Hong Kong Student Science Project Competition 2002

Water Treatment

by electro-coagulation

- Aim: To explore the applicability and the viability electro-coagulation on water treatment

- Part I --- Electro-coagulation Theory
- Part II --- Best conditions
- Part III --- Application
- Part IV --- Conventional waste water treatment
- Part V --- Advantages and limitations

Part I

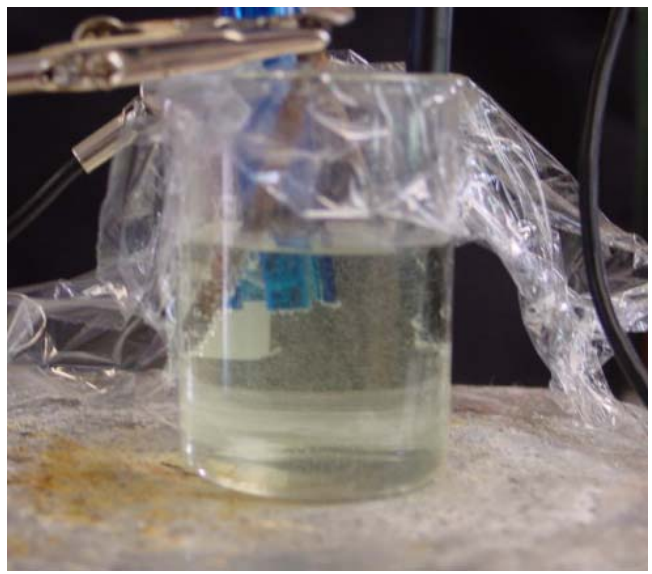
Electro-coagulation Theory

- Combines the effects of

1. Formation of gases :

   hydrogen and oxygen

2. Production of polyvalent metal cations.



Metal cations react with hydroxide ions to form metal hydroxides.

Mechanism 1:

(Acidic medium)

Anode:

$4Fe \rightarrow 4\ Fe^{2+}(aq) + 8e^-$

$4Fe^{2+}(aq) + 10H_2O(l) + O_2(g) \rightarrow 4Fe(OH)_3(s) + 8H^+(aq)$

Cathode:

$8H^+(aq) + 8e^- \rightarrow 4H_2(g)$

Overall:

$4Fe(s) + 10H_2O(l) + O_2(g) \rightarrow 4Fe(OH)_3(s) + 4H_2\ (g)$

Mechanism 2:

(Alkaline medium)

Anode:

$Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$

$Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$

Cathode:

$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

Overall:

$Fe\ (s) + 2H_2O(l) \rightarrow Fe(OH)_2(s) + H_2(g)$

- Iron hydroxide removes pollutants by surface complexation and electrostatic attraction

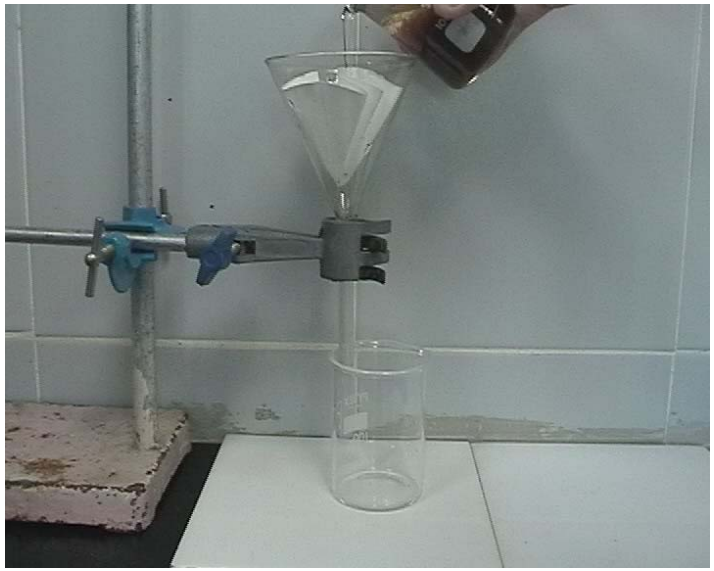
- Positive and negative charges of iron hydroxide attract opposite regions of pollutants

Freshly prepared coagulating agents

Vs

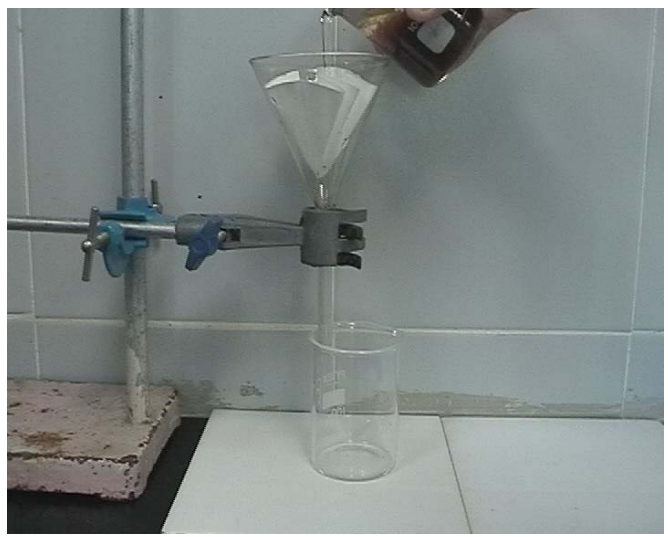
Dated coagulating agents

a.) Freshly prepared coagulating agents



b.) Dated coagulating agents

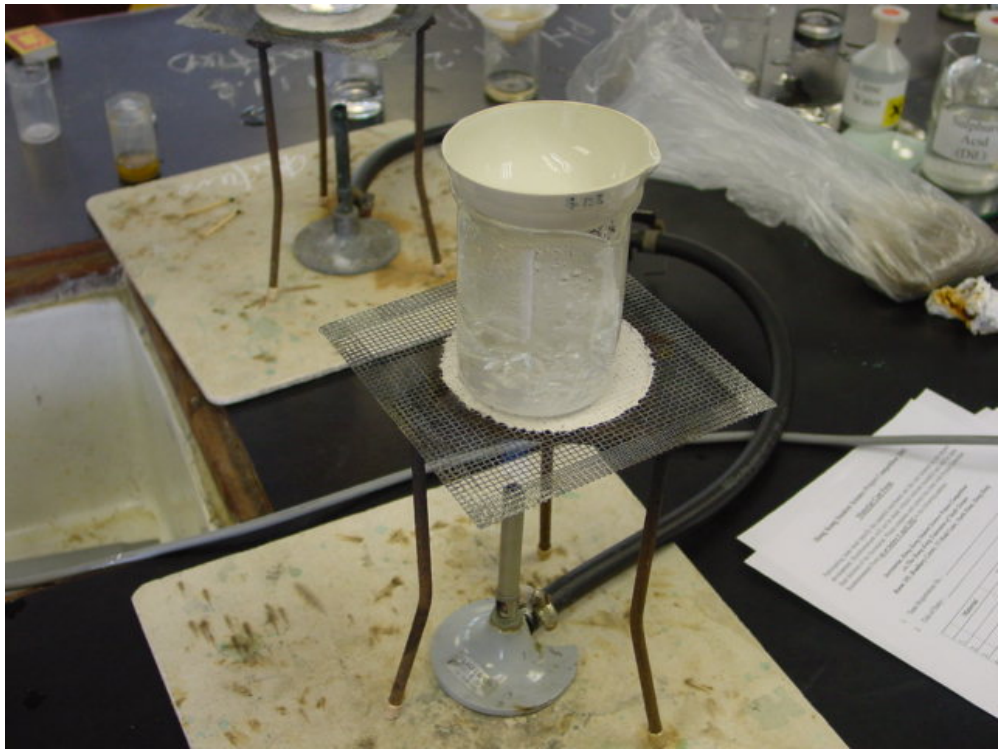
- Freshly prepared coagulating agents can function the best



Testing of water quality

1. Light transmittance of the effluent before and after treatment was measured by a Colorimeter.

2. Biochemical Oxygen Demand (BOD) of the effluent is measured by a dissolved oxygen sensor.



3. The soluble substances in the treated effluent are extracted by evaporation. They are weighed as well.

Part II

Best conditions for electro-coagulation

a.) Material for electrode

Iron	Aluminium	Copper	Zinc	Graphite
★★	-	-	★★	-

★★ = Rate of reaction

- Iron was chosen because Zinc is toxic

b.) Other criteria

Opened area	Closed area	Opened area with magnetic stirrer	Closed area with magnetic stirrer
-	★	★	★★

★ = Rate of reaction

- Closed area with magnetic stirrer was chosen because the rate of reaction was the fastest.

Best conditions

Part III

Application of Electro-coagulation

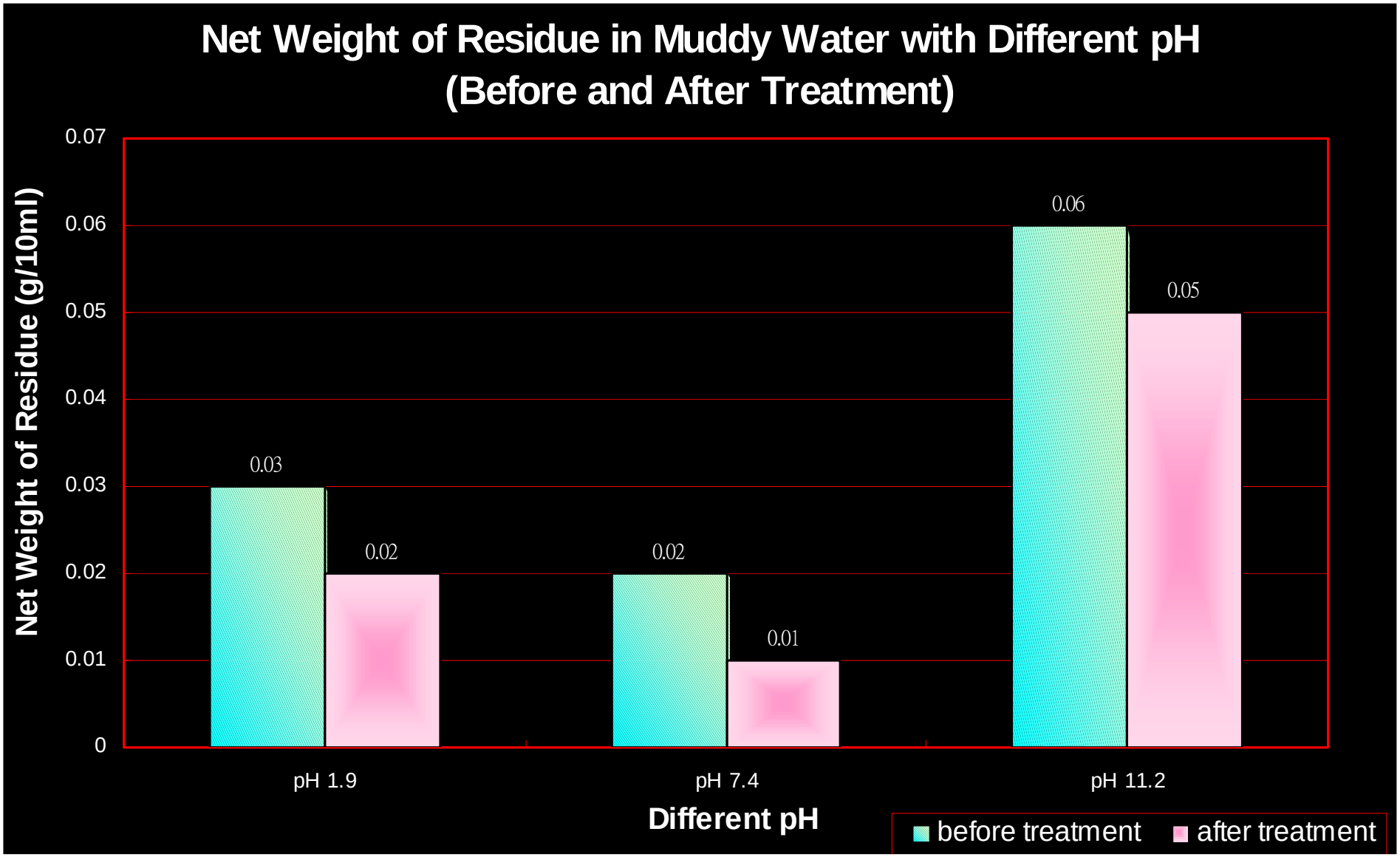
Light transmittance in percentage of muddy water with variation of pH on electro-coagulation

	Red Light	Blue light	Green Light	Orange Light
Acidic medium (pH 1.9)				
Before treatment	94.1	97.5	96.6	97.7
After treatment	96.6	98.0	96.7	98.9
Alkaline medium (pH11.2)				
Before treatment	84.0	63.7	76.8	83.4
After treatment	98.0	96.2	96.8	97.3
Neutral medium (pH 7.4)				
Before treatment	71.4	47.9	62.1	73.3
After treatment	98.4	99.7	100	99.3

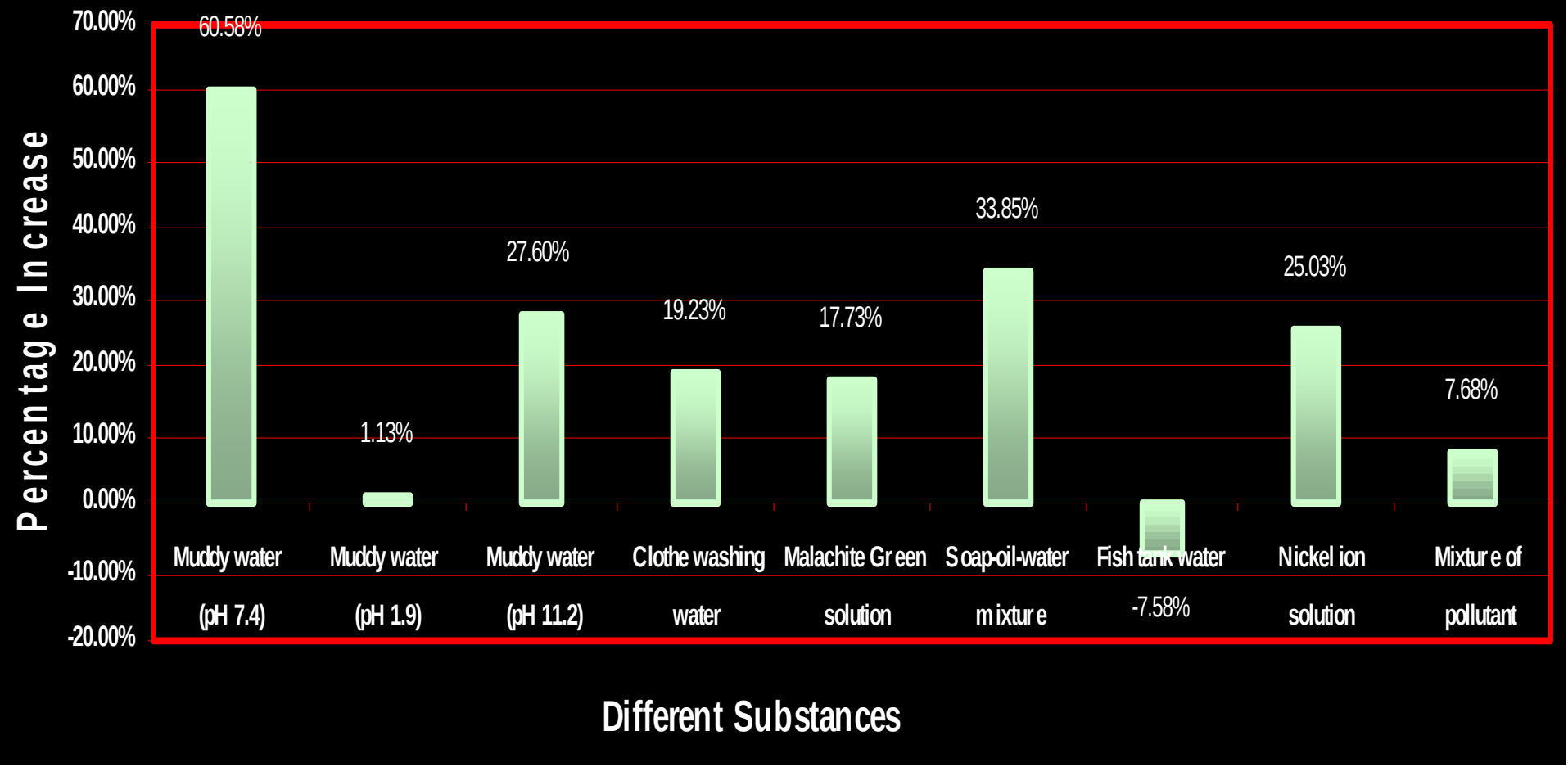
	Suspended solid and varying pH			Dye and emulsion			Organic matters	Heavy metal	
	Muddy water (pH 7.4)	Muddy water (pH 1.9)	Muddy water (pH 11.2)	Clothes washing water + Pink dye	Malachite Green solution	Oil-soap-water mixture	Fish tank water	Nickel ions solution + NaOH	Mixture of pollutant
Blue Light in percentage									
Before treatment	47.9	97.5	63.7	61.2	100	56.8	100	69.7	68.7
After treatment	99.7	98	96.2	73.0	100	95.8	82.9	84.7	79.5
Percentage change	108%	0.50%	51.0 %	19.3%	0%	68.7 %	-17.1 %	21.5%	15.7 %
Green Light in percentage									
Before treatment	62.1	96.6	76.8	67.6	79.5	71.4	100	64.1	87.6
After treatment	100	96.7	96.8	87.6	99.9	97.5	93.4	80.5	93.8
Percentage change	61.0%	0.10%	26.0 %	29.6%	29.4%	37.3%	-6.6%	25.6%	7.10 %

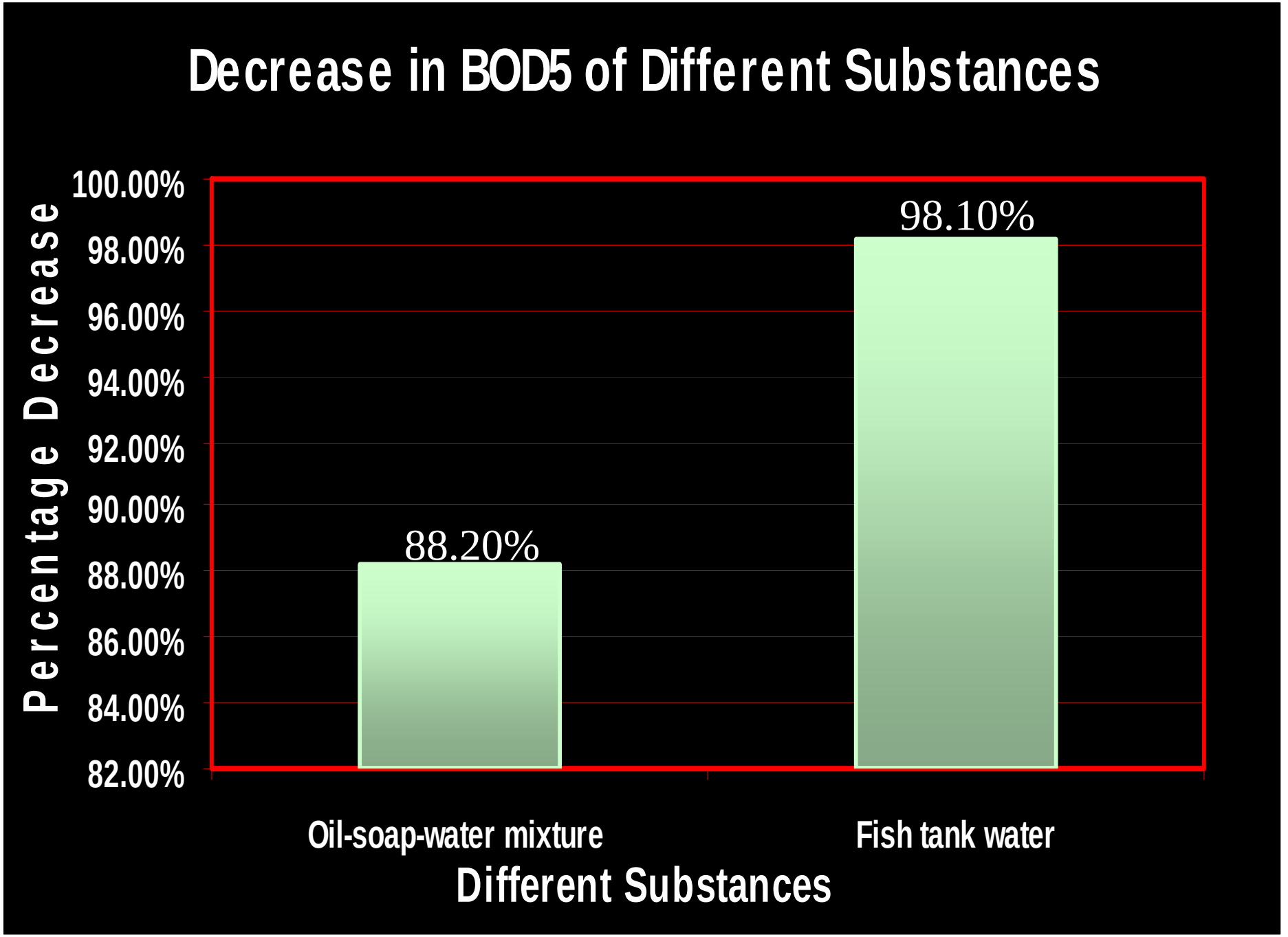
	Suspended solid and varying pH			Dye and emulsion			Organic matters	Heavy metal	
	Muddy water (pH 7.4)	Muddy water (pH 1.9)	Muddy water (pH 11.2)	Clothes washing water + Pink dye	Malachite Green solution	Oil-soap-water mixture	Fish tank water	Nickel ions solution + NaOH	Mixture of pollu-tant
Red light in percentage									
Before treatment	71.4	94.1	84.0	71.9	99.1	91.1	100	92.8	96.6
After treatment	98.4	96.6	98.0	91.6	100	98.6	96.9	97	98.9
Percentage change	37.8%	2.70%	16.7 %	27.4%	0.90%	8.2 %	-3.1%	4.5 %	2.3%
Orange Light in percentage									
Before treatment	73.3	97.7	83.4	73.7	67.7	80.2	100	92.1	90.5
After treatment	99.3	98.9	97.3	90.8	95.2	97.2	96.5	99.9	95.6
Percentage change	35.5%	1.2%	16.7 %	23.2%	40.6%	21.2%	-3.5%	8.5%	5.6%

	Suspended solid and varying pH			Dye and emulsion			Organic matters	Heavy metal	
	Muddy water (pH 7.4)	Muddy water (pH 1.9)	Muddy water (pH 11.2)	Clothes washing water + Pink dye	Malachite Green solution	Oil-soap-water mixture	Fish tank water	Nickel ions solution + NaOH	Mixture of pollutant
BOD_5 Test									
Before treatment	-	-	-	-	-	5.1mg dm^{-3}	5.4mgd m^{-3}	-	-
After treatment	-	-	-	-	-	0.6 mgdm $^{-3}$	0.1mgd m^{-3}	-	-
Percentage change	-	-	-	-	-	-88.2%	-98.1%	-	-
Net weight of residue									
Before treatment	2g/L	3g/L	6g/L	-	-	-	-	-	-
After treatment	1g/L	2g/L	5g/L	-	-	-	-	-	-
Percentage change	100%	66.7%	16.7 %	-	-	-	-	-	-


Net Weight of Residue in Muddy Water with Different pH
(Before and After Treatment)
Net Weight of Residue (g/10ml)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0.03
0.02
0.02
0.01
0.06
0.05
pH 1.9
pH 7.4
pH 11.2
Different pH
before treatment
after treatment

Average Increase in Light Transmittances for Different Substances




Decrease in BOD5 of Different Substances
Percentage Decrease
100.00%
98.00%
96.00%
94.00%
92.00%
90.00%
88.00%
86.00%
84.00%
82.00%
88.20%
98.10%
Oil-soap-water mixture
Fish tank water
Different Substances

- Electro-coagulation can remove a wide range of pollutants at the same time:

- suspended solids
- dyes
- emulsion
- organic matters
- heavy metals

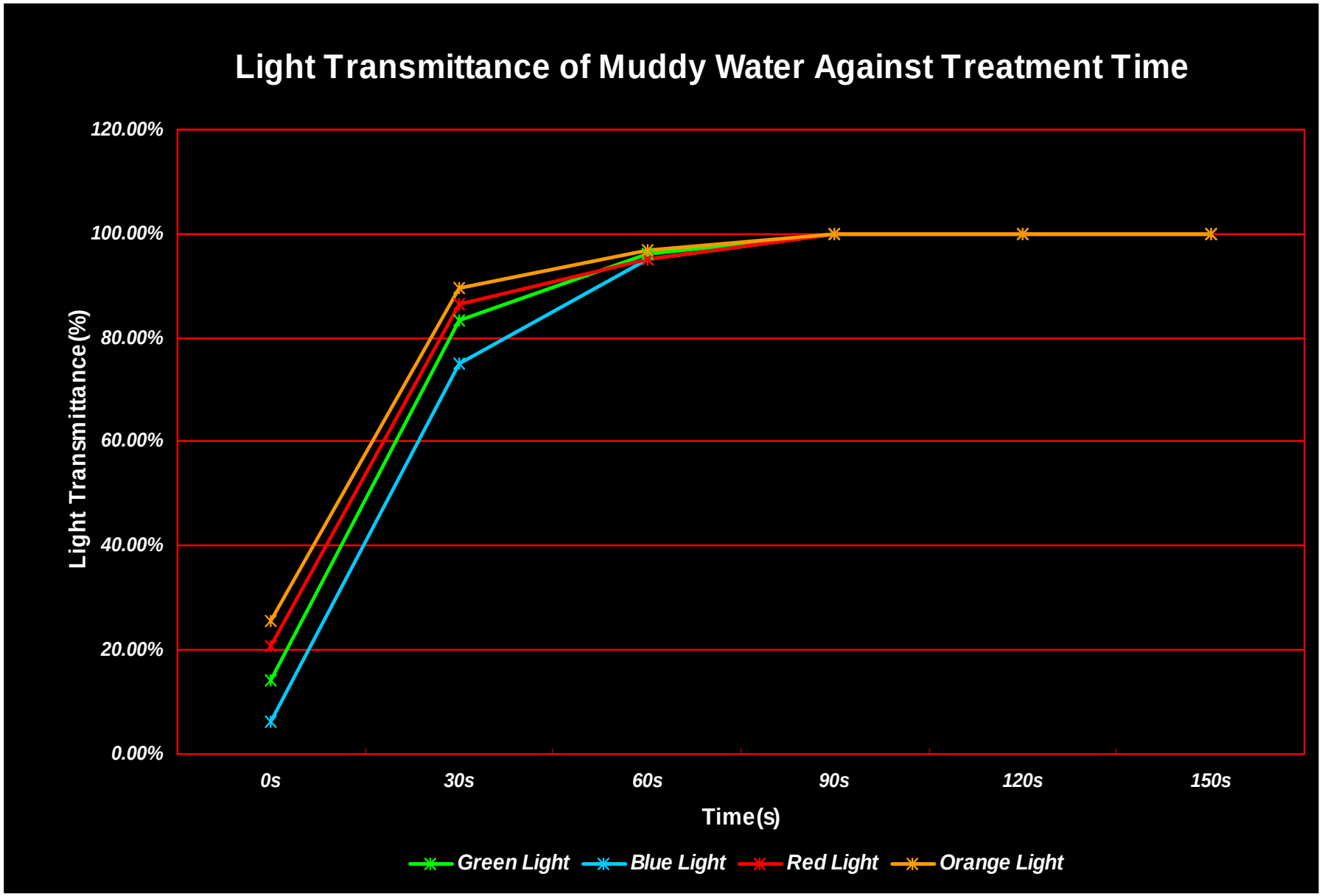
Experimental Procedure

Muddy Water.mpg

Electro-coagulation with variation of time

Light transmittance in percentage

Time	Green Light	Blue Light	Red Light	Orange Light
0s	14.10	6.10	20.70	25.60
30s	83.40	75.10	86.40	89.70
60s	96.20	95.00	95.00	96.90
90s	100	100	100	100
120s	100	100	100	100
150s	100	100	100	100


Light Transmittance of Muddy Water Against Treatment Time
120.00%
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
Light Transmittance (%)
0s
30s
60s
90s
120s
150s
Time(s)
Green Light
Blue Light
Red Light
Orange Light

Energy needed to treat 1m^3 of effluent:

- 2.025 kWh

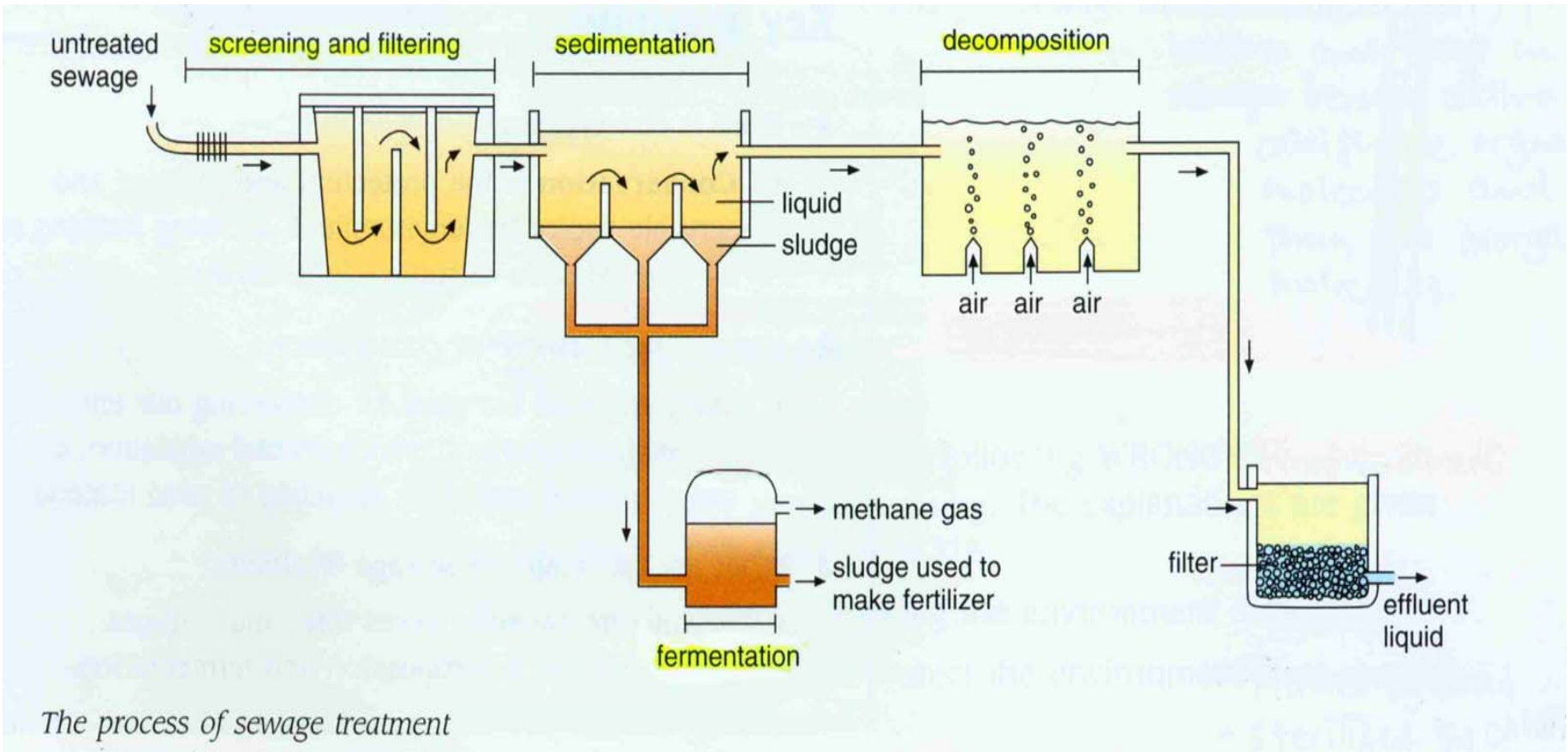
Cost:

- Conventional methods: \$1 per m^3
- Electro-coagulation: \$2 per m^3

  (When it comes into a larger operation, the cost will be lower.)

Part IV

Process of waste water treatment in Hong Kong



The process of sewage treatment

Current Waste Water Treatment in Hong Kong

- Screening is adopted
- Sedimentation and secondary treatment are adopted in some plants only

- Due to

1. Shortage of land for waste water treatment plants
2. Time consuming nature of the treatments

Part V

Advantages and limitations of Electro-coagulation

a) Advantages:

- Able to treat different kinds of pollutants
- Relatively fast
- No pH adjustment
- Less chemicals are needed
- Fewer sludge

b) Limitations:

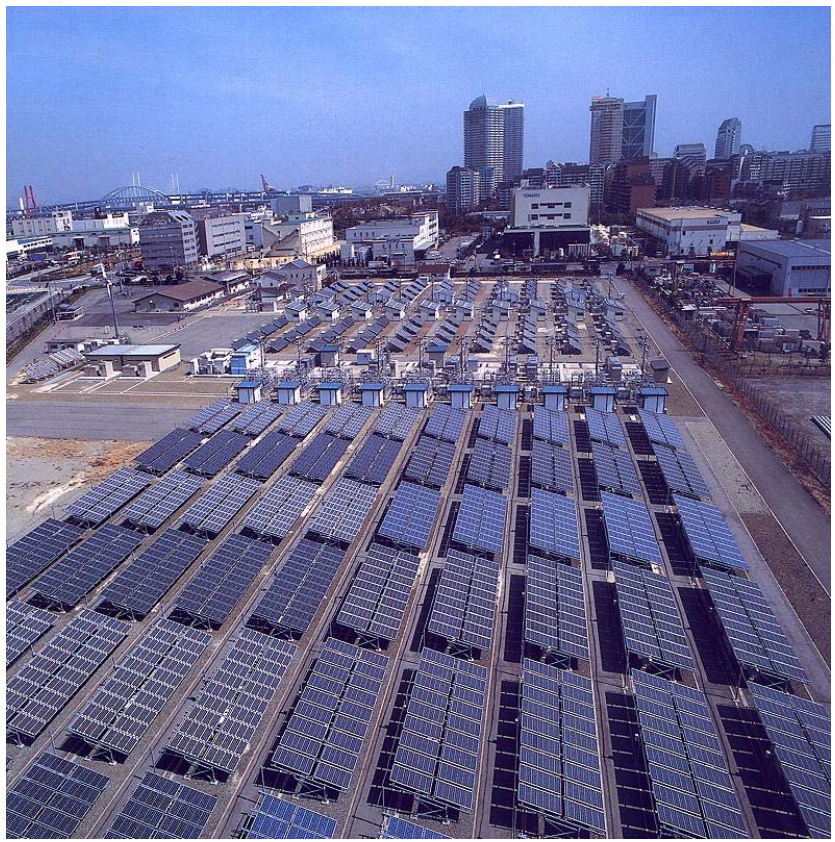
- Consumes electricity

Solutions:

- Uses more economical and environmental friendly energy resources such as solar energy to power the plant

KYOCERA Co. (Japan)

(Solar powered building)



Kansai Solar Power

關西電廠

(Japan)

Conclusion

Electro-coagulation is better than conventional waste water treatment methods.

This concludes our presentation

Thank you !

Acknowledgement

We sincerely thank our chemistry teachers:

- Mr. S.K. Leung
- Miss M.S. Yuen
- Mr. K.Y. Ma
- lab. technicians

For dedicating their personal time to monitor our progress and develop our initiatives.