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Sonochemical Degradation of the Anticancer Pharmaceutical Anastrozole Using Low-Frequency Ultrasound: Kinetic and Mechanistic Study

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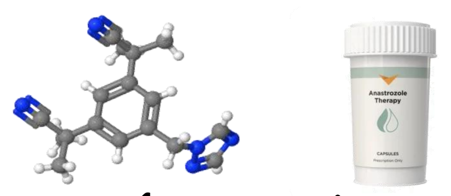
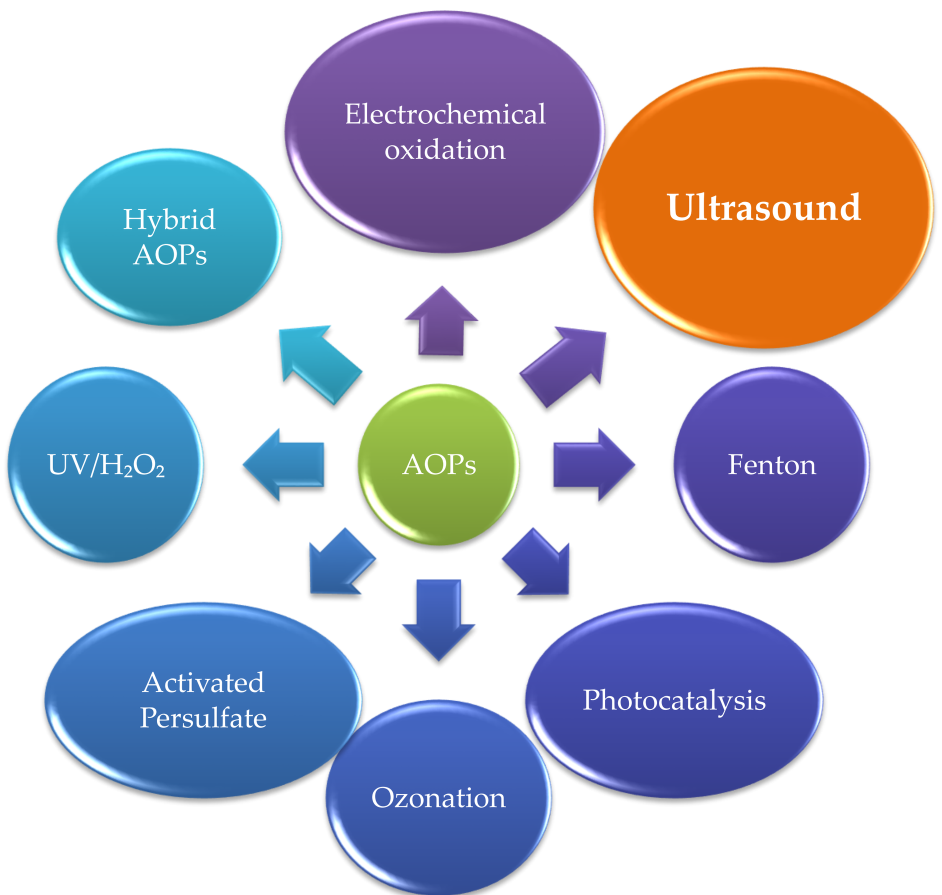
INTRODUCTION & AIM

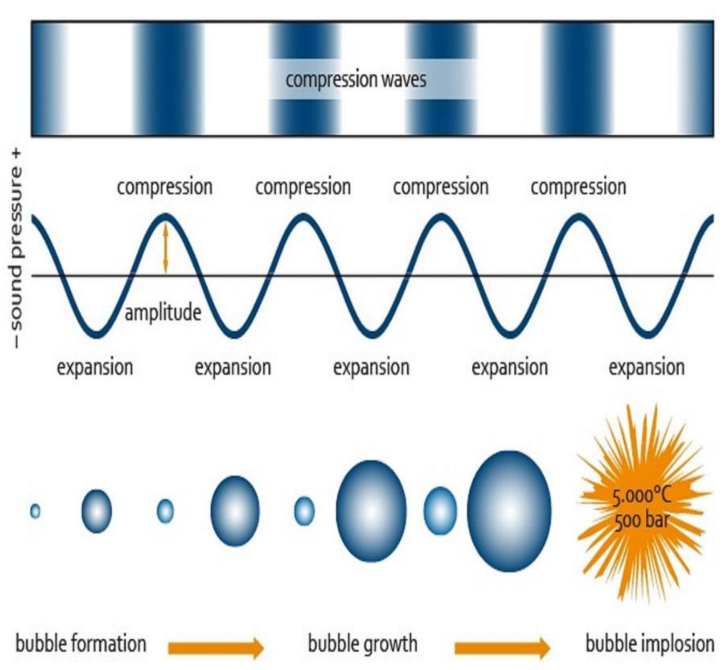
What is anastrozole?



Anastrozole is a drug largely use for treating cancers in women. Its main function is to inhibit estrogen production in your body [1]. Anastrozole (ANZ) is included in is on the WHO's list of Essential Medicines as a pharmaceutical with endocrine-active properties [1]. Even though anastrozole is not officially classified as an environmental endocrine-disrupting chemical, ANZ occurrence in the aquatic system, it is still a concern because it suppresses estrogen synthesis (aromatase inhibitor), so even trace environmental levels could affect e.g., fish reproduction, sex ratios, and endocrine signaling [2].

Advanced oxidation processes (AOPs) ⟹ Acoustic cavitation





Acoustic cavitation refers to the formation, growth, and violent collapse of microbubbles in a liquid exposed to high-frequency sound waves, typically in the ultrasonic range (20 kHz–1 MHz) [3].

These unique physicochemical effects promote the homolytic cleavage of water molecules to generate highly reactive species such as hydroxyl radicals (•OH), hydrogen radicals (•H), and singlet oxygen ($^1O_2$), enabling the degradation of persistent contaminants [3].

The aim of this study is to investigate, for the first time, the sonochemical degradation of ANZ using low-frequency ultrasound.

METHOD

Experiments were conducted in a double-walled batch reactor at a power density of 71 W/L and a temperature of 20 °C, maintained through water circulation (Figure 1). The reactor volume was 200 mL, and ANZ concentrations were monitored using High-Performance Liquid Chromatography (HPLC). ANZ was eluted with a mobile phase consisting of 60% water and 40% acetonitrile and detected at 210 nm with a photodiode array detector within the HPLC system.

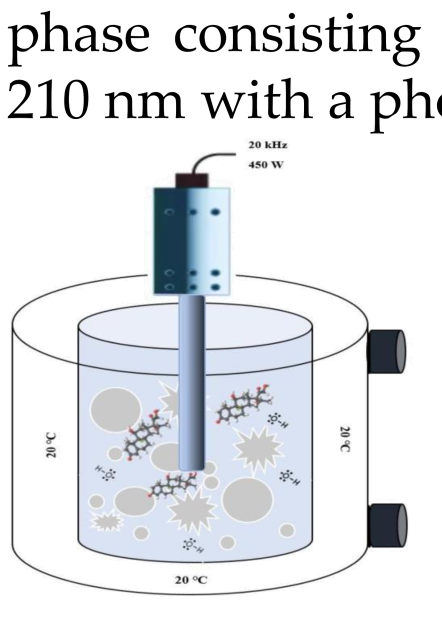


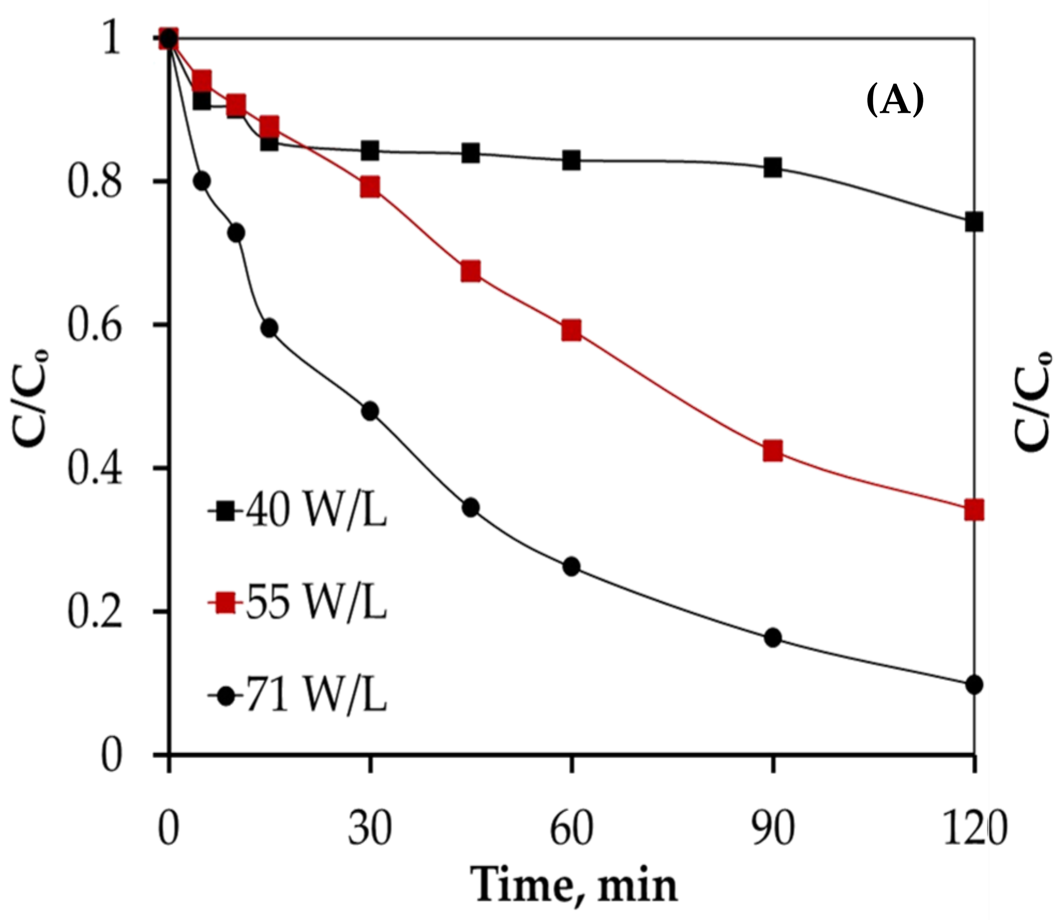
Figure 1: Schematic representation of the experimental setup.

Table 1: Composition of Bottled Water and Secondary-Treated Wastewater

Contents	Bottled Water (mg L^{-1})	Wastewater (mg L^{-1})
HCO_3^-	273.9	278
Cl^-	3.8	262
NO_2^-	0	n.d.
SO_4^{2-}	7.9	0
NO_3^-	1	n.d.
PO_4^{3-}	n.d.	14.9
F^-	0.07	0
Ca^{2+}	75.5	112
Mg^{2+}	5.1	n.d.
Na^+	2.1	n.d
K^+	0.6	n.d.
TDS	254	n.d.
TSS	n.d.	22
TOC	<1	2.5
COD	n.d.	48.5

n.d. = Not detected / Not determined.

RESULTS & DISCUSSION



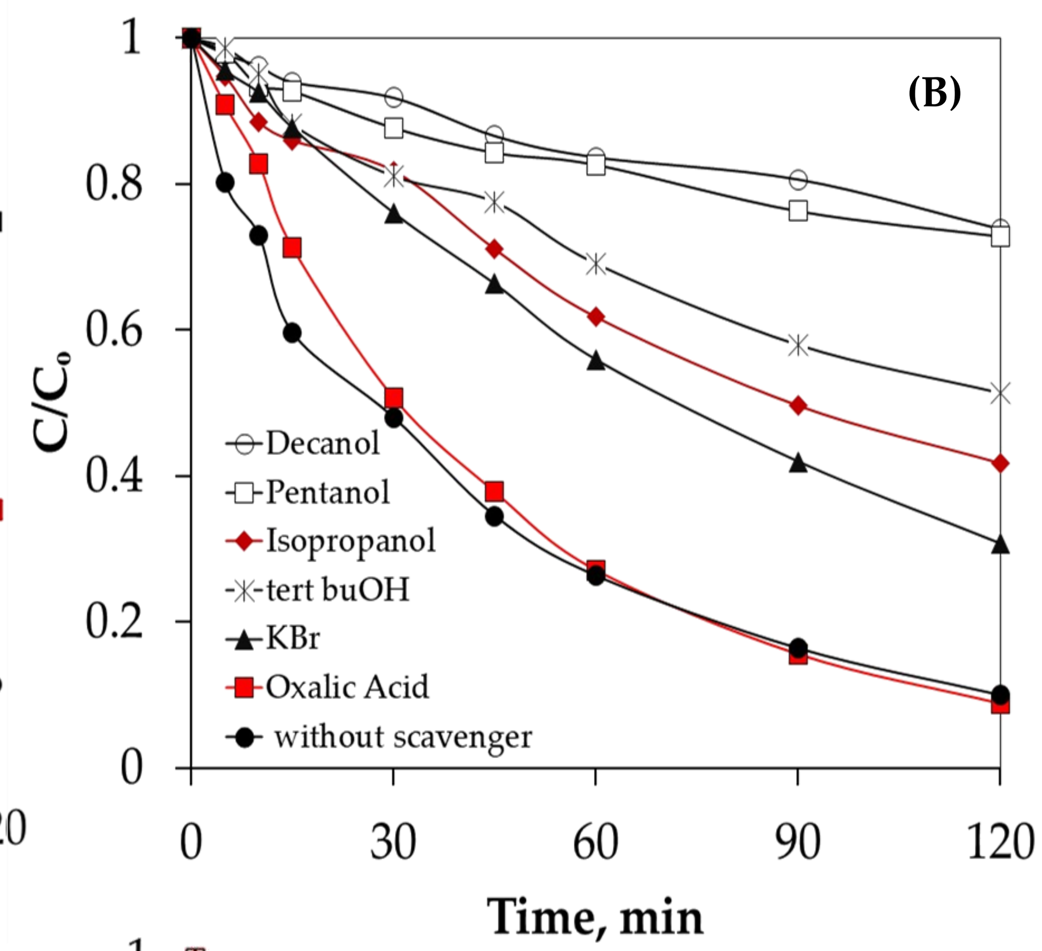


Table 1: Partition coefficients for the reactive oxygen species scavengers used in this study.

Compound	$logK_{ow}$
Oxalic acid	-0.81
KBr	-
Tert-BuOH	0.35
isopropanol	0.05
Pentanol	1.40
Decanol	4.57
Anastrazole (ANZ)	1.58

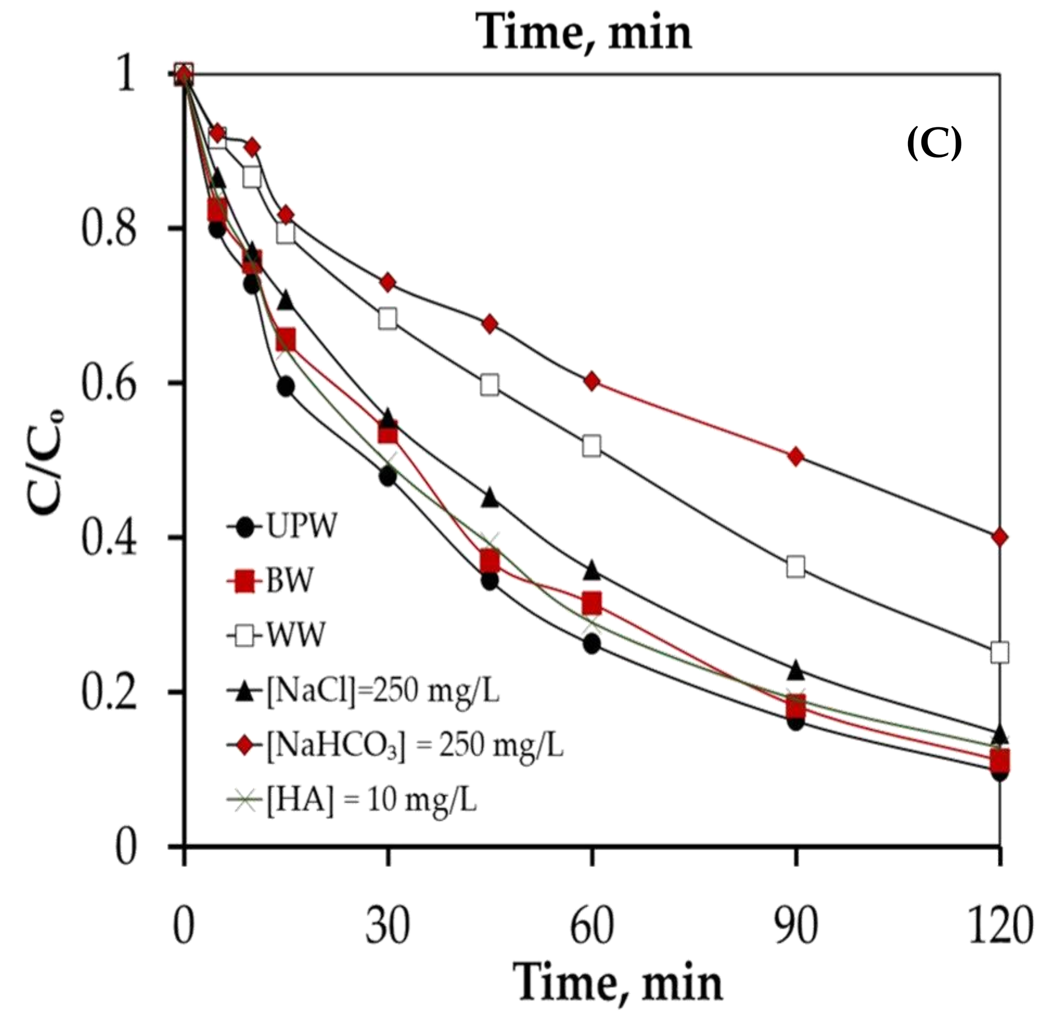


Figure 2: A) Effect of power density on ANZ degradation (Experimental conditions: [ANZ]=0.75 mg/L in UPW at inherent pH and 20 °C). B) Mechanistic investigation using scavengers (experimental conditions: [ANZ]=0.75 mg/L, [scavenger]=0.33 mM, power density=71 W/L in UPW at inherent pH and 20 °C). C) Effect of different water matrices on ANZ degradation (experimental conditions: [ANZ]=0.75 mg/L, power density=71 W/L at inherent pH and 20 °C).

CONCLUSION

The impact of ultrasonic intensity was evaluated, demonstrating that increasing power density enhanced ANZ degradation (Figure 2A). Higher initial ANZ concentrations decreased the apparent rate constant (data not shown for brevity). The effect of pH was also examined; acidic conditions slightly favored degradation, whereas alkaline conditions marginally inhibited it (data not shown for brevity).

Mechanistic analysis (Figure 2B) indicated that ANZ degradation predominantly occurred at the bubble–liquid interface and within cavitation bubbles. The process was further examined in both synthetic and real wastewater matrices. Results showed satisfactory performance, with only a slight reduction in efficiency observed in real wastewater, likely due to bicarbonate ions acting as radical scavengers (Figure 2C). Overall, these findings highlight the potential of sonochemical treatment as a promising approach for the removal of persistent pharmaceutical contaminants from wastewater.

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