Application of combined coagulation-flocculation-decantation/ photo-Fenton/ adsorption process for winery wastewater treatment

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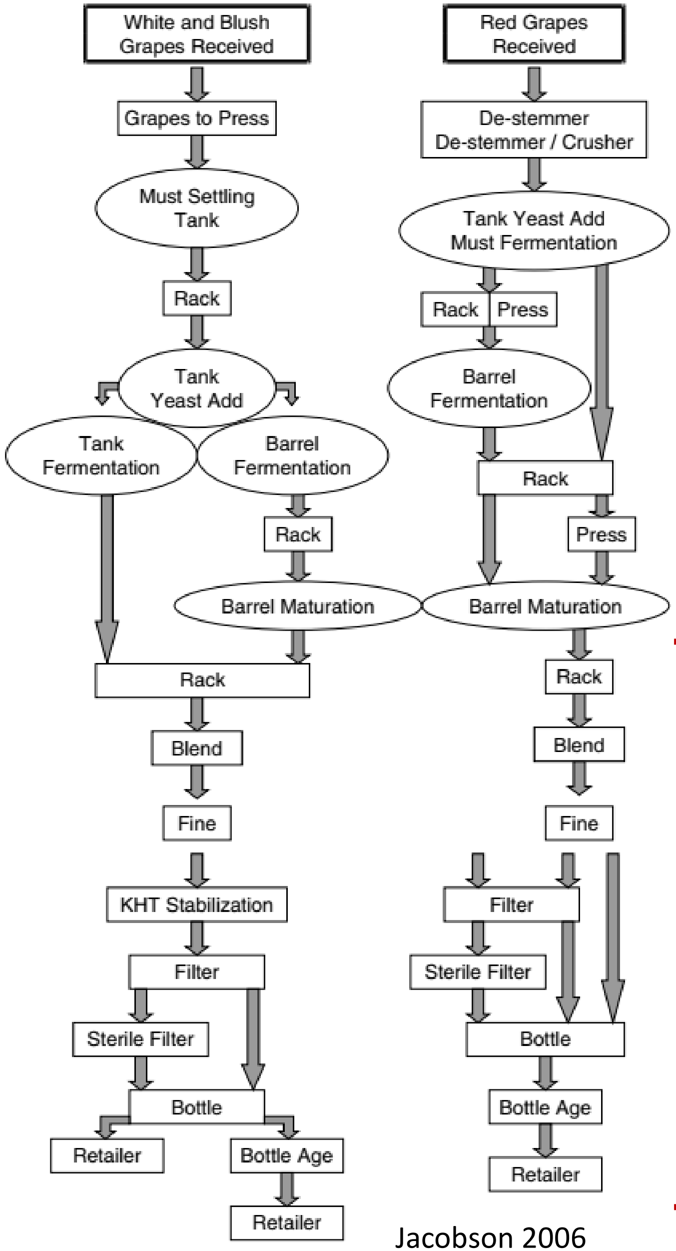
Introduction



Jacobson 2006

1) Grape reception and must vinification

2) Wine stabilization

3) Wine clarification and bottling

The wine industrie

Global wine production in 2018 (279 mhL)

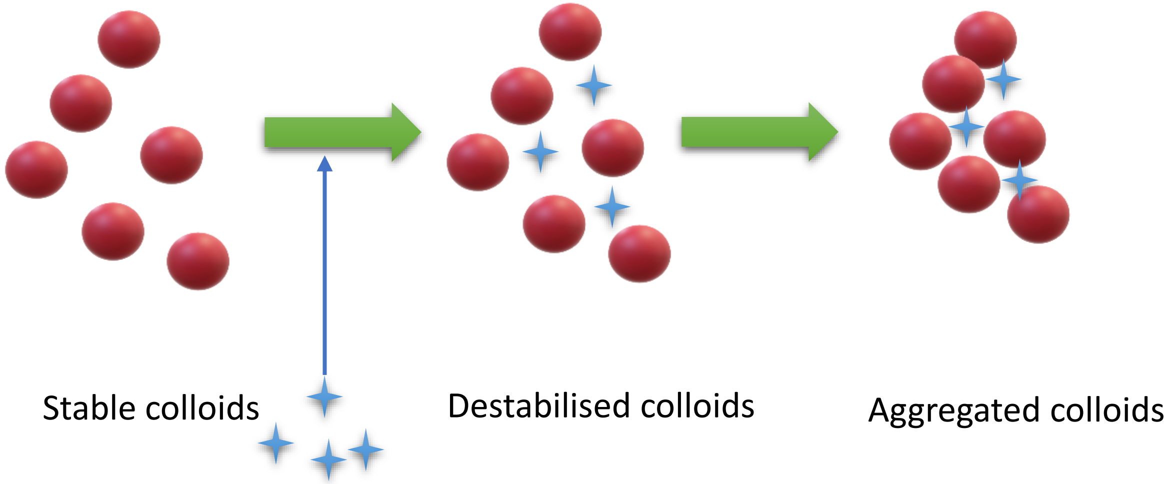
(International Organisation of Vine and Wine, World Vitiviniculture Situation, 2018)

Winemaking operations yields an equivalent or larger amount of wastewater

(Petruccioli et al. 2000)

The winemaking operations are mainly vinification of must, wine stabilization and clarification, cleaning, between others.

Coagulation-flocculation-decantation (CFD)



Add coagulant/flocculant

- Hydrolysable metal salts (mainly, **aluminum** and **iron**)

Most used on waster treatment

Aluminum	Iron
Dialysis encephalopathy Alzheimer's disease	Generally corrosive Strongly dependent on the pH The leach cannot be recycled

Disadvantages

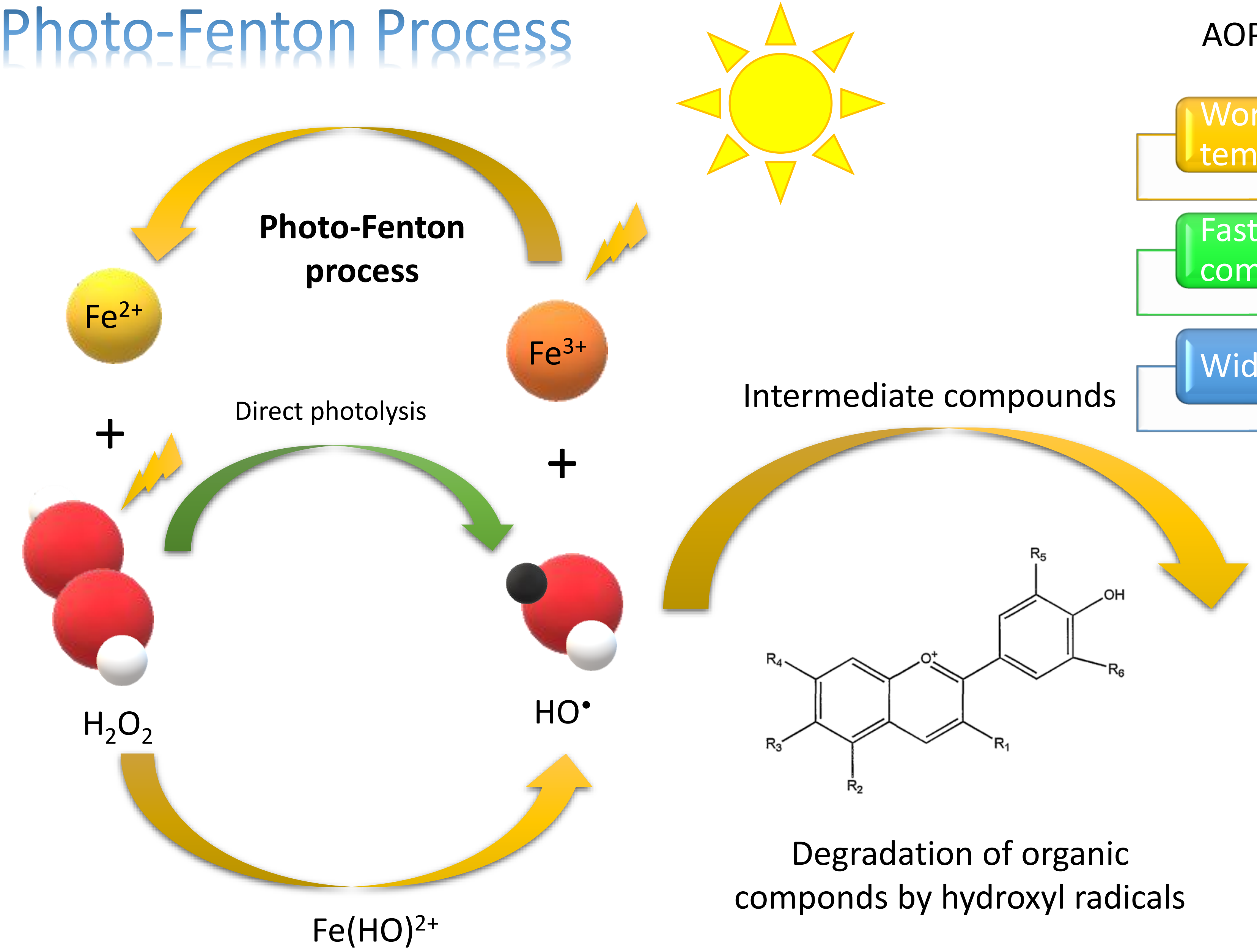
- Oenological coagulants

Used on wine treatment

Advantages

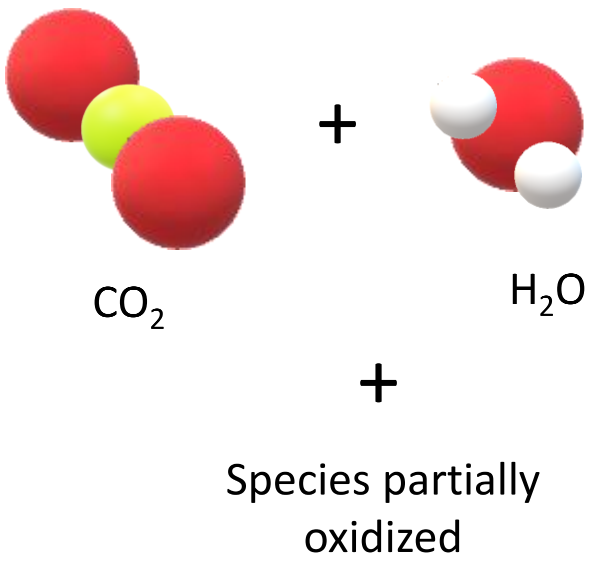
- Alimentary use
- Low cost and accessible
- Do not affect pH
- Leach can be recicled

Photo-Fenton Process



AOP main advantages

- Work near ambiente temperature
- Fast degradation of organic compounds
- Wide pH range

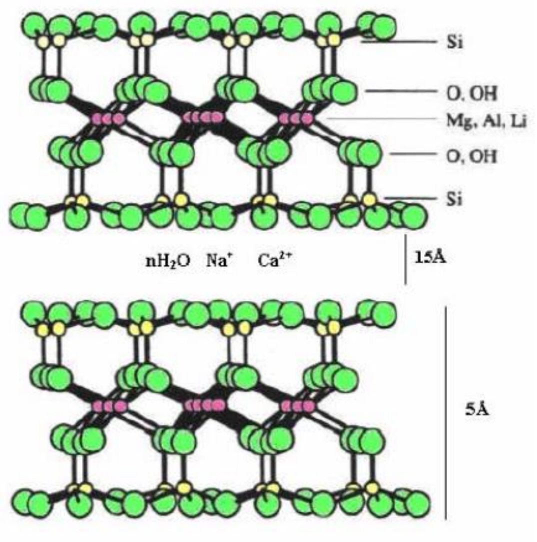


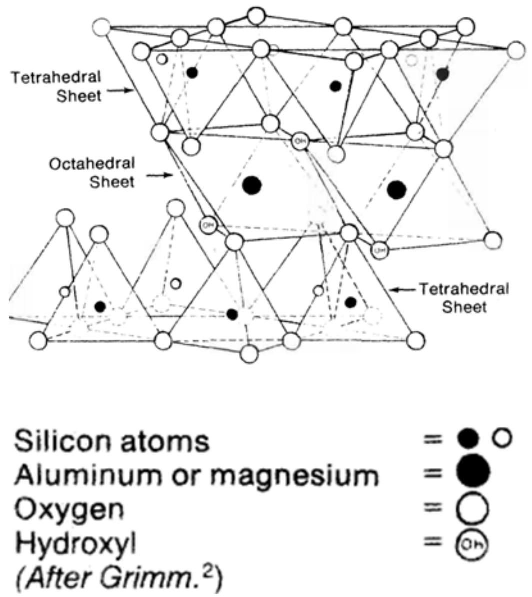
Chemical adsorption

Chemical adsorption, or *chemisorption*, occurs when the adsorbate reacts with the surface to form a covalent bond or an ionic bond.

Activated sodium bentonite

- Bentonite, a natural clay, a dioctahedral smectite with general chemical formula, $M_x(Al_{4-x}Mg_x)\ Si_8O_{20}\text{-}(OH)_4$, where M ($M = Na^+$, Ca^{2+},Mg^{2+}, etc.) is the charge balancing interlayer cation.
- There are sodium and calcium bentonites, however, calcium bentonites have higher intermilecular forces between the sheets, creating more compact stuctures. There for Sodium bentonites are ideal for larger absortion.
- Bentonite has an isoelectric point of 7.





Material and methods

Winery wastewater collection and storage

Main chemical characteristics of winery wastewater (WW)

Parameters	Values
pH	3.61±0.1
Electrical conductivity (µS/cm)	172.5±8.6
Turbidity (NTU)	133±8.19
Total suspended solids – TSS (mg/L)	358±8.46
Chemical Oxygen Demand - COD (mg O_2/L)	5723±25.5
Biochemical Oxygen Demand - BOD_5 (mg O_2/L)	1500±17.4
Total Organic Carbon – TOC (mg C/L)	1601±6.29
Total polyphenols (mg gallic acid/L)	52.1±7.9
Biodegradability – BOD_5/COD	0.32±0.1
[Fe^{2+}] (mg Fe/L)	0.59±0.1

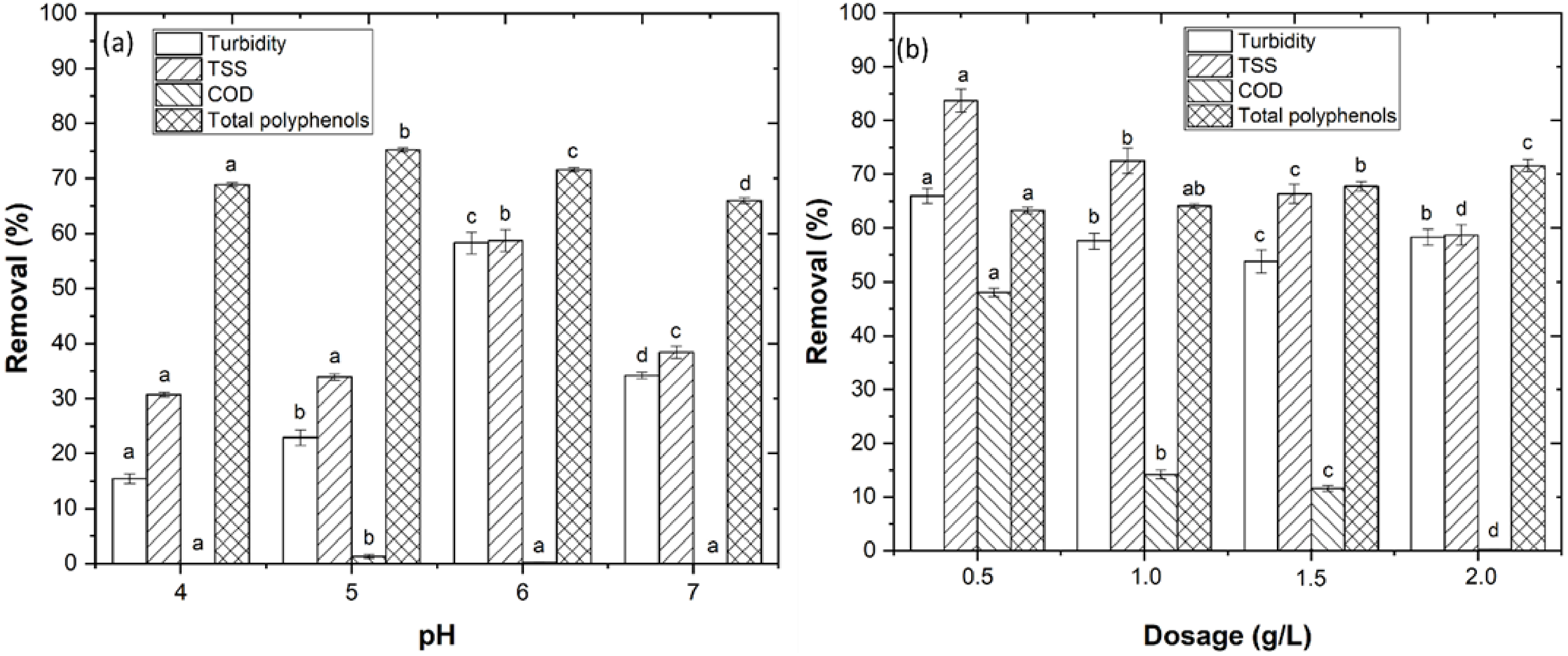
Storage in small containers

Conservation at -40ºC

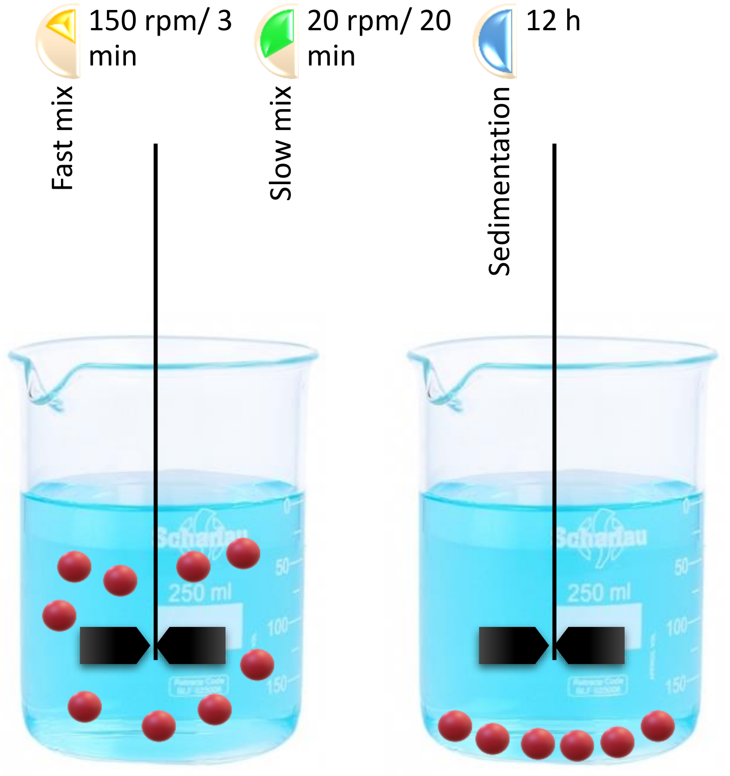
Winery wastewater used in this work

Coagulation-flocculation-decantation experiments

- At pH 6.0 it was achieved a turbidity, TSS, COD and total polyphenols of 58.3, 58.7, 0.2 and 71.6%, respectively
- With application of 0.5 g/L it was achieved a turbidity, TSS, COD and total polyphenols of 66.0, 83.7, 48.0 and 63.3%, respectively



Optimization of (a) pH (4.0 – 7.0) under the following conditions: [PVPP] = 2.0 g/L, rapid mix (rpm/min) = 150/3, slow mix (rpm/min) = 20/20, sedimentation = 12 h; (b) PVPP dosage (0.5 – 2.0 g/L) under the following conditions: pH = 6.0, rapid mix (rpm/min) = 150/3, slow mix (rpm/min) = 20/20, sedimentation = 12 h. Columns with different letters are significantly different.



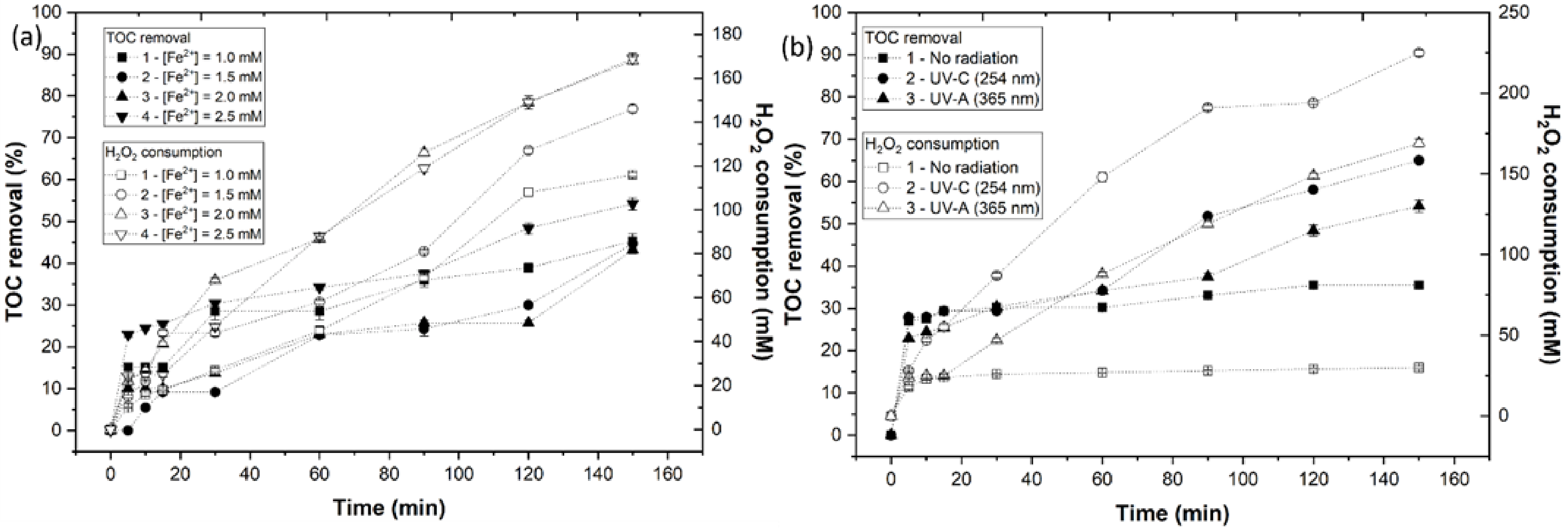
Before CFD process

After CFD process

Results and discussion

Photo-Fenton experiments

- It was achieved a TOC removal of 54.2% with application of 2.5 mM Fe^{2+}
- The results showed a TOC removal of 35.5, 65.0 and 54.2%, respectively, for no radiation, UV-C and UV-A
- The results showed a higher energy consumption with application of UV-A, regarding UV-C (641 and 170 kWh m^{-3} $order^{-1}$, respectively



(a) TOC and H2O2 consumption with Fe^{2+} variation (1.0 – 2.5 mM) under operational conditions: pH = 3.0, radiation = UV-A IUV = 32.7 W/m^2, agitation = 350 rpm, t = 150 min; (b) TOC and H_2O_2 consumption with radiation type variation (no radiation, UV-C and UV-A) under operational conditions: $[Fe^{2+}]$ = 2.5 mM, pH = 3.0, agitation = 350 rpm, t = 150 min.

$$E_{EO} = \frac{38.4 \times 10^{-3} P}{V k}$$

The energy consumption, given by the electric energy per order (E_{EO})

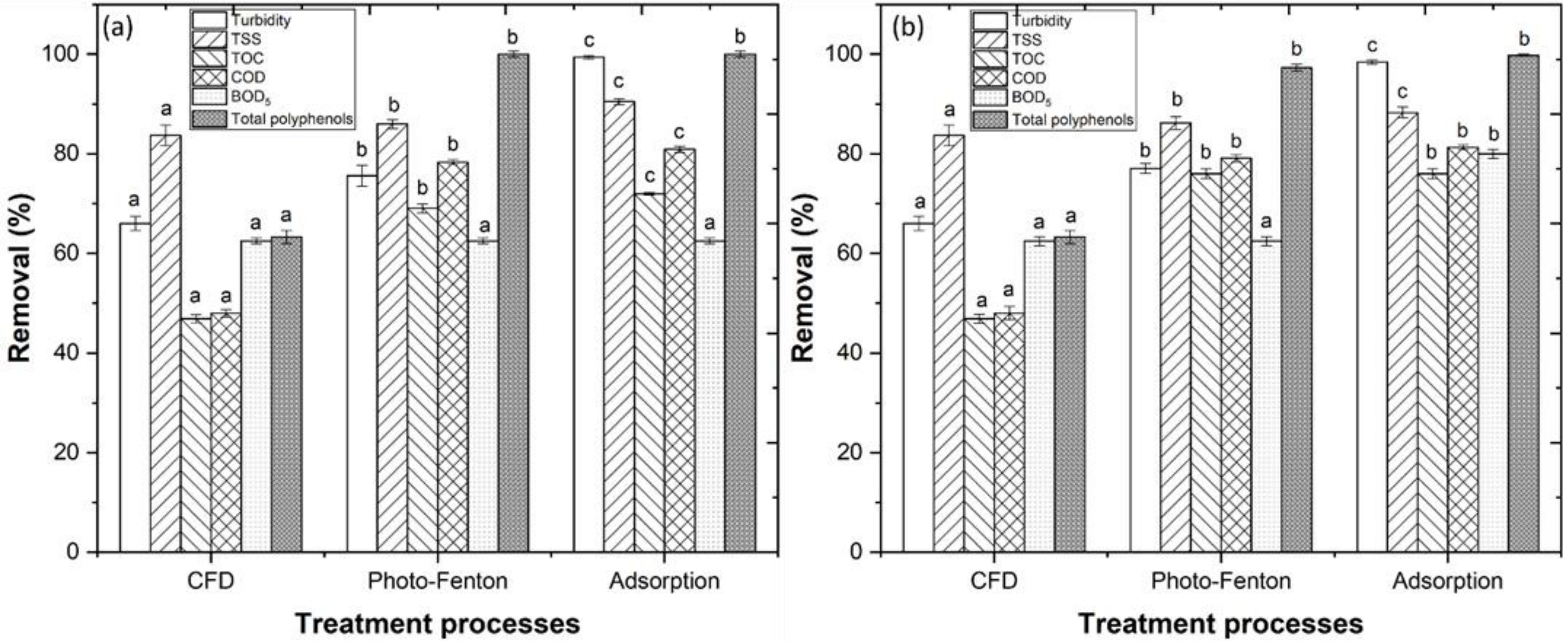
Photo-Fenton experiments with UV-A and UV-C radiation systems; pseudo first-order kinetic rate (k) and electric energy per order (E_{EO}) with V = 500x10^{-6} m^3.

Radiation	P (kW)	K*10^{-3} (min^{-1})	E_{EO} (kWh m^{-3} $order^{-1}$
UV-A (365 nm)	0.0327	3.92	641
UV-C (254 nm)	0.015	6.78	170

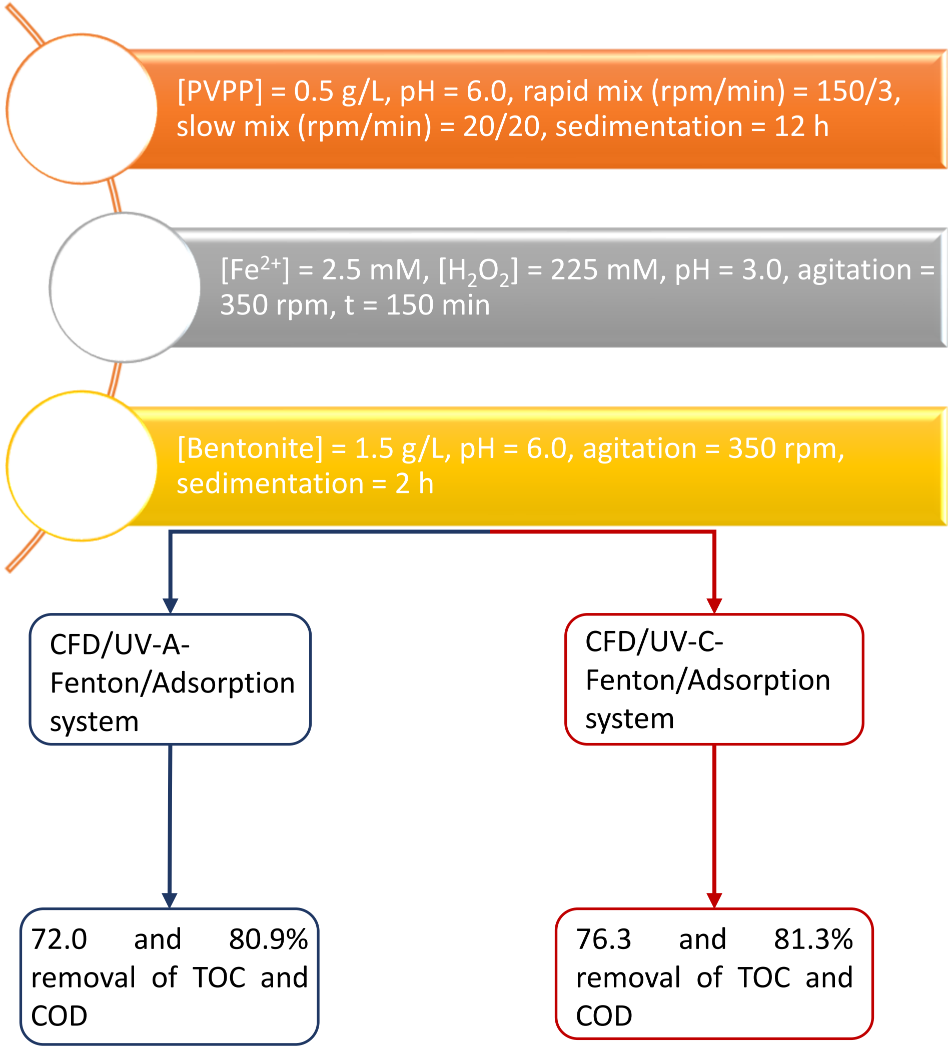
Combination of CFD-Photo-Fenton-Adsorption experiments

Biodegradability (BOD5/COD) observed after each treatment process. $BOD_5/COD > 0.8$ highly biodegradable; $0.8 > BOD_5/COD > 0.7$ biodegradable; $0.7 > BOD_5/COD > 0.3$ slowly biodegradable; $0.3 > BOD_5/COD > 0.1$ slightly biodegradable; $BOD_5/COD < 0.1$ non-biodegradable.

Treatment processes	UV-A-Fenton	UV-C-Fenton
CFD	0.12±0.0 a	0.12±0.0 a
Photo-Fenton	0.45±0.0 b	0.47±0.0 b
Adsorption	0.51±0.0 c	0.28±0.0 c



Removal efficiency of (a) CFD/UV-A-Fenton/Adsorption system, (b) CFD/UV-C-Fenton/Adsorption system. CFD operational con-ditions: [PVPP] = 0.5 g/L, pH = 6.0, rapid mix (rpm/min) = 150/3, slow mix (rpm/min) = 20/20, sedimentation = 12 h. Photo-Fenton operational conditions: $[Fe^{2+}]$ = 2.5 mM, $[H_2O_2]$ = 225 mM, pH = 3.0, agitation = 350 rpm, t = 150 min. Adsorption operational conditions: [Bentonite] = 1.5 g/L, pH = 6.0, agitation = 350 rpm, sedimentation = 2 h.



Conclusions

Based in the results it is concluded

(1) The CFD process with application of PVPP achieves a COD and total polyphe-nols removal of 48.0 and 63.3%, respectively

(2) With application of UV-A-Fenton and UV-C-Fenton process it is achieved 54.2 and 65.0% TOC removal, respectively, with a H_2O_2 consumption of 225 and 169 mM H_2O_2

(3) The UV-C-Fenton achieves lower E_{EO} regarding UV-A-Fenton process (170 and 641 kWh m^{-3} $order^{-1}$, respectively)

(4) The combined CFD/UV-A-Fenton/Adsorption system achieves a COD removal of 80.9% with a biodegradability of 0.51

(5) The combined CFD/photo-Fenton/Adsorption system is efficient for WW treatment

Acknowledgements

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