# Fast And Contactless Assessment Of Waste Water Chemical Parameters In Aceh Province By Near Infrared Technology

**Devianti, Yusmanizar, Syakur, Yuswar Yunus**

**Abstract:** Presented study aimed to assess wastewater treatment installation using near infrared technology. Wastewater samples obtained in eight different districts in Aceh Province and spectral data were acquired in wavenumbers range from 4,000 – 10,000 $cm^{-1}$. On the other hand, actual nitrogen, phosphor and potassium contents were measured using standard laboratory procedures. Spectra data were corrected by applying average smoothing algorithm. The wastewater quality was assessed by constructing prediction models using partial least square regression approach. The results showed that all chemical properties can be determined rapidly and simultaneously with maximum coefficient of determination are: 0.85 for nitrogen, 0.93 for phosphor, and 0.94 for potassium content prediction respectively. Spectra data using average smoothing algorithm found to be more accurate and robust for determining those three quality parameters. Based on obtained performances, it may conclude that near infrared technology was feasible to assess wastewater quality parameters rapidly and without direct contact with the samples.

**Index Terms**: Wastewater, NIRS, Aceh, agriculture, technology, assessment, spectra, non destructive.

## 1. INTRODUCTION

Various environmental problems are closely related to sanitation services for the community, one of the most common example of sanitation problems that is directly related to the community is household wastewater. Domestic waste water comes from residential businesses or activities, restaurants, offices, businesses, apartments and dormitories and other social facilities [1]. Waste water generally contains materials or substances that can be harmful to human health and disturb the environment. Therefore, any wastewater produced needs to be managed properly in order to reduce the quality of pollutants contained in it before being channeled into river bodies so as not to pollute the environment [2], [3]. The problem arose in centralized wastewater management facility is inadequate so that its implementation is ineffective. The public wastewater disposal system that is carried out by the community, namely the disposal of wastewater from the toilet is channeled to the septic tank and runoff water from the septic tank is absorbed into the ground or discharged into the public channel. While non-toilet waste water such as washing water, bathing and kitchen waste discharged into public channels [4]. Banda Aceh City is one of the regions in Aceh Province which has a status as the capital city as well as the administrative center in Aceh Province. According to data from the Central Statistics Agency (BPS) in 2019, the City of Banda Aceh consisted of 9 Districts and 90 villages. The population of Banda Aceh City in 2019 was 259.91 people with 133.73 men and 126.19 women from 64,008 households. An increase in population in 2019 compared to 2018 was 4,552 people/$km^2$, the highest density was found in Baiturrahman District which was 7,932 people/$km^2$ while the lowest density in Kuta Raja District was 2,515 people/$km^2$ [5]–[7].


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Based on the Minister of Public Works Regulation Number: 39/PRT/M/2016 concerning with national policy and strategy for drinking water supply system development, the need for water for cooking and bathroom needs is 120 liters per person in one day. The biggest use is for bathroom needs of 75 liters per person from a total of 45% of the total water usage [8], [9]. Thus, it can be estimated that in the city of Banda Aceh has the potential to produce household waste water, as many as 9,321,165 liters per person in one day. Based on this point of view, the potential of household wastewater generated so large but is still not used and managed optimally.

There are some activities related to waste water treatment plat (WWTP) in several district in Aceh Province, and to date they runs quite well. On the other hand, some of those remaining areas and districts are did not treated waste water. They flow into the river and obviously may cause environmental pollutions [10]. Those waste water was treated and managed in right handed, they can be used as fertilizers for plantation areas, since waste water contained chemical nutrients for plants such as nitrogen, phosphorus and potassium [11], [12]. Nitrogen is a very important element for the growth of plants. It is known as a nutrient element that acts as a stimulant for plant growth. The nitrogen present in the liquid was a mixture of protein and urea substances. Nitrogen is rapidly decomposed by bacteria into ammonia so that the age of wastewater can be reflected by the amount of ammonia present in the wastewater [10], [13]. Moreover, phosphorus in water as well as potassium, are important elements for the growth of plants known as nutrients and stimulants growth. Phosphorus is a component that can fertilize algae and other biological organisms so that it is very appropriate to be used as a benchmark for water quality. Nutrients contained in the Wastewater Treatment Plant (WWTP) households can be analyzed by means of laboratory testing. Generally testing in a laboratory is very difficult because it uses a mixture of chemical materials, time consuming, destructive and may cause other environmental pollutions [14], [15]. Thus, it is inefficient and requires relatively expensive costs, therefore we need an alternative technology that can be used to predict plant nutrients needed in large quantities, simple preparation, rapid, effective and without direct contact with the respective samples [16], [17].

Utilization of one of the modern technologies developed at this time is by using Near Infrared Spectroscopy (NIRS) technology. This technology can analyze and provide information about nutrients found in household WWTPs, based on the principle of interaction between biological material and certain electromagnetic radiations [18], [19]. NIRS technology covers a wavelength range from 1000 to 2500 nm. The advantages of using NIRS when compared to chemical analysis done in the laboratory because it can be done non-destructively, can analyze samples up to 2-5 millimeters depth, can detect various components with one spectral data, and can determine the physical and chemical properties of a material [20], [21], it does not require many treatments to the sample, do not require chemicals so that it can be used to flower the nutrients contained in the WWTP [22], [23]. Based on these problems further research needs to be done to what extent the application of Near Infrared Spectroscopy can detect nutrient content of household WWTPs. Numerous studies have been reported in related to the application of NIRS technology in many fields, especially in agriculture like fruit quality evaluation [24]–[28], animal feed quality parameters prediction [29]–[32], agricultural crops [33]–[36], soil quality assessment, herbal plants and other biological materials [5], [10]–[12]. Therefore, the main objective of this present study is to apply the NIRS technology in assessing waste water quality parameters presented as nitrogen, phosphorus and potassium in waste water treatment plants (WWTPs) in Aceh Province.

## 2 MATERIALS AND METHODS

Samples used in this present study are waste water samples obtained from 8 different WWTPs installation in Aceh Province. On the other hand, the main instrument used in this study is a developed PSD NIRS instrument with a wavelength range of 1000-25000 nm or wavenumber range from 4000 to 10000 $cm^{-1}$, used to acquire the infrared reflection spectrum from a household WWTP samples. Moreover, another kits for nitrogen, phosphorus and potassium nutrient test kits in the laboratory are prepared such as spectrophotometric, magnetic stirrer, 50 ml Erlenmeyer flask, 2 ml cuvette spray bottle, water heater, digital scale, measuring pipette (10 ml, 20 ml 25 ml and 50 ml) glass measure, glass funnel and boil pumpkin. Spectra data were acquired and obtained for all waste water samples using the infrared spectroscopy instruments with workflow configuration is built using Thermo Integration® integrated software. Workflow is made to set the instrument to acquire the diffuse reflectance spectrum of household WWTP samples 32 times then average the results and save the scanning results in two different file formats in NIR wavelength region of 1000-2500 nm. In order to generate more robust and accurate prediction results, spectra data of all samples were corrected using the spectra average smoothing algorithm. Nitrogen, phosphorus and potassium nutrient contents in household WWTPs were predicted and determined based on the NIR spectra data produced through the process (model building). Prediction models were built by regressing the NIR data as variable X and nutrient levels of nitrogen, phosphorus and potassium measured in the laboratory as Y variables simultaneously. The regression method used to develop these models is the partial least square (PLS) regression method. The prediction results of this regression method were then evaluated based on accuracy in predicting the levels of nitrogen, phosphorus and potassium in WWTP waste water. Prediction performances were evaluated based on this following statistical indicators as shown in Table 1. The accuracy and reliability of the prediction model can be seen based on statistical parameters consisting of the correlation coefficient (r) between the predicted results and the results of standard measurements in the laboratory for three nutrient parameters, and ratio prediction to deviation (RPD). Ideally, reliable and accurate prediction models are models with high r and RPD parameter values, low RMSE and fewer number of latent variables involved in PLS regression.

## 3 RESULTS AND DISCUSSION

The sample acquisition process pf near infrared spectrum uses NIRS technology to determine and assesse quality parameters of nutrient levels presented as nitrogen, phosphorus and potassium contained in household wastewater samples, with a wavelength range of 1000-2500 nm. When the near infrared radiation beams directly penetrated to the wastewater samples, it produced approximately 4% of the energy emitted to organic material and reflected back to the outer surface whilst remaining 96% were absorbed by the chemical structures inside ss presented in Fig. 1.

***TABLE 1***
***MODEL PERFORMANCE CATEGORY BASED ON STATISTICAL INDICATORS***

| Statistical indicator | Value | Model category |
|---|---|---|
| Correlation coefficient (r) | 0.90 – 1 | Good prediction |
| | 0.50 – 0.65 | More than 50% of predicted Y can be determined |
| Coeff. of determination ($R^2$) | 0.66 – 0.81 | Sufficient performance |
| | 0.82 – 0.90 | Good performance |
| | > 0.91 | Excellent performance |
| Ratio prediction to deviation (RPD) | 1.5 – 2 | Coarse prediction are possible |
| | >2 – 3 | Good perfromance |
| | > 3 | Excellent and robust performance |

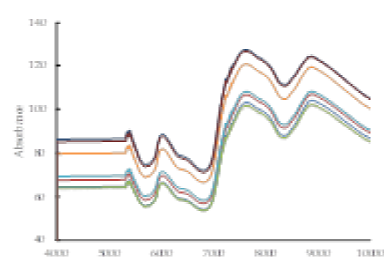


***Fig. 1**. Near infrared spectrum of wastewater samples obtained from WWTPs in Aceh Province*

The raw spectra as shown above in a non-dense and still rough spectrum measurement, this shows the presence of noise so it is necessary to do a spectra correction and pretreatment to reduce the influence of wave interference and noise interference on the infrared spectra data. Spectrum correction aimed to reduce interference with spectrum data so that spectrum data becomes smoother and denser. The spectrum acquisition process will produce raw data with high noise disturbance before spectrum correction is performed. The noise itself is the distance between each spectrum and the disturbance when collecting data, the disturbance can be in the form of overlapping absorption, light gaps affecting objects other than samples, the quality of the lighting source used where this research uses a laser beam splitter. The absorption of infrared wave radiation by the molecules making up the material causes vibrations that cause absorption to rise in accordance with a combination of chemical functional groups from a household WWTP sample showing the existence of wave crests that represent the presence of chemical bonds. The more radiation absorbed can provide a high absorbance value and the wavelength absorbed is stronger. The construction of the calibration model was used to predict nutrient levels of nitrogen, phosphorus and potassium in the IPAL sample of households after taking the spectrum using near infrared spectroscopy and spectrum correction. The calibration model is constructed by regressing the NIRS spectrum as the X variable and the actual data from the laboratory test results are used as the Y variable. The descriptive statistics plot for those three quality parameters is shown in Fig.2.

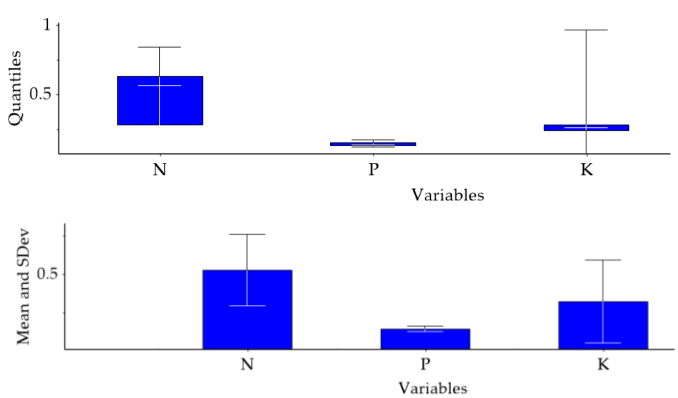


***Fig. 2**. Descriptive statistics plot for quartile, mean and std. deviation of three measured waste water chemical properties.*

Detailed descriptive statistics of measured N, p and K parameters of wastewater samples measured in the laboratory is also presented in Table 2

The difficulty in calibrating is the problem of complex natural information in the infrared spectrum, for example each peak of the spectrum almost always overlaps by one or more other peaks. The purpose of the calibration model construction is to generate the accuracy of the information model nutrient levels of nitrogen, phosphorus and potassium contained in household wastewater samples. In PLS method, data dimension was reduced to seek for the most relevant factors in predicting and describing data. The calibration model is built starting with the raw data, and the spectrum data that has been corrected using the average smoothing algorithm. PLS regression can also be obtained through simple and multiple regression by drawing conclusions from the significance test which aims to select the independent variables that construct PLS components and determine the number of PLS components that are formed. The purpose of PLS is to form components that can capture information from independent variables to predict the dependent variable. The prediction performance for N parameter using raw spectra data and smoothing data is presented in Fig.3.

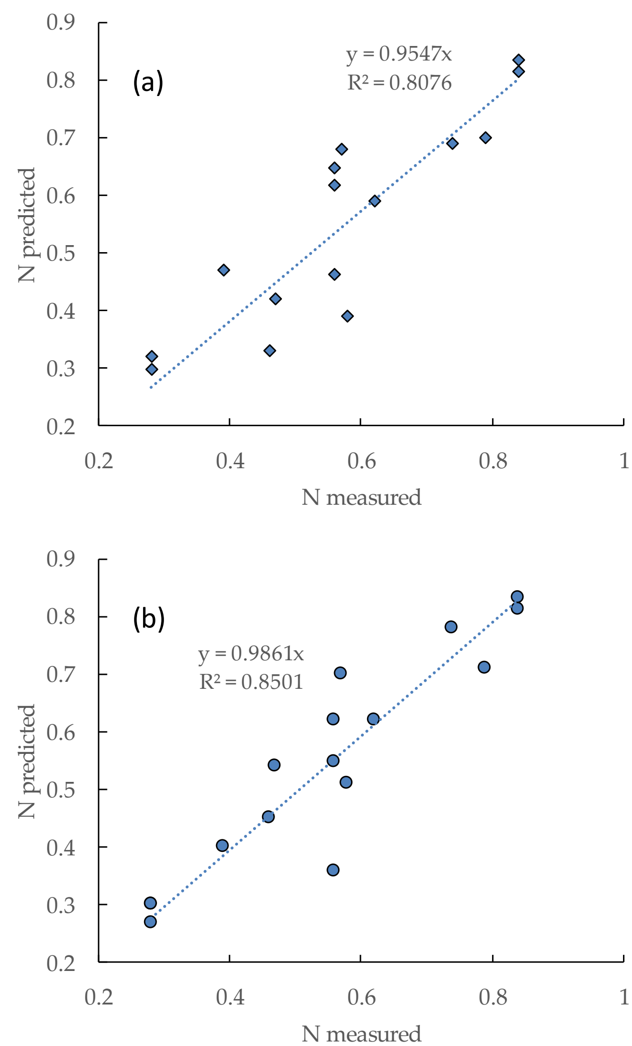


***Fig. 3**. Scatter plot between measured and predicted N using raw spectra (a) and Smoothing spectra data (b).*

The calibration results in Fig. 3 above shows the use of partial least square (PLS) obtained predictive value of raw data with a correlation value (r) of 0.90. the coefficient of determination ($R^2$) is 0.81 The RMSEC value obtained is 0.0315 and using latent variable (LV) factor 5 which served to increase the value of the correlation coefficient and reduce the RMSEC value obtained. This value is in the good prediction category because it has approached 1 and has met the statistical equation of the calibration model. The RPD value is obtained from the standard deviation value divided by the RMSEC value, ideally a reliable and accurate prediction model is a model with high correlation. The standard deviation value from the measurement of the actual data on the prediction of nitrogen nutrient levels is 0.2337, so the RPD value at factor 5 is 7.4190 and this is classified as a very good prediction category. When the models were developed using corrected spectra data like smoothing, the prediction performance becomes better than raw un-corrected spectral data. For phosphorus prediction, the scatter plot between actual measured P and the predicted P is shown in Fig.4.

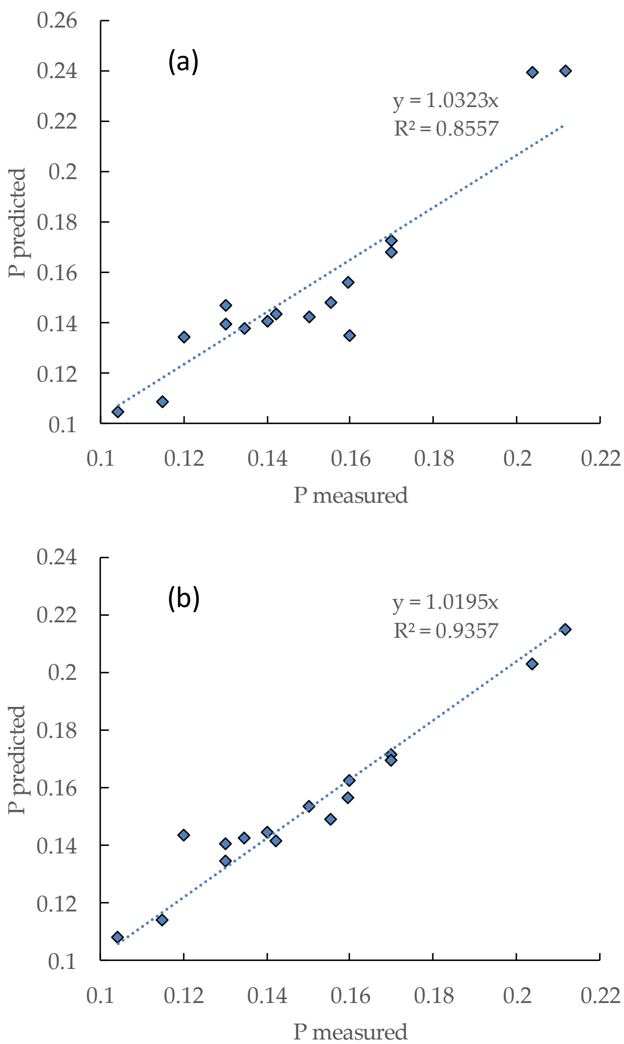


***Fig. 4***. *Scatter plot between measured and predicted P using raw spectra (a) and Smoothing spectra data (b).*

spectral data. As shown in Fig. 4, the coefficient of determination is increase to 0.93. It is obvious that spectra correction is necessary to be performed in order to achieve good prediction results. Moreover, beside nitrogen and phosphor, prediction models were also developed to determine potassium. It serves to help the formation of proteins and carbohydrates, strengthen plant tissue and play a role in the formation of plant antibodies that can fight disease and drought. These models were also established by means of raw and smoothing spectra data as presented in Fig. 5.

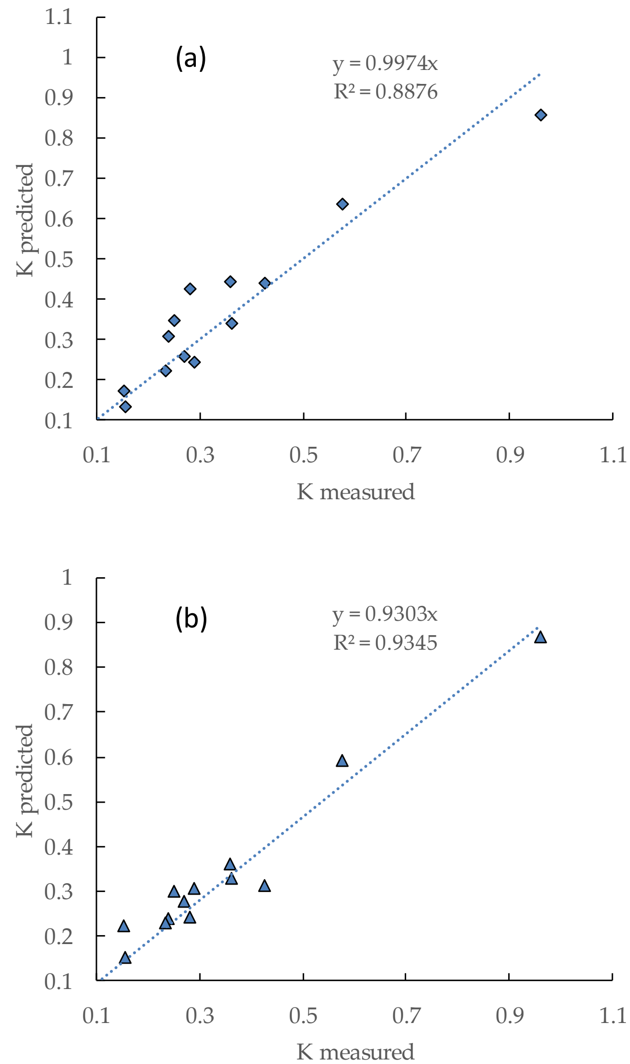


***Fig. 5***. *Scatter plot between measured and predicted K using raw spectra (a) and Smoothing spectra data (b).*

Wastewater or waste water is residual water that is discharged from households, industries or other public places and generally contains substances or substances that can be harmful to human health and disturb the environment. Domestic waste water is waste originating from residential areas which generally consists of waste from the kitchen, bathroom water, washing water, and human waste. In wastewater there are chemicals that are difficult to remove and give life to germs that cause various diseases. Every waste water produced needs to be managed properly based on its characteristics so that it can reduce the quality of pollutants contained in it before being flowed into the river body so as not to pollute the environment. Nutrient content is very useful to improve the physical properties of the soil and can improve the ability of the soil cations. Constraints in increasing the reuse of wastewater include wastewater that does not meet water quality requirements, for various purposes because it contains quite a large number of pollutants that need to be treated to meet the quality of water that is allowed before re-use. Wastewater contains microorganisms that have an important role in biological wastewater treatment, there are also microorganisms that are harmful to human life. These microorganisms include bacteria, fungi, protozoa and algae. Plant productivity is determined by soil fertility, especially nutrient availability, climatic conditions (rainfall and solar radiation), crop varieties, soil management and pest control of plant diseases. Plants can grow and produce optimally according to the potential results. Giving fertilizer also needs to pay attention to nutrient status in the soil. Thus, wastewater treatment plant must be also monitored in order to determine chemical properties rapidly and simultaneously n a real time situation.

## 4 CONCLUSION

This study investigated the feasibility of near infrared technology in rapid assessment of wastewater installation plant in Aceh province. The results showed that studied parameters namely nitrogen, phosphor and potassium can be determined rapidly without a direct contact with maximum coefficient of determination are: 0.85 for nitrogen, 0.93 for phosphor, and 0.94 for potassium content prediction respectively. Spectra data using average smoothing algorithm found to be more accurate and robust for determining those three quality parameters. Based on obtained performances, it may conclude that near infrared technology was feasible to assess wastewater quality parameters rapidly and simultaneously.

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## REFERENCES

[1] V. Khosravi, F. Doulati Ardejani, S. Yousefi, and A. Aryafar, “Monitoring soil lead and zinc contents via combination of spectroscopy with extreme learning machine and other data mining methods,” Geoderma, vol. 318, no. December 2017, pp. 29–41, 2018, doi: 10.1016/j.geoderma.2017.12.025.

[2] T. Shi, Y. Chen, Y. Liu, and G. Wu, “Visible and near-infrared reflectance spectroscopy-An alternative for monitoring soil contamination by heavy metals,” J. Hazard. Mater., vol. 265, pp. 166–176, 2014, doi: 10.1016/j.jhazmat.2013.11.059.

[3] R. K. Douglas, S. Nawar, M. C. Alamar, A. M. Mouazen, and F. Coulon, “Rapid prediction of total petroleum hydrocarbons concentration in contaminated soil using vis-NIR spectroscopy and regression techniques,” Sci. Total Environ., vol. 616–617, pp. 147–155, 2018, doi: 10.1016/j.scitotenv.2017.10.323.

[4] H. Cheng et al., “Estimating heavy metal concentrations in suburban soils with reflectance spectroscopy,” Geoderma, vol. 336, no. August 2018, pp. 59–67, 2019, doi: 10.1016/j.geoderma.2018.08.010.

[5] D. Devianti, S. Sufardi, Z. Zulfahrizal, and A. A. Munawar, “Rapid and Simultaneous Detection of Hazardous Heavy Metals Contamination in Agricultural Soil Using Infrared Reflectance Spectroscopy,” in IOP Conference Series: Materials Science and Engineering, Apr. 2019, vol. 506, no. 1, doi: 10.1088/1757-899X/506/1/012008.

[6] Darusman, Zulfahrizal, Y. Yunus, and A. A. Munawar, “Soil quality assessment by near infrared spectroscopy: Predicting ph and soil organic carbon,” Int. J. Sci. Technol. Res., vol. 8, no. 10, pp. 2512–2516, 2019.

[7] I. Ichwana, Z. Nasution, and A. Arip Munawar, “NEAR-INFRARED SPECTROSCOPY AS A RAPID AND SIMULTANEOUS ASSESSMENT OF AGRICULTURAL GROUNDWATER QUALITY PARAMETERS,” INMATEH Agric. Eng., pp. 233–240, Apr. 2020, doi: 10.35633/inmateh-60-26.

[8] I. Ramli, S. Rusdiana, H. Basri, A. A. Munawar, and V. A. Zelia, “Predicted Rainfall and discharge Using Vector Autoregressive Models in Water Resources Management in the High Hill Takengon,” in IOP Conference Series: Earth and Environmental Science, Jul. 2019, vol. 273, no. 1, doi: 10.1088/1755-1315/273/1/012009.

[9] R. H. Suci, Zulfahrizal, and A. A. Munawar, “Applying LIBS-QCL spectrum coupled with principal component analysis to distinguish gayo arabica and robusta coffee,” Int. J. Sci. Technol. Res., vol. 8, no. 10, pp. 919–924, Oct. 2019.

[10] Syahrul, Y. Yunus, P. Satriyo, and A. A. Munawar, “Applying infrared reflectance spectroscopy to predict water quality in Aceh river,” Int. J. Sci. Technol. Res., vol. 8, no. 10, pp. 969–972, Oct. 2019.

[11] Y. Yunus, Devianti, P. Satriyo, and A. A. Munawar, “Rapid Prediction of Soil Quality Indices Using Near Infrared Spectroscopy,” in IOP Conference Series: Earth and Environmental Science, Nov. 2019, vol. 365, no. 1, doi: 10.1088/1755-1315/365/1/012043.

[12] A. A. Munawar, Devianti, P. Satriyo, Syahrul, and Y. Yunus, “Rapid and simultaneous prediction of soil quality attributes using near infrared technology,” Int. J. Sci. Technol. Res., vol. 8, no. 9, pp. 725–728, Sep. 2019.

[13] A. A. Munawar, Y. Yunus, Devianti, and P. Satriyo, “Calibration models database of near infrared spectroscopy to predict agricultural soil fertility properties,” Data Br., vol. 30, Jun. 2020, doi: 10.1016/j.dib.2020.105469.

[14] C. Pasquini, “Near infrared spectroscopy: A mature analytical technique with new perspectives – A review,” Anal. Chim. Acta, vol. 1026, pp. 8–36, 2018, doi: 10.1016/j.aca.2018.04.004.

[15] F. Comino, V. Aranda, R. García-Ruiz, M. J. Ayora-Cañada, and A. Domínguez-Vidal, “Infrared spectroscopy as a tool for the assessment of soil biological quality in agricultural soils under contrasting management practices,” Ecol. Indic., vol. 87, no. January, pp. 117–126, 2018, doi: 10.1016/j.ecolind.2017.12.046.

[16] E. J. N. Marques, S. T. De Freitas, M. F. Pimentel, and C. Pasquini, “Rapid and non-destructive determination of quality parameters in the ‘Tommy Atkins’ mango using a novel handheld near infrared spectrometer,” Food Chem., vol. 197, pp. 1207–1214, 2016, doi: 10.1016/j.foodchem.2015.11.080.

[17] T. Nordey, J. Joas, F. Davrieux, M. Chillet, and M. Léchaudel, “Robust NIRS models for non-destructive prediction of mango internal quality,” Sci. Hortic. (Amsterdam)., vol. 216, pp. 51–57, 2017, doi: 10.1016/j.scienta.2016.12.023.

[18] I. Ambat, V. Srivastava, and M. Sillanpää, “Recent advancement in biodiesel production methodologies using various feedstock : A review,” Renew. Sustain. Energy Rev., vol. 90, no. February 2017, pp. 356–369, 2018, doi: 10.1016/j.rser.2018.03.069.

[19] V. Hugo, J. M. Santos, V. Z. Pestana, J. S. De Freitas, and L. F. Rodrigues, “Vibrational Spectroscopy A preliminary study on traceability of biodiesel mixtures based on the raw materials pro fi les from Brazilian regions and fourier transform infrared spectroscopy ( FTIR ),” Vib. Spectrosc., vol. 99, no. August, pp. 113–123, 2018, doi: 10.1016/j.vibspec.2018.09.005.
[20] J. F. García-martín, F. J. Alés-álvarez, M. C. López-barrera, I. Martín-domínguez, and P. Álvarez-mateos, “Cetane number prediction of waste cooking oil-derived biodiesel prior to transesteri fi cation reaction using near infrared spectroscopy,” Fuel, vol. 240, no. November 2018, pp. 10–15, 2019, doi: 10.1016/j.fuel.2018.11.142.
[21] Y. Wang et al., “Big data driven outlier detection for soybean straw near infrared spectroscopy,” J. Comput. Sci., vol. 26, pp. 178–189, 2018, doi: 10.1016/j.jocs.2017.06.008.
[22] P. Pimenidou, N. Shanmugapriya, and N. Shah, “Performance and emissions study of diesel and waste biodiesel blends with nanosized CZA2 of high oxygen storage capacity,” Fuel, vol. 239, no. November 2018, pp. 1072–1082, 2019, doi: 10.1016/j.fuel.2018.11.036.
[23] A. F. Constantino et al., “Determination of physicochemical properties of biodiesel and blends using low-field NMR and multivariate calibration,” Fuel, vol. 237, no. August 2018, pp. 745–752, 2019, doi: 10.1016/j.fuel.2018.10.045.
[24] A. A. Munawar, D. V. Hörsten, D. Mörlein, E. Pawelzik, and J. K. Wegener, “Rapid and non-destructive prediction of mango sweetness and acidity using near infrared spectroscopy,” in Lecture Notes in Informatics (LNI), Proceedings - Series of the Gesellschaft fur Informatik (GI), 2013, vol. P-211, pp. 219–222.
[25] Sudarjat, Kusumiyati, Hasanuddin, and A. A. Munawar, “Rapid and non-destructive detection of insect infestations on intact mango by means of near infrared spectroscopy,” in IOP Conference Series: Earth and Environmental Science, Nov. 2019, vol. 365, no. 1, doi: 10.1088/1755-1315/365/1/012037.
[26] A. A. Munawar, Kusumiyati, and D. Wahyuni, “Near infrared spectroscopic data for rapid and simultaneous prediction of quality attributes in intact mango fruits,” Data Br., vol. 27, Dec. 2019, doi: 10.1016/j.dib.2019.104789.
[27] A. A. Munawar, D. von Hörsten, J. K. Wegener, E. Pawelzik, and D. Mörlein, “Rapid and non-destructive prediction of mango quality attributes using Fourier transform near infrared spectroscopy and chemometrics,” Eng. Agric. Environ. Food, vol. 9, no. 3, pp. 208–215, Jul. 2016, doi: 10.1016/j.eaef.2015.12.004.
[28] R. Hayati, A. A. Munawar, and F. Fachruddin, “Enhanced near infrared spectral data to improve prediction accuracy in determining quality parameters of intact mango,” Data Br., p. 105571, Apr. 2020, doi: 10.1016/j.dib.2020.105571.
[29] Samadi, S. Wajizah, and A. A. Munawar, “Rapid and simultaneous determination of feed nutritive values by means of near infrared spectroscopy,” Trop. Anim. Sci. J., vol. 41, no. 2, pp. 121–127, 2018, doi: 10.5398/tasj.2018.41.2.121.
[30] Samadi, S. Wajizah, and A. A. Munawar, “Fast and simultaneous prediction of animal feed nutritive values using near infrared reflectance spectroscopy,” in IOP Conference Series: Earth and Environmental Science, Mar. 2018, vol. 122, no. 1, doi: 10.1088/1755-1315/122/1/012112.
[31] C. D. Iskandar, Zainuddin, and A. A. Munawar, “Rapid assessment of frozen beef quality using near infrared technology,” Int. J. Sci. Technol. Res., vol. 9, no. 5, pp. 156–160, 2020.
[32] C. D. Iskandar, Zainuddin, and A. A. Munawar, “Beef Freezing Optimization by Means of Planck Model Through Simulation,” in IOP Conference Series: Earth and Environmental Science, Nov. 2019, vol. 365, no. 1, doi: 10.1088/1755-1315/365/1/012072.
[33] Y. Saputri, Yusriana, and A. A. Munawar, “Infrared spectroscopic features of turmeric powder,” in IOP Conference Series: Earth and Environmental Science, Nov. 2019, vol. 365, no. 1, doi: 10.1088/1755-1315/365/1/012051.
[34] Agussabti, Rahmaddiansyah, P. Satriyo, and A. A. Munawar, “Data analysis on near infrared spectroscopy as a part of technology adoption for cocoa farmer in Aceh Province, Indonesia,” Data Br., vol. 29, Apr. 2020, doi: 10.1016/j.dib.2020.105251.
[35] Yusmanizar et al., “Fast and Non-Destructive Prediction of Moisture Content and Chologenic Acid of Intact Coffee Beans Using Near Infrared Reflectance Spectroscopy,” in IOP Conference Series: Materials Science and Engineering, Apr. 2019, vol. 506, no. 1, doi: 10.1088/1757-899X/506/1/012033.
[36] A. A. Munawar, H. Syah, and Yusmanizar, “Fast and robust quality assessment of honeys using near infrared spectroscopy,” in IOP Conference Series: Earth and Environmental Science, Nov. 2019, vol. 365, no. 1, doi: 10.1088/1755-1315/365/1/012053.