Feeding preparation strategy for the supercritical water oxidation (SCWO) system for disposing of liquid hazardous waste

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ABSTRACT

Supercritical water oxidation (SCWO) technology has a great potential application for the disposal of liquid hazardous wastes. The feeding process is vital for the safety and normal operation of SCWO. This paper describes the feeding preparation strategy of SCWO with multilevel grouping and programming. Based on the physicochemical properties, the liquid hazardous wastes from various industrial manufacturers were first grouped into acid, neutral and alkaline groups. By C_n^2 mixing between samples, the primary grouping tanks were determined to be acid, alkali, amphoteric reacting, organic and organic high-chlorine liquid wastes. By distributing acid, alkali, amphoteric reacting liquid wastes into organic wastes, three parallel feeding routes are regulated for the homogenizing tank phase, which avoids the reaction between wastes. By calculating with the linear programming optimization model of MATLAB, the waste compatibility ratio of each feeding route was determined to meet the feeding requirements of SCWO. The feeding preparation strategy of this paper provides a practical instruction for the SCWO design and operation.

Key words | feeding progress, feeding strategy, liquid hazardous waste, supercritical water oxidation

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HIGHLIGHTS

- Supercritical water oxidation (SCWO) technology has great potential application for the disposal of liquid hazardous wastes.
- This paper describes the feeding preparation strategy of SCWO with multilevel grouping and programming.
- The feeding preparation strategy of this paper provides a practical instruction for the SCWO design and operation.

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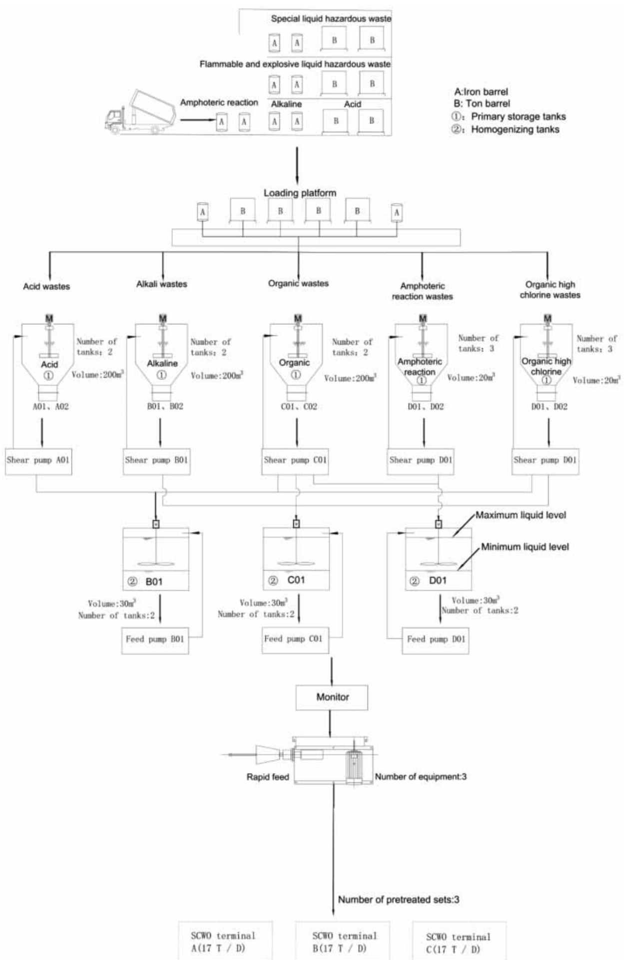
GRAPHICAL ABSTRACT



INTRODUCTION

Hazardous waste liquor, which is identified based on the National Catalogue of Hazardous Wastes (NCHWs, hazardous waste list in China) (Ministry of Environmental Protection of the People's Republic of China 2016) or standards (Ministry of Ecology and Environment of the People's Republic of China 2019), usually has one or more hazardous characteristics, such as corrosiveness, toxicity, flammability, reactivity and infectivity. These characteristics would cause environmental pollution incidents or casualties, if the hazardous waste is inappropriately disposed of (Duan *et al.* 2008; Quah & Cockerham 2017; Yang *et al.* 2020). Therefore, the safe disposal and management of hazardous wastes are essential for humans' wellbeing worldwide (El-Fadel *et al.* 2001). Traditional ways to dispose of hazardous waste are landfill and incineration, but the secondary pollution from landfill leachate (Verma & Kumar 2017) or incineration discharged air still pose health threats to humans.

Supercritical water oxidation (SCWO) is gradually becoming an attractive technique for hazardous waste disposal (Harradine *et al.* 1993; Yang *et al.* 2019) because of its high efficiency, stable operation, wide application and lack of secondary pollution. The mechanism of SCWO is to use supercritical state water as a reaction medium, which exploits the unique solvating properties (TC = 374.15°C, PC = 22.12 MPa), to provide enhanced solubility of organic reactants, so that the organic matter is completely dissolved in water to convert into small molecular compounds and then eventually turned to CO_2, N_2, water, etc. The composed elements such as Cl, S and P are converted into chloride, sulfate and phosphate, and the metal is converted into a non-hazardous substance such as steady-state oxides (Franck 1984). In recent years, China has encouraged SCWO's application to hazardous waste disposal. The first demonstration plant for SCWO was begun in 2015, aiming at harmless disposal of organic waste collected from various industrial factories in Tianjin. The feeding requirements for the demonstrated SCWO process are listed in Table 1. To get the qualified feeding, the grouping strategy is vital because it ensures the stable operating status, maximizes the economic cost and improves the safety management of the SCWO process. However, current research literature on SCWO in currently operational plants is still scarce, especially for the SCWO's feeding preparation process. Besides, the different type of SCWO reactors have their own specific feed requirements, with the feeding source and nature also varying in different regions. Therefore, the operating parameters of feeding preparation units such as material grouping and mixing ratio should be obtained through laboratory studies based on the characters of feeding hazardous liquor.

Table 1 | Feeding requirements for the SCWO system in a demonstration plant in Tianjin, China

Index	Range
pH	6–10
Calorific value	5.10 ± 5% MJ/kg
Total chlorine	<10,000 mg/L
Total phosphorus	<20 mg/L
Total nitrogen	<10,000 mg/L
Total salinity	<80 g/L
Particle size	<500 μm

The feeding process of liquid hazardous waste for SCWO studied in this paper is shown in Figure 1. The liquid hazardous waste enters the primary storage tanks through the raw material collecting platform, and the waste liquid in different primary storage tanks pumps into the corresponding homogeneous tanks based on sample compatibility; meanwhile, the calorific value and pH value are adjusted in homogeneous tanks. The qualified material is fed through the spray or injection pump into the SCWO terminal. Although the feeding process of liquid hazardous waste is relatively conventional, operating parameters such as raw material grouping and mixing ratio need to be determined through laboratory studies.

This paper will propose a feeding preparation strategy for an upcoming demonstrated SCWO process in China. Physicochemical properties of the samples from industrial factories were analyzed first, and then compatibility tests of samples were carried out to determine the group of primary tanks. An algorithm model of compatible feeding was constructed for the homogenizing tank. This paper provides a guiding framework for the design and operation of the feeding treatment process of the liquid hazardous wastes disposal based on the SCWO system.

METHODOLOGY

Hazardous waste properties analysis

Liquid hazardous waste samples were taken from 14 industrial plants (Table 2). The physicochemical properties and the corresponding analysis method are listed in Supplementary Table S1.

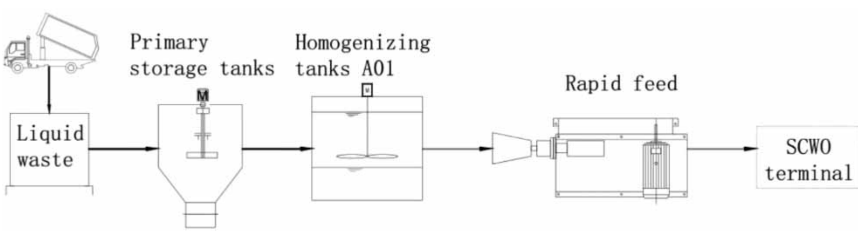


Figure 1 | Liquid hazardous waste feeding process of SCWO terminal.

Table 2 | Industry liquid hazardous waste samples

Number	Liquid hazardous waste information
1	Machinery factory washing waste liquid (1)
2	Water-based paint plant degreaser (2)
3	Resources recycling company metal waste acid (3)
4	Water-based paint factory waste liquid one (4)
5	Water-based paint factory water-containing solvent waste liquid (5)
6	Machinery plant sodium carbonate waste liquid (6)
7	Machinery factory cleaning agent waste liquid (7)
8	Machinery factory cutting waste liquid (8)
9	PPG paint factory water-based cleaning liquid (9)
10	Drug laboratory centrifuge mother liquor (10)
11	Water-based paint factory waste liquid two (11)
12	Food factory containing benzene residue (12)
13	Pharmaceutical factory waste organic solvent (13)
14	Polyurethane factory adhesive waste (14)

Grouping liquid hazardous waste for the primary storage tanks

In the primary storage tank stage, raw liquid hazardous wastes were grouped into acid, alkaline, organics and specific wastes based on their physicochemical properties. Then, the compatibility among the same group wastes was tested by analyzing the composition and carrying out the intermixing experiment. The composition of liquid hazardous wastes was analyzed by GC-MS (ISO 2016). The intermixing experiment of liquid hazardous wastes was carried out to judge the compatibility between the same group samples to see if they could be put into the same storage tanks. The same group samples were paired at C_n^2 combination, the pair was intermixed at equal proportions to observe if exothermic, precipitation and gas production phenomenon emerged. If there was any reaction, the reacted pair would be picked out for further re-pair until all stable coexisting materials were determined. The mixing experiments were conducted in the Erlenmeyer flasks, the pair samples were added in a volume of 50 mL, and then the flask was plugged by silica gel plug. The plug was perforated with an electronic thermometer and a 10-inch balloon. The flasks were oscillated continuously at room temperature for 30 min at 150 r/min to observe if the heat released or balloon bulged.

The coexisting materials were mixed at equal ratios, and then the physicochemical properties of the mixed liquids were tested as 2.1 described to check if any physicochemical properties of the mixed liquids changed. A total of seven important parameters of pH, particle size, salt content, P, Cl, N and calorific value were analyzed based on their physicochemical properties, then the same group hazardous wastes will be mixed for further storage.

Mixing scheme for the homogenizing tank

The homogenizing tank is the core step to provide the qualified feeding waste for the SCWO reactor. The quality standard of the feeding waste is listed in Table 1. To meet the feeding requirement meanwhile maximum consuming low calorific value wastes during the homogenizing phase. The mixing scheme of liquid wastes from primary tanks should be designed based on the compatible mixing regulations, and the feasibility of the process route must be verified by experiments. Then, the theoretical prediction algorithm model is established to obtain the optimal scheme for the stable operation of the system.

Compatible mixing regulations

The safety and stability during mixing wastes from primary tanks should be guaranteed. Any potential reaction should be avoided after the liquid wastes from different primary tanks are pumped into the homogenizing tanks.

The mixing proportion of high phosphorus-containing material from the primary storage tank into homogenizing tanks should be strictly controlled.

Organic high-chlorine liquid waste should be dosed as combustion improver upon reaching the upper limit of Cl because of its high calorific value and Cl content.

Compatible feeding test experiment

After determining the feeding route based on compatible mixing regulations, the mixing experiment was carried out to test the compatibility of materials from different primary tanks by flask test. Because of the stratification characteristics of oil–water mixture in a static state, it is necessary to verify if oil–water mixture can be maintained at the uniform state by agitation shaking.

pH adjustment

The pH of the SCWO reactor should be in the range of 6–9, 30% sodium hydroxide is used in the experiment of the acid group and alkali adjustment, and the proportion is determined.

Compatibility feeding algorithm model

Based on the results of the compatible feeding test, MATLAB software was used to build the batching model. Algorithms and procedures are attached. The linear programming algorithm was applied to determine the mixing portion of wastes from various primary tanks by calculating the ingredients of wastes.

RESULTS AND DISCUSSION

Physicochemical properties of hazardous waste

Table 3 shows that among 14 samples, three samples are water-insoluble organic, one sample stratified into an organic upper layer and water-soluble under layer. The rest of the samples are water-soluble. Therefore, the samples have been classified into acid, neutral and alkaline groups based on the pH value for the primary storage tanks.

The calorific value of hazardous waste from different types of industries varied significantly, and there are huge differences between organic liquids and water-soluble liquids. The organic liquid samples such as samples (12), (2up), (13) and (14) have calorific values more than 12.80 MJ/kg, which is considered as flammable. Meanwhile, the water-soluble liquid sample has a relatively low calorific value, which can be defined as a non-combustible material. The calorific value of samples (5) and (10) is obviously higher than that of other water-soluble liquid samples, and the calorific value of other samples is generally low or almost zero.

As to the Cl and P percentage, benzene residue organic sample (12) contains a much higher Cl, mechanical plant cleaning agent waste (7) and waterborne paint factory waste sample (11) contain much higher phosphorus, which are all more than SCWO system feed requirement. Other elements are in an acceptable percentage. Therefore, it is necessary to focus on these three types of materials in the subsequent compatibility feeding process.

As to the insoluble particulate matter, only cleaning agent waste liquor (7) from the machinery plant has a tiny amount of particulate matter larger than 500 μm. The solid content of this sample was about 0.68%, of which only 1.75% was particulate matter larger than 500 μm. This tiny amount could be separated by the fine sieve pre-filtration process before the material enters the storage tank.

Analysis of organic components

The main soluble and volatile organic components of liquid waste are shown in Supplementary Table S2. Waterborne coating plant deoiling agent organic phase (2up), pharmaceutical plant waste organic solvent (13) and polyurethane plant adhesive waste (14) also contain a certain amount of benzene series, such as toluene, ethylbenzene, and a large number of volatile ketones and esters, such as acetone and ethyl acetate, which are harmful to human blood, nervous systems and reproductive systems. Compared with other water-soluble liquid samples, water-based paint factory aqueous solvent waste liquid (5) and drug laboratory centrifugal mother liquid (10) contain a higher concentration of organic matter, mainly alcohols with a low boiling point, so their flash point is low and can easily cause fires. There are nine kinds of organic components in benzene residue (12) from the food factory, almost all of them aromatic hydrocarbons, and more than half of them containing the Cl group, which is toxic to the organism and can cause direct harm to human health. In addition to the drug laboratory centrifugal mother liquid (10), the organic components in other water-soluble liquid samples are low and mainly aliphatic hydrocarbons, mostly alkanes, ketones, ethers, alcohols and esters.

Primary storage tank grouping

The compatibility of samples in the acid and alkaline group

As shown in Figure 1, primary storage tanks are extremely important units for the long-term stable and safe storage of the raw liquid hazardous wastes, and also act as the ingredient supplying cabinets for the next homogenizing steps. Raw

Table 3 | Physicochemical properties of samples

Sample code	Phase	pH	Calorific value (MJ/kg)	Cl (mg/L)	P (mg/L)	N (mg/L)	Salt content(g/L)	Particle size (μm)	S (mg/L)	I (μg/L)	F (mg/L)	COD (mg/L)
1	WS	2.31	0.00	1,221.30	0.08	341.41	3.00	<500	0.00	341.67	NO	142.00
2down	WS	4.24	0.00	26.10	0.14	94.74	0.00	NO	0.00	698.83	NO	5,700.00
3	WS	1.39	0.01	924.50	0.70	480.22	3.18	<500	3,590.03	1,742.11	197.83	13,333.00
4	WS	6.19	2.54	409.70	3.39	93.86	2.07	<500	136.38	795.25	NO	237,383.00
5	WS	5.90	7.23	32.18	1.03	94.36	4.62	<500	699.71	1,676.83	NO	628,696.00
6	WS	10.32	0.00	211.80	0.69	96.08	16.81	<500	0.00	394.25	NO	61.00
7	WS	9.58	0.57	32.80	865	94.96	2.10	>500	134.82	0.00	NO	55,340.00
8	WS	7.10	0.62	12,187.50	5.49	94.96	0.60	<500	911.82	237.45	NO	47,692.00
9	WS	8.30	0.81	35.20	9.06	96.13	3.29	<500	222.74	0.00	NO	57,857.00
10	WS	7.46	4.21	14.71	0.88	361.28	0.34	<500	849.10	177.25	NO	359,829.00
11	WS	7.45	0.77	27.82	491.10	95.69	9.77	<500	661.93	922.67	NO	69,868.00
12	Organic	NO	21.97	147,264.88	0.63	7,873.20	NO	NO	1,258.20	0.00	NO	NO
2up	Organic	NO	34.77	1,081.40	0.88	345.11	NO	<500	414.50	1,097.50	NO	NO
13	Organic	NO	36.50	1,233.80	1.30	234.90	NO	NO	317.20	604.92	NO	NO
14	Organic	NO	24.40	2,706.10	5.45	290.10	NO	NO	352.40	0.00	NO	NO

WS, water solubility; NO, none.

liquid hazardous wastes were transported in individual barrels to the primary storage tank stage, so they should first be divided into different groups. Reasonable grouping and mixing the raw liquid hazardous wastes could reduce the number of primary tanks, which would reduce investment and facilitate safety management. More importantly, when the same grouping wastes are mixed into the same storage tank, they must stay stable and compatible. That is, overheating, sedimentation and excessive pressure should be strictly prevented in the primary tank after the same grouping wastes are mixed.

The C_n^2 reaction between samples in acid and alkaline liquid hazardous waste is shown in Table 4. The water-based paint factory waste liquid (4) could result in the milky white turbidity and yellow particle sticking on the wall. After adding water-based paint factory aqueous solvent waste liquid (5), the phenomenon is more obvious, indicating that the water-based paint factory waste liquid (4) and corresponding aqueous solvent waste liquid (5) are easy to react with other materials in the acid group. This water-soluble colloidal material will quickly precipitate after mixing with the strong acid waste liquid. The alkaline group showed the water-based paint factory waste liquid (11) reacted with the rest of the alkaline samples, forming black particles sticky on the tube wall. This may be ascribed to neutral (pH = 7.45) of water-based paint factory waste liquid two (11), the water-soluble colloidal substance is quickly precipitated after being mixed with the higher alkali waste. Therefore, the samples from water-based paint factory waste liquid (4, 5 and 11) should be picked out and defined as reactive materials.

The compatibility of samples in organic groups

There was no obvious reaction phenomenon in the samples of the organic group, and it was preliminarily concluded that the organic group samples could be mixed completely. After mixing, the organic components solved mutually well and formed a stable solution. However, the benzene residue from the food factory (12) has an extremely high Cl content; considering its large calorific value, the benzene residue can be used as a liquid combustion improver meanwhile diluting its total Cl content. Therefore, an isolated tank for holding the benzene residue is proposed in the primary stage.

Physicochemical properties of the grouped mixture

Based on the physicochemical properties and equal portion mixing experiment, the liquid hazardous wastes from 14 industries can be initially grouped into five categories, namely acid, alkali, amphoteric reactions, organic and organic high chlorine in the primary storage tanks phase (Table 5).

The physicochemical properties of the mixture of each group are shown in Table 6. The actual measured values are close to the calculated values obtained by summing

Table 4 | Material compatibility reaction in the acid group and the alkaline group

Acid group

Samples	1	2down	3	4	5
1	–				
2down	–	–			
3	–	–	–		
4	–	–	White bonding, sticky bottom precipitation	–	
5	White and orange granules are bonded and wall-precipitated	–	Wall precipitation of white insoluble particulate matter	–	–

Alkaline group

Samples	6	7	8	9	10	11
6	–					
7	–	–				
8	–	–	–			
9	–	–	–	–		
10	–	–	–	–	–	
11	Black insoluble particles	Black insoluble particles	–	Black insoluble particles	–	–

Note: '–' indicates no phenomenon.

Table 5 | Primary storage tanks grouping

Category	Liquid hazardous waste
Acidic	Mechanical washing waste liquid (1), water-based paint factory deoiling agent aqueous phase waste liquid (2down), resource recycling company metal waste acid (3)
Alkaline	Machinery plant sodium carbonate waste liquid (6), mechanical cleaning agent waste liquid (7), mechanical cutting waste liquid (8), PPG paint factory water-based cleaning liquid (9), drug laboratory centrifugal mother liquid (10)
Amphoteric reaction	Water-based paint factory waste liquid (4), water-based paint factory waste liquid (11), water-based paint factory aqueous solvent waste liquid (5)
Organic	Waterborne coating plant deoiling agent organic phase (2up), pharmaceutical plant waste organic solvent (13), polyurethane plant adhesive waste (14)
Organic high chlorine	Food factory containing benzene residue (12)

the individual portion, which illustrated no reaction among the same group wastes.

Homogenizing tank grouping

Three feeding routes are regulated for the homogenizing tank phase, that is (1) the mixing of the acid, the organic high-chlorine and the organic group wastes, (2) the mixing of the alkali, organic high-chlorine and organic group wastes and (3) the mixing of the amphoteric reaction and the organic wastes. There is no reaction observed in each route after three group wastes are mixed, and the mixture can be uniformly mixed by shaking well. After standing, the mixture gradually shows a stratification phenomenon and quickly returns to the turbid state if stirred and shaken again. The physicochemical properties of the mixture in each route do not change significantly after mixing (Table 7).

The feeding plan

The liquid hazardous wastes of various industries are transported to the plant area by hazardous chemical tank truck, and then enter into each temporary storage area according to the group. The materials in each storage area enter the corresponding primary storage tank through the loading platform and mix evenly. Then, the materials in each primary storage tank are divided into three routes and transported to the homogenizing tank according to the compatibility ratio. The material after uniform mixing meets the feeding requirements through monitoring, and then it is fed quickly through the high-speed feed pump in Figure 2.

Table 6 | Physicochemical properties of materials in various storage tanks after equal mixing

Category	pH	Calorific value (MJ/kg)	Cl (mg/L)	P (mg/L)	N (mg/L)	Salt content (g/L)	Particle size (μm)
Acidic	1.84	0.00	735.60	0.31	312.80	2.16	<500
Alkaline	9.92	1.12	2,485.60	176.20	146.20	4.89	<500
Amphoteric reaction	6.36	3.83	162.40	165.20	95.80	5.72	<500
Organic	NO	32.23	1,685.20	2.50	284.80	NO	NO
Organic high chlorine	NO	21.97	147,264.88	0.63	7,873.20	NO	NO

NO, none.

Table 7 | The physicochemical properties of the mixture in each feeding route

Storage tank ratio	Calorific value (MJ/kg)	Cl (mg/L)	P (mg/L)	N (mg/L)	Salt content (g/L)
Acid:Organic high chlorine:Organic (1:1:1)	16.72	48,427.86	1.21	3,015.60	0.74
Alkali:Organic high chlorine:Organic (1:1:1)	17.14	51,434.42	64.82	2,546.70	1.58
Amphoteric reaction:Organic (1:1)	17.85	902.81	85.56	185.19	1.91

Table 8 | Application results of the algorithm model

Route	Compatibility ratio					Calorific value (MJ/kg)	Cl (mg/L)	P (mg/L)	N (mg/L)	Salt content (g/L)
	Acidic	Alkaline	Amphoteric reacting	Organic	Organic perchlorides					
1	13.13			1.87	1.00	5.10	9,993.60	0.587	776.60	1.69
2		17.60		1.50	1.00	5.10	9,998.90	17.59	550.20	4.49
3			73.07	1.00		5.10	233.60	19.86	96.80	3.53

Compatibility feeding algorithm model

(1) Objective function

The ingredients based on the SCWO system should consider the largest possible consumption of materials in acid storage tanks, alkali storage tanks and amphoteric reacting waste storage tanks, and then preferentially select materials in organic high-chlorine storage tanks. Adjust to the upper limit of Cl and increase the calorific value, and finally adjust the calorific value with a small amount of material in the organic storage tank. The objective function is

$$\text{Max} f(x) = x_1 + x_2$$

where $f(x)$ represents the total proportion of liquid hazardous waste in the batch, %; x_1 represents the proportion of the material in the acid storage tank (or the material in the alkali storage tank or the material in the amphoteric tank), %; x_2 represents the proportion of material in the organic high-chlorine storage tank in the batch, %.

(2) Constraints

The constraints of the ingredients in the model are the feed requirements of the SCWO system:

$$\begin{cases} A_1x_1 + A_2x_2 + A_3x_3 \leq 10,000 \\ B_1x_1 + B_2x_2 + B_3x_3 \leq 10,000 \\ C_1x_1 + C_2x_2 + C_3x_3 \leq 20 \\ D_1x_1 + D_2x_2 + D_3x_3 = 5.1 \\ E_1x_1 + E_2x_2 + E_3x_3 \leq 80 \\ x_1 + x_2 + x_3 = 1 \\ 0 \leq x_1,\ x_2,\ x_3 \leq 1 \end{cases}$$

where x_1, x_2, x_3 respectively represent the materials in the acid storage tank in the batch (the material in the alkali storage tank or the material in the double reaction storage tank), the material in the organic storage tank, and the material in the organic high-chlorine storage tank, %; A_1, A_2, A_3 respectively represent the Cl content of the material in the corresponding storage tank, mg/L; B_1, B_2, B_3 respectively represent the N content of the corresponding material in the storage tank, mg/L; C_1, C_2, C_3 respectively represent the P content of the material in the corresponding tank, mg/L; D_1, D_2, D_3 respectively represent the calorific value of the material in the corresponding tank, MJ/kg; E_1, E_2, E_3 respectively represent the salt content of the material in the corresponding tank, g/L.

(3) MATLAB software editing

Linprog command is applied to find the optimal solution to the linear programming problem, the parameter form is [x, fval] = linprog (f, A, b, Aeq, beq, lb, ub).

The programming language of this study can be edited as:

```
f = [−1; −1];
A = [ A1 A2 A3; B1 B2 B3; C1 C2 C3; E1 E2 E3];
b = [10000;10000;20;80];
Aeq = [D1 D2 D3;1 1 1];
beq = [5.1;1];
lb = [0;0;0];
ub = [1;1;1];
[x, fval] = linprog (f, A, b, Aeq, beq, lb, ub)
```

[x, fval]: indicates that x is the optimal solution and fval is the optimal value.

f: represents the coefficient vector in front of each variable in the objective function. If it is the minimum value problem, then f is the coefficient of each variable. If it is the maximum value problem, then f is the opposite of the coefficient of each variable;

A and b: represent the matrix A and the vector b in the inequality constraint $A \times x \leq b$;

Aeq and beq: represent the matrix Aeq and the vector beq in the equality constraint $Aeq \times x = beq$;

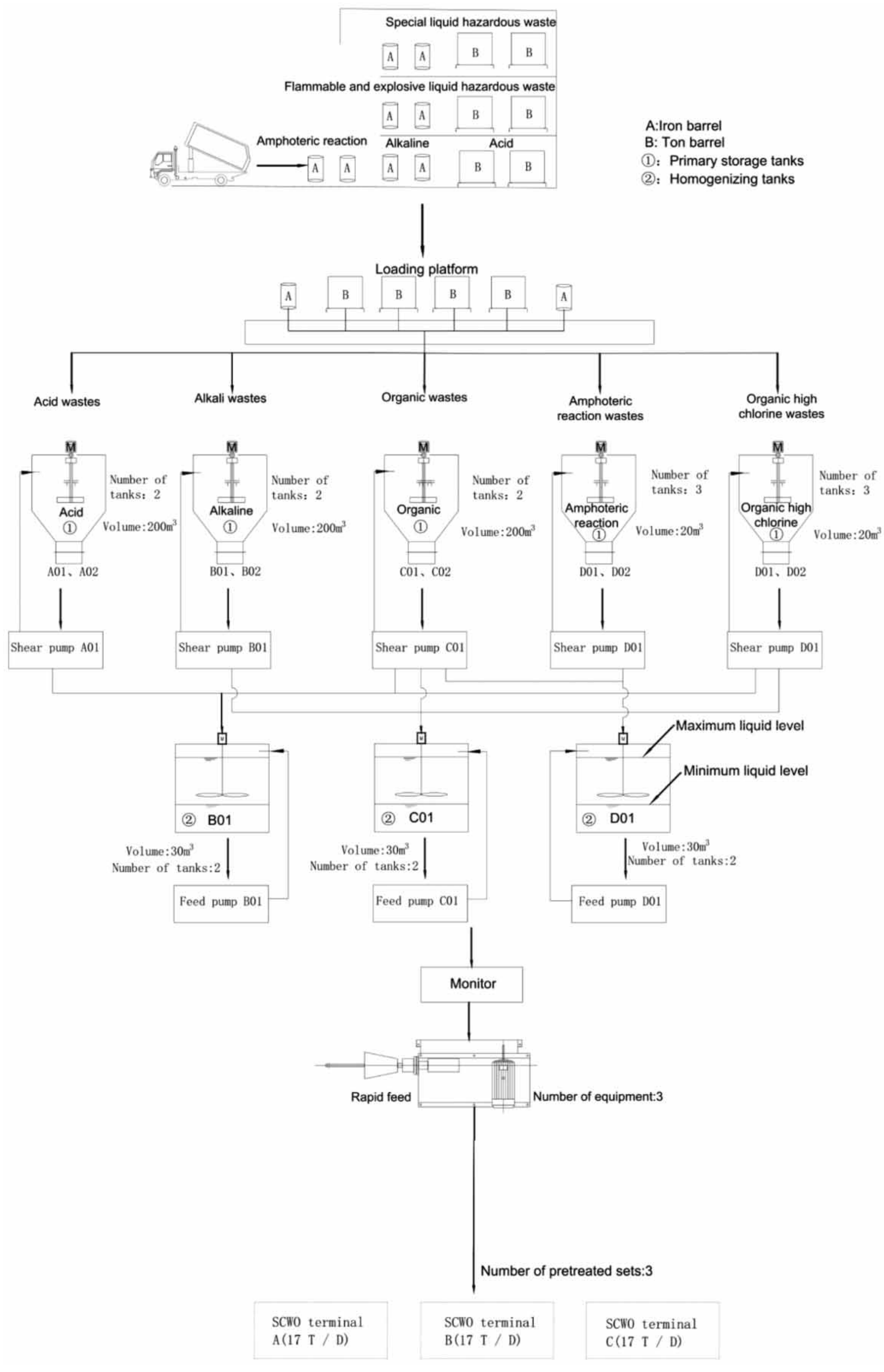


Figure 2 | General process of the feed pretreatment process for liquid hazardous waste.

Lb and ub: vectors representing the upper and lower bounds of the independent variables, respectively.

By using the linear programming optimization model of MATLAB, the optimal compatibility schemes of three feeding routes are simulated and calculated, respectively, in Table 8. The linear programming optimization algorithm model can be applied to three compatible feeding routes, and the materials after the compatibility meet the feeding index of the SCWO system. Therefore, it is certain to be applied in practical industrial operations.

CONCLUSIONS

This paper proposes a systematic strategy on how to design the feeding process of SCWO to not only safely meet the feed requirement but also maximally dispose of liquid hazardous waste. The feeding step of the storage tank was proposed as primary and homogenizing tanks. Based on the composition identification of the unknown hazard wastes, the hazards wastes were grouped to acid, alkaline, amphoteric reacted, organic and organic perchlorides in the primary tank. Then, three mixing routes for the homogenizing tank from the hazard wastes of the primary tank were proposed, that is, the acid, alkali or amphoteric reacted individually mixed with organic and organic perchlorides. Primary storage tanks help optimize process costs and safety management while stabilizing the feed. With the MATLAB programming, the material compatibility optimization model was established based on the linear programming algorithm. The model showed that the first, second and third feeding route compatibility ratio was 13.13 : 1.87 : 1.00, 17.60 : 1.50 : 1.00 and 73.07 : 1.00, respectively. With this strategy, the largest amount of liquid hazardous wastes could be disposed of without adding external fuel, which maximizes economic benefits while guaranteeing the safety.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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