機械学習に基づく嫌気性MBR生活排水処理プロセスにおける膜ファウリング予測モデルに関する研究

Prediction of membrane fouling in a pilot-scale AnMBR treating municipal wastewater by machine learning technologies

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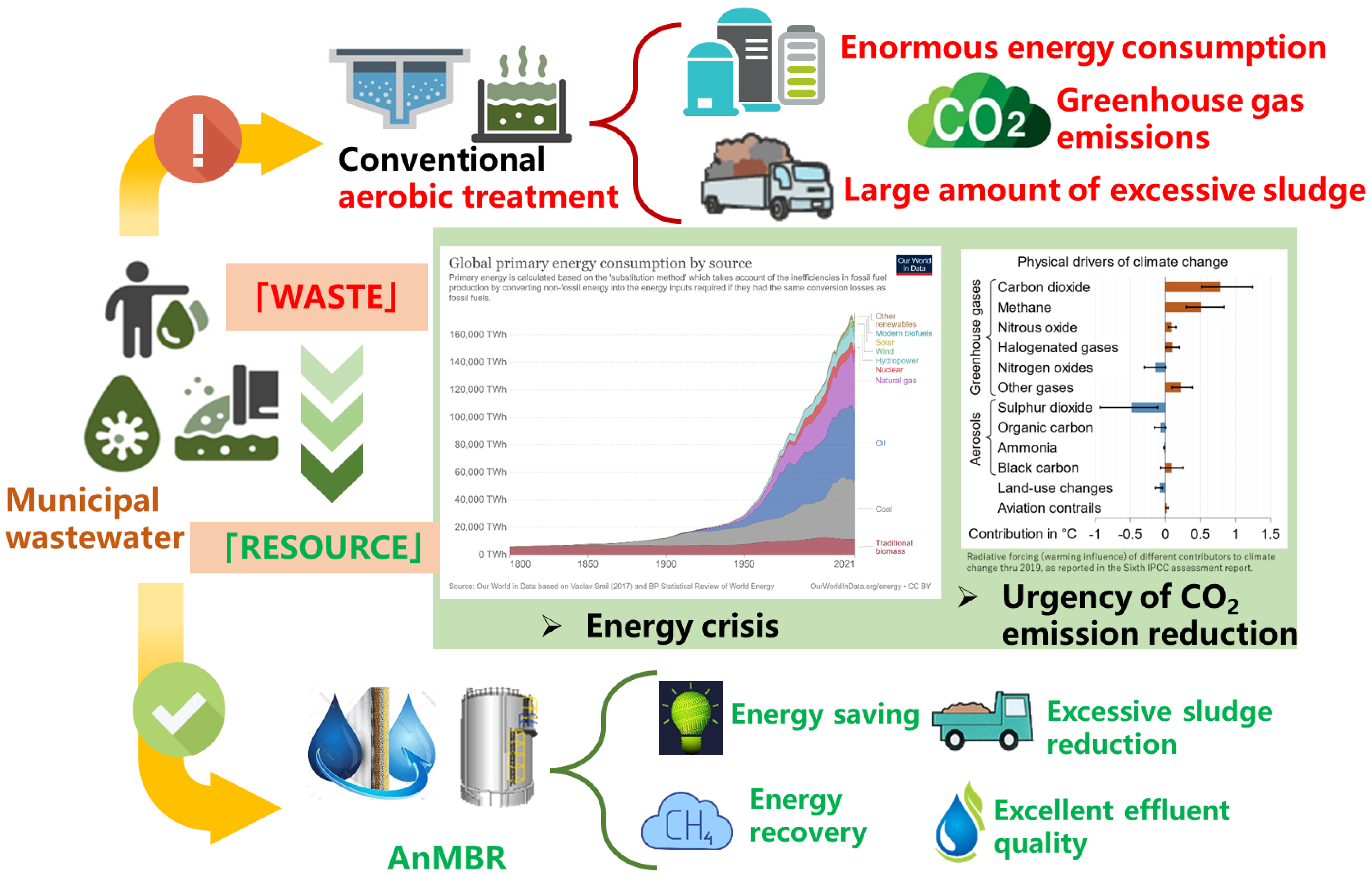
生活排水は日常生活から発生するもので，水量が多く，有機物濃度が低く，浮遊固形物（SS）含有量が高いなどの特徴を有する。近年，膜技術の急速な発展に伴い，嫌気性膜分離法（Anaerobic membrane bioreactor，嫌気性MBR）は従来の嫌気性処理技術の弱点を解決し，優れた生活排水処理技術として注目されるようになった。膜ファウリングは，膜間差圧（TMP）の上昇または膜ろ過フラックスの低下を引き起こし，より頻繁な膜の洗浄と交換で膨大なエネルギー消費とコストの高騰を招くので，解決しなければならない課題である。本研究では，大型嫌気性MBRパイロットプラントによる実生活排水に対する処理の長期運転実証実験からデータセットを抽出し，人工ニューラルネットワーク（Artificial neural network, ANN）と長・短期記憶（Long short-term memory, LSTM）モデルを用いて膜ファウリング予測モデルを構築した。

Background



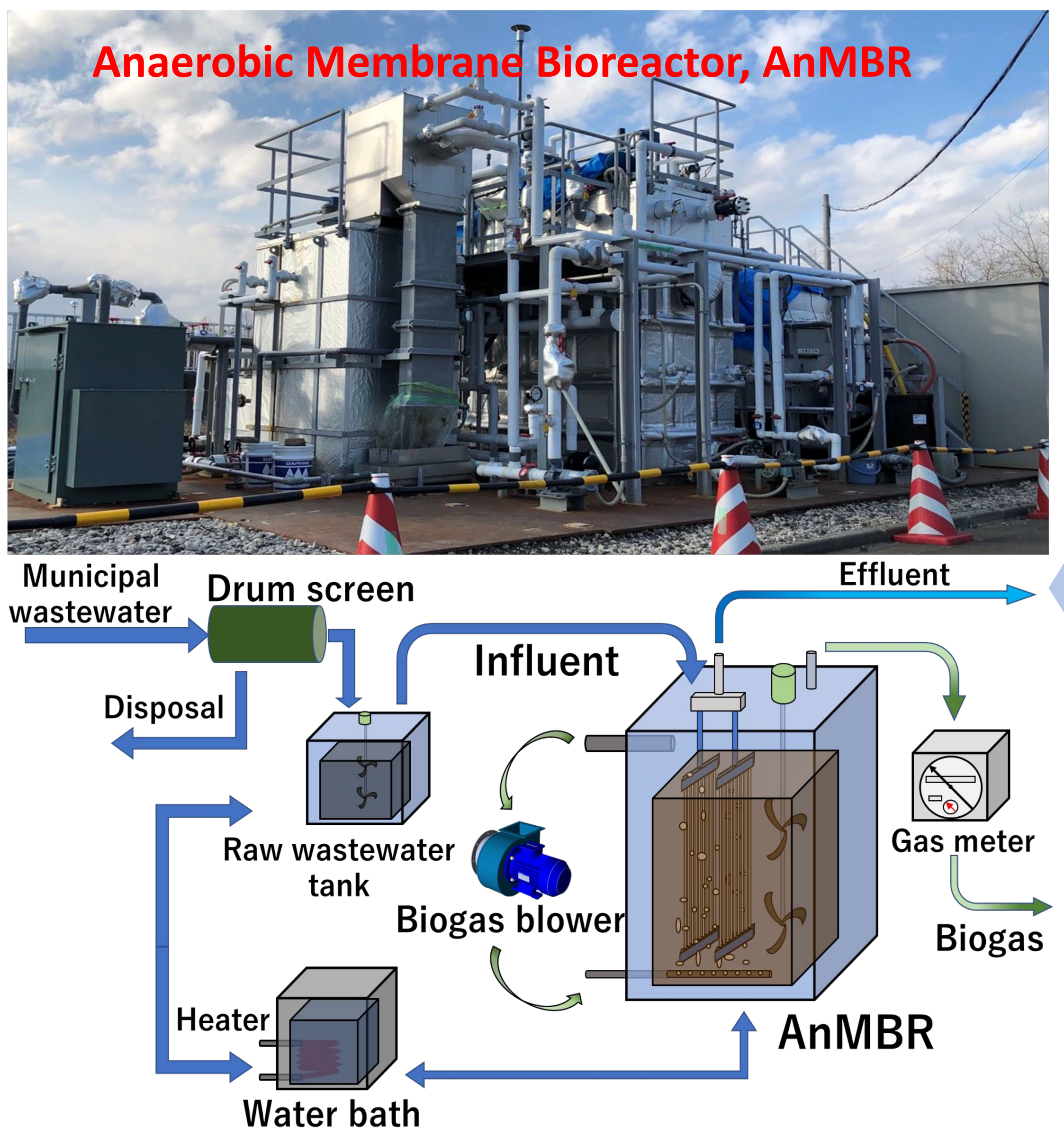


Figure 1. Picture of the entire experimental procedure and schematic diagram of the pilot-scale AnMBR system.

□Reactor configuration
1.Effective volume : 5 m^3
2.Reactor type: Submerged-AnMBR
□Membrane module specification
1.Element type: Hollow fiber
2.Material: polyvinylidene difluoride (PVDF)
3.Total membrane area: 6 m^2/piece × 12 pieces
4.Pore diameter: 0.4 µm

Material and Methods

□The conventional membrane cleaning timing is determined artificially, a time lag occurs.
□Machine learning is introduced to predict the TMP variation that represents the membrane fouling behavior in the AnMBR. Energy consumption and cost reduction can be realized by greatly improving the service life of the membrane according to the accurate membrane cleaning timing based on the prediction results.

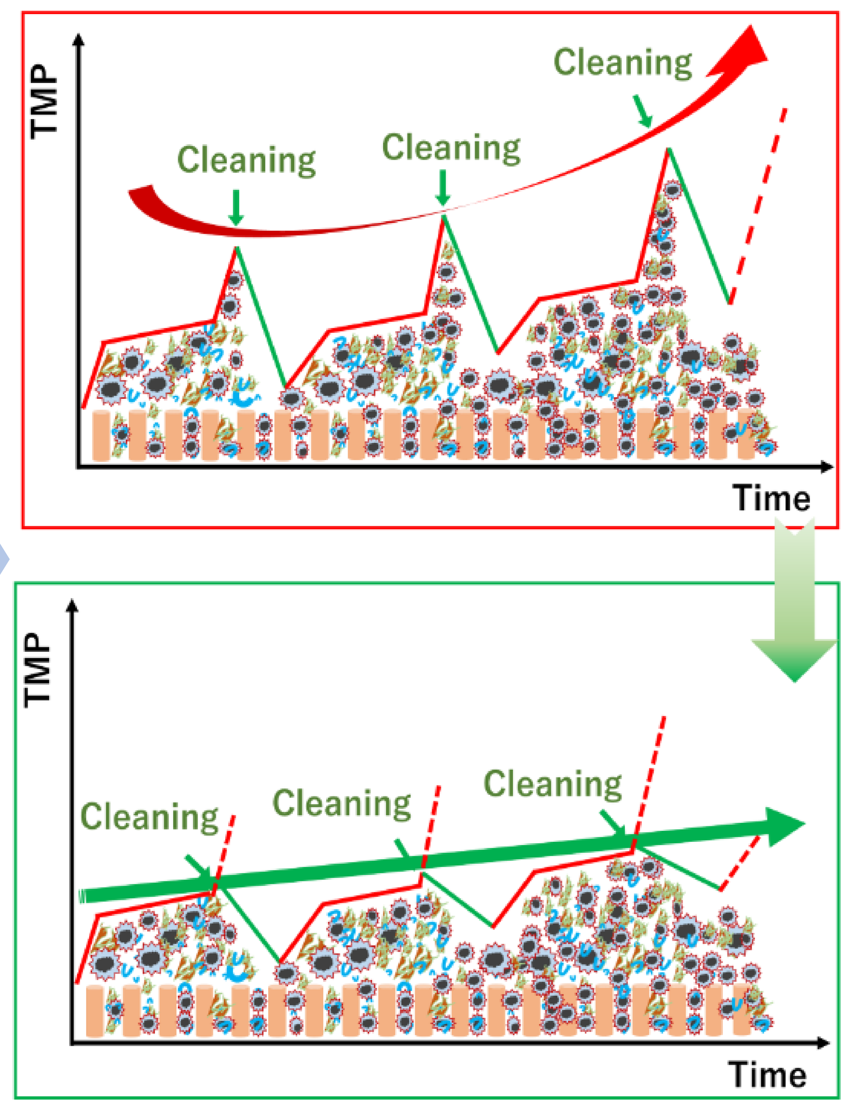


Figure 2. A proper membrane fouling control method.

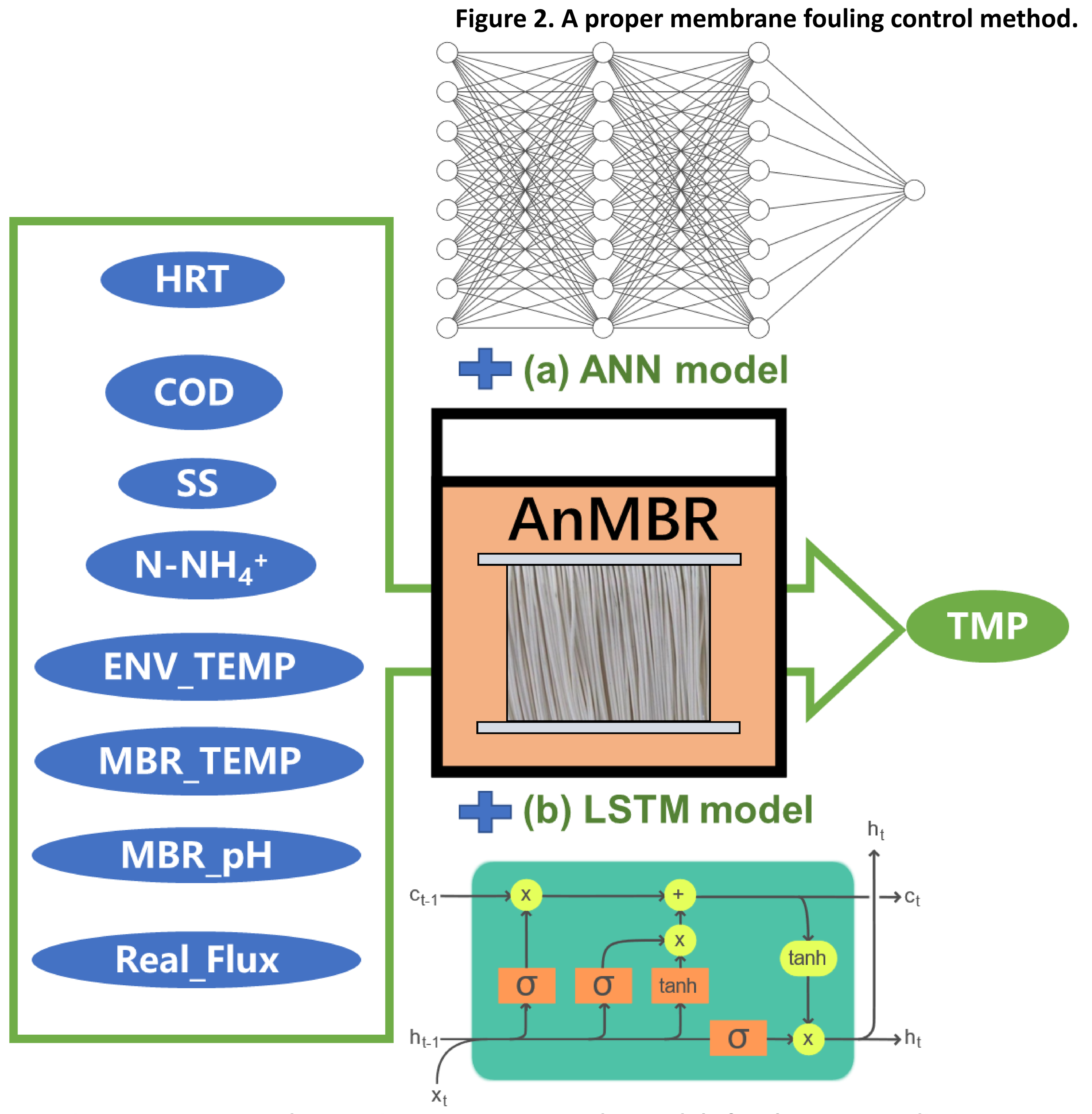


Figure 3. 8 extracted operation parameters and 2 models for the TMP prediction.

□Hyperparameters
➢Learning rate : 0.01
➢Epochs: 1000
➢Batch size: 2
➢Drop out rate: 0.1

Model	Structure	Activation function	Loss function	Optimizer
ANN	8 units for each 2 hidden layers	ReLU	MSE	Adam
LSTM	150 units			

Results and Discussion

□Totally 115 days of data set were extracted and the train: test was 4:1.
□The MSE curves decreased promptly during the training process of each model.
□The R^2 was selected as the accuracy evaluation for predictions. The R^2 of the ANN and the LSTM can reach up to 0.62 and 0.81, respectively.
□The fine-tuning of the models was required for superior prediction performance.

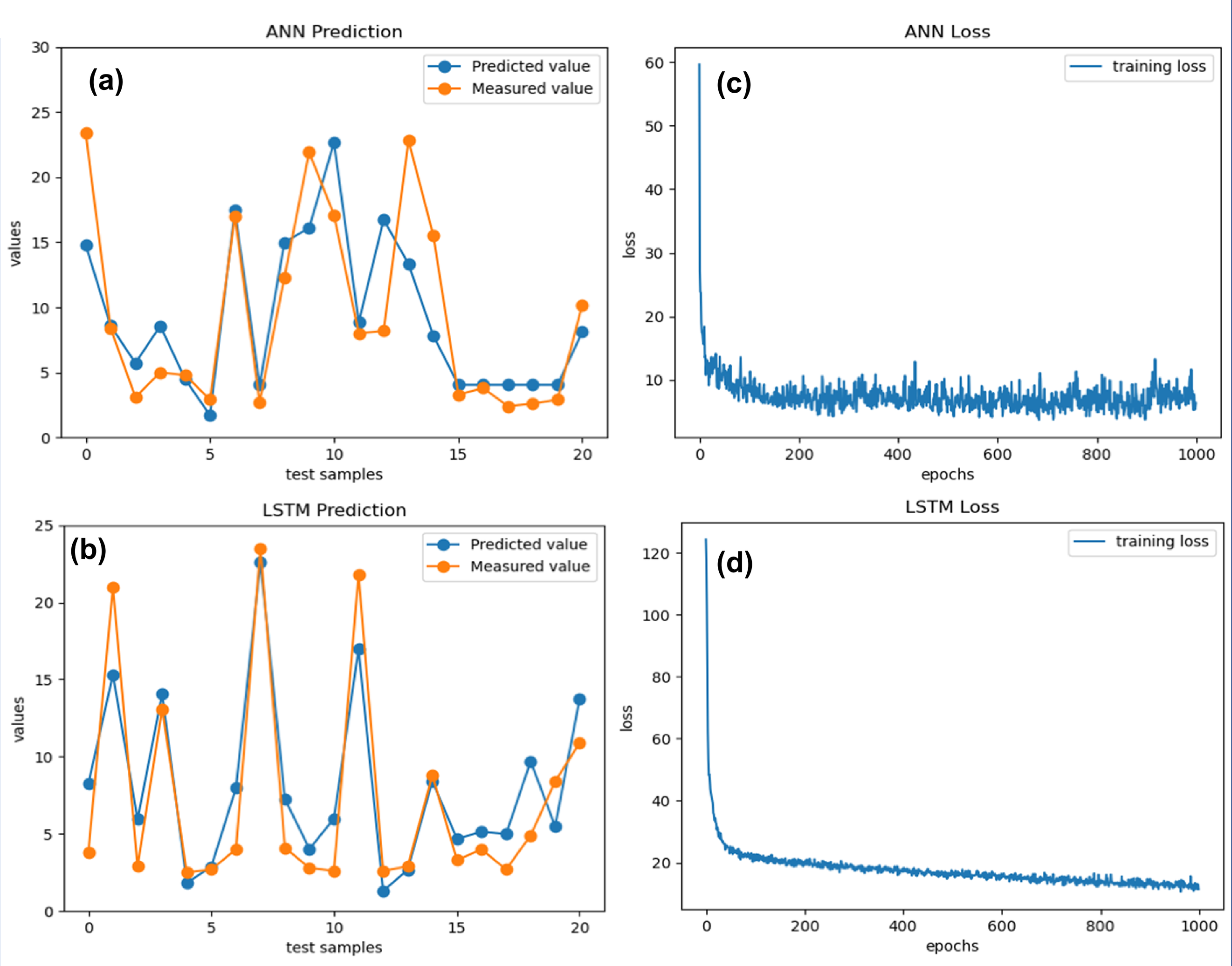


Figure 4. Result of ANN and LSTM models ((a)(b): values comparison,(c)(d): MSE curve).

Reference

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