



Implementation of alternative fuel sources to reduce air pollution in industrial boilers

D.M.C.M. Dissanayake, D.M.S.M. Dissanayaka, M.G.S.S. Bandara, P.K. Tharuke, W.W. Chamil Rajapaksha

Faculty of Technology, University of Sri Jayewardenepura, Sri Lanka
swarnadissanayake40@gmail.com

Received: 05 January 2023; Revised: 23 January 2023; Accepted: 18 February 2023; Available online: 10 April 2023

Abstract: Industrial boilers in Sri Lanka are essential to fulfilling energy requirements in production processes in many industries. However, burning fuels to get needed energy for boiler operations has become a problem for the environment. Many different solid, liquid and gaseous fuels are used in industrial boilers to generate enough heat to produce steam or hot water. The most widely used fuels in the world for boilers are non-renewable energy sources. In Sri Lanka, the primarily used fuel for boilers is furnace oil and biomass. The boiler occasionally uses a combination of fuels to increase efficiency and maintain operating costs. It falls within the categories of biomass fuel and fossil fuel. Fossil fuels include coal, petroleum-based oils, and natural gas. The most harmful fossil fuel for the environment is coal because coal has more dangerous combustion products than other fossil fuels. According to an Environmental Protection Agency (EPA) assessment, burning fossil fuels in industrial plants or boilers for energy production is a significant cause of air pollution. Because they give off a large amount of carbon dioxide when burned, causing a greenhouse effect. This is also the main contributor to the global warming experienced by the earth today. Biomass boilers also have environmental impacts, but the effects on air molecules are less here. The main goal should be reducing air pollution while taking the necessary energy to operate boilers. In alternative fuels, we have to accept both advantages and disadvantages; however, the ultimate objective is to reduce the air pollution generated by fossil fuels.

Index Terms: Industrial Boilers, Air Pollution, Alternative fuel sources, Energy, Currently using fuels.

1 INTRODUCTION

Boilers are vessels that are closed and designed to heat water or other liquids, generate steam or vapor, superheat steam, or do a combination of these things under either pressure or vacuum. The energy required for this process comes directly from the combustion of fuels, from electricity, or from nuclear energy. The industrial revolution led to a shift towards a new path that is heavily dependent on energy since most of our daily activities and manufacturing processes require energy. Nowadays, energy generation, consumption, and conservation play a significant role in the world.

Boilers are commonly used in manufacturing industries and power plants to produce steam through an absorption process of thermal energy into a liquid. However, it is essential to consider the type of fuels used to produce energy. Fossil fuels are widely used for energy production in most boilers, and their consumption has significant disadvantages, with the main issue being air pollution. The combustion of fossil fuels releases many air pollutants, such as NO_x , SO_x , and CO , into the atmosphere [1].

A boiler or steam generator is the piece of equipment used to generate steam. It is also defined as "a closed vessel in which fuel burning produces steam from water." Boilers are heat exchangers with a shell and tubes that convert water to steam or high-pressure hot water. Heat is produced when fossil fuels or biomass are burned.

The steam generated is used for:

- Power generation
- Heating
- Utilization occurs in industries like chemical industries, sugar mills, etc. [2]

Utility boilers and industrial boilers differ significantly from one another, with the biggest variances occurring in three key areas:

- Size of the boilers.
- Applications for the steam and hot water produced by the boilers.
- The design of the boilers.

Steam boilers are intended to continuously generate steam in order to power turbines that generate electricity. Because of the consistent need for steam, utilities typically run at a constant state, however changes in energy market structures may necessitate certain utilities adjusting operating conditions to meet daily national energy demands. The boiler is one of the most important and valuable assets in practically all processing firms across the world. They play a vital role in energy generation while investing heavily in boilers, particularly boiler-feeding fuels. Industrial boilers are primarily used in glove factories, chemical processes, rice mills, the textile industry, pharmaceutical factories, building material factories, the dairy industry, garment factories, paper mills, brewery and food production, commercial buildings, power plants, the cement and steel industry, hotels, and other industries [3].

Different types of fuel are used in different types of boilers depending on the industry and the operating principle of the boiler vessel. Each fuel has unique chemical properties that affect the combustion process. The fuel for a boiler might be liquid, solid, or gas. Instead of producing electricity, most businesses use directly created steam in their production processes. In Sri Lanka, steam produced from biomass boilers and furnace oil boilers is used in a variety of industries. As an energy source, boilers require fuel. Boilers use fuels such as natural gas, coal, oil, electricity, and biomass.

In Sri Lanka, industries are using their waste as fuel for boilers.

- Coconut shells
- Rice husk and straw
- Bagasse, Some of them.

And also, diesel and furnace oil use as energy sources. When only electricity generation, Sri Lanka using coal as fuel to the boilers [1].

2 AIR POLLUTION FROM BOILERS

Many different solid, liquid, and gaseous fuels are used in the industrial boilers to generate enough heat for producing steam or hot water. It can be categorized as fossil fuel, biomass fuel. Coal, petroleum-based oils, and natural gas are fossil fuels commonly use for the boilers. Firewood and alternatives for the firewood (sawdust, paddy husk, Dendro) are considered as biomass fuels. Combustion of fossil fuels for boiler leads to air pollution. The fossil fuels using boilers emit pollutants such as particle pollution and volatile organic compounds (VOC). These pollutants can contribute to health problems that may affect employees, residents, and the community. While Federal, state, local, and Tribal regulations limit the amount of emissions from boilers, dangerous releases of HAPs can occur if a boiler does not operate in compliance with regulations [4].

Emissions from boilers are a function of the type and quantity of primary fuel burned in the boiler unit, the type of boiler, and emissions controls.

Boilers emit a variety of pollutants, such as:

- Nitrogen oxides (NO_x)
- Sulfur dioxide (SO₂)
- Particle pollution
- Carbon dioxide (CO₂)
- Formaldehyde
- Polynuclear aromatic hydrocarbons (PAHs)
- Lead
- Hydrogen Chloride (HCl)
- Cadmium
- Mercury
- Dioxin/furans

These pollutants are lead to,

Nitrogen oxides (NO_x)

Nitrogen oxides can react in the air to form acid rain, ground-level ozone (smog), and other toxic chemicals.

Nitrogen oxides are one of the chief ingredients of ground-level ozone, which has been linked to a number of respiratory effects [4].

Sulfur dioxide (SO₂)

Sulfur dioxides can temporarily cause breathing difficulties for people with asthma who are active outdoors. Long-term exposure to high concentrations of sulfur dioxide and particles can cause respiratory illness and aggravate existing heart conditions.

Carbon dioxide (CO₂)

Carbon dioxide is considered to be responsible for the greenhouse effect and global warming. Low amounts of carbon dioxide can impact those people with cardiovascular problems. People inhaling high amounts of carbon dioxide can experience central nervous system problems such as vision problems, reduced ability to work or learn, and difficulty performing tasks.

Particle pollution

Breathing particle pollution can cause respiratory problems and other harmful health effects.

Formaldehyde

Long-term exposure to formaldehyde can cause eye and respiratory tract irritation, reproductive and developmental problems, and may be a probable human carcinogen. Short term exposure can cause coughing, wheezing, chest pains, and bronchitis.

Polynuclear aromatic hydrocarbons (PAHs)

PAHs are caused by the incomplete combustion of fossil. can lead to cancers.

Lead

Lead is a very toxic metal and can cause adverse health effects at low levels. Short-term exposure can cause brain damage, kidney damage, and gastrointestinal distress. Children are especially susceptible to long-term lead exposure, which can result in slow cognitive development and reduced growth.

Dioxin/furans

Dioxins are persistent, bioaccumulate toxins (PBTs) that remain in the environment for extended periods of time and increase in concentration as they move up the food chain. Dioxins can cause immune system suppression, disruption of hormonal systems, and cancer.

Cadmium

Cadmium is emitted during the burning of fossil fuels. Short-term exposure to cadmium can irritate the lungs. Long-term exposure can cause kidney and respiratory problems.

Mercury

Mercury is emitted during the burning of fossil fuels. Exposure to mercury can result in nervous system and kidney damage. Also, development damages.

Hydrogen Chloride (HCl)

Hydrogen chloride (also known as hydrochloric acid) is produced by the burning of fuels containing chloride. Exposure to hydrogen chloride can cause eye, nose, and respiratory tract irritation, and inflammation and pulmonary edema. Long-term exposure can cause gastritis, chronic bronchitis, dermatitis, photosensitization, and possibly dental discoloration and erosion. Because of these problems by pollutant gasses of using fossil fuels in boiler. Biomass fuels are used for boilers as alternative fuels. Replacing a coal or electric heating system with a biomass boiler can help you reduce your carbon dioxide output by up to 9.5 tons, annually. Biomass energy is a great way to dispose of waste wood. Biomass is considered an environmentally friendly source of energy and Carbon Neutral. That is because unlike coal, which needs

much longer than a lifetime to re-generate, biomass is considered a renewable source of energy because it can be obtained relatively quickly by replacing or growing new plants or trees [5].

3 ALTERNATIVE FUEL SOURCES

According to an Environmental Protection Agency (EPA) assessment, burning fossil fuels in industrial plants or boilers for energy production is a significant cause of air pollution. Flue gas emission is the primary factor affecting air pollution in industrial boilers. Because of this situation, fuel for the boilers is affected. Replacement of fuel with less air pollution fuel source is the primary and major thing which can do. Various solid, liquid and gaseous fuels generate enough heat in industrial boilers to produce steam or hot water. A mix of fuels is sometimes used in the boiler to optimize efficiency and keep operating costs low. It is classified as a fossil fuel or a biomass fuel. Coal, petroleum-based oils, and natural gas are examples of fossil fuels typically used in boilers, whereas firewood and firewood replacements (sawdust, rice husk, Dendro) are examples of biomass fuels. Biomass is a renewable organic substance often consisting of fast-growing trees and plants. However, because of the increased demand for biomass boilers, deforestation occurs. As a result, alternative fuels outperform biomass since they might be trash or byproducts of other processes [1].

Because SO_2 emissions are a function of fuel S content, replacing coal with natural gas or biomass is an appealing option for reducing boiler SO_2 emissions. Natural gas combustion, for example, emits far fewer SO_2 emissions than coal combustion due to natural gas's significantly lower S content.

There are three major parameters that influence the calorific value of wood when choosing it for burning (CV). The quantity of heat created per unit fuel amount is highly dependent on species selection, wood density, and moisture content. There is a separate CV for each type of wood. When considering rubber wood, it is about 18.4 MJ/kg. In tropical countries, rubber wood (*Hevea brasiliensis*) has become a significant agricultural source for biomass production. From the standpoint of using rubber wood as fuel, it is evident that rubber wood is the most promising biomass source. In fact, some experts have determined that the energy content of rubber wood is 40 GJ/ha per year. However, there are several additional options for firewood. Paddy husk, sawdust, coconut shells, coconut leaves, coconut husks, plywood residuals, logging residuals and bagasse are a few examples. Paddy husk (Fig. 1) is mainly used in industries such as rice production and bagasse (Fig. 2) is mainly used in sugar industry.



Fig. 1. Paddy Husk



Fig. 2. Bagasse

When compared to rubber wood, its energy availability is nearly equal, but its moisture content is

relatively high. Some of the widely used biomass crops are summarized with their scientific information in Table 1 [1].

Table 1. Details of moisture content and the Calorific value

Crop	Moisture content (%)	Average calorific value (MJ/kg)
Rubber wood	5	18
Oil palm	20	18.84
Paddy husk	13	14.93
Coconut husk	11.5	19.6
Logging residuals	12	18.41
Wood residuals	12	18.41

The volume of rubber planting has decreased dramatically due to the strong demand for rubber wood from the biomass boiler running sectors. Furthermore, deforestation directly contributes to a shortage of available water sources. Wood density is also essential since denser woods need less volume than softwood when the same amount of weight is considered. Denser wood will usually receive more heat when measured in terms of energy generated per volume. Rubber wood and industrial steam generation Approximately 200 kg/s to 250 kg/s of firewood will be required to boil 1 Ton of water at a starting temperature of 20 degrees Celsius to a boiling point of 100 degrees Celsius under normal temperature and pressure. It may be computed that it takes 200 kilograms of wood to create 1 ton of steam. And also, biomass boiler can use briquette as alternative fuel. This consists of wood chips, logs, and sawdust that have been converted into wood pellets and briquettes for use in biomass boilers and stoves. High yield energy crops, such as wheat, that are developed expressly for energy uses, are another source of biomass material.

Dendro is another type of alternative which can use in biomass boiler. In the form of short rotation coppice, Dendro plantations have become a well-known sustainable biomass source for biomass power generation. It has sparked attention as an energy source for power generation for a variety of reasons. For example, *Gliricidia sepium* is a medium-sized leguminous tree with a short growth season and the potential to become a low-cost indigenous energy source.

Remedies for air pollution due to boilers affect such a problem which had as previously. Adverse effects of biomass boilers,

- Deforestation to collect the amount of biomass demand.
- Water sources depleted
- Atmospheric temperature increased

- High amount of ash generated and finally lead to many environmental pollution problems.

4 CONCLUSION

Boiler operation plays a huge role in industries because most of the process is run with thermal energy, to obtain that energy boiler produced steam, and for that process, the boiler needs an external energy source. Nowadays most industries use fossil fuels for boiler operations due to the huge amount of air impurities released into the air some industries use various kinds of air pollution control technologies but most of the time considerable portion entering to the atmosphere, and because of that various kinds of problems come to day to day life and future. However, at that point would need a solution for that the main problem is excess air molecules of fossil fuels during the combustion process. To avoid that kind of problem we need alternative fuels to replace fossil fuels. Biomass is one of the best solutions for alternative fuels. Because it is renewable and more environmentally friendly than fossil fuels. Most of the time cost is less than fossil fuels. But calorific efficiency is less than fossil fuels which means more amount of biomass needs to replace fossil fuels. Also, biomass can be another problem for the environment because it can be a path to deforestation, and it consumes a lot of water to produce biomass plants. However, through the circular industrial waste management system, we can avoid the above problems like bagasse and paddy husk (waste from the sugar manufacturing process and rice manufacturing process). Boilers can easily be converted to industrial biomass boilers they do the same process as fossil fuels but the environmental impact of air molecules is less. In alternative fuels, we have to accept both advantages and disadvantages however the final goal is to reduce air pollutants emitted from fossil fuels. To achieve our goal, we need more scientific solutions with biomass applications that can be helpful to efficiency increment of the boiler combustion process. Also, that helps full to reduce air pollution through fossil fuels.

5 REFERENCES

- [1] U.S.P.R. Arachchige, SPW Sakuna, Alternative fuel for biomass boilers in Sri Lanka, International Journal of chemical studies, 7 (3), 729-733, 2019. <https://dx.doi.org/10.22271/chemi>
- [2] U.S.P.R. Arachchige, Boiler Operation and Maintenance Technology, Nine Publishing, Sri Lanka, 2020. ISBN: 978-955-7688-26-8.
- [3] Tabatabaei M, Karimi K, Kumar R, Horváth IS. Renewable energy and alternative fuel technologies. Biomed Res Int. 2015;2015:245935. doi: 10.1155/2015/245935.
- [4] J.B. Kitto, Air Pollution Control for Industrial Boilers, ABMA Industrial Boiler Systems Conference, 1996.
- [5] Tao Yue, Xiaoxi Zhang, Chenlong Wang, Penglai Zuo, Yali Tong, Jiajia Gao, Yifeng Xue, Li Tong, Kun Wang, Xiang Gao, Environmental Impacts of the Revised Emission Standard for Air Pollutants for Boilers during the Heating Season in Beijing, China, Aerosol and Air Quality Research, 18: 2853–2864, 2018. Doi: 10.4209/aaqr.2018.02.0046.