Annexure

Codes of TEA

```
import biosteam as bst
import thermosteam as tmo

# Use built-in chemicals with complete thermodynamic properties
water = tmo.Chemical('Water')
o2 = tmo.Chemical('O2')
 # Using glucose as a proxy for compost

# Append chemicals to the chemical set
chemicals = tmo.Chemicals([water, o2])

# Set thermodynamic properties
tmo.settings.set_thermo(chemicals)

# Define unit operations for the flowchart in series

# Material Preparation: Storage Tank -> Mixer -> Pump -> Mixer -> Belt Filter -> Shredder -> Compost Turner -> Curing -> Separator -> Fans -> Biofilter -> Bagging

# Storage Tank
storage_tank = bst.StorageTank('S1', ins='Anaerobic_Digestate', outs='to_mixer_1')

# Mixer to combine streams before feeding to the pump
input_mixer = bst.Mixer('M1', ins=[storage_tank-0])  # Initially only the storage tank is connected

# Pump receives combined output from the mixer
pump = bst.Pump('P1', ins=input_mixer-0)  # The pump receives the combined output from the input mixer
```

```
# Mixing pump output with water before feeding to the belt filter

water = bst.Stream('water_input', water=100)  # Define the water input stream

mixer_input = bst.Mixer('M2', ins=(pump-0, water))


# Belt Filter with one input (combined stream) and two outputs

belt_filter = bst.Splitter('S1', ins=(mixer_input-0,), outs=('liquid_digestate',
'to_compost_turner'), split=0.5)


# Shredder operation running in parallel

shredder = bst.Mixer('Shredder', ins='Agricultural_residue')


# Composting operations using a compost turner

compost_turner = bst.Mixer('M3_Compost', ins=(belt_filter-1, shredder-0))


# Composting process using a Continuous Stirred Tank Reactor (CSTR)

compost_cstr = bst.Splitter('Compost_reactor', ins=(compost_turner-0), outs=('to_storage',
'to_fan'), split=0.5)


# Curing stage using a storage tank (now gets input directly from compost_cstr)

curing_tank = bst.StorageTank('Curing_tank', ins=compost_cstr-0)


# Solid-Liquid Separator (S3_separator now after curing tank)

separator = bst.Splitter('Belt_Filter', ins=curing_tank-0, outs=('usable_compost',
'Unprocessed_compost'), split=0.5)


# Packaging process: Bagging tank directly after usable compost from separator

bagging_tank = bst.StorageTank('Bagging', ins=separator-0, outs='bagged_compost')


# Air handling using fans

fan1 = bst.Mixer('Fan_air', ins=(compost_cstr-1))
```

```
# Biofiltration for exit gases now directly after F1_air_fan1
biofilter = bst.Mixer('Biofilter', ins=fan1-0, outs=('filtered_gas'))

# Recycle the liquid waste from Belt Filter (B2_belt_filter) back to input_mixer
recycle_stream_belt_filter = belt_filter.outs[0]  # The liquid_waste output from the belt filter
input_mixer.ins.append(recycle_stream_belt_filter)  # Add the recycled stream to the mixer
that feeds the pump

# Recycle the liquid waste from S3_separator back to Compost Turner (M4_compost_turner)
recycle_stream_separator = separator.outs[1]  # The liquid_waste_S3 output from the
separator
compost_turner.ins.append(recycle_stream_separator)  # Add the recycled stream to the
compost turner's input

# Define the process system in series, with both recycle streams
system = bst.System('compost_system', path=(storage_tank, input_mixer, pump, mixer_input,
belt_filter, shredder,
                              compost_turner, compost_cstr, curing_tank, separator,
                              bagging_tank, fan1, biofilter))

# Simulate the system
system.simulate()

# Generate and display system diagram with both recycle streams
system.diagram('thorough', format='png')

system.show(data=False)
```

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List of Publications

Journal Publications

[1] **Kushwaha, J.**, Singh, Y., Yadav, S.K., Sheth, P. N., Mahesh, M.S., & Dhoble, A. S. (2024). Deciphering Cleaner and Sustainable Frontiers in Scientific Cow Waste Valorization: A Review. Environmental Monitoring and Assessment, 196, 988.

[2] **Kushwaha, J.**, & Dhoble, A. S. (2024). Evaluating digestate and raw manure in floral waste composting: physicochemical properties and microbiome dynamics. Environment, Development and Sustainability, 1-19.

[3] **Kushwaha, J.**, & Dhoble, A. S. (2024). Exploring core microbiome diversity in digested versus raw manure impact on rice straw composting. Environment, Development and Sustainability, 1-22.

[4] Priyadarsini, M., **Kushwaha, J.**, Pandey, K. P., Rani, J., & Dhoble, A. S. (2023). Application of flow cytometry for rapid, high-throughput, multiparametric analysis of environmental microbiomes. Journal of Microbiological Methods, 106841.

[5] **Kushwaha, J.**, Priyadarsini, M., Rani, J., Pandey, K. P., & Dhoble, A. S. (2023). Aquaponic trends, configurations, operational parameters, and microbial dynamics: A concise review. Environment, Development and Sustainability, 1- 34.

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[7] Pandey, K. P., Jha, U. R., **Kushwaha, J.**, Priyadarsini, M., Meshram, S. U., & Dhoble, A. S. (2023). Practical ways to recycle plastic: current status and future aspects. Journal of Material Cycles and Waste Management, 25(3), 1249- 1266.

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[9] Rani, J., Pandey, K. P., **Kushwaha, J.**, Priyadarsini, M., & Dhoble, A. S. (2022). Antibiotics in anaerobic digestion: Investigative studies on digester performance and microbial diversity. Bioresource Technology, 361, 127662.

Book Chapters

[1] **Kushwaha, J.**, Rani, J., Priyadarsini, M., Pandey, K. P., & Dhoble, A. S. (2024). Assessment of wastes for future bioprospecting. In Processing of Biomass Waste (pp. 9-20). Elsevier.

[2] Priyadarsini, M., Pandey, K. P., **Kushwaha, J.**, & Dhoble, A. S. (2023). Application of Cutting-Edge Molecular Biotechnological Tools in Microbial Bioprocessing. In Microbial products for future industrialization (pp. 77-100). Singapore: Springer Nature Singapore.

[3] Priyadarsini, M., Rani, J., **Kushwaha, J.**, Pandey, K. P., Singh, Y., & Dhoble, A. S. (2023). An Introduction to Omics in Relevance to Industrial Microbiology. In Industrial Microbiology and Biotechnology: Emerging concepts in Microbial Technology (pp. 23-39). Singapore: Springer Nature Singapore.

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Patent

1. A Composting System for Waste Management (*Application No.: 202311089682)* ***Inventors:*** Jeetesh Kushwaha, Abhishek Suresh Dhoble (Status: Published)

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Figure 2.1.: KL256AEF23

Figure 3.1.: HI298ZJKL3

Graphical abstract for Chapter 4: KY289ZKL9C

Graphical abstract for Chapter 5: HJ274ZVGHX

Graphical abstract for Chapter 6: LM256KLUIX

Declaration

During the preparation of this thesis, language refinement tools were used to assist in rephrasing and enhancing the clarity of certain sections. All content generated with the assistance of these tools was thoroughly reviewed, revised, and approved by the author, who takes full responsibility for the final content and accuracy of the thesis.