International Journal of Technology 15(4) 803-811 (2024)

International Journal of Technology

http://ijtech.eng.ui.ac.id

Catalyzing Clean Energy: The Role of Hydrogen and Ammonia Technology Processes

Yudan Whulanza[1]*, Eny Kusrini[2,3,4], Heri Hermansyah[2], Mahmud Sudibandriyo[2], Muhamad Sahlan[2], Sutrasno Kartohardjono[2]

[1]*Department of Mechanical Engineering, Faculty of Engineering, Universitas Indonesia, Kampus Baru UI, Depok 16424, Indonesia*
[2]*Department of Chemical Engineering, Faculty of Engineering, Universitas Indonesia, Kampus Baru UI, Depok 16424, Indonesia*
[3]*Research Group of Green Product and Fine Chemical Engineering, Laboratory of Chemical Product Engineering, Department of Chemical Engineering, Universitas Indonesia, Kampus Baru UI, Depok, 16424, Indonesia*
[4]*Tropical Renewable Energy Research Center, Faculty of Engineering, Universitas Indonesia, Kampus Baru UI, Depok, 16424, Indonesia*

Energy and Environmental Harmony

Hydrogen, the most abundant element in the universe, is increasingly recognized for its potential to serve as a clean energy carrier. Hydrogen is a clean energy source that produces no emissions when used, making it a good choice for reducing air pollution. Additionally, it is an abundant energy source that can be produced from a variety of sources such as air, biomass, and natural gas. Unlike fossil fuels, hydrogen combustion only produces water, making it an environmentally friendly alternative. There are two primary methods for hydrogen production: steam reforming of methane, which results in significant CO_2 emissions, and electrolysis, the splitting of water into oxygen and hydrogen using electricity. When this electricity is derived from renewable sources like wind or solar, the result is green renewable energy, such as hydrogen (H_2) gas, which is seen as key to a sustainable energy future. Globally, the majority of hydrogen gas production still relies on natural gas, resulting in significant greenhouse gas emissions. The challenge is to increase the share of green hydrogen to make this energy source truly sustainable and environmentally benign.

The urgency of adopting hydrogen technologies is amplified by the need to meet climate goals set by global agreements like the Paris Accord. According to forecasts from University College London, to limit global warming to 2°C, it is necessary to keep a third of all oil, half of all natural gas, and 80% of coal in the ground by 2050. Achieving these targets requires a shift to renewable energy sources that do not solely rely on the intermittent availability of wind and solar. The transition to hydrogen is also driven by practical needs in the energy market. For instance, the recent energy shortages in the UK, exacerbated by non-wind days in the North Sea, highlighted the limitations of current renewable energy infrastructures and the necessity for alternatives like hydrogen that can provide reliable, continuous power.

Hydrogen gas can be used as an energy source, energy storage, and energy carrier, and also used for infrastructure purposes. This gas is particularly suited for heavy industries and

*Corresponding author's email: yudan.whulanza@ui.ac.id, Tel.: +62-217270032; Fax.: +62-217270033
doi: 10.14716/ijtech.v15i4.7171

long-haul transport where direct electrification is impractical. Industries such as steel, cement, and heavy manufacturing, which are significant contributors to carbon emissions, stand to gain substantial benefits from transitioning to hydrogen. For instance, replacing coal in steel production with hydrogen can drastically cut emissions, helping to decarbonize a notoriously difficult sector. Companies like ThyssenKrupp and Salzgitter AG are pioneering the shift to hydrogen-based processes. Similarly, the chemical industry benefits from green hydrogen in ammonia synthesis, reducing the overall environmental impact of chemical production.

Economic and Financial Challenges

The path to a hydrogen-driven future is fraught with technical and economic hurdles. Historically, the perception of hydrogen has been marred by safety concerns, notably exemplified by the Hindenburg disaster. Critics argue that direct electrification may offer greater efficiency for certain applications compared to hydrogen. Additionally, the production of hydrogen is characterized by high energy intensity, necessitating substantial electricity inputs. When sourced from non-renewable energy, this can undermine its environmental advantages. In 2020, producing one kilogram of green hydrogen cost between around $5 and $7. This is significantly higher if the source is coal ($1.00 to $1.80 per kg) and natural gas ($1.40 to $2.40 per kg). The range of cost heavily depends on the location.

Financially, the transition to hydrogen technology requires considerable investment. Currently, there are over 350 large-scale projects worldwide, with total projected expenditures upwards of $500 billion. These projects span various applications from industrial processes to transportation and energy storage, indicating a growing confidence in hydrogen's role in reducing carbon footprints. The U.S. alone, through a recent bipartisan infrastructure bill, has allocated $9.5 billion towards hydrogen initiatives, including the creation of hydrogen hubs and the advancement of hydrogen transportation and research. This substantial investment underscores the commitment to integrating hydrogen into the national energy strategy, aiming to ensure a stable, reliable energy supply.

The commitment to hydrogen technology is also robust, with countries such as Germany dedicating approximately €7 billion to hydrogen projects. The country committed to establishing a core hydrogen grid extending 1,800 kilometers by 2027-2028 and is boosting its domestic electrolyzer capacity to at least 10 gigawatts by 2030. The project, located near Puerto Llano, Spain, is part of Iberdrola's broader plan to invest €3 billion in hydrogen technology by 2030. The goal is to link renewable energy production directly to hydrogen and ammonia production facilities, enhancing the sustainability of industrial processes.

India's central government has committed a significant investment of (approximately $2.5 billion) to the National Green Hydrogen Mission. This initiative is designed to create export opportunities, decarbonize energy production, and develop local manufacturing capabilities. The ambitious goal is to reduce the production cost of green hydrogen from the current range of $4.5 per kg to about $1.2 per kg. China targeting the deployment of 1 million fuel-cell vehicles by 2030. These investments underscore a strong belief in hydrogen's capacity to support a low-carbon economy.

Hydrogen and Ammonia Nexus

Hydrogen's potential is limited by its low density at room temperature, which is roughly one-third that of natural gas. This means that hydrogen either needs to be cooled

to -250°C to become a liquid or compressed to up to 300 times atmospheric pressure in order to be transported. This introduces significant energy losses in hydrogen production, estimated at about 30% of overall efficiency. Despite these challenges, the energy sector sees hydrogen as an attractive option because, in its compressed form, hydrogen contains approximately 40,000 Watt hours of energy per kilogram, significantly more than the best lithium-ion batteries, which hold about 280 Watt-hours per kilogram.

Ammonia gas has several advantages over hydrogen gas. It is easier to liquefy, requiring only -33°C, and needs to be compressed to just 10 times atmospheric pressure. Additionally, ammonia does not react with steel or leak from containers as hydrogen does, making it a superior carrier. Indeed, ammonia contains 50% more hydrogen by volume than hydrogen itself and converts back into hydrogen and nitrogen when needed without the intense conditions required for storing pure hydrogen gas.

Parallel to hydrogen, ammonia production is undergoing a transformation. Traditionally reliant on the Haber-Bosch process, which is energy-intensive and carbon-heavy. This process is responsible for about 2% of the world's fossil fuels and accounts for 1.2% of global CO_2 emissions. Evidently, this contributes significantly to CO_2 emissions, nitrate pollution, and nitrous oxide emissions. Ammonia is a critical industrial chemical used primarily in agricultural fertilizers and in the manufacture of plastics and pharmaceuticals. With global production exceeding 200 million tonnes annually in a market worth nearly $100 billion and growing. Due to its potential as a clean alternative to fossil fuels, the efficient and environmentally friendly production of ammonia is increasingly vital.

To achieve the vision of fully green ammonia, the industry must transition away from hybrid and conventional plants. The future lies in using electrochemical cells that operate solely on electricity and catalysts to combine air and water components into ammonia. This process does not require the high heat and pressure typical of traditional ammonia synthesis. However, there is a challenge in producing ammonia efficiently at normal temperatures and pressures. Researchers are currently working towards developing a single cell that can effectively produce ammonia under these conditions.

Monash University’s breakthrough in synthesizing ammonia from water and air using renewable energy illustrates the potential for significant reductions in energy consumption and carbon emissions. This method, if scalable, could revolutionize ammonia production and provide a blueprint for clean industrial processes worldwide. This new process, detailed in the online journal Science, has demonstrated ammonia production rates significantly closer to industrial targets than previous attempts at electrolytic ammonia synthesis. The team has established a startup, Jupiter Ionics, which has already attracted $1.8 million in seed investment.

Future Potential

Ongoing advancements in hydrogen production, such as improved electrolysis techniques and the scaling up of infrastructure, are critical. The development of green ammonia as a derivative of hydrogen for easy storage and transport is also a promising avenue, particularly for sectors like maritime shipping, transportation, and heavy industry where traditional battery storage is unfeasible. Whether hydrogen or battery electrification will dominate the future of transport remains to be seen, but the integration of hydrogen into global energy systems represents a significant step toward achieving a sustainable and clean energy future.

This issue

This volume documents the inquiry into cleaner energy, human mobility, and industrial and manufacturing practices that prioritize the well-being of individuals. Additionally, reports were generated about a proof of concept that involves value chain and artificial intelligence. Multiple publications emphasize an innovative approach that advocates environmental concerns.

The first paper is written by B. Tuktin, A. Omarova, G. Saidilda, S. Nurzhanova, S. Tungatarova, and Y. Ongarbayev. The study explores the hydroprocessing of tetradecane and diesel oil fractions, designed to enhance motor fuel quality. Experiments demonstrated that these catalysts effectively reduce sulfur levels and pour points while maintaining high liquid yields. Moreover, the catalysts show promising multifunctional capabilities that are essential for enhancing the quality of diesel fuel to meet international standards.

The second paper is written by W. Astuti, D. Avista, P. Prihutami, K.C. Wanta, A. Prakosa, F. Anggara, and H.T.B.M. Petrus. The study examined the atmospheric leaching behavior and kinetics of nickel and cobalt extraction from Halmahera limonite. The study found that sulfuric acid is more selective towards leaching cobalt over nickel, which is significant for optimizing metal recovery processes. These findings underscore the importance of temperature and acid concentration in enhancing the leaching kinetics of valuable metals from limonite ores.

The third paper is written by H.F. Jamahori, M.P. Abdullah, A. Ali, and A. AlKassem. The paper examines the optimal design and performance of multiple photovoltaic (PV) units integrated with grid-connected commercial loads. The research determined the most effective placements and sizes for PV units in grid systems, enhancing power loss reduction and PV penetration. This study underscores the potential of scalable PV integration in commercial setups, improving energy sustainability and operational efficiency within grid networks.

The fourth paper is written by A. Reseda, D. Sutjiningsih, and S.S. Moersidik. The paper developed a new protocol for predicting reservoir sedimentation in Indonesia, which incorporates the dynamics of land use and precipitation changes over time. The study was applied to the Wonogiri Reservoir in Indonesia, demonstrating the protocol's effectiveness through simulations that align with field-validated data. This innovative protocol helps with reservoir planning, operation, and maintenance by providing predictions of future sedimentation patterns and volumes.

The fifth paper is written by Y.W. Mirzayanti, L. Marlinda, H. Irawan, M. Al Muttaqii, Z. Ma'sum, N.P. Asri, and J.-M. Chern. The paper explores the impact of CaO/Hydrotalcite catalyst loading ratios and stirring rates on the transesterification of Nannochloropsis sp. microalgae into biodiesel. This study demonstrates the effectiveness of the chosen metal oxide catalysts and operational parameters in enhancing the biodiesel yield from microalgae, offering a promising approach for sustainable biofuel production.

The sixth paper is written by F.A. Lahin, R. Sarbatly, and C.C. Ken. The paper reports the development and effects of microorganism growth on clogging in up-flow sand filters. Results indicated differential growth of microorganisms across various bed heights during the 8-week acclimatization period. The study concluded that the up-flow configuration of the sand filter effectively prevented bio-clogging, thereby reducing maintenance demands and improving operational sustainability.

The seventh paper is written by L. Simatupang, R. Siburian, E. Ginting, B.M.T. Pakpahan, K.A.P. Simatupang, D.G. Siagian, E.R. Laoli, R. Goei, and A.I.Y. Tok. The paper uncovers the potential of porous silica derived from the volcanic ash of Mount Sinabung in Indonesia for its effectiveness as a corrosion inhibitor. The research highlighted that silica-coated iron

plates exhibited superior corrosion resistance compared to uncoated samples. This study suggests that silica extracted from volcanic ash not only serves as a sustainable material but also effectively enhances the durability of metals against corrosion.

The eighth paper is written by R.F. Darmayanti, M. Muharja, B. Airlangga, A. Widjaja, and A.N. Nalawati. The paper reports the production of bioacetone through extractive fed-batch fermentation using both free and immobilized cells of Clostridium saccharoperbutylacetonicum N1-4. The study found that palm oil significantly enhanced acetone yields, reducing the inhibitory effects of by-products on the bacterial culture. This approach not only increased acetone production but also presented a method that minimizes nutrient requirements and enhances overall process sustainability.

The ninth paper is written by A.D. Tulegenkyzy, P.S.M. Megat-Yusoff, K.M. Al Azzam, B.L. Kairatovna, A. Goyal, G. Eshmaiel, E.-S. Negim, M. Samy, and B. Ravindran. The paper reports the synthesis, characterization, and application of Poly(Styrene-Co-Glycidyl Methacrylate) (Poly(St-co-GMA)) as reactive diluents for epoxy resin. The study demonstrated that incorporating Poly(St-co-GMA) significantly reduced the viscosity of epoxy resins, facilitating better processing and application characteristics. The results confirmed their potential as effective modifiers to improve the performance of epoxy resins in anti-corrosion coatings.

The tenth paper is written by A. Raaf, F. Mulana, Y. Syamsuddin, N. Suriaini, and M.D. Supardan. The paper examines the impact of different drying pretreatment methods on the extraction of bioactive compounds from Amla (Emblica officinalis). The research showed that the drying method significantly affects the yield and antibacterial efficacy of the extracts. This study underlines the importance of the drying method in maximizing the extraction efficiency and therapeutic potential of Amla extracts, providing valuable insights for the nutraceutical industry.

The eleventh paper is written by A.F. Nisya, R. Rochmadi, and A. Budiman. The mass transfer phenomena during ultrasound-assisted extraction of algal oil from Spirulina sp. were investigated. The research utilized a combination of isopropyl alcohol and n-hexane as solvents. Mathematical modeling was used to determine mass transfer coefficients and diffusivity. The study shows the potential of this method for efficient biofuel production.

The twelfth paper is written by O. Soloveva, S. Solovev, and R. Shakurova. The efficiency of surface-modified porous materials in separating water-oil emulsions was extensively reviewed. The study explored the use of superhydrophobic and superhydrophilic materials, such as metal and polymer foams, to enhance the separation process through selective wettability and absorption capacity. This comprehensive review categorizes various methods and materials used in emulsion separation and emphasizes the potential enhancements brought about by surface modifications.

The thirteenth paper is written by D. Setyaningsih, M.S. Sarfat, F. Fahma, and N.S. Indrasti. The paper studies the reinforcement of polypropylene-based bio-nano composites with cellulose nanocrystals (CNC) and mono-diacylglycerols (M-DAG) to enhance their antistatic properties. These bio-nano composites offer promising potential for applications requiring durable, static-resistant materials, showcasing an innovative approach to enhancing polymer properties through bio-based additives.

The fourteenth paper is written by H.A. Ariyanta, H. Nainggolan, S.A. Denti, Y. Segara M, C.M. Setiyanto, I. Mayrosa, W. Fatriasari, Y. Yulizar, and T.A. Ivandini. The study highlighted the unique optical properties of the black gold nanostructures (AuNS) and explored their potential applications due to the anisotropic growth of nanocrystals facilitated by the high sulfur content of garlic extract. However, these black AuNS did not exhibit antibacterial

properties against tested strains. The cytotoxic properties of the nanostructures underscore their potential for biomedical applications.

The fifteenth paper is written by F.D. Utari, Z.D. Siqhny, A. Purbasari, T.D. Kusworo, D.P. Utomo, and M. Djaeni. The properties of brewer rice flour biodegradable films were enhanced through ultrasonication and acetylation treatments. The modifications improved the mechanical properties, hydrophobicity, and crystallinity of the films. These advancements not only increased the elongation at the break of the films but also demonstrated their potential as a sustainable alternative to conventional plastic films in various applications.

The sixteenth paper is written by Y. Astuti, L. Annisa, D.S. Widodo, and A. Darmawan. The paper studies the properties of Bismuth Oxide/Rice Husk-based Activated Carbon/Graphite (BO/RH-AC/G) composites. High crystallinity and specific monoclinic crystal structures of bismuth oxide were noted in composites with lower precursor concentrations, which also exhibited improved electrical conductivity over pure bismuth oxide. These findings suggest the potential of BO/RH-AC/G composites for applications such as electrodes for energy storage devices, highlighting their enhanced electrical properties and stability.

The seventeenth paper is written by I.G.A.K.C. Adhi, K.A. Atmika, N.M. Dwidiani, and I.D.G.A. Subagia. The paper investigates the influence of adhesive types on the burning rate and emission properties of honeycomb sandwich composites. The study concludes that Dextone-Epoxy adhesives are preferable for use in sandwich composites due to their superior flame-retardant properties and reduced health risks, highlighting. These findings underscore the importance of selecting appropriate adhesives to enhance safety in composite materials.

The eighteenth paper is written by D. Wijaya, S.S. Utami, and R.A. Mangkuto. The multi-objective optimization of skylight design parameters for a low-rise building in the tropics was examined to improve daylight penetration. The study varied skylight shape, opening area, and thickness to analyze their effects on daylight autonomy and sunlight exposure. The research offers valuable insights to architects and engineers, providing strategic guidance for the design of skylights in tropical climates to improve indoor environmental quality and energy efficiency.

The nineteenth paper is written by C.J.P. De Guzman, J.S. Sorilla, A.Y. Chua, and T.S.C. Chu. The study utilized ultra-wideband (UWB) systems for accurate indoor localization for object detection. Different particle swarm optimization (PSO) algorithms were compared, revealing that the stochastic inertia weight variant (Sto-IW PSO) outperformed others across multiple metrics. The research advocates for real-world application through field experiments and further refinement of PSO algorithms to enhance the system's efficiency and response to dynamic environments.

The twentieth paper is written by A. Ma'ruf, A.A.R. Nasution, and R.A.C. Leuveano. The research utilized multi-linear regression, random forest, and gradient boosting models to estimate costs in make-to-order (MTO) manufacturing. Key predictors included mate and assembly features and the number of parts, which were identified through data collected from historical 3D CAD files and processed using a tailored program. The findings underscore the efficacy of machine learning in reducing subjectivity and enhancing the accuracy of cost estimations.

The next paper is written by J.A. Al-Doori, Z. Alkhazali, R. Al Aqrabawi, and K. Al-Daoud. The research utilizes structural equation modeling to analyze survey data from supply chain managers within the fast-moving consumer goods (FMCG) sector in Iraq. Key findings reveal that trust, developed over time within firm relationships, forms a competitive

capability that is difficult for competitors to replicate. Despite its localized focus, the study provides valuable insights into the mechanisms by which technology and trust foster improved operational outcomes through effective supply chain collaboration.

The twenty-second paper is written by L. Villaverde, and D. Maneetham. The project utilized Computer-Aided Design (CAD) and Denavit-Hartenberg (DH) conventions to develop a detailed kinematic model, which informed the construction of the robot, enabling precise control of the robotic arm's movements for arc welding applications. The simulation and analysis phases were carried out using MATLAB Robotics Toolbox. The successful implementation of this robotic system demonstrated its capability to perform welding tasks with high precision, highlighting the potential for enhanced productivity in industrial applications.

The twenty-third paper is written by T. Karasu, Zulkarnain, and P. Leviäkangas. The research identified agri-machinery companies and structured 90 initial challenges, applying Quality Function Deployment (QFD) to prioritize and address these challenges effectively. The methodology focused on enhancing the first mile of agricultural supply chains by integrating stakeholder cooperation, particularly with regulators and farmers, to improve operational efficiency. This comprehensive approach not only highlighted the critical role of collaboration in tackling supply chain challenges but also advanced the implementation of sustainable practices in the agricultural sector.

The twenty-fourth paper is written by K. Khazimov, Z. Sagyndykova, Z. Khazimov, I. Daurenova, Y. Umbetkulov, and M. Khazimov. The research focused on optimizing welding parameters for sealing the neck of vacuum containers made of polyethylene film. The team established the optimal welding temperature which provided the highest burst pressure resistance for maintaining the vacuum and stability of the sealed containers. This study contributes to improving the reliability of flexible containers used in agricultural storage by ensuring robust sealing methods that withstand internal pressures.

The twenty-fifth paper is written by A.L.F. Chuen, K.W. How, P.Y. Han, and Y.H. Yen. The research tested different convolutional recurrent neural network (C-RNN) architectures to optimize the recognition process., finding that the ConvBiLSTM variant achieved the highest accuracy. This method utilizes both spatial and temporal data from hand gestures, captured through air signatures. The study represents a significant advancement in biometric verification, offering a more hygienic and equally effective alternative to traditional methods during times of health crises such as the COVID-19 pandemic.

The twenty-sixth paper is written by Indrawanto, I.A.A. Saputro, V. Virdyawan, and T. Tjahjowidodo. The research utilized the Modified Prandtl-Ishlinskii (MPI) model to effectively capture and compensate for the nonlinear hysteresis behavior of piezoelectric materials. Through rigorous system identification processes and experimental validations, the actuator exhibited a significant decrease in hysteresis effects, thereby enhancing its precision in micro-scale movements. The study underscores the potential of advanced control strategies in enhancing the performance of piezoelectric actuators, which are critical in high-precision applications.

The twenty-seventh paper is written by M.F. Hikmawan, B. Azhari, E. Yazid, A.S. Nugraha, and M. Mirdanies. The paper introduces a novel piezoelectric energy harvester (PEH) design for vehicle suspension. The system leverages the linear vibrations of suspension due to road roughness, utilizing a pressurized liquid cylinder-piston mechanism to amplify these vibrations and deform a piezoelectric bar, generating up to 67.5 watts of electricity. The study showcases the potential of this technology in enhancing vehicle energy efficiency and contributing to renewable energy solutions.

The twenty-eight paper is written by F. Hendra, R. Mohammad, A. Amrin, N. Maarop, and T.Y. Zagloel. The review included a comprehensive analysis of 73 publications from the last ten years, focusing on risk management, assessment, and analysis within the railway sector, and outlined the standards and regulations adopted internationally. It highlighted a significant gap in risk assessments at railway level crossings, where accidents are frequent, yet studies are minimal. The study also proposed directions for future research, emphasizing the need for specific guidelines and detailed risk assessment methods in high-risk areas to enhance overall railway safety and management practices.

The twenty-ninth paper is written by A. Andoko, P. Kurniawan, S. Suprayitno, F. Gapsari, and M. Manawan. The article explores the causes of failure in leaf springs through the study of residual stresses and crystal textures using experimental techniques. The application of X-ray diffraction techniques revealed specific crystallographic planes with varied levels of strain, which contributed to the material's overall vulnerability to failure. Additionally, the examinations of the fracture morphology, which involved SEM analysis, revealed the presence of voids and inconsistencies on the surface of the leaf springs. These imperfections served as focal points for stress concentration, ultimately leading to material failure.

The thirtieth paper is written by L. Mahdieh, and S. Lenjannejadian. Utilizing biomechanical modeling, the study varied knee flexion angles and hip and knee angular displacements to observe their effects on knee torque and anterior cruciate ligament (ACL) stress. Results indicated that increased knee and hip flexion during initial contact significantly decreased ACL stress and knee torque, providing a preventive strategy against ACL injuries. The findings are crucial for athletes, suggesting modifications in landing mechanics can substantially reduce the likelihood of ACL injuries, particularly in high-impact sports.

The last paper is written by E. Shkarupeta, A. Babkin, S. Palash, E. Syshchikova, and S. Babenyshev. It employs various quantitative metrics, such as the Economic Diversification Index (EDI) and the Digital Transformation Index (DTI), to assess the influence of digitalization on ten Russian regions. The findings highlight a significant heterogeneity in outcomes; regions that effectively harnessed digitalization witnessed enhancements in economic security, while those lagging in digital adoption saw compounded economic difficulties. The study underscores the pivotal role of digital transformation in economic security strategies, offering insights into its nuanced impact on regional economic policies and growth.

In summary, the integration of contemporary technology with recent advancements has opened up new possibilities for addressing complex problems in various fields. As scientific advancements progress, innovation is expected to play a growing role in shaping our future. Ijtech eagerly welcomes and gladly accepts your articles, with the aim of sharing your research with our audience.

Greetings from Jakarta,

Prof. Dr. Yudan Whulanza
Editor in Chief

Dr. Eny Kusrini
Managing Editor

Prof. Dr. Ir. Heri Hermansyah
Editorial Board

Prof. Ir. Mahmud Sudibandriyo
Editorial Board

Dr. Muhamad Sahlan
Editorial Board

Prof. Dr. Sutrasno Kartohardjono
Editorial Board