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Machine learning as a support tool in wastewater treatment systems – a short review

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Introduction

Machine learning (ML) is a subset of artificial intelligence (AI). It is based on teaching computers how to learn from data and how to improve with experience. This valuable technique has been increasingly supporting different spheres of life. This includes ML application in enhancement and optimisation of many ecological and environmental engineering solutions, such as wastewater treatment systems (WWTS). Complexity of processes triggers challenges in ensuring good effluent quality by adequate response to dynamic process conditions. That is why techniques such as ML which, after being trained, have strong prediction ability, have been applied in WWTS.

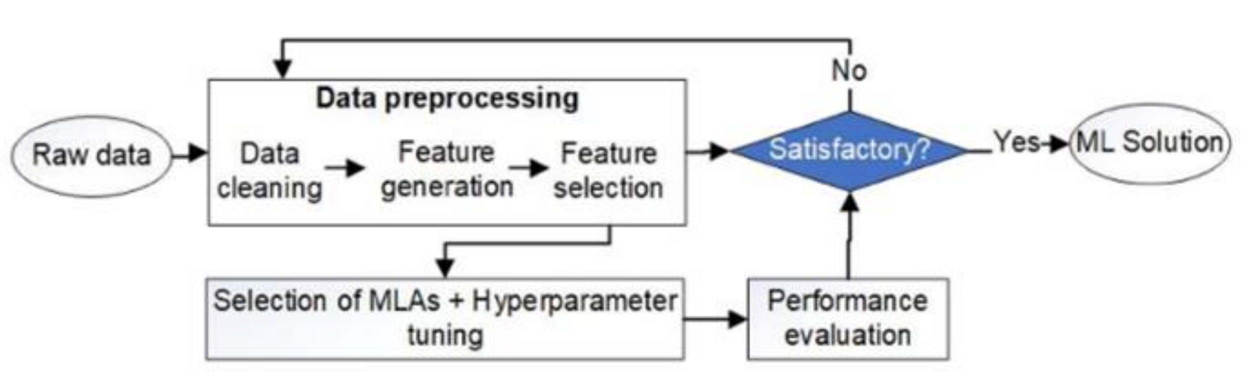

Figure 1
Machine learning model workflow (Sundui et al., 2021)

ML algorithms

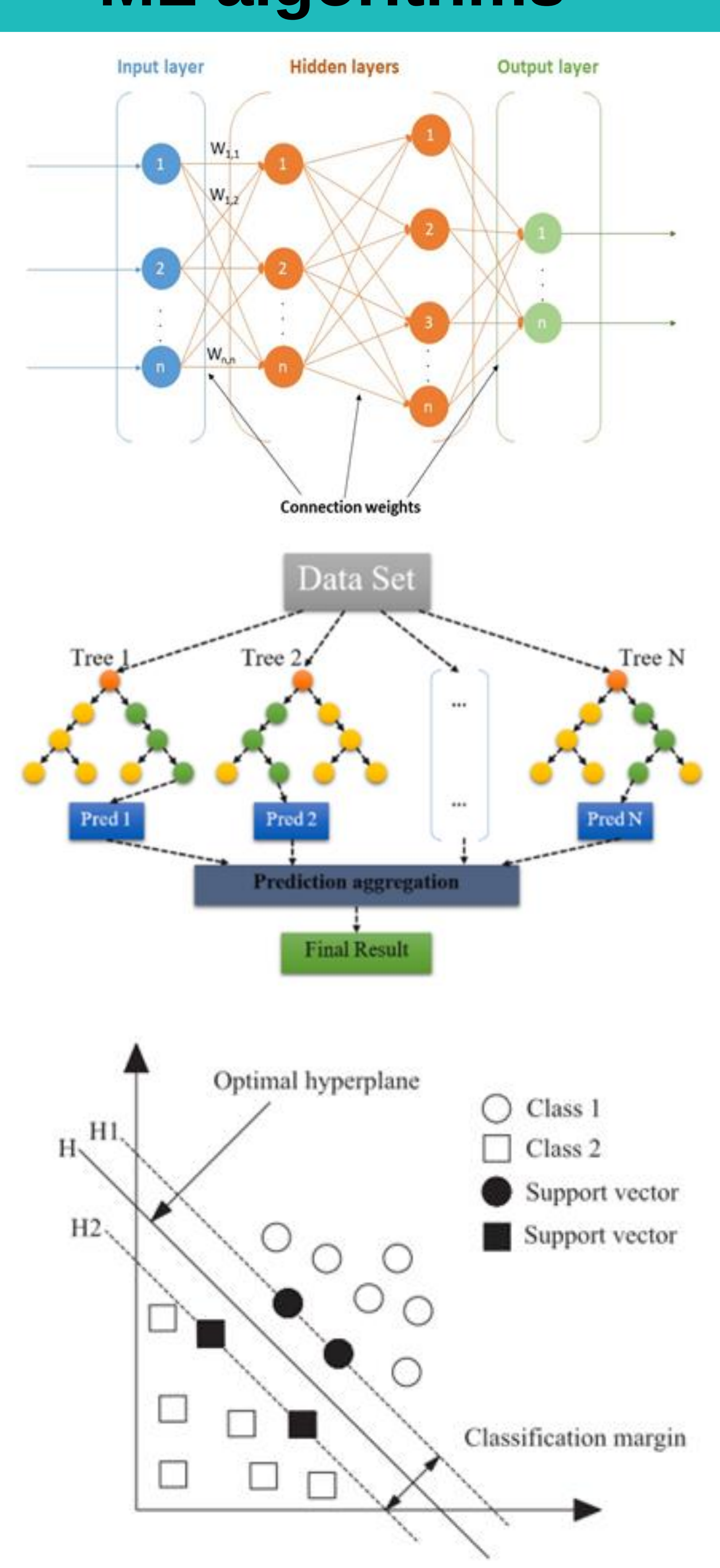

Figure 2
Artificial neural network (ANN), Random forest (RF) (Bagherzadeh et al., 2021) *and Support vector machine (SVM)*(Li et al., 2019) *schematic model representation*

Results

ML utilization within WWT sector could be overviewed through 3 basic groups of application:

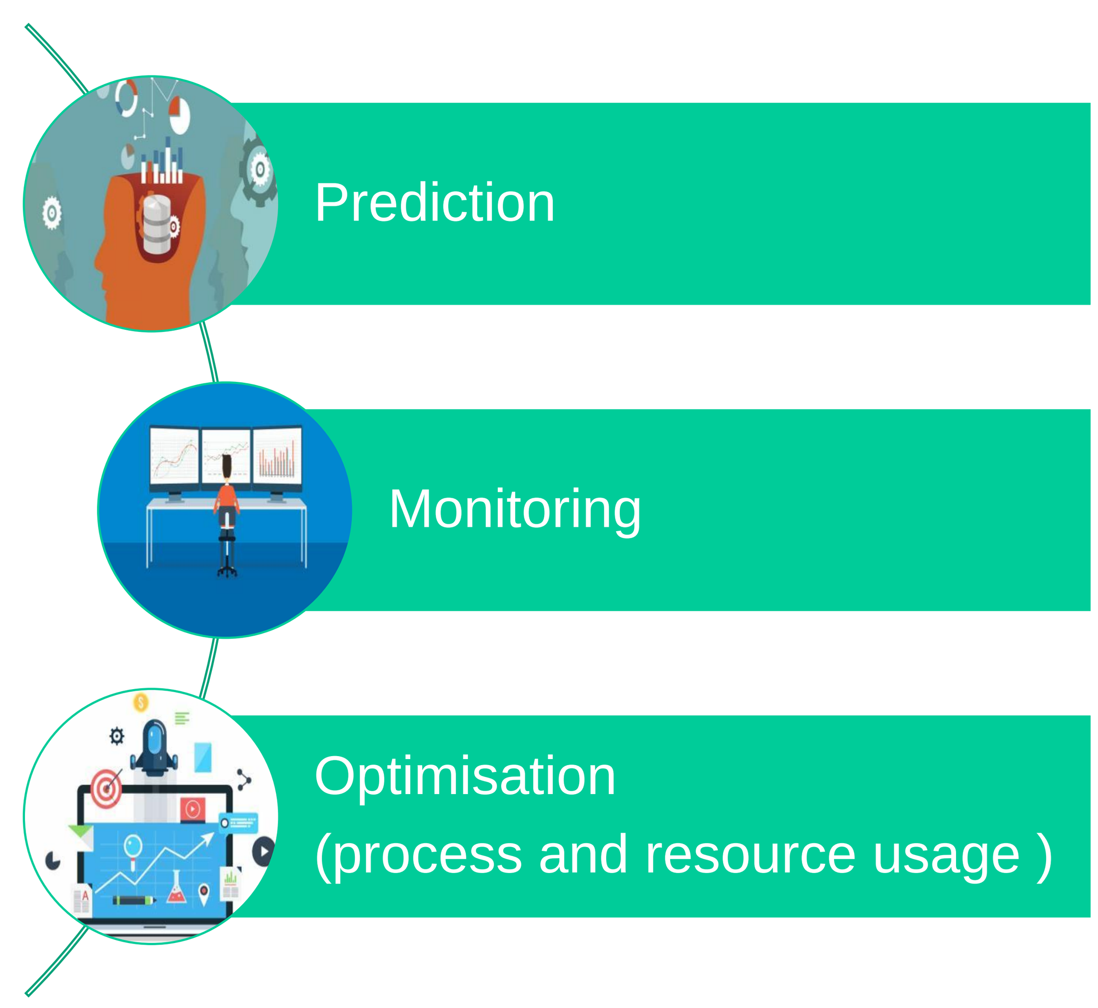

Table 1
Examples of different ML models utilisation within WWT systems

Algorithm	Application	Reference
ANN and DNN	Improving effluent quality control in WWTP (as validation of RF model used for the same purpose)	(Wang et al., 2021)
	Generation of energy cost model in WWTPs	(Torregrossa et al., 2018)
	Prediction of breakthrough curves in adsorption study	(Moreno-Pérez et al., 2018)
	Modeling and optimisation of the extraction process	(Genuino et al., 2017)
	Support of modeling arsenic removal by adsorption process	(Rodríguez-Romero et al., 2020)
	Wastewater inflow prediction	(El-Din and Smith, 2002)
	optimisation of coagulant dosage by modeling jar-test experiments	(Haghiri et al., 2018)
	Prediction of ciprofloxacin adsorption	(Salawu et al., 2022)
	Estimation of phosphorus reduction	(Kumar and Deswal, 2020)
	Generation of support sensors	
	Development of software sensors	(Dürrenmatt and Gujer, 2012)
	optimisation of naproxen adsorption by biochar	(Bhattacharya et al., 2021)
RF	Improving effluent quality control in WWTP	(Wang et al., 2021)
	Generation of energy cost model in WWTPs	(Torregrossa et al., 2018)
	Prediction of phosphorus content in hydrochar	(Djandja et al., 2022)
	Modelling and evaluation of the performance of a full-scale subsurface constructed wetland plant (prediction of pollutants removal)	(Salem et al., 2022)
	Wastewater inflow prediction	(P. Zhou et al., 2019)
	Estimation of phosphorus reduction	(Kumar and Deswal, 2020)
	Monitoring of odor in WWTPs	(Cangialosi et al., 2021)
	Ozone-membrane process optimisation	(Mousavi et al., 2022)
	Development of software sensors	(Dürrenmatt and Gujer, 2012)
SVM and SVR	Prediction of an adsorption performance	(Li et al., 2019)
	Performance prediction of biological WWTP	(Manu and Thalla, 2017)
	Nitrogen removal process modeling	(Yang, 2006)
	optimisation and modelling of tetracycline removal from wastewater	(Foroughi et al., 2020)
	Wastewater inflow prediction	(Szelag et al., 2017)
	optimisation of flocculation conditions	(Li et al., 2021)

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Discussion / Conclusion

Generally, ML approach is a beneficial tool for processing large amounts of complex data, which might be insufficiently understood and interpreted by traditional statistical approaches. ML is a time and cost-beneficial technique, however, it is in the early stages of application in environmental science and engineering field. Lack of knowledge about its proper employment might lead to incorrect applications of ML algorithms to certain data sets (Zhong et al., 2021). Hence, those and similar problems that might occur if ML is used inadequately should be considered before the actual application of the ML. More articles which include several algorithms utilizations and viability comparison for the same purpose should be included, if possible. That way, the most appropriate model with the highest performance could be chosen. Furthermore, comparison with traditional models might give an additional justification of ML application in further studies. Currently, there are not many articles which included this aspect. In the field of resource management, literature is sparse with research which include energy cost optimisation, which could be characterized as one of the most influential parts of cost-benefit analysis of the wastewater treatment. Additionally, there is an increment in the application of circular-economy principles within adsorption technology, where different waste materials could be used as starting materials for the adsorbent production. This way self-life of a material is prolonged and less raw materials were used.

ML approach has been increasingly valued in the wastewater treatment sector as it provides a viable, flexible and high performing tool for optimisation, prediction, monitoring and other enhancements of wastewater quality management. Its further implementation in environmental engineering and the complex wastewater technology sector might lead to a further decrease in resource depletion, energy and time consumption, as well as to the development of real-time control systems and a consequently timely reaction on extreme conditions.

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