EVALUATING AEROBIC LANDFILL BIOREACTIONS USING A NUMERICAL MODEL

By

G.R. Walter, S.J. Smith, L. Major, and J. Tang

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BACKGROUND

- SPACE FOR MUNICIPAL SOLID WASTE (MSW) LANDFILLS IS AT A PREMIUM
- DEGRADATION OF ORGANIC WASTE IN LANDFILLS IS SLOW DUE TO ANAEROBIC CONDITIONS
- CLOSED MSW LANDFILLS CAN GENERATE METHANE AND UNDERGO SUBSIDENCE FOR DECADES
- METHANE RECOVERY FOR ENERGY FROM SMALL LANDFILLS IS UNECONOMICAL

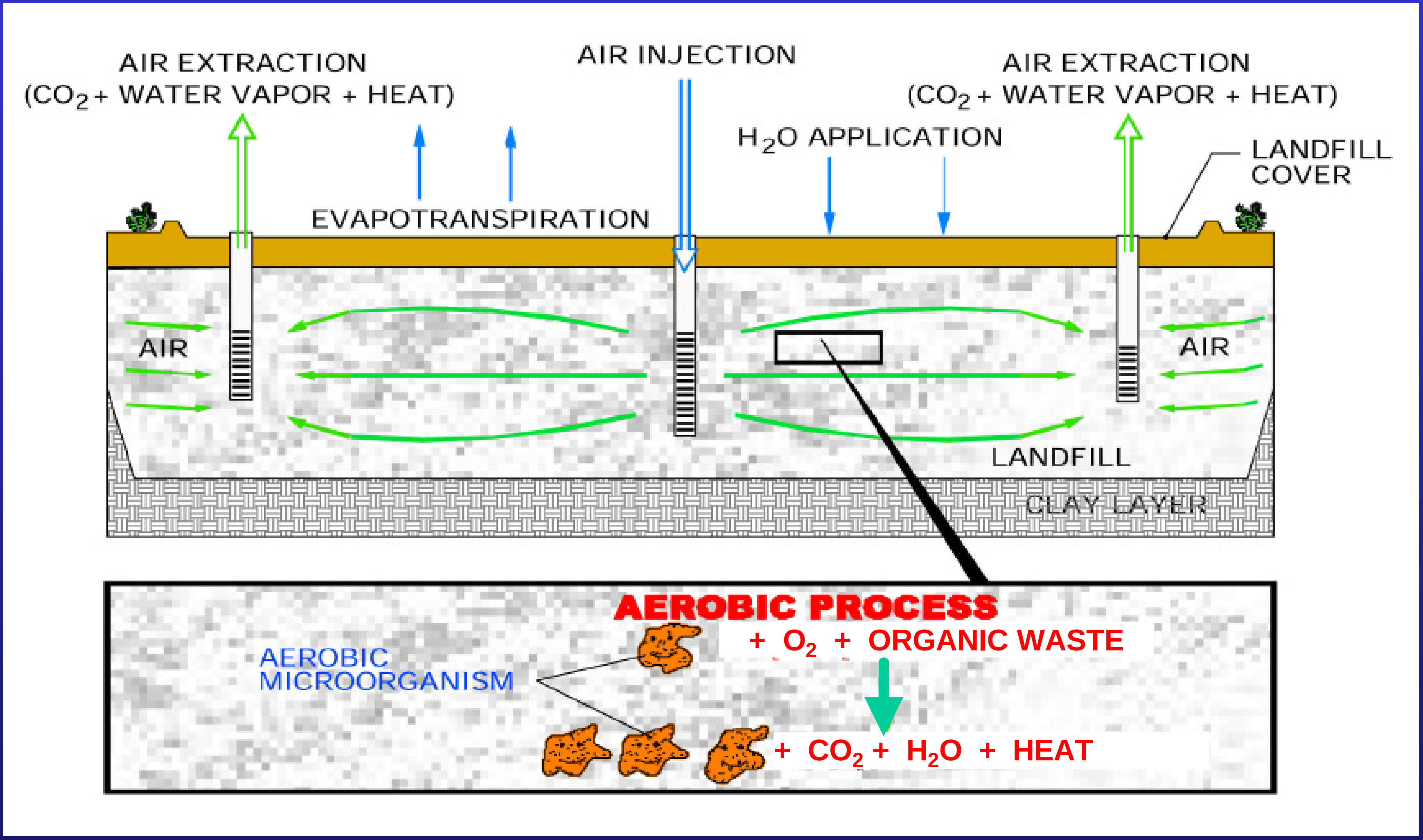
CONCEPT OF A SUSTAINABLE LANDFILL (SWITZERLAND, 1986)

- EACH GENERATION SHOULD MANAGE ITS WASTE TO FINAL STORAGE QUALITY (30 YEARS)
- FINAL STORAGE QUALITY: Any emissions to the environment are acceptable without further treatment or control
- UK FINAL STORAGE QUALITY CRITERIA
  - Reduce landfill gas generation by 99.9 % (200 cubic meters/metric ton to 0.1 cubic meters/metric ton)
  - Leachate quality determined by local environmental conditions

CONCEPT OF THE AEROBIC BIOCELL

- PURPOSE:
  - Speed the degradation of organic waste by creating aerobic conditions
- ADVANTAGES:
  - Preserve disposal space in active landfills and extend their life
  - Limit or eliminate methane production in closed landfills
  - Promote consolidation of refuse to improve future land use
- OPERATING PRINCIPLES:
  - Derived from composting science and experience

CONCEPTUAL MODEL OF AEROBIC BIOCELL



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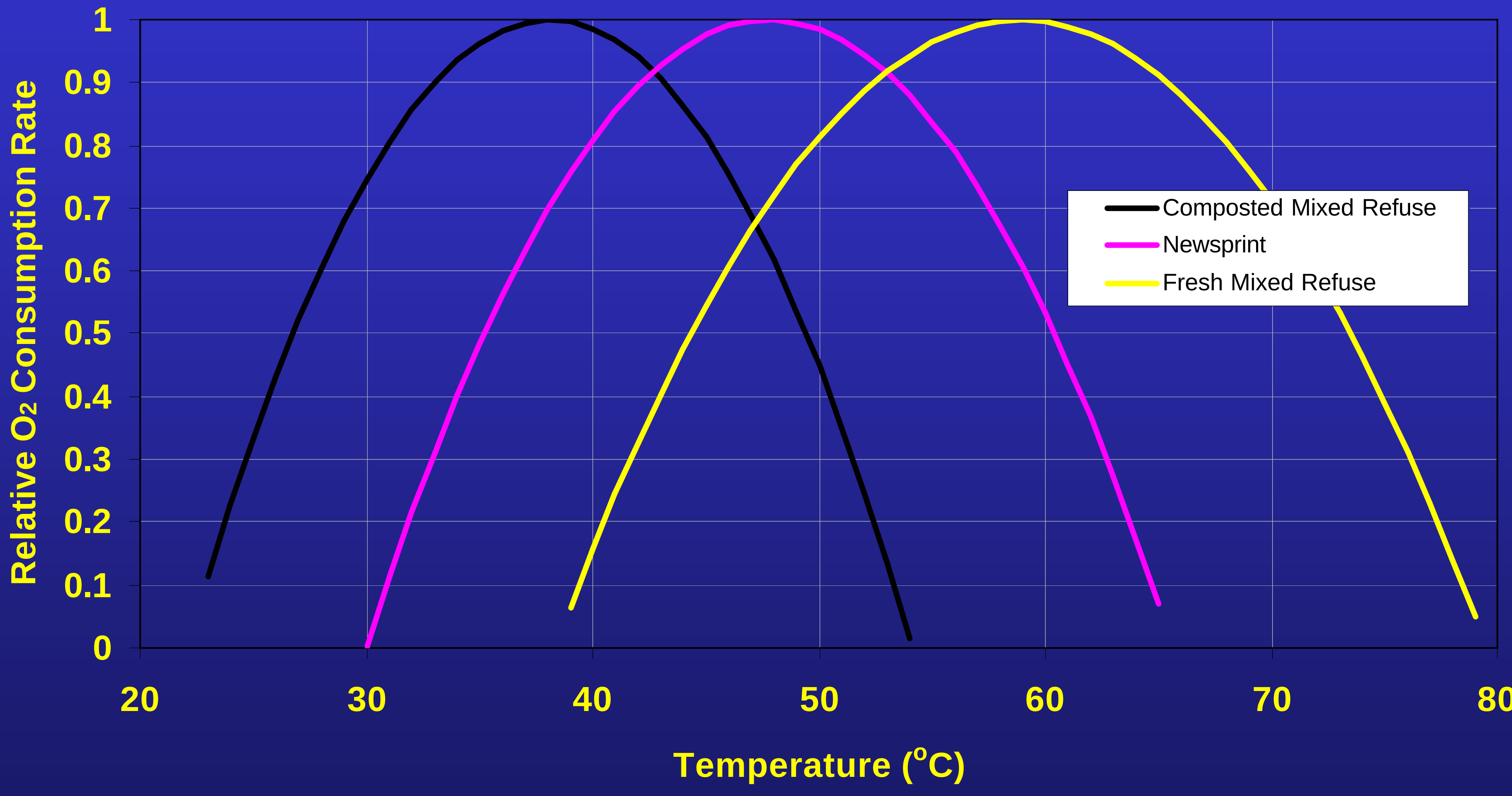
OPERATING FACTORS

- WATER APPLICATION
  - Maintain Desired Moisture Content to Support Microbial Population
  - Replace Water Removed by Evaporation
- TEMPERATURE CONTROL
  - Aerobic Biodegradation Releases Approximately 3600 cal/gm substrate oxidized
  - Optimal Biodegradation: 40 to 60 ^{o}C (100 to 140 ^{o}F)
  - Prevent Hot Spots that May Result in Spontaneous Combustion
    - > 80 ^{o}C (180 ^{o}F)

BIODEGRADATION RATE AS A FUNCTION OF TEMPERATURE

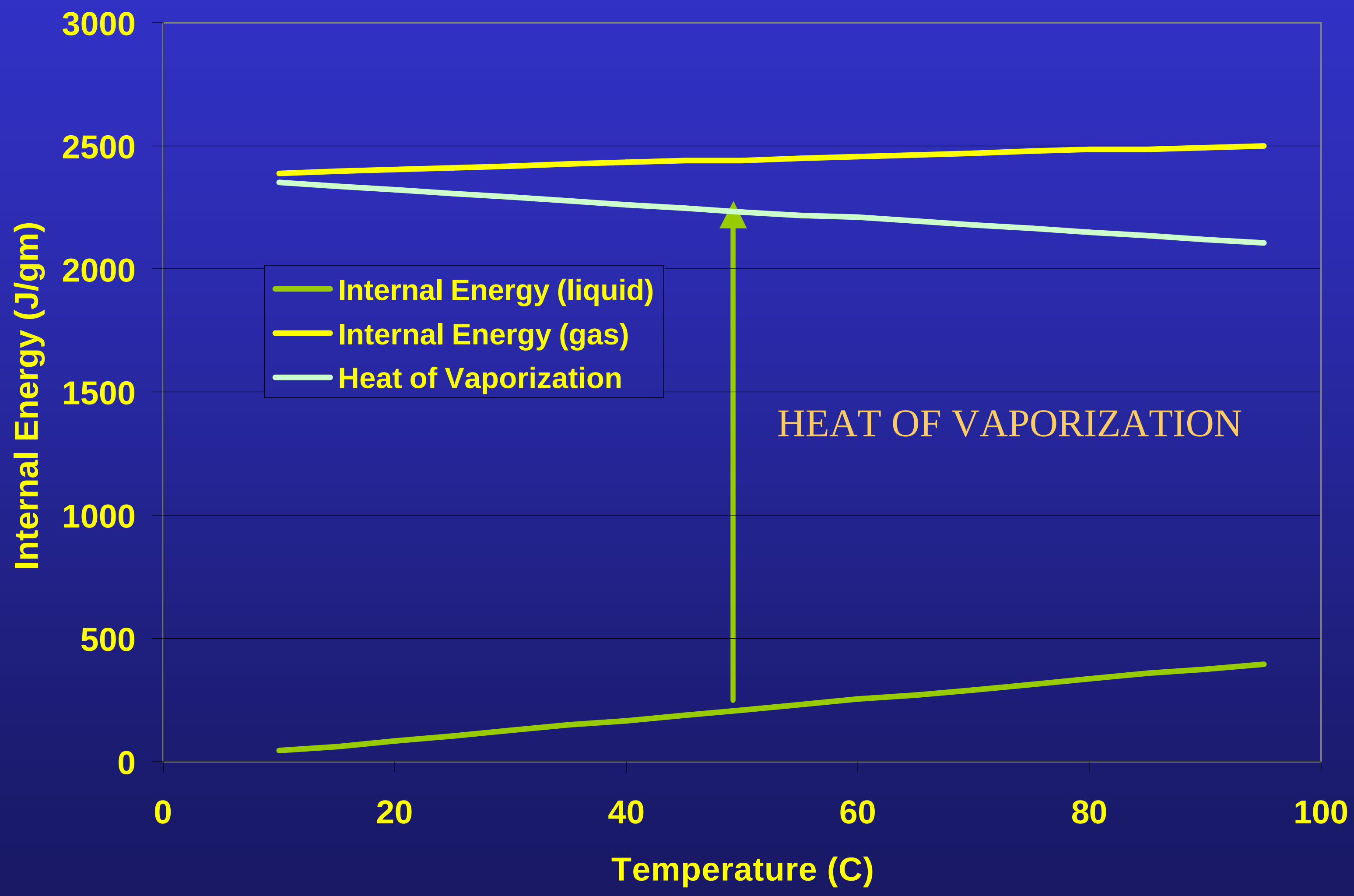


Reference: Practical Handbook of Compost Engineering, pg.360

PRIMARY HEAT REMOVAL PROCESSES

- VAPORIZATION OF WATER
- ADVECTIVE TRANSPORT OF HEAT IN AIR FLOW

VAPORIZATION OF WATER



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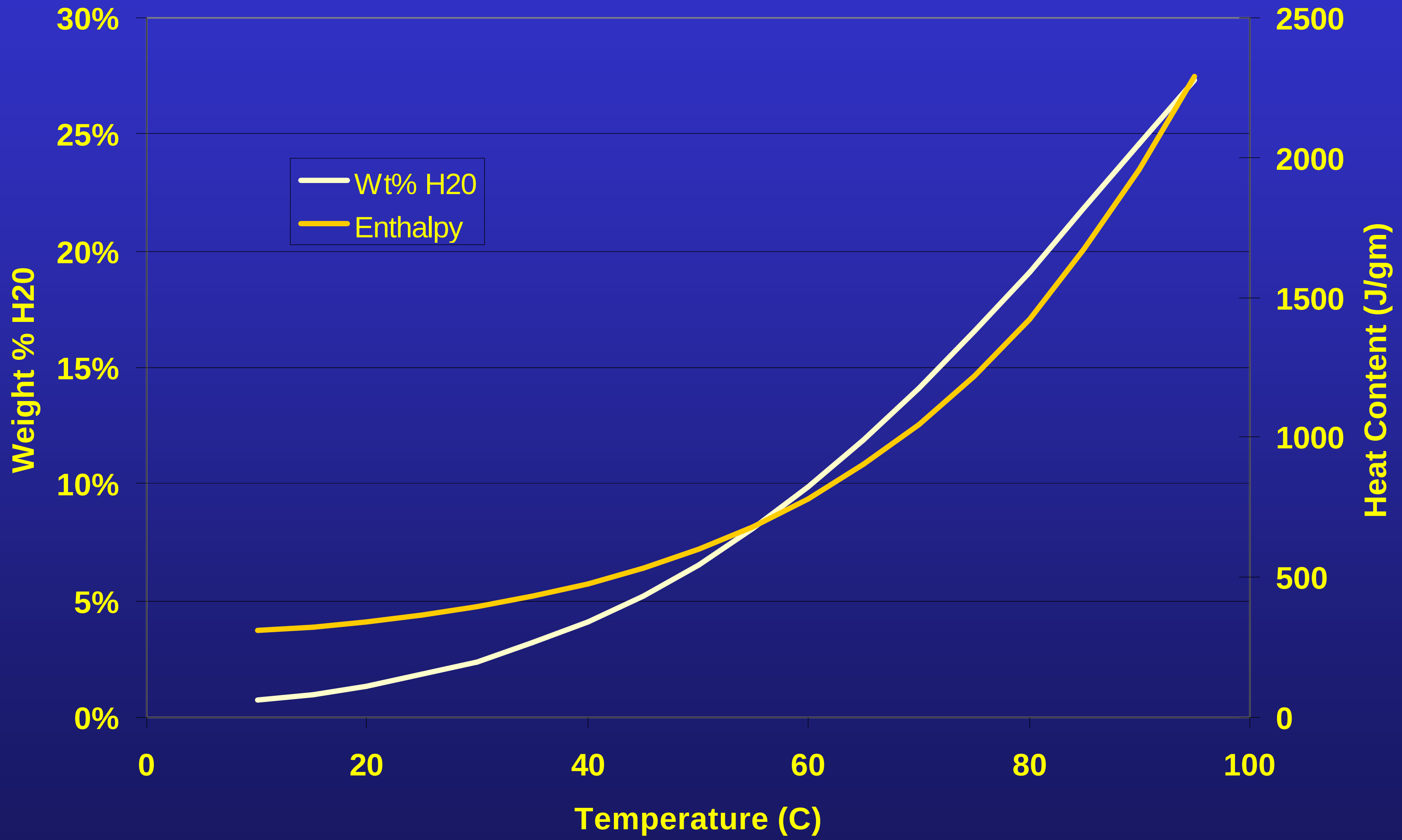
THERMAL PROPERTIES OF WET AIR



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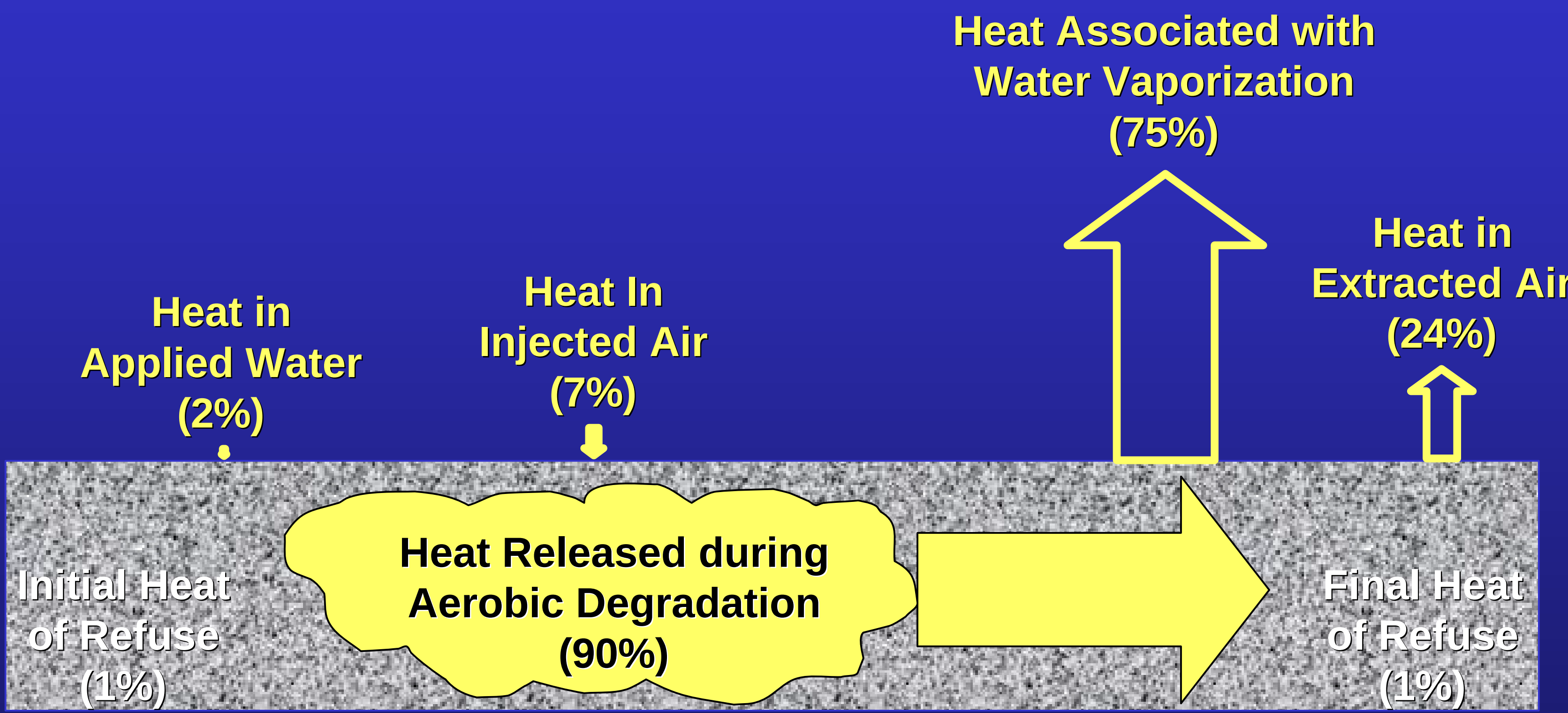
TYPICAL ENERGY BALANCE

(% of total energy)



PROCESSES SIMULATED

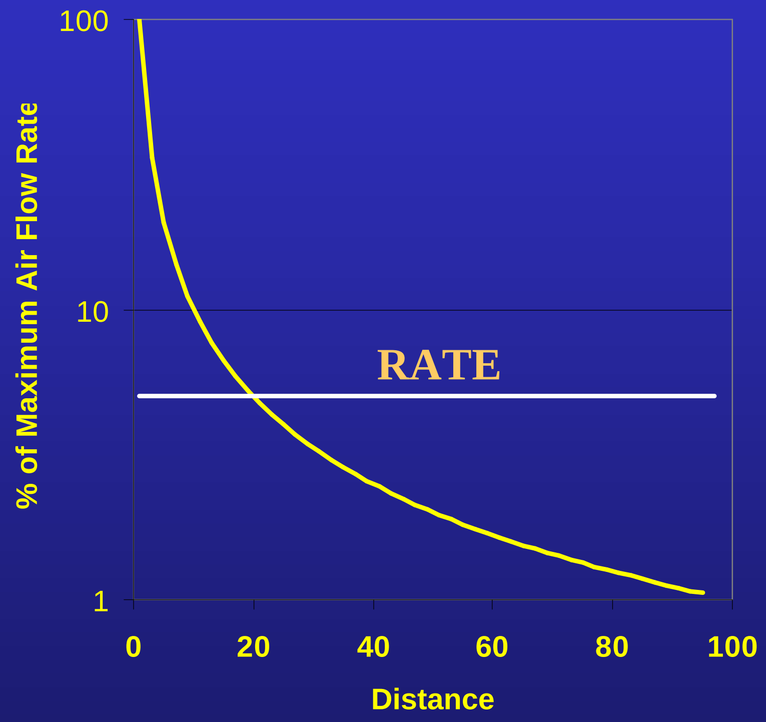
- AIR FLOW
  - DARCY'S LAW APPLIED TO COMPRESSIBLE FLUID
  - LINEARIZED
- HEAT TRANSPORT
  - ADVECTION IN AIR FLOW
  - CONDUCTION THROUGH SOIL
  - HEAT CAPACITY OF AIR FUNCTION OF TEMPERATURE AND WATER CONTENT (ABSOLUTE HUMIDITY)
- OXYGEN TRANSPORT
  - ADVECTION AND DISPERSION IN AIR FLOW
- BIOGENIC HEAT PRODUCTION
  - IMMOBILE SUBSTRATE (REFUSE)
  - HEAT GENERATION FUNCTION OF:
    - Temperature
    - Oxygen (Monod Rate Equation)

COUPLED, NON-LINEAR PROCESSES

- HEAT FLOW, HEAT GENERATION, AND OXYGEN TRANSPORT ARE COUPLED
- SIMPLIFICATIONS IN MODEL
  - AIR FLOW PROPERTIES NOT DEPENDENT ON TEMPERATURE
  - TRANSPORT EQUATIONS DECOUPLED (LINEARIZED)
  - ACCURACY CONTROLLED THROUGH TIME STEP
  - AIR ASSUMED TO APPROACH 100% HUMIDITY RAPIDLY IN REFUSE

COMPLEXITIES ASSOCIATED WITH USING WELLS

- AIR FLOW RATE DECREASES RADIALLY FROM WELL
- ASSUMING ADEQUATE OXYGEN AND EQUAL TEMPERATURE, BIODEGRADATION RATE IS CONSTANT



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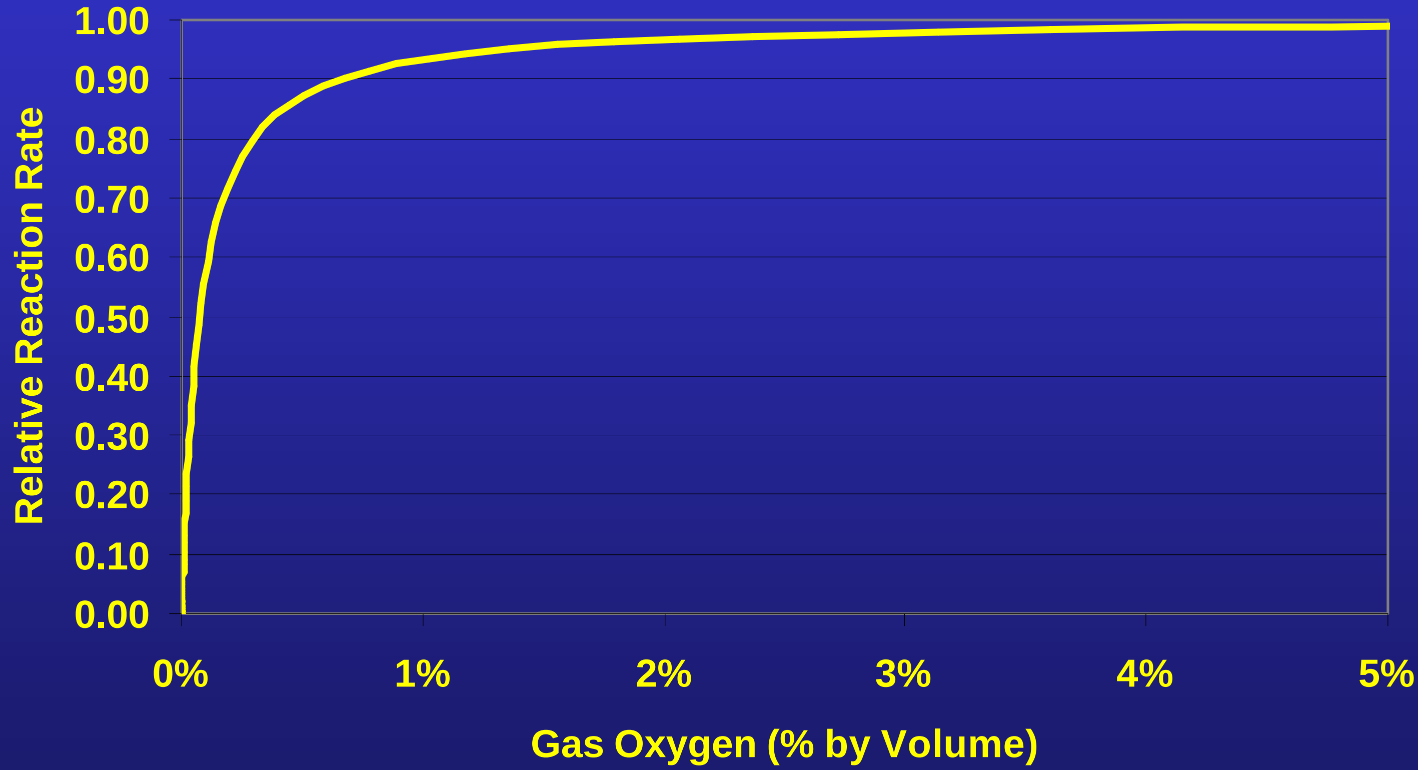
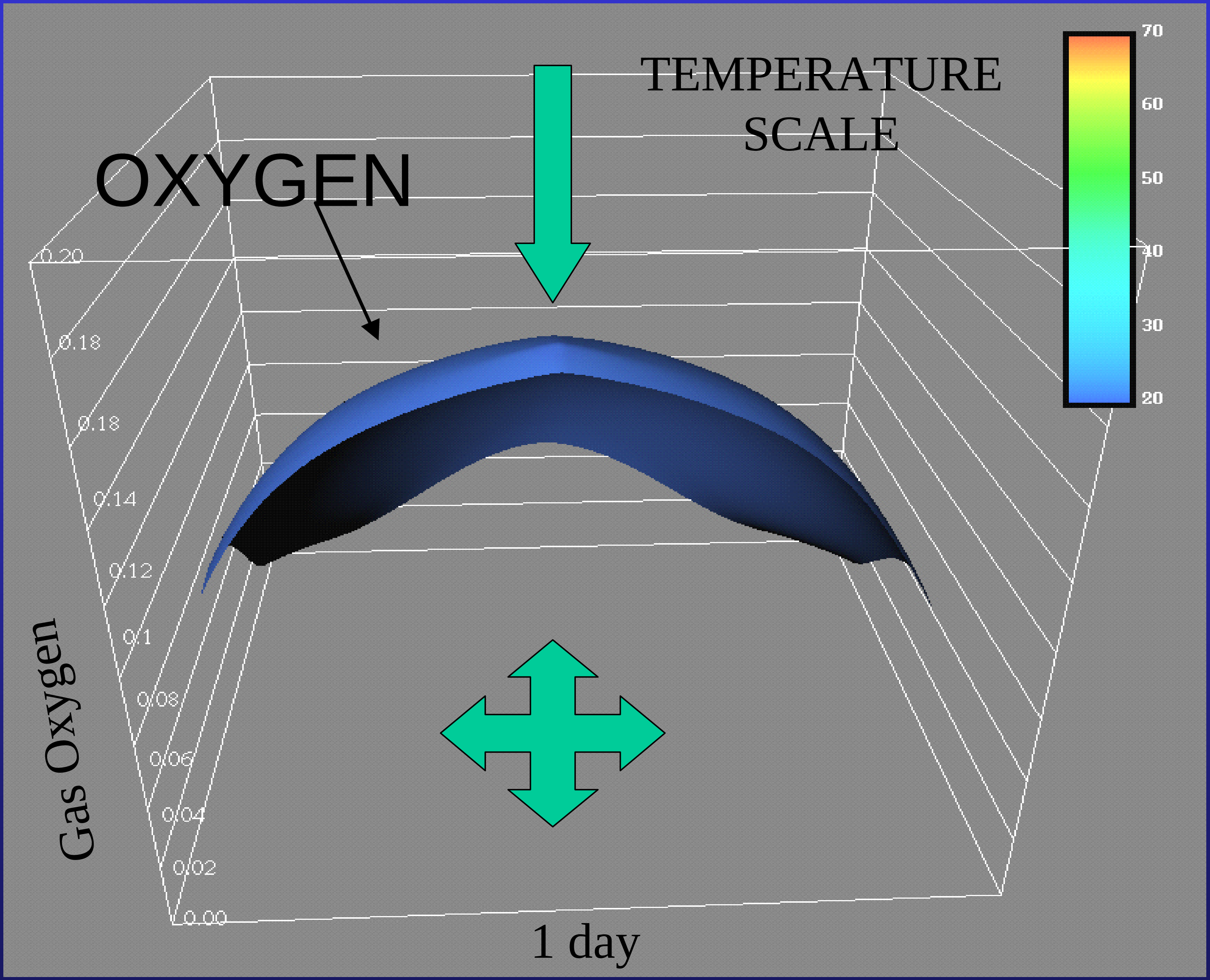
RELATIVE REACTION RATE VS GAS OXYGEN CONTENT





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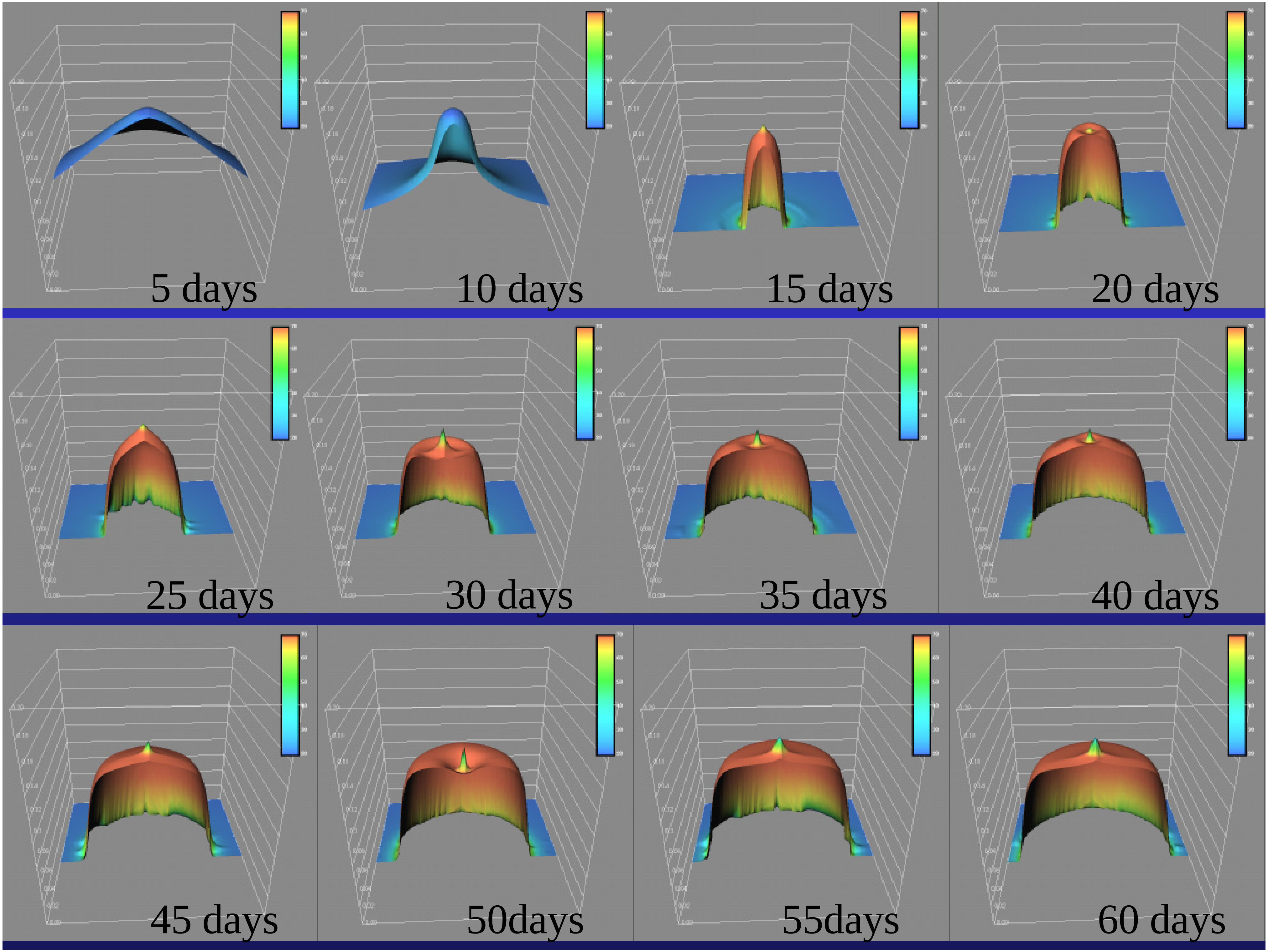
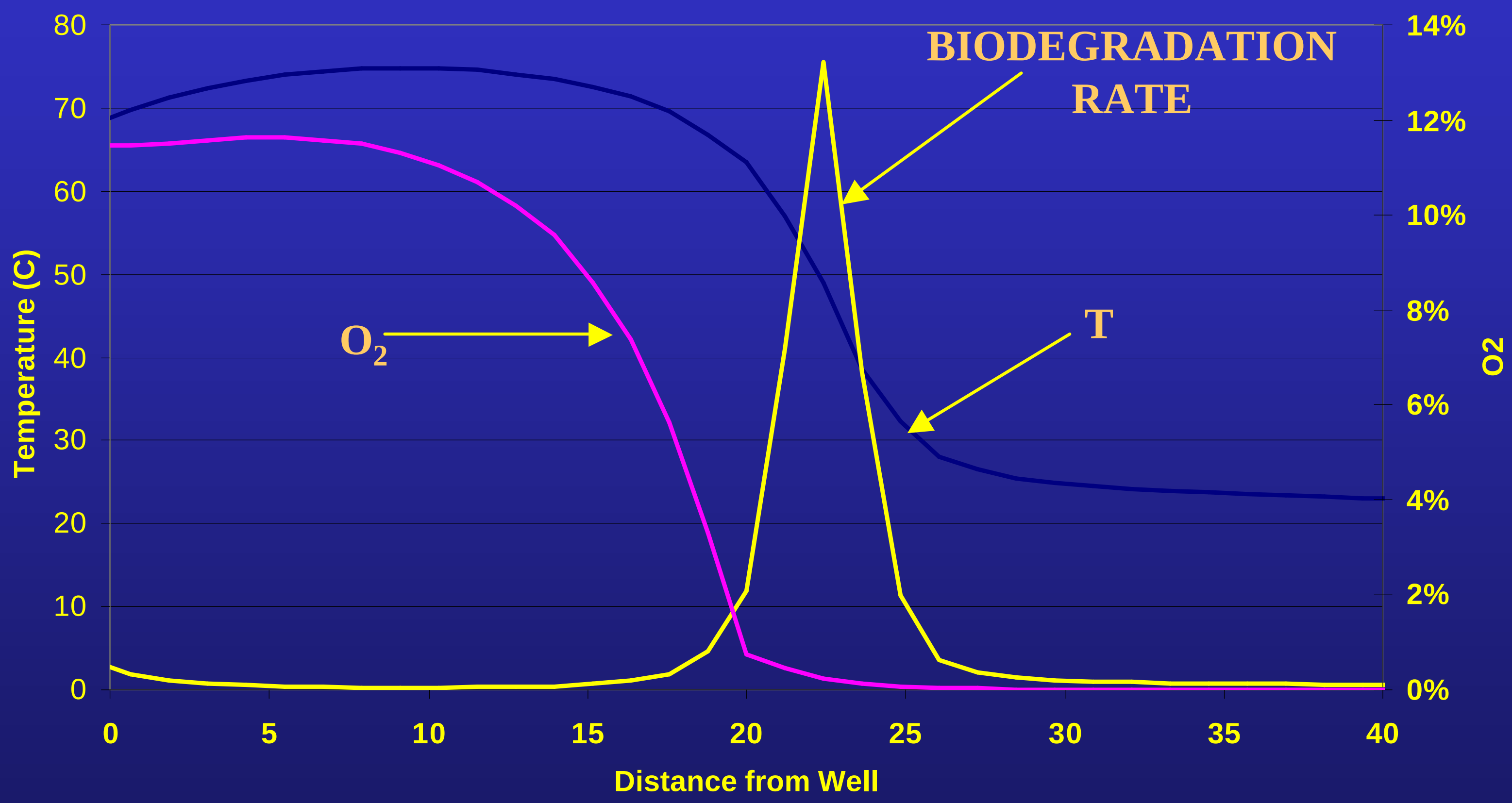

5 days
10 days
15 days
20 days
25 days
30 days
35 days
40 days
45 days
50days
55days
60 days

TEMPERATURE AND OXYGEN VS DISTANCE



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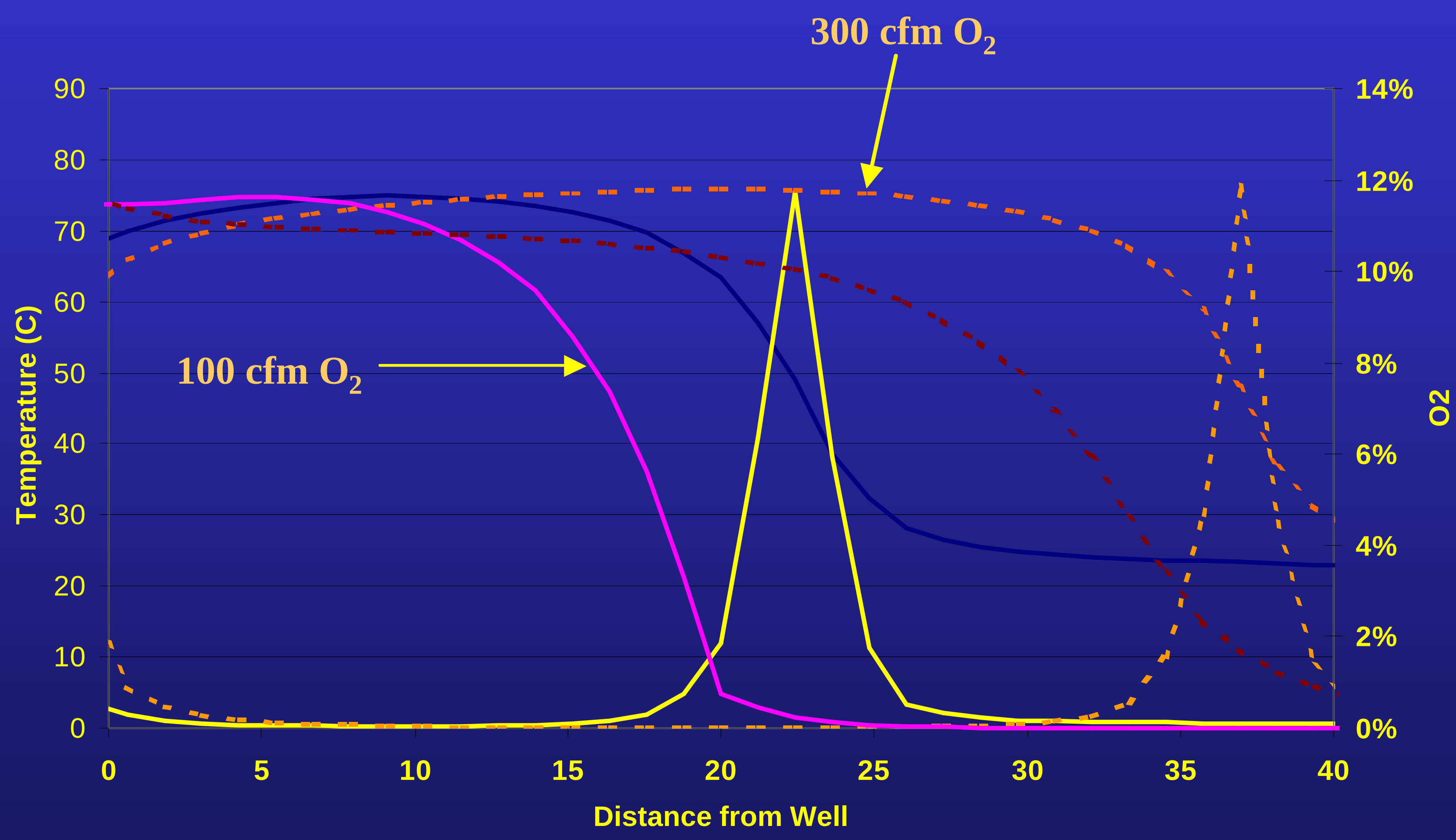
SUMMARY

- AEROBIC BIODEGRADATION REACTIONS ARE GOVERNED BY COMPLEX INTERACTION BETWEEN AIR CIRCULATION RATES AND TEMPERATURE
- THESE INTERACTIONS CAN LEAD TO INTERESTING AND SOMETIMES SURPRISING BEHAVIOR (AT LEAST IN NUMERICAL MODELS)
- THE MODELS DISPLAY SELF-LIMITING BEHAVIOR IN TERMS OF TEMPERATURE REGIME

T, O_2, and BIORATE AFTER 20 DAYS



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