



UNIVERSITÀ  
DELLA  
CALABRIA

**IDROGEL MAGNETICI A BASE DI  
ALGINATO ED OSSIDO DI GRAFENE:  
CARATTERIZZAZIONE ED  
APPLICAZIONI IN CAMPO AMBIENTALE  
E FARMACEUTICO**

**DIPARTIMENTO DI FARMACIA E SSN**  
**TESI DI LAUREA SPERIMENTALE IN CHIMICA-FISICA**



**RELATORI**

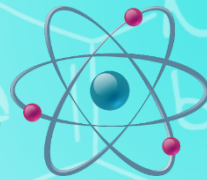
**PROF. FIORE PASQUALE NICOLETTA**

**DOTT.SSA MANUELA CURCIO**

**CANDIDATO**

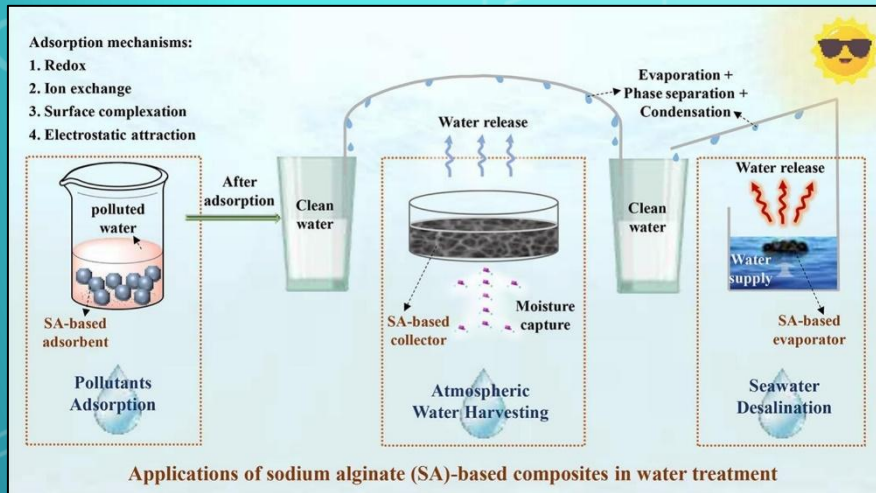
**CARCHEDI FOCA MARCO**

**MATRICOLA 216323**



# Progettazione – Realizzazione – Caratterizzazione

## SISTEMA COMPOSITO IDROGEL – NANOPARTICELLE



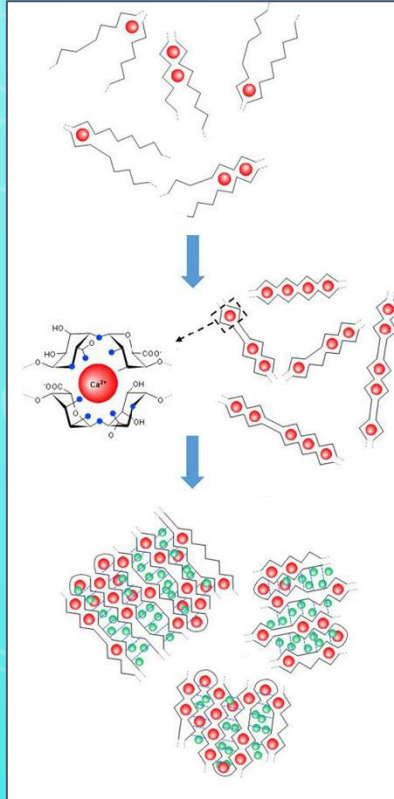
**SODIO ALGINATO –  
CLORURO DI CALCIO –  
OSSIDO FERRICO –  
OSSIDO DI GRAFENE –  
BLU DI METILENE –**



**DISPOSITIVO SENSIBILE AL DUPLICE STIMOLO MAGNETICO-PH  
IN GRADO DI ADSORBIRE GLI INQUINANTI NONCHÉ DI RILASCIARE UN  
AGENTE TERAPEUTICO IN MANIERA MODULABILE**



# RETICOLAZIONE IONICA



## INDOTTA DA IONI $\text{Ca}^{2+}$

- 1) Interazione  $\text{Ca}^{2+}$  - guluronato
- 2) Formazione di dimeri egg-box
- 3) Formazione di multicomplessi

## GELIFICAZIONE

Incorporazione di  $\text{Fe}_2\text{O}_3$  e GO durante il processo



# I QUATTRO IDROGEL OTTENUTI

$H_{SA}$  (Bianco)

$H_{SAGO}$  (Nero)

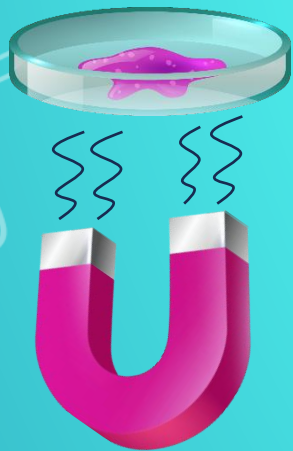
$H_{SAFe}$  (Ruggine)

$H_{SAFeGO}$  (Marrone)



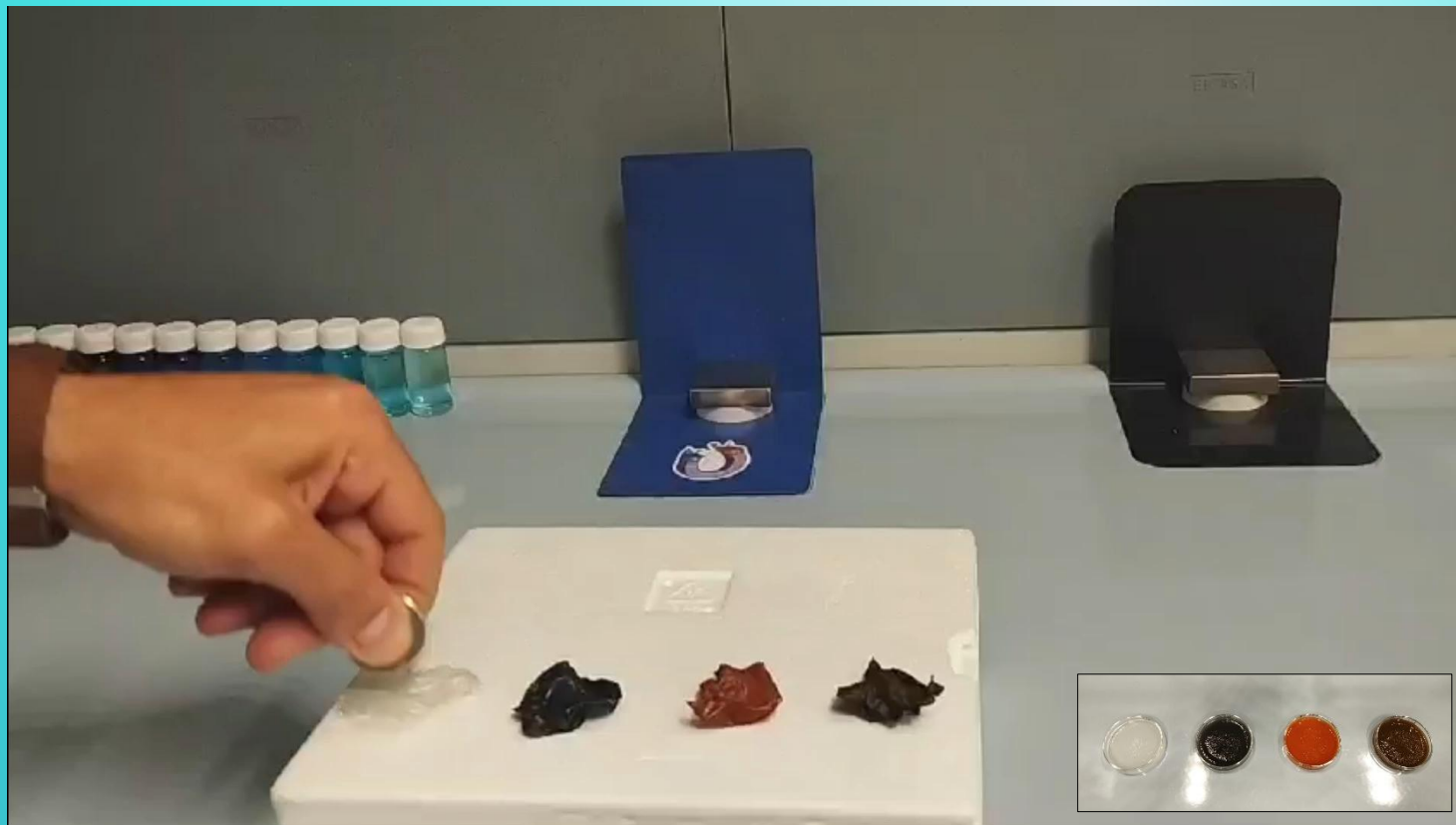


# RESPONSIVITÀ MAGNETICA

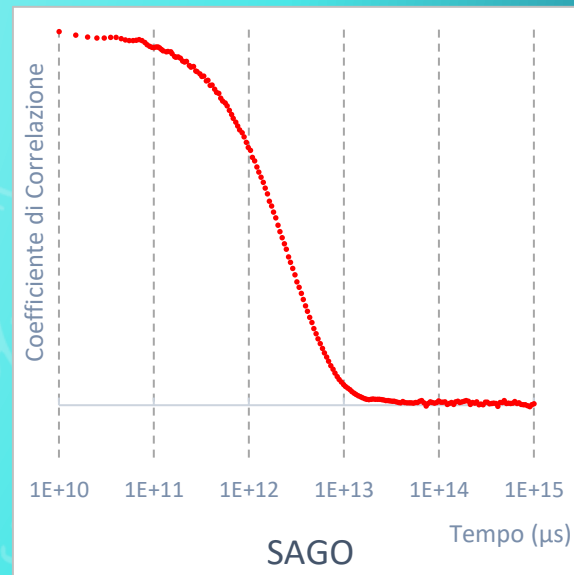
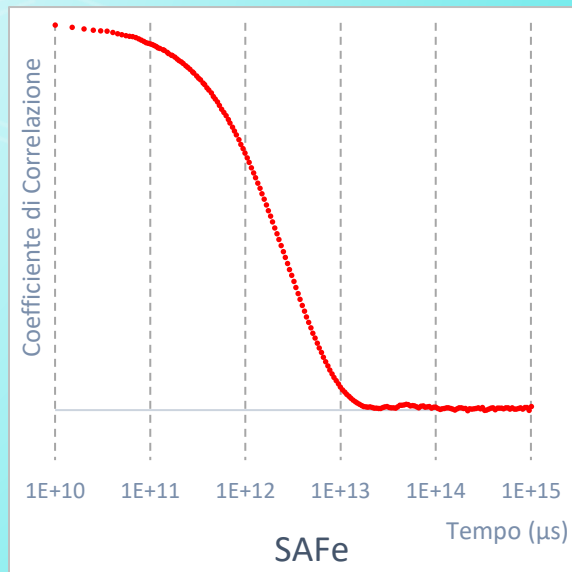
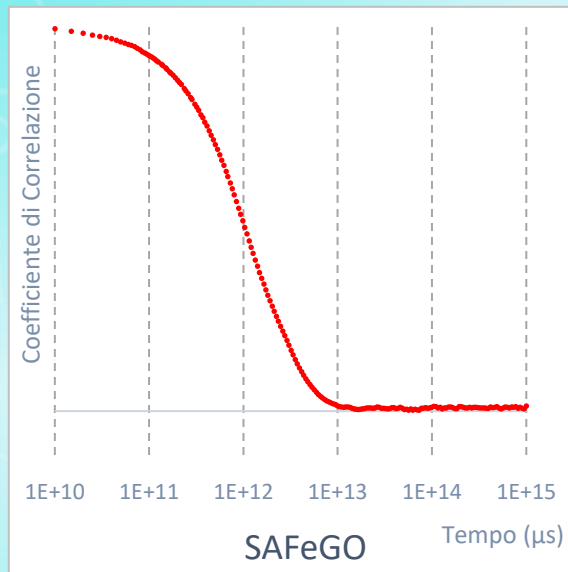




# RESPONSIVITÀ MAGNETICA



# ANALISI DYNAMIC LIGHT SCATTERING



**I risultati confermano l'omogeneità  
del sistema disperso**

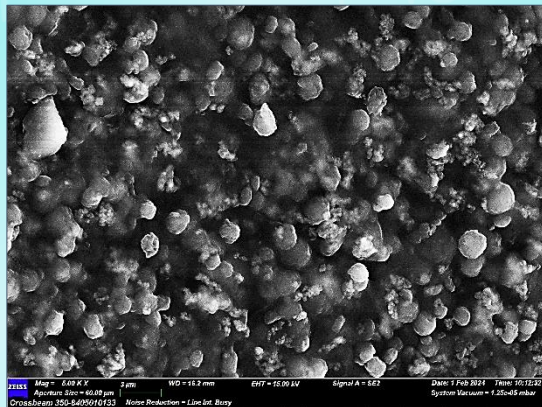




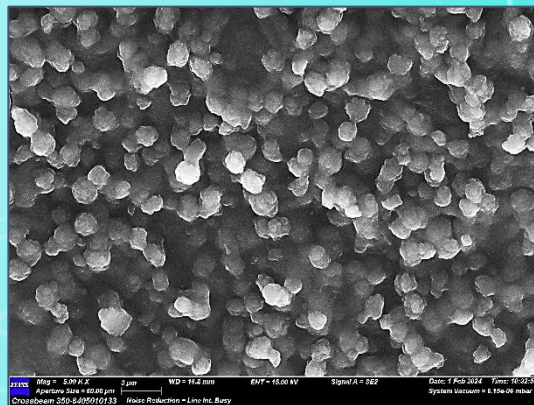


# ANALISI MORFOLOGICA

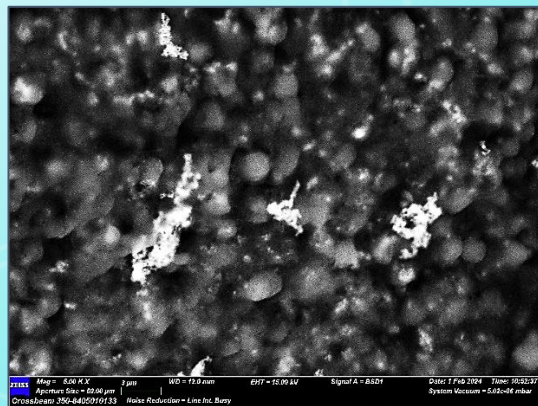
$H_{SAFeGO}$



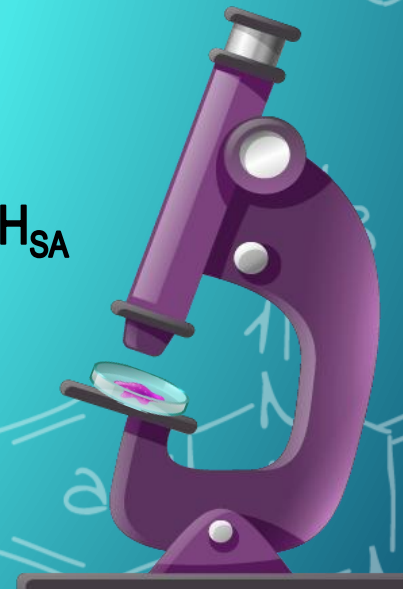
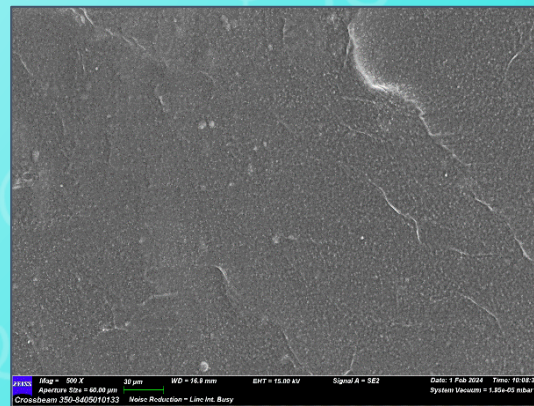
$H_{SAGO}$



$H_{SAFe}$

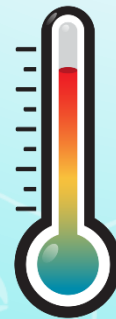
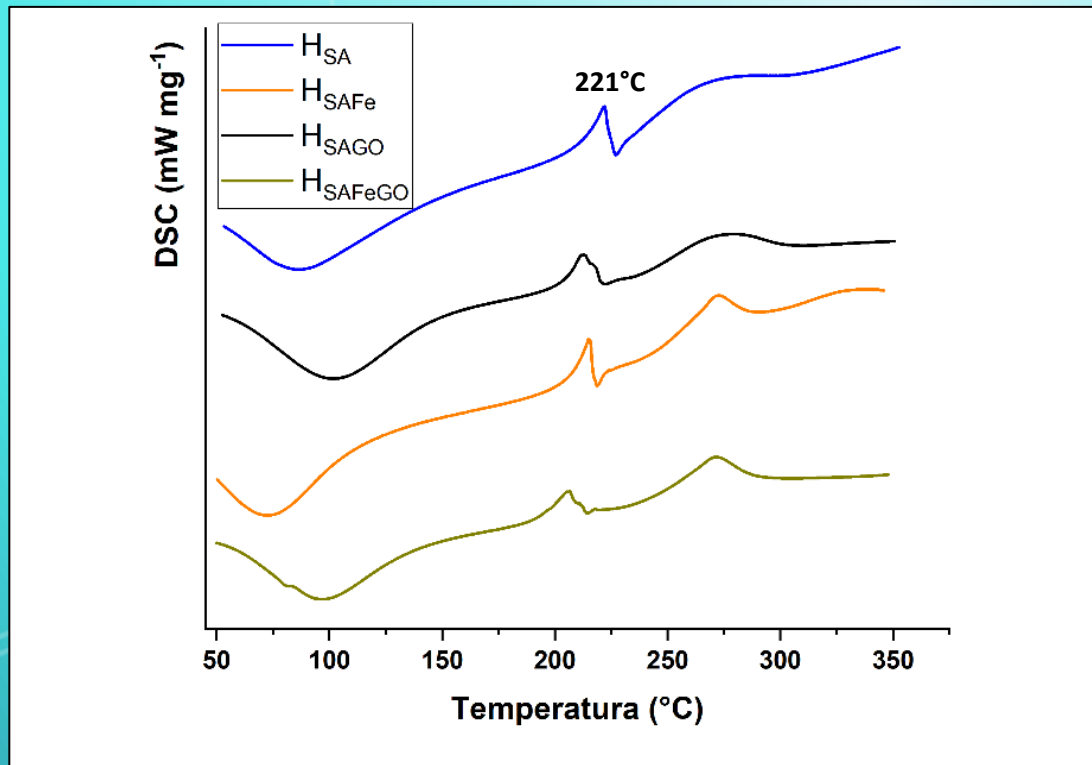


$H_{SA}$



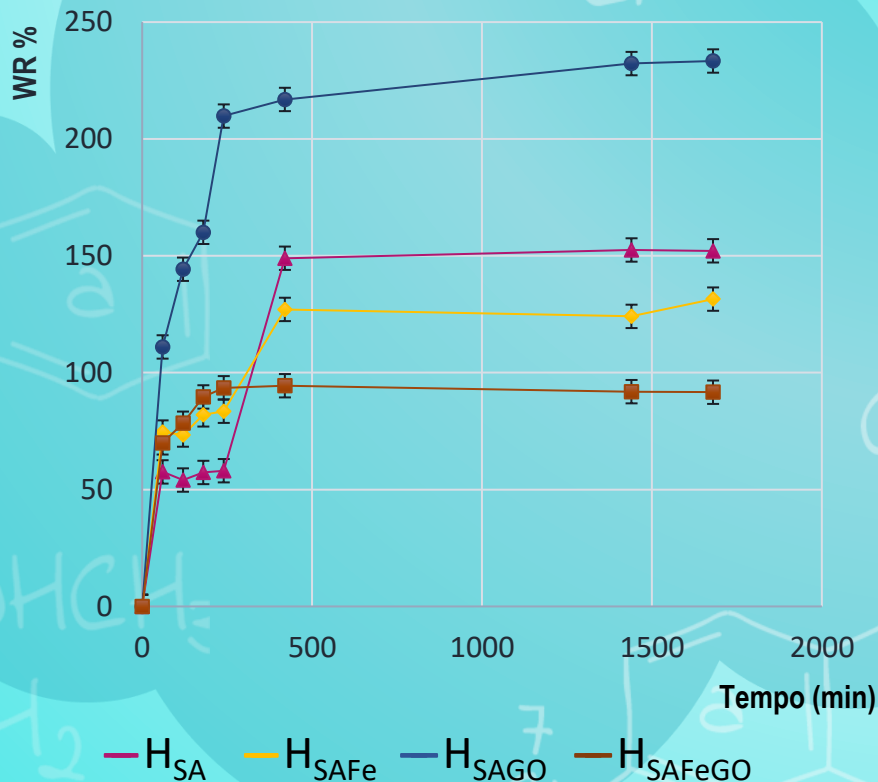


# ANALISI CALORIMETRICA (DSC)



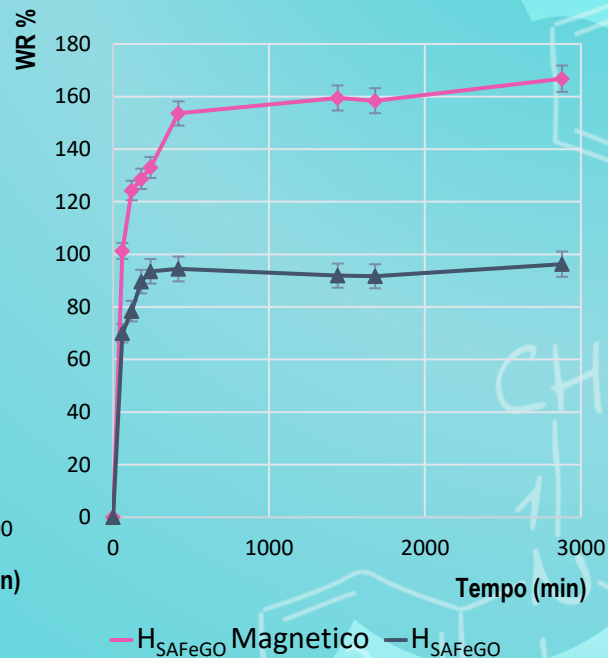
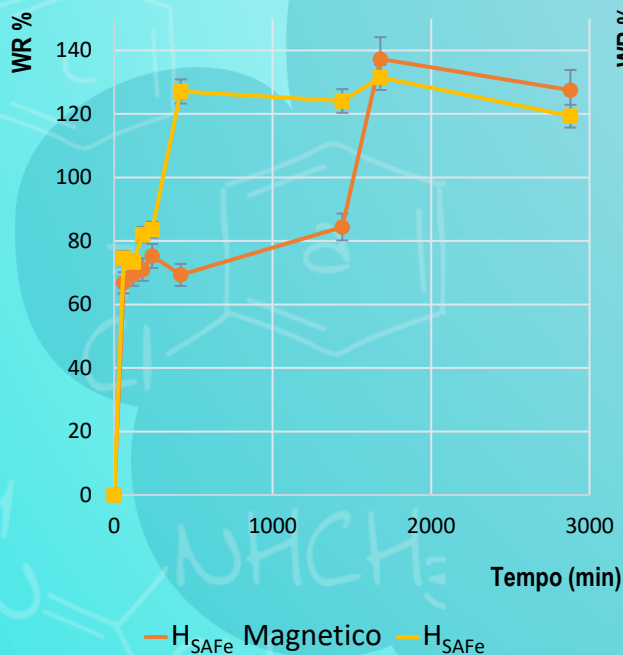
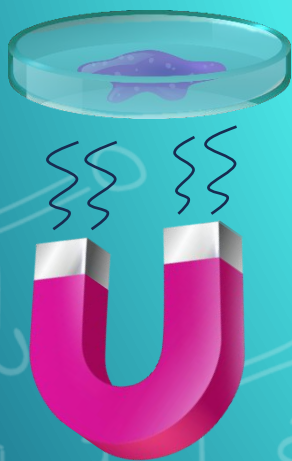
# PROFILI DI RIGONFIAMENTO

$$WR = \frac{W_s - W_d}{W_d} \times 100$$



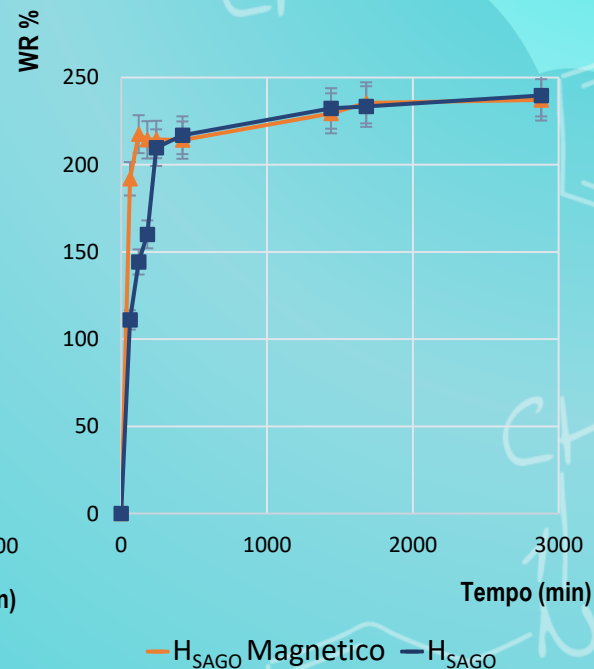
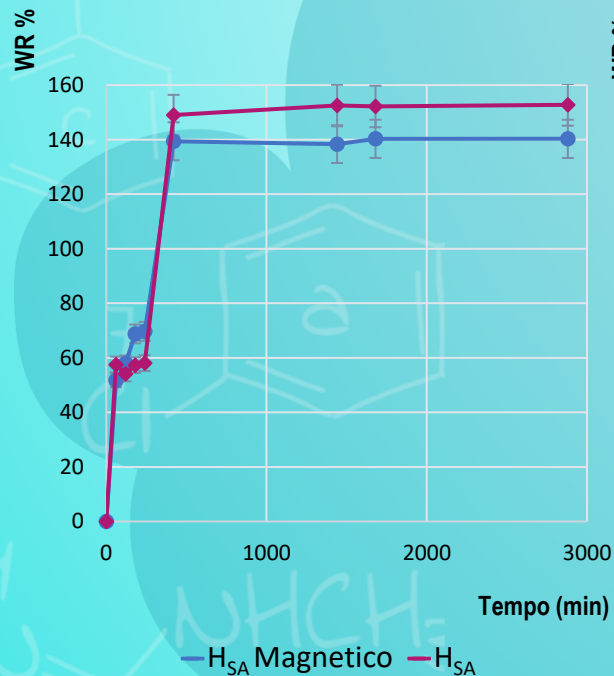
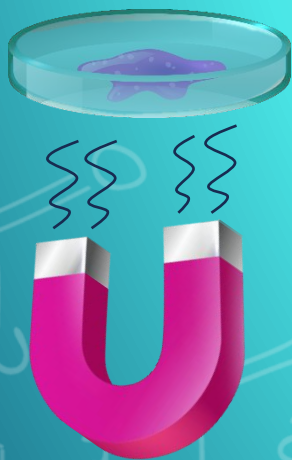
# PROFILI DI RIGONFIAMENTO

Campo Magnetico Applicato



# PROFILI DI RIGONFIAMENTO

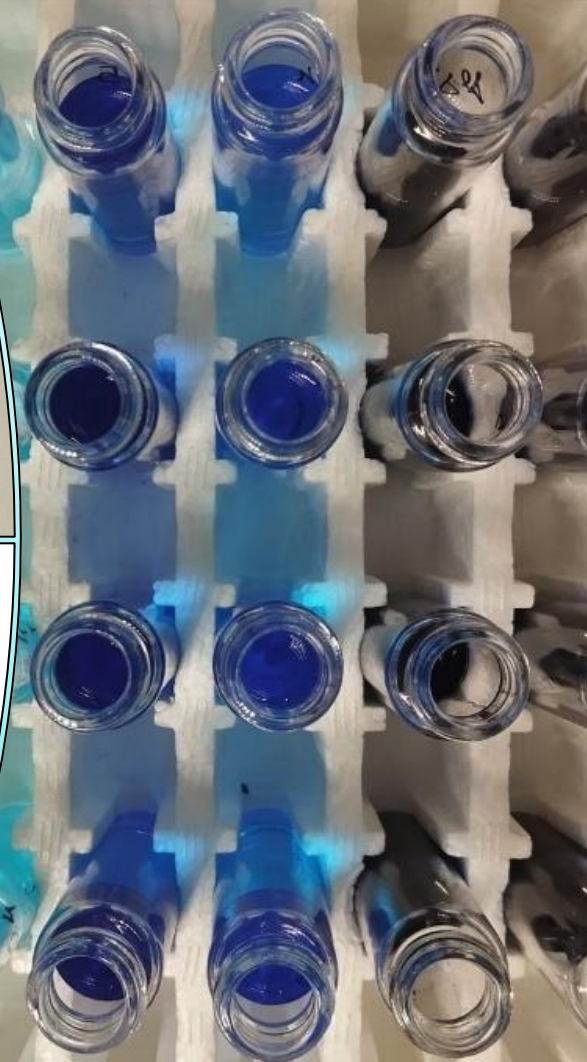
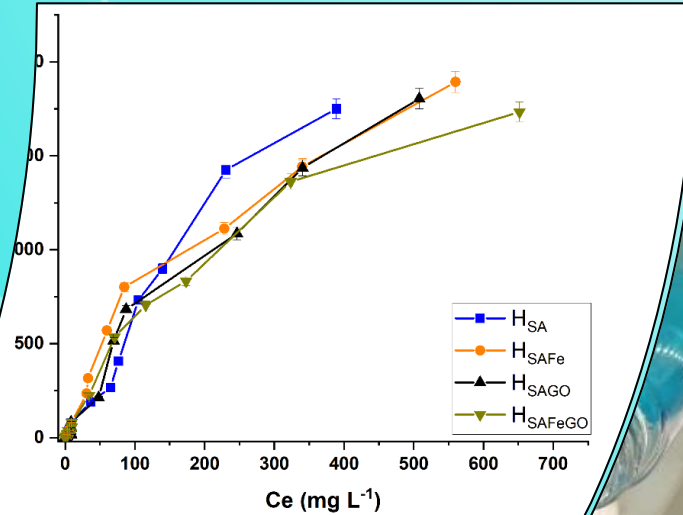
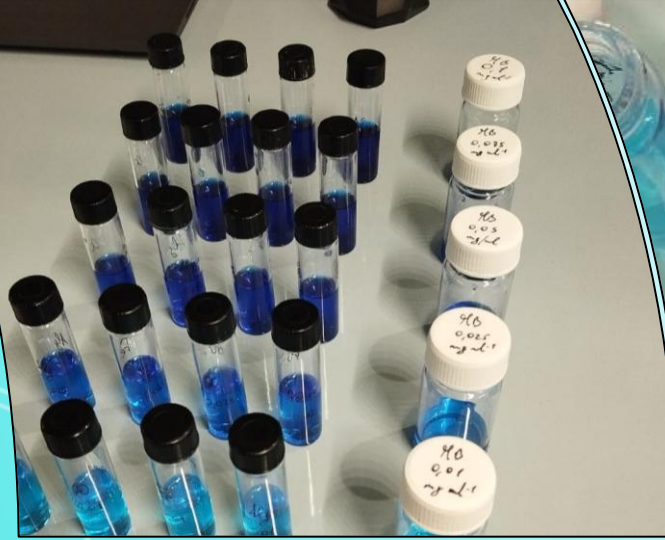
Campo Magnetico Applicato





# ISOTERME D'ASSORBIMENTO

Assorbimento in funzione della  
concentrazione



# ISOTERME D'ASSORBIMENTO

Langmuir

$$q_e = \frac{q_{max} k_L C_e}{1 + k_L C_e}$$

Freundlich

$$q_e = k_F C_e^{1/n_F}$$

Red- Pet

$$q_e = \frac{k_{RP} C_e}{1 + \alpha_{RP} C_e^g}$$

Sips

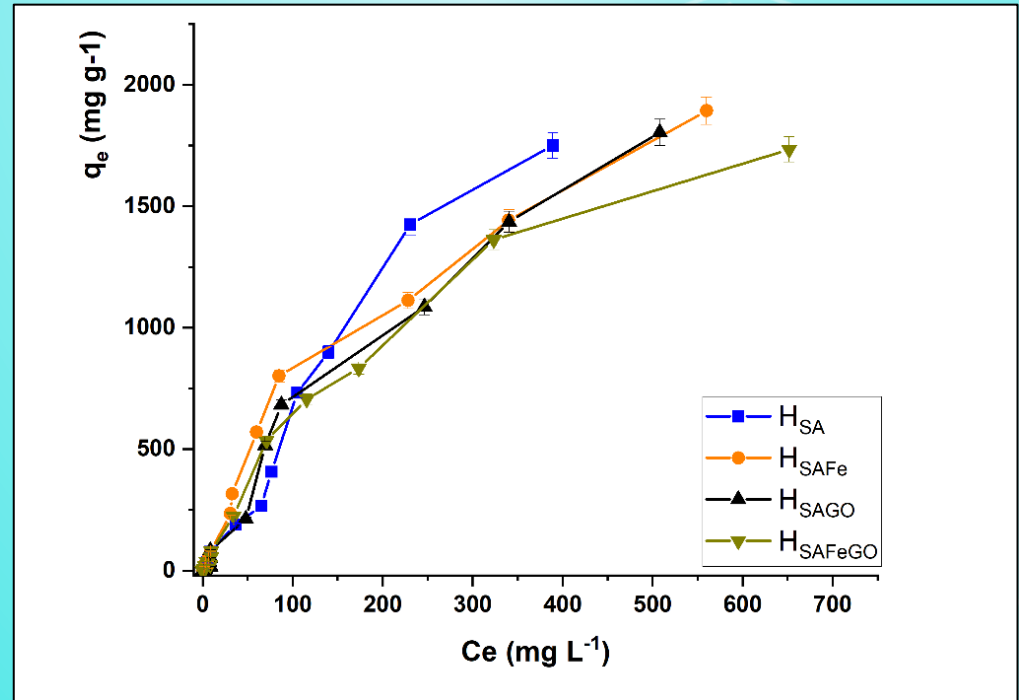
$$q_e = \frac{q_{max} k_S C_e^{n_s}}{1 + k_S C_e^{n_s}}$$

Dub-Rad

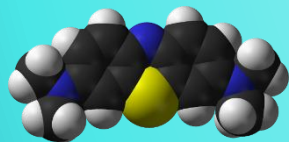
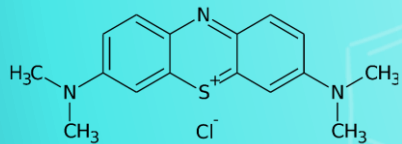
$$q_e = q_{max} e^{(-\beta D R \epsilon)^2}$$

Temkin

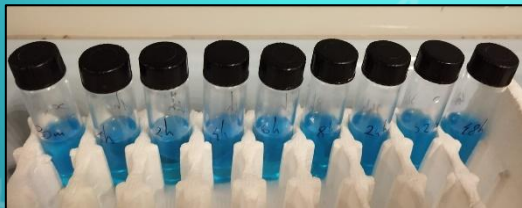
$$q_e = B \ln(A_T C_e)$$



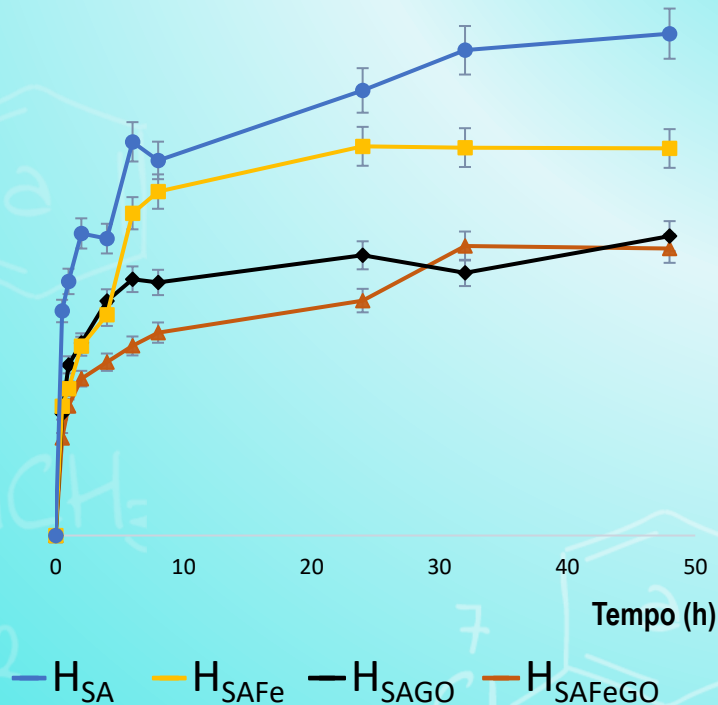
# CINETICHE D'ASSORBIMENTO



Piccoli frammenti di ciascun idrogel sono stati posti in vials contenenti una soluzione a concentrazione nota di Blu di metilene.



$q_t$  (mg g<sup>-1</sup>)

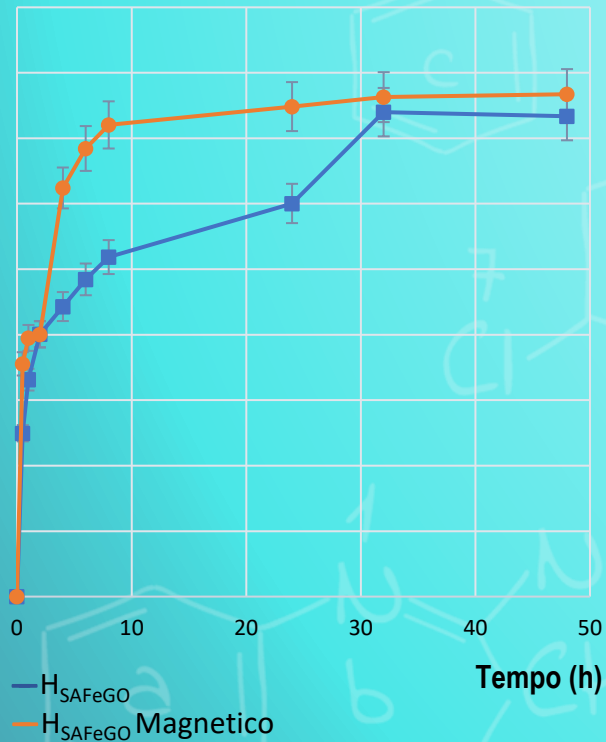




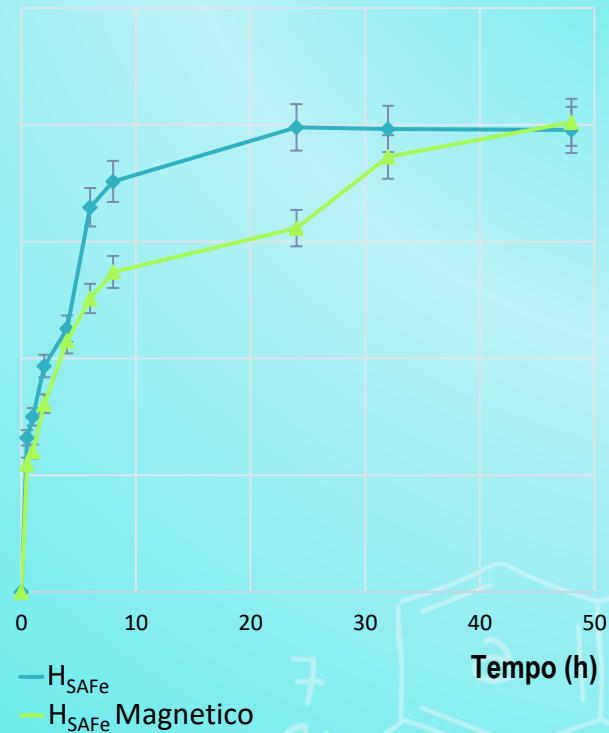
# CINETICHE D'ASSORBIMENTO



$q_t$  (mg g<sup>-1</sup>)



$q_t$  (mg g<sup>-1</sup>)





# CINETICHE D'ASSORBIMENTO

Pseudo-1°ordine

$$q_t = q_e (1 - e^{-k_1 t})$$

Pseudo-2°ordine

$$q_t = \frac{k_2 q_e^2 t}{1 + k_2 q_e t}$$

Avrami

$$q_t = q_e [1 - e^{-(k_A t)^n}]$$

Potenza frazionaria

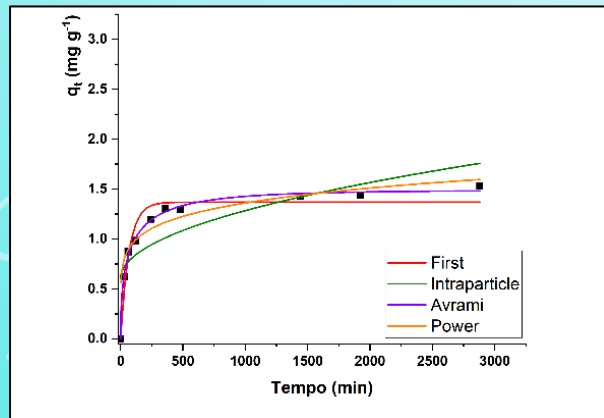
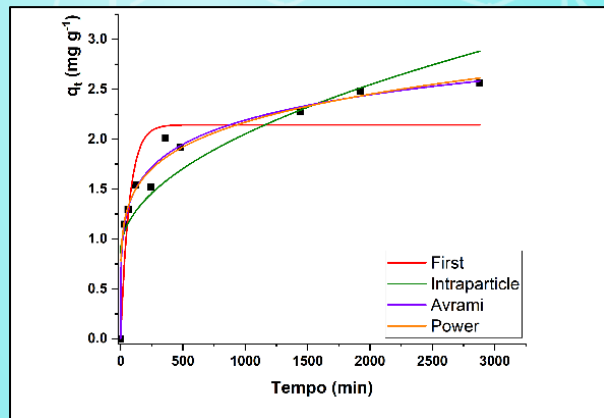
$$q_t = k_p t^v$$

Diffusione intraparticellare

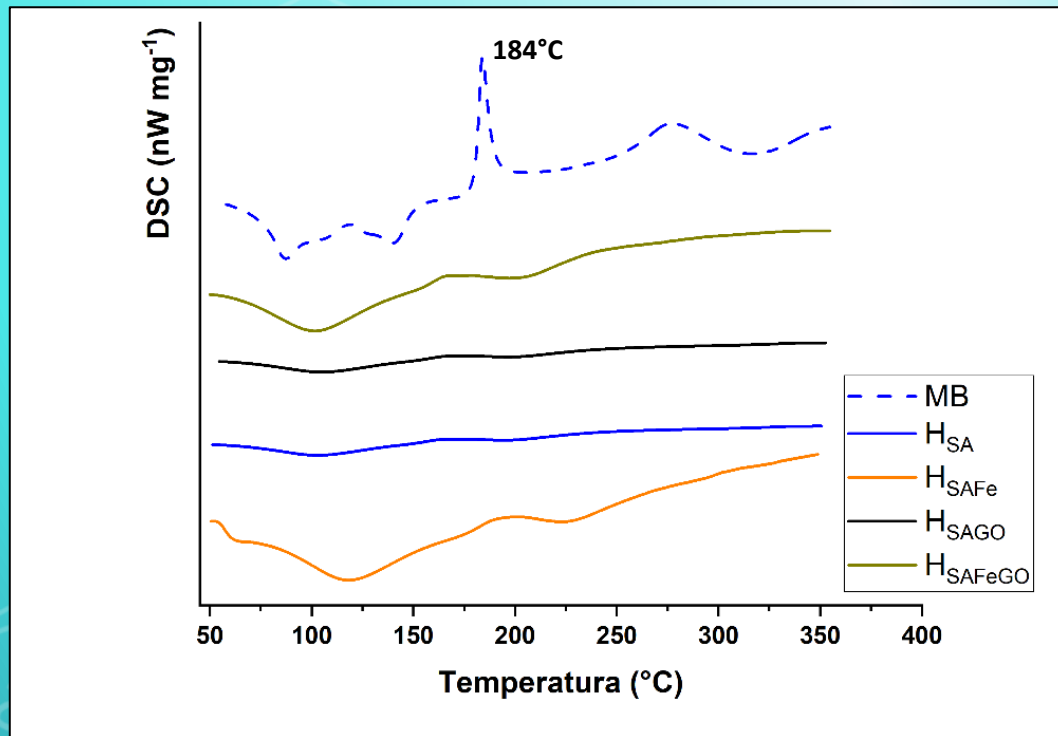
$$q_t = k_i t^{1/2} + C$$

Elovich

$$q_t = \frac{1}{\beta} \ln(\alpha \beta t)$$



# ANALISI CALORIMETRICA (DSC)



# PROFILI DI RILASCIO



## Rilascio a pH neutro

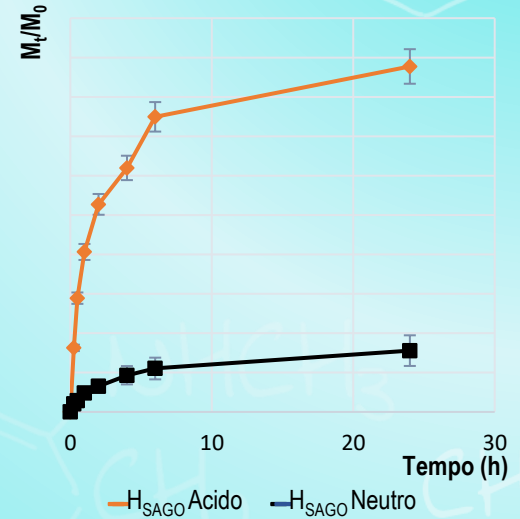
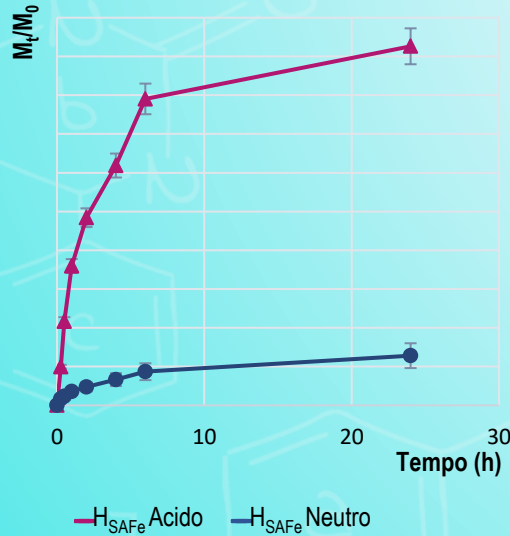
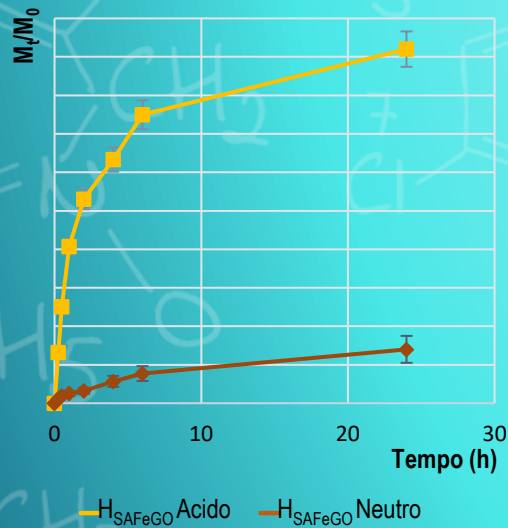
Per determinare la cinetica di rilascio si pongono frammenti di idrogel impregnati di MB in vials con un volume noto di acqua



## Rilascio a pH acido

Si nota un incremento netto della quantità di MB rilasciata dall'idrogel

# Profili di Rilascio



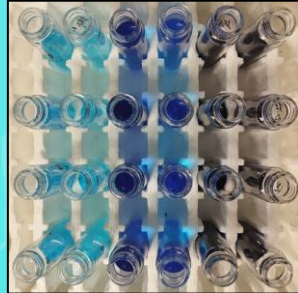
Reis: 
$$\frac{M_t}{M_0} = M_{max}(1 - e^{-(k_R/M_{max})t})$$

Peppas-Sahlin: 
$$\frac{M_t}{M_0} = K_1 \cdot t^{1/2} + K_2 \cdot t$$





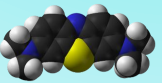
# CONCLUSIONI



- Idrogel ibridi versatili



- Assorbimento di tipo fisico, superficiale, termodinamicamente favorito

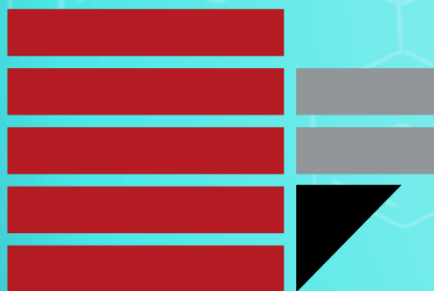


- Velocità di assorbimento influenzata da campo magnetico esterno



- Rilascio indotto da abbassamento del pH





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