The applied progress of orthogonal experiment in wastewater treatment

Ruqiong Qin[a]

Guangxi Polytechnic of Construction, Nanning 530003, China

[a]qinruqiong@163.com

Abstract. The method of orthogonal experiment design ("orthogonal method" for short) is an important branch of mathematical statistics, base on statistics probability theory, professional and technical knowledge and practical experience, arrange experiment plan by made full use of standardization of orthogonal table, and mainly used in industrial and agricultural production and scientific research. This paper introduces the basic principle of the orthogonal method and the methods of orthogonal experiment design, systematically state the applied progress of orthogonal experiment in wastewater treatment research at home and abroad, finally, take perspectives for the role of orthogonal experiment in wastewater treatment research in the future.

1. Introduction

In the scientific research process, in order to find the main relation and optimal collocation conditions of the experiment, it is often necessary to pass trial and error. Have practical experience of comrades know, well test arrangement, not only can greatly reduce test times, and save the test expenditure, but also avoids the blindness, to get useful information from the test results. Otherwise, it is not only the number of trials, but also the waste of manpower, material resources and time, and the result is not always satisfactory. Therefore, how to arrange the experiment is a question worthy of serious study.

Orthogonal test is the most commonly used process optimization experiment design and analysis method by far, is part of the main factor design method, it is based on probability theory, mathematical statistics and practice experience, the use of standardized orthogonal table arrangement experiment scheme, and the calculation and analysis results, finally find the optimization solutions quickly, is a kind of efficient processing scientific calculation method of multi-factor optimization problem. Orthogonal experiments were first started in agricultural experiments, and now some advanced countries have been widely used. Especially in Japan, the economic development has played a very good role. At the end of the 1950s, some mathematical statisticians made preliminary explorations on the application of orthogonal test methods in textile industry and agriculture. Since the 1970s, many achievements have been achieved in scientific experiments in scientific research [1]. Principle and design method of the orthogonal experiment, the author of this paper, the application of orthogonal test in water pollution control experiment made a comprehensive study, in order to for future in water pollution control experiments with the orthogonal method of workers have certain help.

2. Principle of orthogonal test [2]

There is a chemical reaction X+Y= Z, and the main factors known to affect the z-test index are 3: reactant ratio, reaction temperature and reaction time. The purpose of the experiment is to find out the influence of three factors on the test index and determine the optimum reaction conditions.

If you follow a regular network design approach (that is, a full-scale trial), you need to match all the factors and levels. In the three levels of the above three factors, 33=27 tests should be done. The equivalent of 27 nodes on a cube, as shown in figure 1. This design has a clear analysis of the relationship between factors and levels, but it is often too often. If it is a 4 factor 3 level test, 34=81 times; If 10 factor 3 level, the test number will reach 310= 59049.The number of repeated trials is not calculated for the offset error. Obviously, such a workload is unacceptable. So, can we use a small number of tests to spread out some of the characteristics of a comprehensive test? Orthogonal design can solve this problem.

Orthogonal experimental design is a part of the test for all the factors (i.e., made a part of the comprehensive test), but for any of these two factors is with such as repetition (two factors between different level match the number of the same) a comprehensive test. As mentioned above, the experiment of 3 factor 4 level can be done 9 times by orthogonal design. The black dots in the cube network shown in figure 1 are orthogonal test points. From the distribution of the nine sites we can see: every surface cube just have three sites, and the cube of each line also has a point, nine sites evenly distributed in the whole cube, each test has a very strong representative, can more fully reflect an overview about the selection area. The equilibrium distribution of the test points in the selected region is mathematically called "orthogonal". This is also the origin of "orthogonal" in orthogonal design.
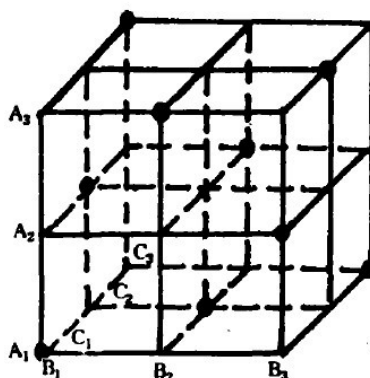

Fig. 1 Network design and orthogonal design drawing.

3. The design method of orthogonal test

Orthogonal test design has many methods, but the design principle is designed according to the orthogonal table. Therefore, the rational selection of orthogonal table becomes the basis of orthogonal design. Orthogonal table will test factors, the combination between the various levels of uniform collocation, reasonable arrangement, the average distribution of the various levels for the test factors, realize the factors and levels of neat uniform dispersion and comparability, greatly reducing the number of test, and the results can provide more information, the method is a highly efficient, economic factors, multiple levels[3].The orthogonal table has the same horizontal orthogonal table and the mixed horizontal orthogonal table.

The codename of the orthogonal table is expressed as Ln (qm), in which, L means orthogonal table, n means test number, q is the number of factors, m is the number of factors, and the number of columns is represented in the orthogonal table.

When orthogonal rows and columns in a table changes, test plan and there is no essential change in the geometrical structure of orthogonal table, so it is worth noting that the codes of the same orthogonal table is not the only, but the code the same orthogonal table are equivalent. In the test

design process, the orthogonal table and the test can be selected according to the number of factors and the number of horizontal Numbers. See the relevant information for the orthogonal table.

4. The application of orthogonal test method in urban sewage treatment

4.1. removal of nitrogen and phosphorus

With the development of social economy, a large amount of nitrogen and phosphorus fertilizer production wre used, industrial wastewater, city life sewage, especially phosphorus detergent wastewater emissions, make water rich in nitrogen, phosphorus and other material in the lakes, causing eutrophication of water body, municipal wastewater with high content of phosphorus problem is very serious, therefore, the task of denitrification and phosphorus removal is imminent. Li Yanping [4] in modified form, such as oxidation ditch experiments of nitrogen and phosphorus, dissolved oxygen (DO) is studied through orthogonal test (MLSS), sludge concentration, sludge reflux ratio (R) for improved oxidation ditch, and the effects of nitrogen and phosphorus. During the test, each factors and the corresponding level of the orthogonal experiment were analyzed: the DO concentration of quasi using oxidation ditch to lack, aerobic area 0.2, 0.3, 1.5, 0.3, 1.5, 0.5, 2.0, 2.5, 0.5, 0.7, 2.5, 0.7 mg/L three levels; MLSS will adopt the three levels of 4500, 5000 and 5500mg/L; The R is proposed to be 50 %, 65% and 85 %.The experimental results showed that the optimal operating conditions of the oxidation ditch system were: DO=0.3 -- 0.5mg/L, good oxygen region DO= 2.0-2.5mg/L, MLSS= 5000mg/L, and sludge reflux ratio R= 65%.

Ming-yan shi [5], the urban sewage mixed wastewater removal effect of nitrogen and organic matter, in the actual fecal sewage and sewage simultaneous removal of nitrogen and organic matter for the target to the orthogonal experiment, the selected hydraulic retention time (HRT), dissolved oxygen (DO) concentration, sludge aerobic pool reflux ratio (R) and mixture reflux ratio (R) [25], four factors three levels, from each factor selection orthogonal table, the experimental results show that the high carbon fecal sewage into the urban sewage carbon source has played a larger role; Hydraulic retention time is the limiting factor that affects the removal efficiency of mixed wastewater; When the water temperature is between 28~ 35, fecal sewage and urban sewage, the optimal operation parameter is HRT= 8h, DO= 2.0mg/L, R= 80%, and R= 150%, when the volume of the sewage and the urban sewage is 20d compared with the mixing and SRT.

4.2. determine the best operating conditions

Liu chang [6] in xinjiang shihezi city wastewater such as CODcr above 1000 mg/L, the characteristics of SBR process for processing test, with sludge load, anaerobic, aerobic time, oxygen time as the influencing factors and the removal rate of CODcr as evaluation indices for the four factors three levels orthogonal test, by calculating the removal rate of various factors in the same level, and will be the best in all factors together, can predict the optimal level combination is put forward, in order to further test and research, and obtained the optimal processing scheme: sludge load of 0.16;Anaerobic time is 1.5h;Aerobic time is 4h;The hypoxia time is 1.5h.

Wang Sheng [7] for research level of intensive treatment of urban sewage of the optimum technological conditions and the influence of various factors on treatment effect, has carried on the + (weak non-ionic and anionic and cationic) 6 groups of 4 of 6 kinds of drug combination factors 3 levels orthogonal test, the selection of orthogonal table, the experimental results show that with PAC + + polymer coagulant aid polymer coagulant aid little difference of two series of COD removal efficiency, weak + best phosphorus removal effect of cationic polymer coagulant aid, namely + polymer coagulant aid series is better than PAC + polymer coagulant aid the effect of the series.

In addition, the orthogonal method is also applied in the later treatment of urban sewage. Xiang-feng huang [8] and so on has carried on the urban sewage plant secondary biological treatment effluent research to the influential factors of chlorine disinfection effect, determine factors orthogonal test as follows: pH, COD, ammonia nitrogen and organochlorine, low temperature test is used to examine the influence of temperature factor, by monitoring the change of water quality, at the same time reference

experience data, determine the test level of factors, choose orthogonal table arrangement experiment, the results showed that the sodium hypochlorite, carbon dioxide disinfection effect is the biggest impact of the pH, the second is the organochlorine, COD and ammonia nitrogen effect is relatively small.

5. Application of in industrial wastewater

5.1. treatment of organic wastewater

Organic wastewater has always been the focus of social attention because of its high toxicity, high concentration and difficulty in governance [15]. In recent years, there have been many researches on organic wastewater. YanDan [9] under TO2 suspension system, such as in the simulation of organophosphorus pesticide wastewater in semiconductor photocatalytic oxidation degradation of static test, the pH value, dosage of catalyst, light intensity and air as factors, according to the orthogonal table, establish three levels orthogonal table 4 factors, under the experimental condition, the factors the influence of light catalytic oxidation is in order of importance: light intensity, pH value, oxygen and catalyst dosage, best test condition is: pH value of 2, catalyst dosage is 300 mg/L, 40 W light intensity, air 1.5 L/min.

Zhang Ling [10], with the same method for methyl benzene sulfonic acid as the YanDan photocatalytic oxidation treatment, with pH, catalyst dosage, light intensity and illumination time for factors orthogonal test, the results with YanDan slightly different. Under certain experimental conditions, the impact of the size of the photocatalytic degradation reaction of methyl benzene sulfonic acid wastewater order for various factors: illumination time st13 light intensity st13 initial pH st13 of catalyst dosage, best in test conditions (pH = 3, catalyst dosage is 80 mg/L, light intensity, 500 W, illumination time is 120 min), the degradation of methyl benzene sulfonic acid can completely.

5.2. removal of heavy metals

All kinds of heavy metals are widely used in many fields, but its and its compounds, inorganic or organic, even if the content is little, also will bring the environment pollution, to cause human disease, so the detecting their levels for subsequent processing, it is very necessary. Huang Shaoji [11] experiment, mercury content in acidity, gas liquid ratio, carrier gas flow rate and dosage of SnCl2 do orthogonal test, determine the number of four factors three levels, build orthogonal table, found the orthogonal experiment on multi-factor analysis can play a powerful role in operation conditions were determined, economical and efficient, the results confirmed the cold atomic absorption mercury method, the optimum operating conditions as follows: the concentrated sulfuric acid plus 0.7 ml (1.5 ml) instead, 10% SnCl2 solution with 1 ml (instead of 2 ml), N2 flow rate of 1.4 l/min (rather than 1.0 l/min) is good, while the absorbance can be increased from 0.0386 to 0.0545.

ChuHongBo [12], etc by Hitachi 180-80 atomic absorption spectrophotometer for water quality in the heavy metals (copper, lead, zinc, cadmium) for continuous measurement, they selected in atomic absorption method for greater influence on the absorption value of lamp current, gas flow rate, air flow three factors, choose the orthogonal table, test evaluation index for the absorption value of ABS, by comparing the test results, it besides zinc, the optimal values of lamp current 5.0 mA, and the biggest influence of the lamp current, less than 2.5 Hitachi sure of 7.5 mA, mA, and improve absorption value, increased reliability; For zinc, the flow of gas tested will be determined by Hitachi increased from 0.2 kg/cm2 to 0.3 kg/m2, the air flow from 1.60.3 kg/m2 to 1.40.3 kg/m2 can improve the absorption values, for the cadmium, these three conditions can be adjusted, the lamp current is reduced to 5.0 from 7.5 mA mA, gas flow rate reduced from 0.3 kg/m2 to 0.2 kg/m2, air flow rate reduced from 1.6 kg/m2 to 1.4 kg/m2, more can improve the reliability of the results.

6. Conclsion

Orthogonal test method has a long history and wide application field. Based on the optimization design theory proposed by crane Dan [13], the orthogonal design scheme is determined by the normal

fitting method, which is the enrichment and improvement of the traditional orthogonal test method, and a breakthrough in theory. Chinese scholars have combined the principle of number theory and multivariate statistics to create a new design method, which is the uniform design method which is often applied in the field of scientific research. [14]. The method is similar to the orthogonal test design for multi-factor multi-level experiment design. The uniform design can make the test number less, the test results can be fitted by computer and can be returned to the quantitative equation for data processing. In a word, the orthogonal experiment method play an important role in every field, the law, how to master better and more flexible to make scientific experimental research work to develop more efficient, scientific, convenient, we experiment design thinking of one of the problems.

References

[1]   xu zhongan, wang tianbao, li changying, li changying, liyan, ma qingmei, miao yining. Introduction of orthogonal experimental design [J]. Science and technology intelligence development and economy, 2002,05:148-150.

[2]   sheng yongli. Orthogonal test design and its application [J]. Journal of jinan university (comprehensive edition), 1997,03:69-73.

[3]   liu ruijiang, zhang weiwang, wen chongwei, tang jian. Research on orthogonal experimental design and analysis [J]. Experimental technology and management, 2010,09:52-55.

[4]   li yanping, liu qiang, li simin. The orthogonal experimental study on the removal of nitrogen and phosphorus from modified oxidation ditch [J]. Journal of hebei engineering university (natural science edition), 2011,03:42-46.

[5]   shi mingyan, mo donghua, feng zhaoyu, yu jianheng, wang shaolin, xia geng dong. The orthogonal experimental study on the removal of nitrogen and organics in mixed faeces of urban sewage [J]. China rural water conservancy and hydropower, 2011,03:6-9.

[6]   liu chang, cheng xiao, zheng xu-rong, gong bing, zeng yong. Research on the orthogonal test of wastewater treatment in high concentration cities [J]. China rural water conservancy and hydropower, 2004,06:34-36.

[7]   wang sheng, xu zuxin, qu ning ning. An orthogonal test of the treatment of urban wastewater by aluminum salt primary intensification [J]. Water supply and drainage in China, 2005,01:37-40.

[8]   huang xiangfeng, zhu huan, wu zhichao, wang rongsheng. Research on the influence factors of secondary biological treatment of water chlorination in municipal wastewater treatment plants [J]. Environmental protection science, 2005,05:5-8.

[9]   yan Dan, liu kanghuai, chin xu jiang, Chen yu, cao changchun, shi jiayang, yan li. Orthogonal test of photocatalytic oxidation of organophosphorus pesticide wastewater [J]. Journal of guilin institute of technology, 2008,01:109-112.

[10]   zhang ling, chang zhixian, zhang yu-pei, ren cong, li deliang. Orthogonal experimental study on the catalytic oxidation of photocatalytic oxidation of methylbenzene sulfonate wastewater [J]. Chemical research, 2010,03:54-58.

[11]   huang shaoji. Application of orthogonal test in mercury measurement [J]. Environmental monitoring management and technology, 1992,03:41-43.

[12]   chu hongbo, wenxinyu. Using the orthogonal test design method to determine the operating conditions of copper, lead, zinc and cadmium in water by atomic absorption spectrophotometry [J]. Instrumentation and analysis monitoring, 1999,03:60-62.

[13]   yu Dan, li hewei, shi guangyi, yao guangbin. The design and application of orthogonal experimental optimization [J]. Journal of mathematical medicine, 1996,01:89-90.

[14]   zhang xianzhou, pan chi-gui, li rongling, CAI hongsheng. Application of uniform design in Chinese medicine research [J]. Chinese medicine, 1994,01:51.

[15]   Jianheng Yu, Shaoqi Zhoua, Weifeng Wang. The Combined treatment of domestic wastewater with landfill leachate by using A2 / O process [J]. Journal of Hazardous Materials, 2010178 (35): 81-88.