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Application of gray relational analysis to the experimental design on adsorption of U(VI) by *pseudomonas aeruginosa* loaded by nano-Fe_3O_4

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ABSTRACT

This paper determines the main influence factors on the experiment of adsorption of U(VI) by *Pseudomonas aeruginosa* loaded by nano-Fe_3O_4(NFPA) through gray correlation analysis, based on the experimental design on adsorption of U(VI) by *Pseudomonas aeruginosa* loaded by nano-Fe_3O_4. Results show that the method is simple, objective, reliable, and providing a scientific basis for experimental design to treatment the wastewater containing U(VI).

KEYWORDS

Uranium;
Pseudomonas aeruginosa loaded by nano-Fe_3O_4 (NFPA);
Experiment;
Gray relational analysis.

INTRODUCTION

The booming of nuclear power causes the demand of natural uranium soaring. The development of uranium mining and metallurgy industry inevitably result in larger uranium tailings and substantial radioactive waste water. So the restoration of the uranium mining and metallurgy of radioactive waste water is a major and urgent technology which needs to be on the problem. The treatment of containing U(e&) radioactive waste water is always a hot issue for domestic and foreign academician. Exploring control technology of high efficiency and low energy of uranium and other radioactive water pollution is a major issue in the nuclear industry sustainable development and nuclear environment about the livelihood of the people.

Pseudomonas aeruginosa loaded by nano-Fe_3O_4,or simply "NFPA" for short, is a chemical-biological composite material. Which use *Pseudomonas aeruginosa* as material,nano-Fe_3O_4 as carrier and ultrasonic vibration to make *Pseudomonas aeruginosa* adhere to nano-Fe_3O_4 to compound. The process of NFPA adsorption of U(e&) is complex,which is affected by many nature of itself and external environment chemical factors. Therefor, it is of great significance about Pseudomonas aeruginosa loaded by nano- Fe_3O_4 to make sure the main influence factors in the experiment and discuss the optimum adsorption condition.

With the emergence and development of the grey system theory,it gradually become a kind of widely used evaluation methods which can analysis each factor in the incomplete information by data handling and find their relevance,main problem,leading feature or major factor among random factors sequence. This paper determines the main influence factors on the experiment of adsorption of U(VI) by *Pseudomonas aeruginosa* loaded by nano-Fe_3O_4 through gray correlation analysis, which can provide a scientific basis for experimental design to treatment the wastewater containing U(VI).

THE PRINCIPLE OF GRAY RELATIONAL ANALYSIS[1~3]

Gray Relational Analysis is a new analysis method in Gray system theory. It is a method of combining quantitative and qualitative analysis after using quantitative methods of grey relation degree to distinguguish system (or effect) to the size of the close degree between the main body. It differentiate between the various factors in the system by comparing system statistics sequence geometrical relationship. The more the connection degree between sequence curve geometry get close,the more they will be related.

Definite reference sequence and comparison sequence

Calculation of relational coefficient

$$\xi_{0,i}(k)=\frac{\min_i \min_k |x_0(k)-x_i(k)|+\rho \max_i \max_k |x_0(k)-x_i(k)|}{|x_0(k)-x_i(k)|+\rho \max_i \max_k |x_0(k)-x_i(k)|} \quad (1)$$

In which :

$\xi_{0,i}(k)$——the I index samples point k's relational coefficient; ρ ——resolution coefficient,and $\in(0,1)$ get ρ =0.5; $|x_0(k)-x_i(k)|$——the m index's reference sequence statistic and relevant index's the i statistic difference between absolute value.

$\min_i \min_k |x_0(k)-x_i(k)|$——the second minimum difference; $\max_i \max_k |x_0(k)-x_i(k)|$——the second maximum difference

Calculation of correlation $r_{0,i}$

Synthesizing each correlation coefficient and computing $r_{0,i}$,formula is :

$$r_{0,i}=\frac{1}{n}\sum_{k=1}^{n}\xi_{0,i}(k) \quad (2)$$

APPLICATION EXAMPLE

The major factor

Many studies have shown that microorganisms' ability of dislodging metal ion depend on not only the self characteristic but also the environment factors. At the experiment of adsorption of U(VI) by *Pseudomonas aeruginosa* loaded by nano- Fe_3O_4,pH value, as one of the important factors that influence the adsorption, can control the state of ion adsorbent surface functional groups and surface composition of hydrolysis and U(VI) in the form of existence in the water, and water in H^+ will compete with U(VI) adsorption, thus affecting the adsorbent adsorption of U(VI). Temperature can provide the adsorbent energy,overcome the barrier of energy,affect the state of hydrolysis as well so it can affect the process of absorption. Moreover,NFPA's initial quantity and initial potency of uranium solution also have effects on test. Some factor's test result were shown in Figure.1~4.

pH,temperature, adsorbent dosage and uranium concentration have different effects on removal rate of uranium. Traditional ways to judge the importance of each factor are graded by specialists,analytic hierarchy process. It contain too many human factors and subjective factors even though it is convenient. So the result of test in this research avoids the human factors by

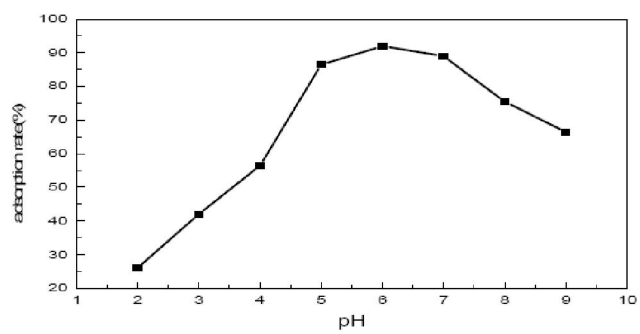

Figure1 : The effect of pH on the removal of U(VI) by NFPA(conditions:[U(VI)]=30mg•L^{-1}, m(NFPA)=0.07 g, 30°C)

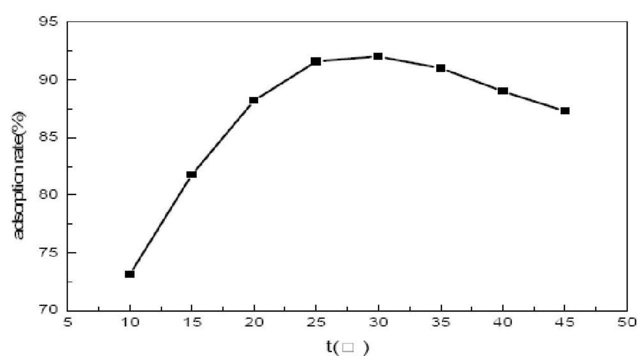

Figure 2 : The effect of temperature on the removal of U(VI) by NFPA(conditions:[U(VI)]=30mg•L^{-1}, m(NFPA)=0.07 g, pH=6.0)

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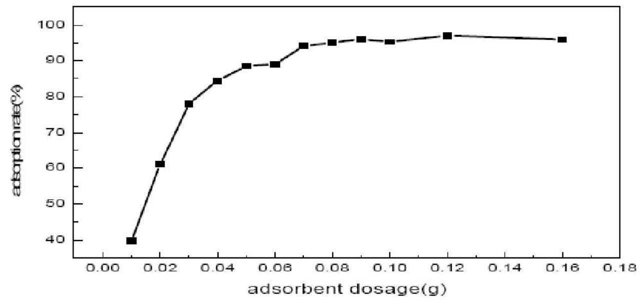

Figure 3 : The effect of adsorbent dosage on the removal of U(VI) by NFPA(conditions:[U(VI)]=30mg•L-1, 30°C, pH=6.0)

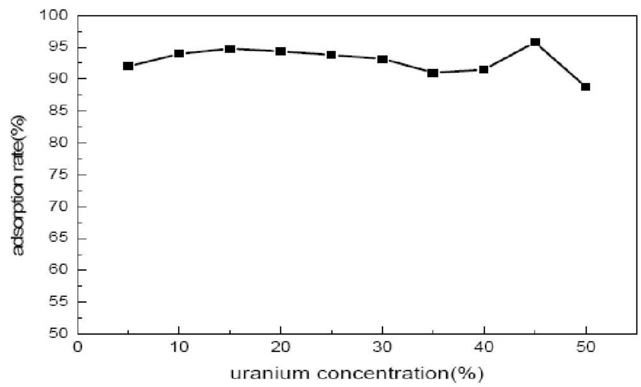

Figure 4 : The effect of uranium concentration on the removal of U(VI) by NFPA(conditions: m(NFPA)=0.07g, 0°C, pH=6.0)

figuring out the factors' correlation and effect coefficient.

Effect factors discriminate standard and quantitative

The main factor that affect experiment result is the main variables quantity that judge removal ration of uranium. Looking from it's measure, normal variable quantity is the core in this test. The ways to discriminate quantitative factors order is in given region, depending on the range each value of each level. Although the quantitative value is different, but it belongs to the same properties and taking the same parameter value. For example, NFPA's hydration surface and *Pseudomonas aeruginosa* has different absorption activity. When 0<pH<4,it is $(FeOH_2)^+$ to predominate,which can form electrostatic repulsion with U(VI). When 4<pH<9, Fe_3O_4 's surface happen hydrolysis reaction which strengthen the NFPA's complexation with U(VI). When pH=6,FeOH has the most percentage and hydroxy, during the period, *Pseudomonas aeruginosa* has the best absorption activity[4]. o pH=6.0 is the best condition for U(VI) absorption. When pH>9,at Fe_3O_4's surface FeO^- is dominant[5],which also affect absorption activity of *Pseudomonas aeruginosa*. U(VI) will hydrolysis into $UO_2(OH)_2$ and $UO_2(OH)_3^-$[6],which go against the absorption. So, it can be divided into four regions that is 5< pH ≤7,4< pH≤5 or 7< pH ≤9, 2≤pH≤4 or 9≤pH<10 and pH <2or pH ≥10 and given 4,3,2,1 for represented. In this way quantitative factor can transform value. The four main effect factors in this test base on quantitative principle and ensure each factor's particular index value(TABLE 1).

Each factor of influence coefficient

Each factor of influence coefficient is measure of effect degree in adsorption of U(VI) by *Pseudomonas aeruginosa* loaded by nano-Fe_3O_4. The research uses the above test result. The removal rate of uranium by adsorption of U(VI) by *Pseudomonas aeruginosa* loaded by nano- adsorption of U(VI) by *Pseudomonas aeruginosa* loaded by nano-Fe_3O_4 was divided into four levels. Remove well(removal rate above

TABLE 1 : The Factors criterion test on the experimental of U(VI) adsorption by *Pseudomonas aeruginosa* loaded by nano-Fe_3O_4

Discrimination factor	Quantitative index value	Affect level	Discrimination factor	Quantitative index value	Affect level
pH	5< pH ≤7	4	Temperature(℃)	20<T≤30	4
	4< pH≤5 or 7< pH <9	3		10<T≤20	3
	2≤pH≤4 or9≤pH<10	2		30<T≤45	2
	pH <2 or pH ≥10	1		T≤10 或 T>45	1
Adsorbent dosage (g)	≥0.1	4	Initial potency of uranium (mg·L-1)	C_0≤10	4
	0.06≤C <0.1	3		10< C_0≤30	3
	0.02≤C <0.06	2		30< C_0≤50	2
	C <0.02	1		C_0>50	1

90%),remove better(removal rate range from 80% to 90%),remove generally(removal rate range from 50% to 80%) and remove poorly(removal rate below 50%). According to the principle of quantification determine its rating value for 4,3,2,1.

According to gray relational analysis, figure out respectively pH, temperature, adsorbent dosage and uranium concentration and the removal rate of the uranium. First, using formula(1) relational coefficient to synthesize every coefficient and using formula(2) to figure out relation, at last working out the relationship between effect factors and removal rate are that: pH is 0.7674,temperature is 0.7308, adsorbent dosage is 0.7113 and uranium concentration is 0.67821. With the normalization method, through the above to calculate the correlation of each influence factors on the U(VI) removal rate coefficient, we can get the answer are that: pH is 0.2657,temperature is 0.2531, adsorbent dosage is 0.2463 and uranium concentration is 0.2349.

Therefore, the ordering of effect degree of removal rate about U(VI) is pH, temperature, adsorbent dosage and uranium concentration.

CONCLUSION AND DISCUSSION

Above all, pH is the main effect factor of the test about absorption of U(VI) by *Pseudomonas aeruginosa* loaded by nano- Fe_3O_4. pH can control the state of ion adsorbent surface functional groups and surface composition of hydrolysis and U(VI) in the form of existence in the water and water in H^+ will compete with U(VI) adsorption, thus affecting the adsorbent adsorption of U(VI). It can be confined by experiment that NPFA have the best influence on absorbing U(VI) when PH=6. Second is temperature, which can provide the adsorbent energy, overcome the barrier of energy, affect the state of hydrolysis as well and so it can affect the process of absorption. The result shows that, the ability of NPFA's absorbing U(VI) increase as temperature increasing. But, too high temperature can affect membrane set ability. Which stops the transmission of metal icon and decreases the adsorption energy. The result shows that, when temperature up to 30 ! ,the removal rate reach the maximum.

Adsorption of U(VI) by *Pseudomonas aeruginosa* loaded by nano- Fe_3O_4 is an efficient method of radioactive wastewater containing treatment. The paper determines the main influence factors on the experimental of adsorption of U(VI) by *Pseudomonas aeruginosa* loaded by nano-Fe_3O_4 though ensuring the main factor of the experiment,which can provide a scientific basis for experimental design to treatment the wastewater containing U(VI).

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