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Industrial application of electron beam (EB) irradiation for wastewater treatment in China

Dr. Shijun HE

Tsinghua University, Beijing, P. R. China

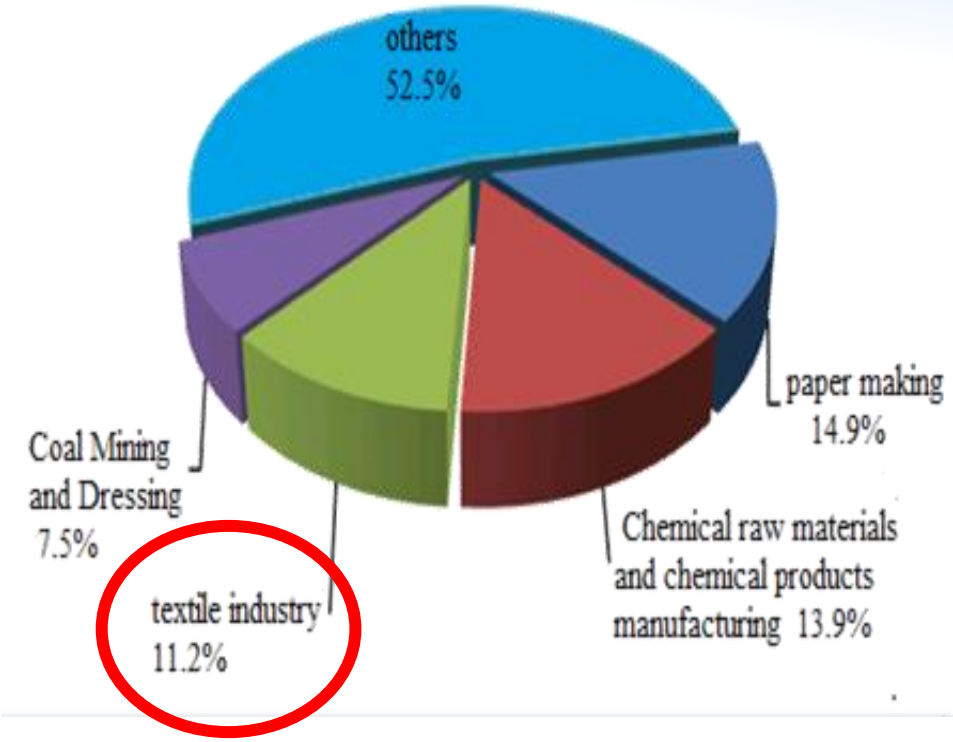
Outline

- Background
- Lab-scale results
- Industrial-scale EB for textile wastewater treatment
- New progress: Decomposition of antibiotics and antibiotics resistance genes by irradiation
- Conclusions

1. Background

1.1 Wastewater pollution in China

- In 2014, the total domestic wastewater discharge was 72 billion tons.
- Industrial wastewater discharge was 20 billion tons (equal to 29%).
- Textile is the third largest source of industrial pollution with high COD concentration and various refractory compounds.



Industrial wastewater discharge

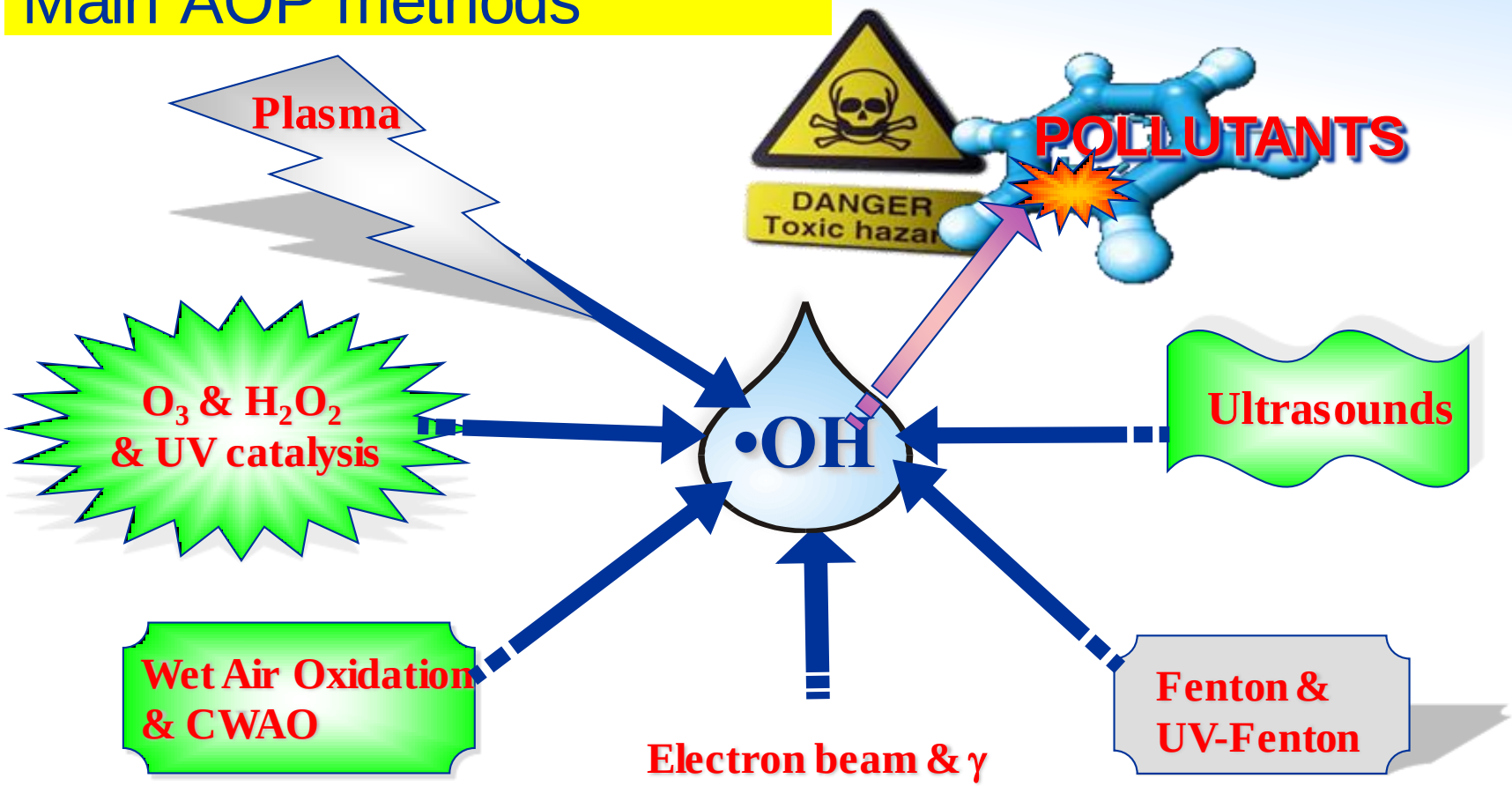
1. Background

1.2 Textile wastewater treatment technologies

Biological methods	Physical-chemical methods	AOPs
• Aerobic • Anaerobic • Anaerobic-aerobic • Membrane Bioreactor (MBR) • ….	• Coagulation and sedimentation • Filtration • adsorption • Membrane (MF,UF,) • ….	• Wet Air Oxidation (WAO) • Super Critical Water Oxidation (SCWO) • Fenton reaction • Photocatalytic oxidation • Ozone, Plasma • ….

- Advanced Oxidation Processes are a family of methods for hazardous compounds destruction making use of the hydroxyl radical.
- With few exceptions, •OH can oxidize practically any organic compound dissolved in water.

Main AOP methods



Principle of wastewater treatment by EB irradiation

In dilute aqueous solutions, primary effect of irradiation is radiolysis of water

$$H_2O \longrightarrow {}^{\bullet}H,\ e_{aq}^{-},\ {}^{\bullet}OH,\ H^{+},\ OH^{-},\ H_2O_2,\ H_2$$

G ($^{\bullet}H$) = 0.06 µm J^{-1}; G($^{\bullet}OH$) = 0.28 µm J^{-1}; G(e_{aq}^{-}) = 0.28 µm J^{-1}

2. Lab-scale results

Electron beam facility used

IBA Rhodotron : 10 MeV, 10 mA

2. Lab-scale results

Case study One

- **Sample source：** **Shengfang, Shaoxing city, Zhejiang Province**
- **Major products：** **umbrella cloth , lining cloth , Case fabric**
- **Existing treatment process：** **Biological method+ physicochemical process + membrane separation (UF+RO)**
- **Main problems：** **Unstable performance , serious membrane fouling**

2. Lab-scale results

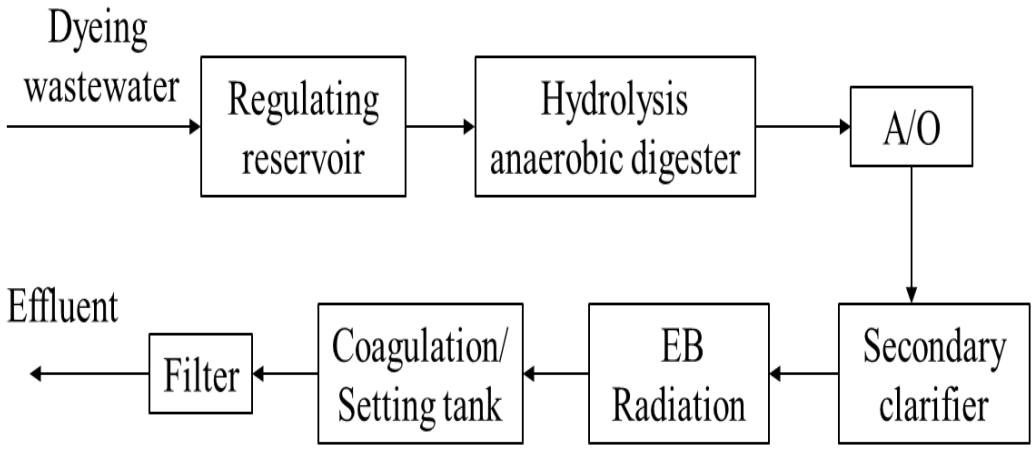
Case study One

Sample	COD (mg/L)	Color（times）	Conductivity (us/cm)
wastewater before RO	117 ± 4	25	1197
EB treated	**24~38 (1kGy)**	5	1683
RO rejected solution	259 ± 26	40	2960
EB treated	**86 (1kGy)**	20	2863

2. Lab-scale results

Case study Two

- **Sample source：** Shenzhou, Ningbo city, Zhejiang Province
- **Major products：** knitted garments
- **Existing treatment process ：**



2. Lab-scale results

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Case study Two

	COD (mg/L)	Color (times)	SS (mg/L)	Hardness (mg/L)	pH
Effluent	180-200	100	28-35	125-130	6-9
EB treated	<30	8-10	<5	120-125	7-8
Standards for reuse	≤50	≤25	≤20	≤450	6-9

2. Lab-scale results

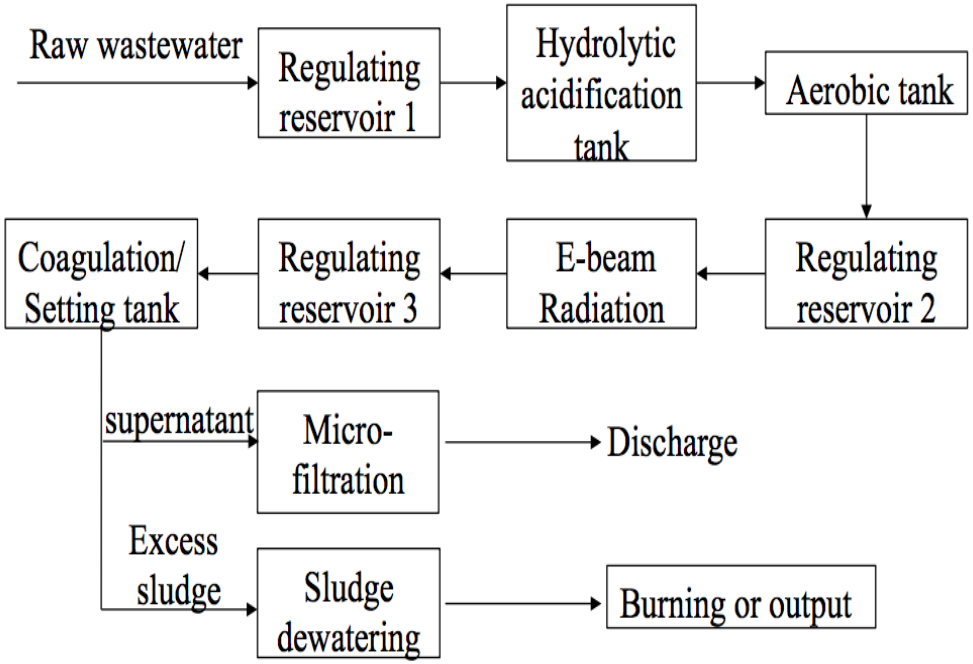
Case study Two

- **Absorbed dose: 1kGy**
- **Operation cost:** 2.47 RMB / m^3 (include energy consumption, reagent and sludge treatment)

2. Lab-scale results

Case study Three

- **Sample source：** Hengchang, Jinhua city, Zhejiang Province
- **Existing treatment process：**



2. Lab-scale results

Case study Three

	COD (mg/L)	Color（times）	SS (mg/L)	TN (mg/L)	NH_3-N（mg/L）	TP（mg/L）	pH
Biological effluent	150-200	32-40	150	6-8	3-5	1.5-1.9	6-9
EB treated	<50	<10	3-5	4-6	1-2	<0.2	7-8
Discharge standard	<60	10	20	<12	<8	<0.5	6-9

2. Lab-scale results

Case study Three

- **Absorbed dose: 1kGy**

➢Benefits：

Now, the operating cost (including ozonation) is 3.95 RMB/m^3. if changed to the new process of EB irradiation ,the operating cost will decrease to 2.45 RMB/m^3.

3. Industrial-scale EB for textile wastewater treatment

- Lab- scale experiments: from Nov., 2015 to Mar., 2016
- Industrial plant Construction: from May, 2016 to Dec., 2016
- Capacity designed: 2000 m^3/d (one injector)
- Objectives: EB (discharge), EB+RO (10 m^3/d for high quality reuse)

3. Industrial-scale EB for textile wastewater treatment

Capacity: 2000 m^3/d (one injector)

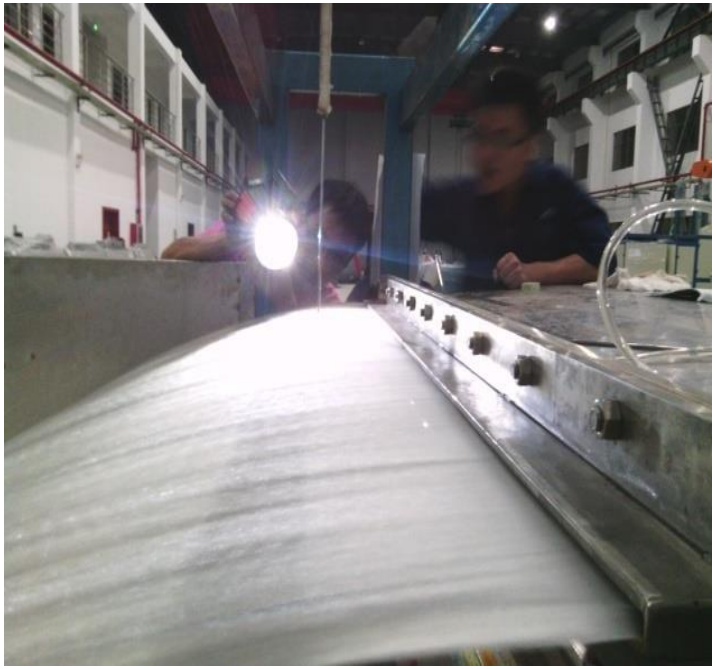
EB Accelerator: 1.5 MeV, 60 mA

Treatment: Biological method-EB-Flocculation-Sedimentation

Effluent:
COD < 50 mg/L, Color < 10 times

3. Industrial-scale EB for textile wastewater treatment

Injector:
1500mm X 4 mm



3. Industrial-scale EB for textile wastewater treatment

Absorption tower for irradiated air

(1)Make advantages of highly reactive radicals and ozone in the irradiated air to improve wastewater treatment

(2) Reduce ozone (O_3) emission into the air at the same time

3. Industrial-scale EB for textile wastewater treatment

Regulating tank

Flocculation and Sedimentation

3. Industrial-scale EB for textile wastewater treatment

Chemicals Storage

3. Industrial-scale EB for textile wastewater treatment

Reports

4. New progress: decomposition of antibiotics and antibiotics resistance genes by irradiation

Visit Kelun Pharmaceutical Manufacturer
(4th March 2017, Xinjiang Province)

Penicillin Waste
(10% solid)

4. New progress: decomposition of antibiotics and antibiotics resistance genes by irradiation

Irradiation-induced decomposition of Penicillin

Dose (kGy)	Penicillin residual- (mg/kg)	
	Harbin Institute of Technology	Tsinghua University
0	50.7	53.3 ± 2.3
1	13.6	—
2.5	0	13.7±15.8
5	0	22.1+8.0
7.5	0	—
10	0	13.2±5.6

Antibiotic resistance genes of Penicillin (10% of solid)

Dose (kGy)	TEM	CTX	SHV
0	-	+	-
1	-	+	-
2.5	-	+	-
5	-	+	-
7.5	-	+	-
10	-	-	-

4. Conclusions

- **Lab-scale results showed that EB is an effective method to purify the textile and dyeing wastewater.**
- **Since this March 2017, China first industrial-scale wastewater treatment plant has been established in the city of Jinhua, using electron beam irradiation in combination with conventional biological methods.**
- **The maximum capacity is 2000 m^3 per day at a dose of 1 kGy. The running costs, including energy consumption, chemicals and workers salaries, is 0.35 US$/$m^3$ for wastewater reuse.**
- **EB or gamma irradiation is a promising method to decompose antibiotics and antibiotics resistance genes.**

5. Acknowledgements

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电子加速器　高电压加速管

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THANK YOU!