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# Acid Rain Purification Technologies for Tailored Mitigation Strategies in Developing Countries

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**Abstract:**

Acid rain, caused primarily by $SO_2$ and $NO_x$ emissions from fossil fuel combustion, remains a major environmental challenge with significant ecological and human health consequences. This review compares existing control technologies, focusing on efficiency, cost, feasibility, and applicability to developing countries where resources and infrastructure may be limited. For $SO_2$ mitigation, calcium-based flue gas desulfurization (FGD) is widely applied because it is relatively simple and cost-effective, although its efficiency is somewhat lower than alternative methods. Sodium-based sorbents, by contrast, can achieve higher removal efficiency but are constrained by elevated costs and more complex disposal requirements, which limit large-scale adoption. For $NO_x$ control, combustion modifications represent low-cost options that can be implemented during the design or operation of boilers, but their effectiveness is limited compared with post-combustion methods. Advanced techniques such as selective catalytic reduction (SCR) provide high removal efficiency and reliability, yet demand substantial investment, sophisticated operation, and continuous maintenance. Considering these trade-offs, developing countries should prioritize technologies that balance cost and performance. A practical pathway involves adopting calcium-based FGD for $SO_2$ reduction, while integrating hybrid $NO_x$ reduction strategies that combine low-cost combustion modifications with selective downstream treatment, ensuring both technical feasibility and alignment with local economic conditions.

**Keywords:** Acid rain; $SO_2$ control; $NO_x$ reduction; flue gas desulfurization; selective catalytic reduction.

# 1. Introduction

Acid rain originates from multiple sources, most notably the combustion of fossil fuels and vehicle emissions. These processes release sulfur compounds and nitrogen oxides, which, in the presence of water, oxygen, and other atmospheric components, are transformed into sulfuric and nitric acids. The resulting acidic substances are deposited onto the Earth's surface through dry and wet deposition [1-2]. Given the widespread reliance on fossil fuels, controlling acid rain remains a persistent challenge. Current mitigation approaches can be broadly divided into those targeting sulfur dioxide ($SO_2$) and those targeting nitrogen oxides ($NO_x$). Flue Gas Desulfurization (FGD) is the primary technology for $SO_2$ removal, whereas Selective Catalytic Reduction (SCR) and Selective Non-Catalytic Reduction (SNCR) are commonly applied to control $NO_x$ emissions. These technologies vary significantly in mechanism, operating conditions, and overall effectiveness.

With growing global concern over acid deposition, new purification technologies have emerged, necessitating systematic evaluation alongside conventional methods. A comprehensive comparison based on efficiency, cost, technical complexity, and applicability allows for a clearer understanding of the strengths and limitations of different approaches.

Globally, $SO_2$ and $NO_x$ emissions have shown divergent trends. While reductions have been achieved in OECD countries, many developing regions—particularly in Asia—have continued to experience emission growth due to rapid economic expansion and rising energy demand. Such developments risk undermining the effectiveness of acid rain control efforts [3].

Economic and technological constraints further complicate mitigation in developing countries, making it essential to identify strategies that balance efficiency, feasibility, and affordability. This review therefore compares a range of control methods across diverse application contexts, with the goal of determining the most suitable acid rain purification strategies for developing nations.

# 2. Formation of acid rain

The formation of acid rain is a complex atmospheric process driven primarily by chemical reactions involving anthropogenic emissions. Sulfur dioxide ($SO_2$) and nitrogen oxides ($NO_x$) are the main precursors, originating largely from fossil fuel combustion in power plants, industrial facilities, and vehicle exhaust, although natural sources such as volcanic eruptions and forest fires also contribute [4]. Once released into the atmosphere, these gases dissolve in water vapor and react with oxygen and other compounds to generate acidic substances, most notably sulfuric acid ($H_2SO_4$) and nitric acid ($HNO_3$) [1].

In thermal power plants, low-grade coal typically contains approximately 0.5% sulfur and 35–40% ash. During combustion, sulfur is oxidized to $SO_2$, which can be further transformed into sulfite ions ($SO_3^{2-}$) and subsequently oxidized into sulfuric acid under atmospheric conditions (Prakash et al., 2023) [1]. The abundance of water vapor and oxidizing agents such as ozone accelerates these transformations. By contrast, nitric acid formation is primarily associated with vehicular emissions. Nitrogen in fuel reacts with oxygen during high-temperature combustion to form nitric oxide (NO), which undergoes a series of photochemical reactions to produce nitrogen oxides that ultimately convert into nitric acid.

The deposition of these acidic products occurs through two primary pathways: dry and wet deposition. Dry deposition refers to the direct absorption of $SO_2$, $NO_x$, and other acidic species onto dust particles or aerosols, which subsequently settle on the Earth's surface. Wet deposition occurs when acidic gases and particles are scavenged by precipitation. Processes within clouds, known as rainout, differ from those below clouds, where falling rain or snow captures pollutants in a process referred to as washout [5].

# 3. Methods for controlling sulfur dioxide

## 3.1 Change fuel

To address the issue of excessive sulfur dioxide emissions, the most straightforward solution is to switch to alternative fuels. Since sulfur dioxide is mainly found in coal, substituting coal with natural gas, oil, hydropower, or nuclear energy can reduce SO2 emissions. However, compared to coal, natural gas and oil are more expensive, hydropower is regionally unstable, and nuclear energy entails high capital investment and safety concerns.Finally, the replacement of coal will affect the efficiency of the power station.According to an estimate made by PEDCo. Environmental Inc. , if clean energy is used to replace coal in order to reduce the annual emission of 6 million tons of sulfur dioxide, then the power company will need to spend approximately 1.4 billion $ each year. This means that it costs 250 $ to remove each ton of sulfur dioxide [6].

## 3.2 Flue Gas Desulfurization (FGD) Process

The flue gas desulfurization (FGD) process is a method that removes sulfur dioxide emissions by having the adsorbent come into contact with the sulfur dioxide gas.

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When the adsorbent comes into contact with sulfur dioxide, it will react with it, eventually forming either a liquid or a dry solid, which are respectively called the dry-method and the wet-method.Among them, dry desulfurization will utilize various types of catalysts, such as calcium-based sorbent, sodium-based sorbents, activated carbon, metal oxides and zeolites [7-9].

**3.2.1 calciumbased sorbent**

Calcium-based adsorbents are a type of adsorbent manufactured based on the calcium cycle. The core process involves carbonization and calcination, and is achieved through a fluidized bed reactor. Therefore, they are suitable for large-scale emission sources such as coal-fired power plants. During the FGO process, the commonly used calcium-based adsorbents include limestone($CaCO_3$), hydrated lime($Ca(OH)_2$), modified dolomite($CaO \cdot MgO$), fly ash composite adsorbent($CaO\text{-}SiO_2$) and synthetic adsorbent($CaO/Al_2O_3$ etc.). In addition, the advantages of calcium-based adsorbents include low raw material costs, high stability of the desulfurization products, simple processing, and high temperature resistance [10]. Due to these advantages, its common application scenarios include the removal of acidic gases such as $SO_2$, HCl, and HF in coal-fired power plants and waste incineration plants [10]. However, calcium-based sorbents also have some drawbacks. For instance, after multiple cycles, the pores become clogged, which leads to a decrease in the adsorption capacity. Additionally, they have a slower reaction rate and some adsorbents have insufficient strength [11].

**3.2.2 sodium-based sorbents**

Sodium-based sorbents mainly use sodium bicarbonate as the adsorbent. Their main advantage lies in the fact that it not only has a strong attraction for acidic substances such as sulfur dioxide, but also can remove carbon oxides to a certain extent.[8] This means that it can reduce more sulfur dioxide with fewer adsorbents, thereby lowering the cost of sulfur reduction. At the same time, this method can also maintain a high degree of reactivity at relatively low temperatures (140°~ 300°), which gives it the advantage of being able to be directly used in low-temperature gas flow devices.[8]However, for the adsorbent, the most important factors are not only efficiency, but also hygroscopicity and price. For sodium-based adsorbents, although their efficiency is higher than that of calcium-based adsorbents, their cost is also higher [9]. Meanwhile, sodium-based sorbents are hygroscopic, so during use, it is necessary to strictly control the humidity to prevent premature deliquescence, which could lead to a decrease in the reversibility of the reaction and the service life.

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**3.2.3 Comparison between sodium-based sorbents and calcium-based sorbents**

For sodium-based sorbents and calcium-based sorbents, as the main methods for cleaning sulfur dioxide, they have different characteristics. Therefore, when evaluating them, one should consider multiple aspects.First and foremost, and most importantly, the efficiency of the adsorbent is the most crucial factor.For calcium-based adsorbents, their desulfurization efficiency is relatively low. Moreover, traditional calcium-based desulfurizers require a calcium-sulfur ratio of 5:1 to 10:1 to meet emission standards. However, for sodium-based adsorbents, a ratio of 1.3:1 to 1.6:1 is sufficient [11].Furthermore, calcium-based adsorbents are highly dependent on the temperature and humidity of the flue gas. For instance, at 150°C and with a humidity of 25%, the desulfurization efficiency is several times higher than that of dry flue gas. This indicates that the optimal reaction window is adjacent to the dew point. [10]However, for sodium-based sorbents, their desulfurization efficiency is higher, and they exhibit stability over a wide temperature range (180° to 350°), with minimal influence by humidity.However, for temperatures above 350°, the sodium sulfite in the sodium-based adsorbent may be oxidized to sodium sulfate, resulting in a decrease in its activity.[10]

Meanwhile, when choosing the adsorbent, cost is also a very important factor.For calcium-based adsorbents, their cost advantage is obvious. The cost for treating each ton of sulfur dioxide is only $615.65, which is only 1/6 of the $3709.68 for sodium-based adsorbents. Meanwhile, the generation cost of sodium-based adsorbents is 5.36 times higher than that of calcium-based adsorbents [12].

Apart from measurable data such as cost and efficiency, the technical threshold is also a very important consideration for developing countries when choosing adsorbents. During the operation of calcium-based adsorbents, it is necessary to precisely control the temperature and humidity of the flue gas in order to optimize the reaction rate. For sodium-based adsorbents, their applicable temperature and humidity range is wide, and no strict regulation is required, making the operation simpler [10]. However, at the same time, the by-products of calcium-based adsorbents, such as calcium sulfate and calcium sulfite, do not dissolve in water, which is beneficial for disposal. [10]This is different from sodium-based adsorbents like sodium sulfate and sodium sulfite, which have high water solubility and thus more complex disposal methods, such as landfilling salt mines. Additionally, they can be regenerated through steam activation to increase the number of cycles, which is a significant advantage compared to the hygroscopic property of sodium-based adsorbents.

Finally, when evaluating the two adsorbents, their application scenarios should also be taken into consideration [10]. Calcium-based adsorbents are suitable for scenarios where the humidity of the flue gas can be controlled and where there are cost constraints, such as coal-fired power plants and waste incineration plants [10]. For sodium-based adsorbents, considering their significant advantages in low-humidity and high-temperature flue gas, they are suitable for scenarios where the flue gas temperature fluctuates greatly while efficiency is also a priority, such as in the chemical and metallurgical industries [10]. However, their hygroscopic property also limits their application in high-humidity environments.

The following table summarizes and compares the various attributes of the two adsorbents.

**Table 1. Comparative performance of calcium- and sodium-based sorbents in $SO_2$ removal.**

| Criteria | Calcium-Based Sorbents | Sodium-Based Sorbents |
|---|---|---|
| Efficiency | • Lower efficienecy (Ca/S ratio: 5:1–10:1)<br>• Highly dependent on temperature/humidity (optimal near dew point)<br>• Improved recyclability after modification (e.g., steam activation increases carbonation rate to 70%) | • High efficiency (Na/S ratio: 1.3:1–1.6:1)<br>• Stable across wide temperature ranges (180–350°C)<br>• Humidity sensitivity low |
| Cost | • Low cost (~615 CNY/ton $SO_2$ treated)<br>• Raw materials (e.g., $Ca(OH)_2$) inexpensive | • High cost (~3,710 CNY/ton $SO_2$ treated, 6× calcium-based)<br>• Production cost 5.36× higher |
| Technical Barriers | • Complex operation (precise T/HR control required)<br>• Water-insoluble byproducts (easy disposal)<br>• Steam reactivation feasible | • Simple operation (tolerant to T/HR fluctuations)<br>• Water-soluble byproducts (complex disposal, e.g., special landfill)<br>• Deliquescent (corrosion risk) |
| Application Scenarios | • Cost-sensitive, humidity-controlled settings (e.g., coal/gas power plants, waste incineration)<br>• Superior HF adsorption<br>• Byproducts reusable in construction | • Efficiency-critical, variable-temperature gases (e.g., chemical/metallurgical industries)<br>• Optimal for low-humidity/high-temperature flue gas<br>• Limited in high-humidity environments |
| Recycling Potential | • High (reactivation enhances cyclic stability) | • Limited (no widely adopted regeneration technology) |

# 4. Methods for controlling nitric oxide

## 4.1 Combustion control method

### 4.1.1 Low $NO_x$ Burners

Low $NO_x$ burners are a type of burner that reduces flame temperature and oxygen concentration by altering the burner's structure. This design lowers the temperature in the high-temperature zone and shortens the fuel's residence time, thereby reducing $NO_x$ formation [13]. This method offers several advantages. For instance, it requires no additional chemical reagents, resulting in low operating costs. It is also easy to modify and can be directly applied in existing boilers. Moreover, it can reduce fuel consumption [13]. However, this method also has several drawbacks. Altering the burner structure may lead to uneven combustion, resulting in carbon monoxide production. Furthermore, high operating temperatures may cause

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equipment corrosion.

#### 4.1.2 Staged Combustion

The principle of staged combustion is to regulate oxygen concentration in order to suppress high-temperature conditions that promote $NO_x$ formation. Unlike low-$NO_x$ burners, this method supplies combustion air in successive stages. In the first stage, fuel is burned under oxygen-deficient conditions, reducing $NO_x$ generation. In the second stage, the remaining air is introduced to complete the combustion process [13]. The main advantage of this method is its compatibility with other combustion control technologies, which can reduce fuel consumption and enhance energy efficiency. However, its drawbacks include unstable combustion performance and the potential for secondary $NO_x$ formation during the second stage, resulting in inconsistent efficiency.

#### 4.1.3 Flue Gas Recirculation(FGR)

The main method of FGR is to return part of the exhaust gas to the combustion zone. Since these exhaust gases are inert gases, they will absorb heat, thereby reducing the oxygen concentration and lowering the flame temperature, thus minimizing the formation of thermal $NO_x$ [13].The principle of this method is different from the previous two methods, so its advantages and disadvantages are also different. The advantage of this method lies in that it can significantly reduce the peak temperature, thereby reducing the formation of $NO_x$ and making the combustion more uniform, preventing the occurrence of excessively high local temperatures.[13]However, because it needs to send the exhaust gas back to the combustion zone, it may lead to a decrease in combustion efficiency and an increase in fuel consumption. At the same time, the presence of exhaust gas may also increase the risk of equipment corrosion [13].

#### 4.1.4 High-Temperature Combustion

High-Temperature Combustion reduces the formation of $NO_x$ by burning the fuel at extremely high temperatures above 1000°, ensuring complete oxidation of the fuel [14]. The advantage of this method is its high emission reduction efficiency, which makes it suitable for scenarios with high $NO_x$ loads, and it can also save space within the furnace. However, at the same time, due to the extremely high temperature required, it is prone to cause equipment corrosion and damage. Moreover, the high temperature also means higher energy consumption and carbon dioxide emissions. Post-combustion treatment methods

The smoke gas treatment methods are used to process the exhaust gas after combustion, employing chemical or physical processes to remove $NO_x$. Evidence shows that these methods are highly efficient, but they have high costs and technical barriers, and are often used as supplementary measures for combustion control.

#### 4.1.5 Selective Catalytic Reduction(SCR)

Under the action of a catalyst (such as V2O5), the reducing agent selectively reduces $NO_x$ to N2 and H2O. The principle is to provide active sites through a catalyst, thereby facilitating the reaction to proceed at lower temperatures (250° to 400°) and enhancing the reduction efficiency.The advantage of this method lies in its extremely high efficiency in removing $NO_x$, and it can also handle multiple pollutants simultaneously.The drawbacks are also quite obvious. The catalyst is expensive and prone to poisoning. Moreover, during use, there is a risk of ammonia leakage, which leads to secondary pollution.

#### 4.1.6 Selective Non-Catalytic Reduction(SNCR)

The difference between Selective Non-Catalytic Reduction and Selective Catalytic Reduction lies in the fact that it does not use a catalyst. Instead, ammonia and uric acid are directly injected into the high-temperature zone to directly reduce $NO_x$ to N2. The key difference between its principle and Selective Catalytic Reduction is that it provides activation energy through high temperature. [13]Also, precisely because this method does not require a catalyst, its cost is lower, and the equipment is simple and easy to install. However, this method also has drawbacks. For instance, the temperature needs to be strictly controlled within the range of 900 to 1000 degrees. As a result, the efficiency is unstable. Secondly, this method consumes a large amount of ammonia, which may lead to ammonia leakage or the formation of N2O as a by-product.

#### 4.1.7 Wet Scrubbing

Wet scrubbing differs from other control methods in that it relies on gas–liquid mass transfer, where an alkaline solution absorbs $NO_x$ to form nitrates or nitrites. Its primary advantage is the ability to simultaneously remove $NO_x$, $SO_x$, and other pollutants, making it suitable for treating flue gas with relatively low $NO_x$ concentrations. However, this method generates wastewater and solid residues due to the use of alkaline solutions, and it exhibits low overall efficiency with limited effectiveness for species other than $NO_2$ . The principle of Wet Scrubbing is different from other methods. It achieves this by means of gas-liquid mass transfer, using an alkaline solution to absorb $NO_x$, thereby forming nitrate or nitrite. The advantage of this method lies in that it can simultaneously absorb $NO_x$ and $SO_x$, as well as other pollutants, and is applicable to low concentrations of $NO_x$. However, because this method requires the use of alkaline solutions, it will produce wastewater and waste residue. Moreover, its efficiency is low and it has poor removal effect on substances other than NO2 (nitrogen dioxide) [14].

#### 4.1.8 Non-Selective Catalytic Reduction(NSCR)

This method is somewhat similar to Selective Catalytic Reduction, but it is non-selective, so it may also reduce other oxidants. The principle is the same as Selective Catalytic Reduction, where a reducing agent is used to promote the reduction reaction [13]. Because multiple catalysts and reductants were used, it can handle various pollutants and has high efficiency under rich combustion conditions. However, the use of multiple catalysts is accompanied by an increase in costs, and because they are prone to deactivation, they need to be regenerated repeatedly [14].

### 4.2 Comparison of methods

When comparing control methods, various factors should be taken into consideration, including efficiency, cost, technical threshold, and usage scenarios. The following table lists the various indicators of the methods mentioned earlier.

**Table 2. Three Scheme comparing**

| Method | Efficiency ($NO_x$ Reduction Rate) | Cost | Technical Barriers | Application Scenarios |
|---|---|---|---|---|
| Combustion Control Methods | | | | |
| Low NOx Burners | ~60% (Medium) | Medium capital, Low operating | Low | Power plants, Industrial furnaces |
| Staged Combustion | 50-70% (Medium-High) | Low capital, Low operating | Low-Medium | Oxy-fuel plants, Chemical plants |
| Flue Gas Recirculation (FGR) | 70-90% (High) | Medium capital, Medium operating | Medium | Gas turbines, Internal combustion engines |
| High-Temperature Combustion | ~90% (High) | High capital, High operating | High | Large power plants, Metallurgical plants |
| Combustion control method | | | | |
| SCR (Selective Catalytic Reduction) | 80-90% (Very High) | High capital, High operating | High | Power plants, Automotive exhaust |
| SNCR (Selective Non-Catalytic Reduction) | 40-60% (Medium) | Medium capital, Medium operating | Medium | Waste incinerators, Medium/small boilers |
| Absorption/Wet Scrubbing | 30-50% (Low) | Medium capital, High operating | Medium | Chemical plants, Marine vessels |
| NSCR (Non-Selective Catalytic Reduction) | 50-70% (Medium) | High capital, High operating | High | Automotive, Specific industries |

## 5. Conclusion

Acid rain remains a critical environmental issue, largely driven by $SO_2$ and $NO_x$ emissions. This review compared major control technologies and proposed tailored strategies for developing economies.

For $SO_2$ mitigation, fuel substitution with low-sulfur alternatives (e.g., natural gas, nuclear energy) offers direct emission reduction but is constrained by high costs, unstable supply, and safety risks. Flue Gas Desulfurization (FGD) remains the dominant approach: calcium-based sorbents are inexpensive, stable, and easy to dispose of, making them suitable for coal-fired power plants, though they exhibit low efficiency and pore blockage after repeated use. Sodium-based sorbents, by contrast, provide higher efficiency and broader temperature applicability but are costly, hygroscopic, and require complex disposal. In developing countries, calcium-based options are more appropriate for cost-sensitive, humidity-controlled applications, while sodium-based methods are better suited to industries with variable flue gas conditions.

For $NO_x$ reduction, combustion modifications such as low-$NO_x$ burners and staged combustion achieve moderate reductions (50–70%) at low cost, but may cause CO emissions and unstable combustion. Flue Gas Recirculation (FGR) is highly effective (70–90%) but reduces thermal efficiency and increases corrosion risk. Among post-combustion treatments, Selective Catalytic Reduction (SCR)

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remains the most effective (80–90%) but is capital-intensive and prone to catalyst poisoning, while Selective Non-Catalytic Reduction (SNCR) is cheaper and easier to implement though less stable (40–60%) and temperature-sensitive. Wet scrubbing enables simultaneous $SO_x$/$NO_x$ removal but has low $NO_x$ efficiency and wastewater concerns.

For developing economies, a context-specific strategy is essential. Small- and medium-sized facilities should combine low-$NO_x$ burners with SNCR for cost-effectiveness, whereas large-scale power plants should adopt SCR despite higher costs. Overall, priority should be given to low-capital, technically simple methods such as calcium-based FGD and SNCR, supplemented by scenario-specific combinations (e.g., FGD + SCR in power generation, sodium-based FGD + staged combustion in metallurgical industries).

Policy support will be crucial, including regulatory enforcement, affordable technology transfer, and regional cooperation. Looking ahead, emerging technologies such as advanced sorbents and hybrid SNCR–SCR systems hold promise, but their adoption will require local adaptation, capacity building, and international collaboration to address the transboundary nature of acid rain.

## References


[1] Prakash J., Agrawal S. B., Agrawal M. Effects of acid rain on crop productivity and soil quality. Journal of Soil Science and Plant Nutrition, 2023, 23(2): 398.

[2] Larssen T., Lydersen E., Tang D., He Y., Gao J., Liu H., Duan L., Seip H. M., Vogt R. D., Mulder J., Shao M., Wang Y., Shang H., Zhang X., Solberg S., Aas W., Okland T., Eilertsen O., Angell V., Liu Q., Zhao D., Xiang R., Xiao J., Luo J. Acid rain in China. Environmental Science & Technology, 2006, 40(2): 418.

[3] Riahi K., Rao S., Krey V., Cho C., Chirkov V., Fischer G., Kindermann G., Nakicenovic N., Rafaj P. RCP 8.5—A scenario of comparatively high greenhouse gas emissions. Climatic Change, 2011, 109(1–2): 33.

[4] Idowu S. O., et al. Encyclopedia of Sustainable Management. Cham: Springer International Publishing, 2020.

[5] Fuzzi S., Baltensperger U., Carslaw K., Decesari S., Denier van der Gon H., Facchini M. C., Fowler D., Koren I., Langford B., Lohmann U., Nemitz E., Pandis S., Riipinen I., Rudich Y., Schaap M., Slowik J. G., Spracklen D. V., Vignati E., Wild M., Williams M., Gilardoni S. Particulate matter, air quality and climate. European Physical Journal E, 2004, 14(1): 7.

[6] Viscusi W. K. The lulling effect: The impact of child-resistant packaging on aspirin and analgesic ingestions. Regulation, 1984, 8(4): 53.

[7] Dahlan I., Lee K. T., Mohamed A. R. Oxy-fuel combustion for $CO_2$ capture: A review. Journal of Scientific and Industrial Research, 2013, 72(1): 8–19.

[8] Korczewski Z., Rudnicki J., Zadrag R. Influence of fuel injection parameters on exhaust emissions. Combustion Engines, 2017, 168(1): 32–37.

[9] Jung J.-H., Lee J.-J., Lee G.-W., Yoo K.-S., Shon B.-H. Reuse of waste shells as a $SO_2$/$NO_x$ removal sorbent. Korea: Hanseo University, 2008.

[10] Zach B., Pohořely M., Šyc M., Svoboda K., Punčochář M. Waste-to-energy technologies and environmental issues. WIT Transactions on Ecology and the Environment, 2016, 205: 291–297.

[11] Erans M., Manovic V., Anthony E. J. Calcium looping process for $CO_2$ capture: A review. Applied Energy, 2016, 180: 722–742.

[12] Lü J., Fu Y., Wang J., Chen H. Characteristics of desulfurization byproducts in limestone systems. Research Square, 2022, rs.3.rs-1716413/v1.

[13] Normann F. Oxy-Fuel Combustion – The Control of Nitrogen Oxides. PhD Thesis, Chalmers University of Technology, 2010.

[14] Chen Z., Lin H., Mecke A., Lee I. Nitric oxide removal via gas–liquid processes. European Physical Journal E, 2004, 14(1): 7.