mainly including two categories: the one is exposure assessment pattern,

Table 4. Reclaimed water exposure pathways and exposure calculation

Exposure Applications	Exposure Calculation
Dietary intake	CDIoral=(CW × IR × EF × ED)/(BW × AT)
Skin absorption	AD=(CW × SA × PC × ET × EF × ED)/(BW × AT)
Breath inhalation	CDIinhalation=(CA × IR × ET × EF × ED)/(BW × AT)

which is mainly used to calculate the dose that human absorb ingest or inhale chemicals, on the basis of this, analyzing the exposure level of human body; the other is calculation pattern of risk representation, which is used to represent the human health risk of reclaimed water.

Exposure assessment model

The exposure pathways of using reclaimed water mainly include food, drinking, breathing, skin absorption and so on (He et al. 2006), exposure is closely related to reuse applications and methods. Annual exposure times under different situations should be considered when calculating the annual risk. **Table 4** shows the reclaimed water exposure applications and exposure calculation.

CDI oral represents chronic daily absorption of dietary pathways, AD represents chronic daily absorption of skin absorption, CDI inhalation represents chronic daily absorption of breath inhalation, mg/(kg·d); CW represents the concentration of chemical substances in water, mg/L; IR represents intake rate, L/day; EF represents exposure frequency, days/year or event/year; ED represents exposure time period, year; BW represents body weight, kg; AT represents average time, days; SA represents accessible surface area of the skin,cm2; PC represents permeation constant of specific chemical pollutants on the surface of skin, cm/h; ET represents exposure time, h/day or h/event; CA represents the concentration of pollutants in the air, mg/m3.

CDI oral represents chronic daily absorption of dietary pathways, AD represents chronic daily absorption of skin absorption, CDI inhalation represents chronic daily absorption of breath inhalation, mg/(kg·d); CW represents the concentration of chemical substances in water, mg/L; IR represents intake rate, L/day; EF represents exposure frequency, days/year or event/year; ED represents exposure time period, year; BW represents body weight, kg; AT represents average time, days; SA represents accessible surface area of the skin,cm2; PC represents permeation constant of specific chemical pollutants on the surface of skin, cm/h; ET represents exposure time, h/day or h/event; CA represents the concentration of pollutants in the air, mg/m3.

When conducting the assessment for carcinogen risk, we should make certain assumptions for average body weight, the amount of air inhaled and the intake rate of drinking, etc. USEAP determines a series of standard values, such as 70kg is the average weight of men, and 60kg is the women's, and 2L/day is the water consumption of adult residents. Due to the differences about regions and living habits, we need to consider the actual situation in China to determine these standard values.

The calculation model of risk representation

(1)The assessment model of carcinogenic risk

The health risk model of carcinogenic pollutants (Wan et al. 2009) can be expressed as:

$$P = 1 - exp(-qD) \quad (1)$$

P represents lifelong risk of developing cancer; D represents average daily exposure dose of per unit weight of chemical carcinogen, mg/(kg·d);q represents carcinogenic potency factor,$[mg/(kg \cdot d)]^{-1.}$

If considering multiple exposure pathways of various chemical carcinogens, it be expressed as:

$$P_{ij} = 1 - exp(-q_{ij}D_{ij}) \quad (2)$$

P_{ij} represents the risk of developing cancer caused by chemical carcinogen i pass through exposure way j, dimensionless; D_{ij} represents average daily exposure dose of per unit weight that chemical carcinogen i pass through exposure way j,mg/(kg·d);q_{ij} represents carcinogenic potency factor that chemical carcinogen i pass through exposure way j,$[mg/(kg \cdot d)]^{-1}$.

When there are a variety of toxic substances which act on human body together, assuming that the total risk of human health hazards is equal to the sum of risk induced by single pollutant, that is to say, the risk of each toxic substances is equal and it can perform arithmetic addition, and without considering the toxicity termination and the synergistic and antagonistic action of different toxic substances. Total risk P can be expressed as:

$$P = \sum_i \sum_j P_{ij} \quad (3)$$

(2) The assessment model of non-carcinogenic risk

The health risk model of non-carcinogenic pollutants (Wang et al. 2009) can be expressed as:

$$P = \frac{d}{RfD} \times 10^{-6} \quad (4)$$

P represents lifelong risk of developing health hazards, dimensionless; d represents average daily exposure dose of per unit weight of non-carcinogenic pollutants, mg/(kg·d); RfD represents the reference dose of this chemical substance, mg/(kg·d).

If considering multiple exposure pathways of various chemical non-carcinogens, it can be expressed as:

$$P_{ij} = \frac{d_{ij}}{RfD_{ij}} \times 10^{-6} \quad (5)$$

P_{ij} represents the risk of developing health risk caused by pollutant i pass through exposure way j, dimensionless; d_{ij} represents average daily exposure dose of per unit weight that pollutant i pass through exposure way j, mg/(kg·d); RfD_{ij} represents the reference dose that pollutant i pass through exposure way j, mg/(kg·d).

Total risk P can be expressed as:

$$P = \sum_i \sum_j P_{ij} \quad (6)$$

(3) The assessment model of pathogenic microorganisms

There are two commonly used mathematical model, one is index model, the other is Beta-Poisson model (Haas 1996, Hamilton et al. 2007). Index model can be expressed as:

$$P_i = 1 - e^{-rd} \quad (7)$$

r represents the probability of infection about random single pathogen is constant; d represents ingested dose of human; P_i represents infection probability.

As for many pathogens, the incidence of infection under certain dose less than the calculated probability, it reflects that the interaction between different pathogens and host exist differences. Assuming that the probability of infection about single pathogen obeys Beta distribution, we can deduce the Beta-Poisson model by the formula:

$$P_i = 1 - \left[1 + \frac{d}{N_{50}}\left(2^{\frac{1}{\alpha}} - 1\right)\right]^{\partial} \quad (8)$$

P_i represents the probability of contacted infection; d represents the number of virus ingested in human; N_{50} represents the number of virus which infects 50% exposed population; ∂ represents the slope parameter, the ratio of N_{50} and P_i.

Table 5. The severity scale of Carcinogenic chemicals

Category		Description	
	A	Identified as carcinogens	
B	B1	Be likely to develop cancer	There is a small amount of evidence that human develop cancer
	B2		There is enough evidence that animals develop cancer, and there is insufficient evidence that human develop cancer
C		It may be carcinogens	
D		Not enumerate among the carcinogens for human	
E		Evidence suggests that it is somatic toxic chemical pollutant	

Comprehensive Risk Assessment

To evaluate the human health comprehensive risk of reclaimed water by using the risk matrix, drawing the severity and probability of all kinds of hazardous substances in reclaimed water which harms human health through calculation model, then constructing the risk matrix according to $R=f(S, P)$, and founding the comprehensive risk level of human health caused by reclaimed water.

With regard to the severity, which represents the severity of hazardous substances in reclaimed water which harms human health, we can divide the severity by using statistical data. Drawing lessons from the classification method in the calculation of carcinogenic risk of USEPA, we can classify the weight of evidence that the cancer developed by chemicals, and it is divided into six categories (A, B1, B2, C, D, E), **Table 5** is the severity scale of Carcinogenic chemicals.

To the possibility P, it represents the probability of human health risk for reclaimed water. Determine the weight of each index by using AHP, calculate the probability of risk by using exposure assessment model and the calculation model of risk characterization, process data by using computer program and probability theory. For example, the calculation software of Monte-Carlo Crystal ball is applied to calculate lifelong carcinogenic risk and yearly carcinogenic risk of all kinds of carcinogens, then analyzing the probability distribution of all risk values. Finally, we can draw the probability distribution of carcinogenic risk and the range of risk values and other statistical information.

After determining the severity S and possibility P, identifying the overall risk level which is corresponding to reclaimed water through risk matrix, and then defining whether the overall risk can be accepted.

Eisenberg et al. (1996) proposed a method for estimating the distribution of microbial risk assessment and used Monte Carlo method (Monte Carlo Method) to evaluate the health risk of Giardiasis in reclaimed water for recreational use. Hamilton studied on quantitative model of microbial risk assessment of reclaimed water for crop irrigation (Hamilton et al.

2007). The Indian Basu made a study on multi-route risk assessment from trihalomethanes in drinking water supplies (Basu et al. 2011). In China, The exposure level and health risk of reclaimed water used for road dust exposure were investigated and studied by He Xinghai et al. (He et al. 2007). They established a health risk assessment model for the use of reclaimed water for road dust removal, and evaluated the health risks of 19 major pollutants such as chloroform. Zhang Deyou applied Beta-Possion model to evaluate the health risk of exposure to rotavirus in the reclaimed water (2009). Zhang Jianlong et al. (2010) improved the Monte Carlo method by using Logistic chaotic system, and applied it to the health risk assessment of reclaimed water. However, the research on the risk assessment of reclaimed water in China is still in its infancy. The risk assessment of reclaimed water reuse for human health and ecological environment has not yet formed a system. Therefore, it is necessary to further strengthen the research in this field, so as to establish a risk assessment system for reclaimed water reuse.

CONCLUSION

(1) According to the current domestic existing water quality standards and reclaimed water reuse applications, summarizing the characteristics of risk assessment that the reclaimed water affects human health in its process.

(2) By deducing risk scenario and analyzing the consequences, the risk transfer path of reclaimed water reuse was constructed; on this foundation, with the analysis of the impact of human health indicators, 3 levels of reclaimed water safety assessment index system for human health risk was created.

(3) By combining the traditional risk assessment theory, the USEPA's four-step method with the characteristics of human health risk for reclaimed water, the procedure and model of human health risk assessment for reclaimed water were established.

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REFERENCES

Aaron A, Jenning, P Suresh (1986) Risk Penalty function hazardous waste management. Journal of Environmental Engineering, 112(l):105-122.

Bai Z, Wang J, You Y (2009) Environmental Risk Assessment. Higher Education Press, Beijing.

Basu M, Gupta SK, Singh G, Mukhopadhyay U (2011) Multi-route risk assessment from trihalomethanes in drinking water supplies. Environmental Monitoring and Assessment, 178(1-4): 121-134.

Chen X, Zhang J, Chen X (2003) Discussion on the Directions of Wastewater Reclamation and Reuse and the Water Quality Standards. China Water & Wastewater, 19(1): 92-94.

Duan X (2012) Study on migration and accumulation of Quinolones antibiotics in vegetables. Anhui Agriculture University.

Eisenberg JN, Seto EYW, Olivieri AW, Spear RC (1996) Quantifying Water Pathogen Risk in an Epidemiological Framework. Risk Analysis an Official Publication of the Society for Risk Analysis, 16(4): 549.

Haas CN (1996) How to Average Microbial Densities to Characterize Risk. Water Research, 30: 1036–1038.

Hamilton AJ, Stagnitti F, Kumarage SC, Premier RR (2007) RIRA: a tool for conducting health risk assessments for irrigation of edible crops with recycled water. Computers and electronics in agriculture, 57(1): 80-87.

Han B, He J, Chen H, Chen H, Shi J (2006) Primary Study of Health-based Risk Assessment of Organic Pollution in Groundwater. Earth Science Frontiers, 13(1): 224-229.

He X, Ma S, Li A, Pan X, Chen Q, Wang J (2006) Exposure Assessment of Various Reclaimed Water Uses. Environmental Science, 27(9): 1912-1915.

He X, Ma S, Pan X, Chen Q, Li A, Wang J (2007) Research on the Health Risk Assessment of Chemical Pollutants in Reclaimed Water Used for Streets Watering. Environmental Science, 28(6): 1290-1294.

Li A (2015) Study of concentration distribution of 12 antiboiotcis in Reclaimed Water for farmland irrigation in Beijing. 2015 Symposium on water resources ecological protection and water pollution control, 183-190.

Liu X (2013) The biological toxicity analysis of PAHs fluorene in the recycled water. Tianjin Chengjian University.

Luo Y, Fan Y, Ma X (2005) Risk Analysis and safety Assessment. Chemical Industry Press, Beijing.

Ma X, Li H (2016) Progress in research on water biological toxicity monitoring and recycling in China. Environmental and sustainable development, 41(4): 67-70.

Qiu F, Wang X (2003) Risk Assessment on Health Effects of Viruses in Urban Reused Wastewater. J Environ Health, 20(4): 197-199.

Wan Y, Kang T, Zhou Z, Li P, Zhang Y (2009) Health Risk Assessment of Volatile Organic Compounds in Water of Beijing Guanting Reservoir. Research of Environmental Sciences, 22(2): 150-154.

Wang L, Gu G, Zhang M (2007) Effect of antibiotic residues on safety of agricultural products and ecological environment. Anhui Agri. Sci. Bull., 13(2): 74-76.

Wang Q, Zhang Z, Liu W (2009) Environmental Health Risk Assessment of Drinking Water Source in Tianjin. Environmental Science & Technology, 32(5): 187-190.

Wang Z (2014) Toxicity evaluation on organic extracts from reclaimed water of a wastewater treatment plant in Zhengzhou. Zhengzhou University.

Writing by ‘Guidelines for urban reclaimed water series standard’ Writing Group (2008) Guidelines for urban reclaimed water series standard. Standards Press of China.

Wu X, Mo C, Yan Q, Jiang Y, Xiang L, Li Y, Huang X, Su Q, Wang J (2013) Content levels and health risk of quinolone antibiotics from vegetables of Dongguan farms. China Environmental Science, 33(5): 910-916.

Yin Q, Wang L, Jiao Y, Sui T (2008) The Concept and Method of Health Risk Assessment for Urban Wastewater Reuse. Journal of Shandong Jianzhu University, 23(2): 141-144.

Zhang D, He X, Cheng L, Xie X, Wang D, Wang Z (2009) Change of Rotavirus in Sewage Treatment Processes and Associated Health Risk Assessment. Asian Journal of Ecotoxicology, 4(5): 751-757.

Zhang J, Xie J, Wang N, Huang J, Shen Y (2010) Health risk assessment in the reuse of reclaimed water based on improved Monte Carlo method. Acta Scientiae Circumstantiae, 30(11): 2353-2360.