AP 5

The spread of mold on surfaces is influenced by environmental and biological factors, including humidity and surface susceptibility. This report extends the classical SIR (Susceptible, Infected, Recovered) model to include a fourth equation accounting for the dynamics of environmental humidity. By analyzing the model, we provide insights into how environmental conditions can accelerate or mitigate the growth of mold, offering strategies for effective intervention.

Mold growth poses a significant challenge in various settings, such as homes, industrial environments, and food storage facilities. Understanding the dynamics of mold spread is crucial for developing strategies to control it. The SIR model, commonly used in epidemiology, can be adapted to model the interaction between clean surfaces (susceptible), mold-covered areas (infected), and treated regions (recovered). To incorporate the critical role of environmental humidity, we introduce a fourth equation that models the effect of humidity on the spread rate.

(It was my idea to do it about the spread of mold, it's a toy model generated by chatgpt)

Mold model:

Susceptible (S):

$$\frac{dS}{dt} = -\beta S I$$

Represents the rate at which clean surfaces become mold-infected.

Infected (I):

$$\frac{dI}{dt} = \beta S I - \gamma I$$

Represents the growth of mold-infected areas, balanced by treatment or exhaustion of resources.

Recovered (R):

$$\frac{dR}{dt} = \gamma I$$

Represents the surfaces treated or where mold can no longer grow.

Environmental Humidity (H):

$$\frac{dH}{dt} = -\delta H + \xi$$

Represents the dissipation (δ) and replenishment (ξ) of humidity over time.

The spread rate β is modeled as a function of humidity:

$$\beta(H) = \beta_0 H$$

where β_0 is a base spread rate dependent on temperature or other factors.

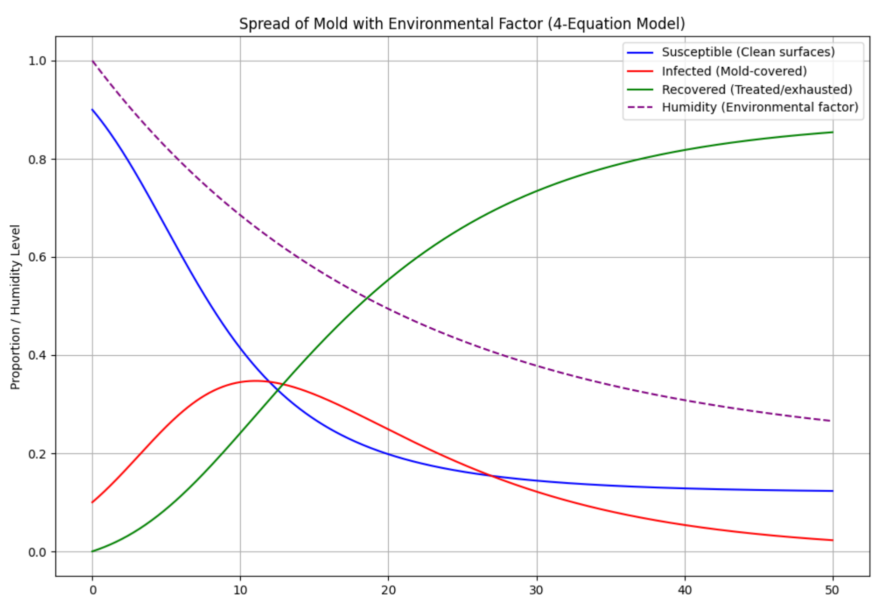
The equations are solved using Euler method, i chose this method because it is easy:

- $\beta_0 = 0.4$: Base mold spread rate.
- $\gamma = 0.1$: Recovery rate due to treatment.
- $\delta = 0.05$: Humidity dissipation rate.
- $\xi = 0.01$: External humidity source.

Initial conditions are:

- S (0) =0.9: 90% of surfaces are clean.
- I (0) =0.1: 10% are mold infected.
- R (0) =0.0: No treated surfaces.
- H (0) =1.0: Initial normalized humidity level.

Result:



Surface Dynamics:

- The susceptible proportion (S) decreases as mold spreads.
- The infected proportion (I) initially increases, then decreases as recovery dominates.
- The recovered proportion (R) increases steadily due to treatment.

Impact of Humidity:

- Humidity (H) influences the spread rate (β\betaβ).
- High humidity accelerates mold spread, while low humidity slows it down.
- Over time, humidity stabilizes based on dissipation and external sources.

Control Strategies:

- Reducing humidity (H) effectively slows mold spread.
- Treating infected areas (I) quickly reduces the recovery time for surfaces.

Code:

```
import numpy as np
import matplotlib.pyplot as plt

# Define the system of ODEs for the spread of mold
def mold_model(t, y, beta0, gamma, delta, xi):
    S, I, R, H = y
    beta = beta0 * H
    dS_dt = -beta * S * I
    dI_dt = beta * S * I - gamma * I
    dR_dt = gamma * I
    dH_dt = -delta * H + xi
    return [dS_dt, dI_dt, dR_dt, dH_dt]

# Parameters
beta0 = 0.4
gamma = 0.1
delta = 0.05
xi = 0.01

# Initial conditions
S0 = 0.9
I0 = 0.1
```

```python
R0 = 0.0
H0 = 1.0
y0 = [S0, I0, R0, H0]

# Time setup
t_start, t_end, dt = 0, 50, 0.1
steps = int((t_end - t_start) / dt)

# Arrays to store results
t = np.linspace(t_start, t_end, steps)
S, I, R, H = np.zeros(steps), np.zeros(steps), np.zeros(steps), np.zeros(steps)

# Initialize
S[0], I[0], R[0], H[0] = S0, I0, R0, H0

# Euler method
for i in range(1, steps):
    dS, dI, dR, dH = mold_model(t[i-1], [S[i-1], I[i-1], R[i-1], H[i-1]], beta0,
gamma, delta, xi)
    S[i], I[i], R[i], H[i] = S[i-1] + dS * dt, I[i-1] + dI * dt, R[i-1] + dR *
dt, H[i-1] + dH * dt

# Plot
plt.figure(figsize=(12, 8))
plt.plot(t, S, label="Susceptible (Clean surfaces)", color="blue")
plt.plot(t, I, label="Infected (Mold-covered)", color="red")
plt.plot(t, R, label="Recovered (Treated/exhausted)", color="green")
plt.plot(t, H, label="Humidity (Environmental factor)", color="purple",
linestyle="--")
plt.xlabel("Time (days)")
plt.ylabel("Proportion / Humidity Level")
plt.title("Spread of Mold with Environmental Factor (4-Equation Model)")
plt.legend()
plt.grid()
plt.show()
```

Conclusion:

The four-equation system demonstrates how reducing humidity and applying timely treatments can effectively mitigate mold spread.