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Guidelines for wastewater treatment and reuse in thermal power plants

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Foreword

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This document was prepared by Technical Committee ISO/TC 282, *Water reuse*, Subcommittee SC 4, *Industrial water reuse.*

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at ~~www.iso.org/members.html~~www.iso.org/members.html.

Introduction

Global water scarcity is becoming increasingly pronounced as a result of the massive demand for water brought aboutcaused by population growth, public life and industrial growth. Due to the increasing cost of water and sewage disposal, wastewater reuse in thermal power plants is being initiated. The number of wastewater recycling projects in thermal power plants is increasing and water treatment and reuse technologies are being developed. Studies have shown that electric power plants account for approximately half the global industrial water withdrawal[1], which means the problem of water shortage will be aggravated with the expansion of thermal power plants.

Although the generation of electricity from renewable sources (e.g. wind, hydro and solar photovoltaic) with almost zero water consumption is growing, the proportion of world gross electricity generated by combustible fuels still accounted for 64.1 % in 2020[2]. In addition, the wastewater from thermal power plants (power plants that generate electricity from combustible fuels) is diverse, with a high volume and complex pollutant components[3], and its discharge poses a threat to the ecology of water environments. Therefore, the reuse of wastewater from thermal power plants has dual benefits of water saving and environmental protection.

The increasing efforts to control water scarcity and water pollution in some countries have made industrial wastewater reuse a valuable means of augmenting the existing water supply and reducing wastewater discharge to the environment. In terms of wastewater treatment and reuse in thermal power plants, the United States[4], China[5], Japan[6] and International Energy Agency (IEA)[7] have all introduced relevant policies to encourage wastewater reuse or even zero discharge in thermal power plants.

However, the reclaimed water quantity of wastewater in thermal power plants is not high, and the different characteristics of wastewater generated from different systems are ignored. Therefore, it is necessary to strengthen the classification and characteristic analysis of wastewater, adopt more reasonable and efficient treatment and reuse technologies in thermal power plants to optimize the reclaimed water quantity of wastewater, to realize zero liquid discharge of wastewater and to improve the benefits of water saving and environmental protection and ultimately achieve the sustainable development goals (see www.un.org/sustainabledevelopment).www.un.org/sustainabledevelopment).

Guidelines for wastewater treatment and reuse in thermal power plants

1 Scope

This document specifies guidelines for wastewater treatment and reuse in thermal power plants, including the types and characteristics of wastewater and the technologies of wastewater treatment and reuse.

In this document, thermal power plant drainage systems are divided into fuel supply, chemical water treatment, boiler and auxiliary, recirculating cooling, flue gas processing, gasification scrubber and ash handling. Wastewater from these systems is classified in accordance with its system sources. In addition, technical guidelines for wastewater treatment and reuse are provided according to the water requirements of systems in the thermal power plant. This document is formulated to provide feasible technical guidance for the treatment and reuse of wastewater in thermal power plants.

It is applicable to coal-fired, oil-fired, gas-fired (including gas turbine), biomass-fired, waste incineration and integrated gasification combined cycle (IGCC) thermal power plants.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 20670, *Water reuse — Vocabulary*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the terms and definitions given in ISO 20670 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at ~~https://www.iso.org/obp~~https://www.iso.org/obp

— IEC Electropedia: available at ~~https://www.electropedia.org/~~https://www.electropedia.org/

3.1 Terms ~~and,~~ definitions and abbreviated terms

3.1.1
advanced treatment for TDS
advanced treatment for total dissolved solids
process of further reducing the salt content in wastewater by using advanced treatment technology after pretreatment to achieve certain reuse water targets

3.1.2
ash handling system
system that includes all the equipment, pipelines and monitoring devices for collecting bottom ash and fly ash from combustion or gasification of fuel in boilers and transferring it out of the power plant

3.1.3
boiler and auxiliary system

system that includes primary production equipment for the combustion or gasification of fuel and other auxiliary machinery

3.1.4
chemical water treatment system
system that treats the raw water to achieve water quality requirements for the different water applications in the power plant

Note 1 to entry: A chemical water treatment system includes the raw water pretreatment, boiler replenishment water treatment, condensate polishing treatment and wastewater treatment

3.1.5
flue gas processing system
system that purifies boiler flue gas and reduces pollutants such as sulfur dioxide, nitrogen oxides, particulate matter and organic gas in flue gas

3.1.6
fuel supply system
system that collects, stores, pre-treats and transports combustible fuels for power generation

3.1.7
gasification scrubber system
system that purifies gaseous fuel after gasification of solid or liquid fuel

3.1.8
recirculating cooling system
system that circularly uses a cooling medium (e.g. water, air) to transfer heat

Note 1 to entry: A recirculating cooling system consists of heat exchange equipment, cooling equipment, treatment facilities, pumps, pipelines and other related facilities.

3.1.9
reclaimed water quantity
amount of water that is directly cascade-utilized or reused after proper treatment in the production process of the thermal power plant

3.1.10
thermal power plant
power plant that converts heat, such as that released by the combustion of carbonaceous fuels, into electricity

Note 1 to entry: Carbonaceous fuels include coal and coal products, oil and oil products, natural gas, biofuels from biomass, industrial waste and municipal waste.

[SOURCE: ISO 27919-1:2018, 3.1.42, modified — Definition revised and note to entry added.]

3.2 Abbreviated terms

A/O	anoxic/oxic
BOD_5	biochemical oxygen demand after 5 days
COD	chemical oxygen demand
EDTA	ethylene diamine tetraacetic acid
FGD	flue gas desulfurization
IGCC	integrated gasification combined cycle
MBR	membrane bioreactor
MVR	mechanical vapor recompression
NF	nanofiltration
NTU	nephelometric turbidity unit
PAHs	polycyclic aromatic hydrocarbons
RO	reverse osmosis
TDS	total dissolved solids
TP	total phosphorus
TSS	total suspended solids
UASB	upflow anaerobic sludge blanket
UF	ultrafiltration
WESP	wet electrostatic precipitator

4 General principles

The following principles should be followed for the treatment and reuse of wastewater in thermal power plants~~:~~.

a) The wastewater should be treated and reused separately if its water quality and reuse target are different.

b) If wastewater has similar water quality and the same reuse target, similar treatment processes can be adopted.

c) Wastewater that meets the water quality requirements of the reuse target can be directly utilized in the target system.

d) The process flow of wastewater treatment and reuse in thermal power plants should be determined taking requirements of the effluent water quantity and quality, influent water quality of reuse targets, site conditions, environmental protection and other factors into account during the technical and economic review~~.~~.

e) The entire plant water balance should be optimized before designing a water reuse plan. The water withdrawal, consumption and drainage of each system should be considered through a water balance. The water quality requirements of each system should also be considered. (See Annex A)

5 Types and characteristics of wastewater in thermal power plants

Wastewater in thermal power plants can be classified based on the following systems: fuel supply, chemical water treatment, boiler and auxiliary, recirculating cooling, flue gas processing, gasification scrubber and ash handling~~[.][8][.]~~ The types of wastewater in each system are shown in Table 1.

Table 1 — Types of wastewater in thermal power plants

System source	Type	Involved power plants
Fuel supply	Coal wastewater[a]	Coal-fired power plants, IGCC
	Oily wastewater[b]	All power plants
	Leachate[c]	Biomass-fired power plants, waste incineration power plants
Chemical water treatment	RO concentrated water[d]	All power plants
	Membrane washing wastewater[e]	
	Resin reclaimed wastewater[f]	
Boiler and auxiliary	Boiler blowdown[g]	All power plants
	Boiler chemical cleaning wastewater[h]	
	Auxiliary equipment cooling water blowdown[i]	
Recirculating cooling	Cooling tower blowdown[j]	All power plants
Flue gas processing	WESP blowdown[k]	Coal-fired power plants
	FGD wastewater[l]	Coal-fired power plants, oil-fired power plants, biomass-fired power plants, waste incineration power plants
Gasification scrubber	Tar-containing wastewater[m]	Biomass gasification power plants, IGCC
Ash handling	Ash handling wastewater[n]	Coal-fired power plants, biomass-fired power plants, waste incineration power plants

[a] Coal wastewater has high TSS, COD, chroma and turbidity. The TSS concentration can be between 200 mg/l and 5,000 mg/l. Coal wastewater includes the leakage caused by the spraying and dustproofing in the coal yard, the washing waste water caused by the washing of the coal transporting trestle, the rain water in the coal yard and the effluent water after dust removal in the coal conveying system.

[b] Oily wastewater includes oil slick, disperse oil, emulsified oil and dissolved oil.[9] It can come from the oil storage facilities, the leakage of the oil system in the main plant during the operation of the steam engine and the power generation turning machine bearings, and the oily wastewater generated during the operation, cleaning or overhaul of the equipment.

[c] Leachate has high COD, BOD_5, ammonia nitrogen, TSS and heavy metals, with a pH of 5~7.[10] It comes from the biochemical degradation during the stacking process of biomass or waste. Its quantity and quality are different due to the types of waste generated from various sites, fuel composition and climatic conditions at the power plants.

[d] RO-concentrated water is of high salinity, and its quality is related to the quality of raw water. It is concentrated wastewater generated during the operation of the RO membrane filtration system in the chemical water treatment system of the power plants.[11]

[e] Membrane washing wastewater is acidic or alkaline and has a high salinity. It comes from the physical and chemical cleaning of membrane components in chemical water treatment system. Its quantity and quality are related to the quality of raw water and the concentration of chemical cleaning agent.

[f] Resin reclaimed wastewater is the acid or alkali wastewater from the regeneration of ion-exchange resin in the chemical water treatment system. It is of high TDS and TSS. Its quantity and quality are related to resin regeneration time and acid and base dosage.

[g] Boiler blowdown can be divided into boiler continuous blowdown and boiler regular blowdown. The boiler continuous blowdown contains only a small amount of Na^+, ~~PO_4^{3-}, CO_3^{2-}, SiO_3^{2-},~~ PO_4^{3-}, CO_4^{2-}, SiO_4^{2-}, Fe^{2+}, Fe^{3+} and other salts. The iron content in the boiler regular blowdown is high and contains ammonia nitrogen, TSS and COD.[12]

[h] Boiler chemical cleaning wastewater has high TDS, COD and TSS. Major pollutants are dependent on the type of acid cleaning agent, such as hydrochloric acid, citric acid, complex acid and EDTA, used in the process of boiler chemical cleaning.

[i] Auxiliary equipment cooling water blowdown contains a small amount of TDS and the water quality is high. It comes from the cooling water system of auxiliary equipment of the power plant.

[j] Cooling tower blowdown has high salinity, which has the largest flow rate in thermal power plants. Its quantity and quality are related to the concentration ratio. The common pollutants include TSS, colloid, organic matter, inorganic salts, microorganisms and algae. These pollutants come mainly from supplemental water and chemicals added to the water cycle, as well as pollutants that grow in the system.

[k] WESP blowdown can be split into WESP continuous blowdown and WESP regular blowdown since the cleaning types of WESP include continuous-flow water cleaning and spray cleaning. The WESP blowdown is acidic wastewater, including TSS, TDS and heavy metal. Its quantity is related to the cleaning type of WESP.

[l] FGD wastewater is acidic, with a pH value between 4 and 6, containing a large number of TSS (e.g. gypsum particles, SiO_2, CaF_2) and a certain amount of COD. TSS is about 10,000 mg/l or more, TDS ranges between 30,000 mg/l to 65,000 mg/l. The hardness is relatively high. The anions in wastewater are mainly Cl^- and sulfate radical ions, and there are many kinds of heavy metal cation, such as mercury, lead, zinc, nickel and arsenic.

[m] Tar-containing wastewater is the organic wastewater with tar as the main pollutant produced by wet gas purification equipment. Tar can be considered a mixture of several acidic, alkaline and neutral compounds. The acidic components include acids and phenols, the basic components include nitrogen-containing compounds and the neutral components include PAHs.[12] In addition, the wastewater also contains ammonia nitrogen, chloride and other inorganic substances.

[n] The quality of ash handling wastewater is determined by the chemical composition of ash. Since the fuel source is not fixed, the water quality of ash handling wastewater is also unstable. In general, ash wastewater is of high pH and TDS. The pH value is generally greater than 9 and sometimes more than 10.5. It contains heavy metal elements and fluoride dissolved from ash residue. The TSS of ash handling wastewater in the slurry concentration pool is higher.

Field Code Changed

6 Wastewater treatment and reuse technologies

6.1 Water quality requirements for reuse water in thermal power plants

To ensure the proper operation of each system, it is recommended that the reuse water quality after treatment meet the requirements of influent water for the given target. The required water quality parameters of various types of industrial reuse water are given in Table 2.

Table 2 — Required water quality parameters of reuse water

No.	Parameter	Fuel supply system		Chemical water treatment system-	Boiler and auxiliary system		Recirculating cooling system-	Flue gas processing system		Gasification scrubber system- Process water	Ash handling system- Ash handling water
		Washing water	Dust-suppressing water	Influent water	Boiler make-up water[a]	Cooling water	Cooling water	WESP cleaning water	Process water		
1	pH (25 °C)	6,5 to 9,0	6,5 to 9,0	C	8,8 to 9,3	7,0 to 9,5	6,5 to 8,5	6,0 to 8,0	6,5 to 9,5	C	6,5 to 9,0
2	TSS (mg/l)	≤ 30	≤ 30	C	C	C	≤ 30	≤ 150	≤ 50	O	≤ 30
3	Turbidity (NTU)	O	O	O	C	C	≤ 5	C	O	O	O
4	Chroma	≤ 30	≤ 30	C	C	C	≤ 30	C	C	C	≤ 30
5	BOD_5 (mg/l)	≤ 30	≤ 30	C	C	C	≤ 10	C	C	C	≤ 30
6	COD (mg/l)	O	O	O	O	C	≤ 60	O	O	O	O
7	Fe (mg/l)	≤ 0,3	≤ 0,3	O	O	C	≤ 0,3	C	C	C	≤ 0,3
8	Mn (mg/l)	≤ 0,1	≤ 0,1	O	C	C	≤ 0,1	C	C	C	≤ 0,1
9	Cl^- (mg/l)	≤ 250	≤ 250	C	O	C	C	≤ 200	≤ 1,000	C	≤ 250
10	SiO_2 (mg/l)	O	O	O	≤ 0,02	C	≤ 50	O	O	O	O
11	Total hardness (mg/l)	≤ 450	≤ 450	C	≤ 0,002	C	≤ 450	≤ 200	≤ 250	C	≤ 450
12	Total alkalinity (mg/l)	≤ 350	≤ 350	C	C	C	≤ 350	C	C	C	≤ 350
13	Sulfate (mg/l)	≤ 250	≤ 250	C	C	C	≤ 600	≤ 200	≤ 400	C	≤ 250
14	NH_3-N (mg/l)	O	O	O	C	C	≤ 10	≤ 10	≤ 10	O	O
15	TP (mg/l)	O	O	O	C	C	≤ 1	≤ 5	≤ 5	O	O
16	TDS (mg/l)	≤ 1,000	≤ 1,000	C	≤ 0,1	C	≤ 1,000	C	C	C	≤ 1,000
17	Petroleum (mg/l)	C	O	O	C	C	≤ 5	0	0	C	O

NOTE The values in this table refer to References [14] to [21].

[a] The water quality of boiler make-up water in the boiler and auxiliary system should meet the following additional targets: TOC (total organic carbon) ≤ 0,4 mg/l, conductivity (25 °C) ≤ 0,4 µS/cm.

Key

C: The indicator is controlled; the value or range of the indicator is conditional.

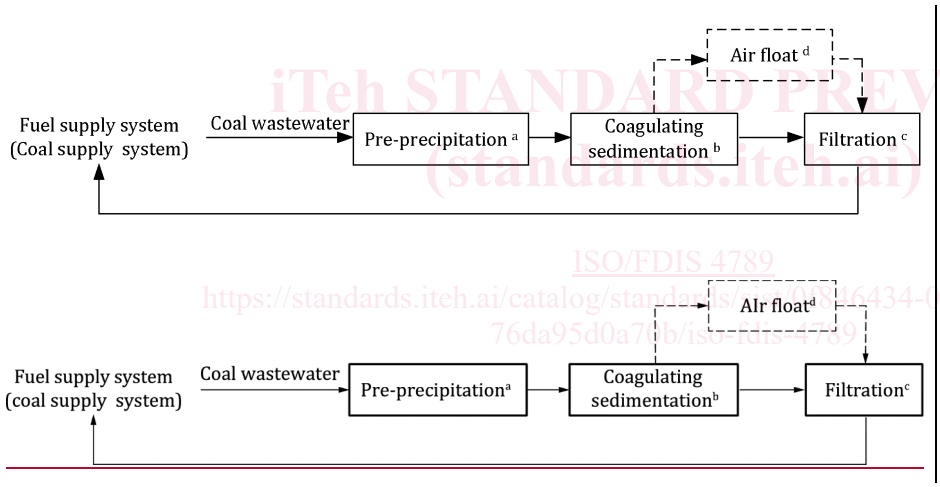
O: The indicator is optional.

6.2 Fuel supply system wastewater treatment and reuse

6.2.1 Coal wastewater

According to the effluent water quality of coal wastewater and the influent water quality requirements for the reuse targets, pre-precipitation, coagulating sedimentation, filtration, etc. or a combination of processes can be adopted to treat the coal wastewater. Options for treatment and reuse processes are shown in Figure 1.

The effluent after pre-precipitation, coagulating sedimentation and filtration treatment can be reused in the coal supply system (washing water for coal conveying facilities, dust-suppressing water for spraying in dry coal yard).



[a] The pre-precipitation of coal wastewater is used to separate large particles of solids from wastewater. Sedimentation by gravity can be used.

[b] The coagulating sedimentation of coal wastewater is used to remove TSS in wastewater. Chemical flocculation, electronic flocculation, etc. can be used.

[c] The filtration of coal wastewater is used to separate sludge formed by coagulating sedimentation from wastewater. Mechanical filtration, membrane filtration, etc. can be used.

[d] If there is oil in the coal wastewater, an air float treatment unit can be added after coagulating sedimentation to remove the oil in the wastewater.

Figure 1— Process flow of coal wastewater treatment and reuse

6.2.2 Oily wastewater

The separation treatment system should be set up for oily wastewater. According to the effluent water quality of oily wastewater and the influent water quality requirements for the reuse targets, oil