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Implementation of Alternative Fuel sources for Industrial Boilers

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Abstract: Mainly this research paper investigates some main points on industrial boilers and their categories, main functions, fuel types and industrial boiler-related air pollution issues. During the combustion, many gases are emitted by these boilers. Because of fossil and non-fossil type fuels, the emission of gases can be changed. NOx, SOx, hydrocarbons, CO and CO2 are some of the polluted gases which add to the atmosphere because of these industrial boilers. This air pollution results from many health issues and environmental impacts, such as global warming and acid rain. But as a technologist, we all can innovate new ideas and techniques which are not caused to ecological issues. We can use alternative fuels such as waste wood, waste liquids, refinery oil gasses, biogas, trash, excess hydrogen, Coke Oven Gas (COG), and Blast Furnace Gas (BFG), which is very useful for reducing air pollution. So, this report mainly concludes with the Implementation of alternative fuel sources to reduce air pollution in Industrial Boilers

Index Terms: Air pollutants, alternative fuel, emission reduction, emission sources, fuel consumption, fuel exchange, industrial boilers.

1 INTRODUCTION

Many industries use boilers to generate steam or fulfil their need for hot water for the production process of that industry. By using large and high-technology boilers, they can create steam or hot water with high efficiency. They use a massive part of the money invested in the company for boiler installation, maintenance and the fuel used to generate heat by burning because we cannot use electricity for the heating process of boilers. As well as many industries monitor and maintain their feed water quality and install economizers, condensate returns, pre-heaters to increase the efficiency of boilers and, reduction of heat losses and mainly reduction of repairing costs of the boiler. But the high-temperature steam requirement for the industry is also high. So many industries like to reduce the cost of fuel using their boiler by using alternative fuel sources. Some agricultural and rubber-based production industries use their byproducts or waste as an alternative fuel source. It helps to reduce the cost. Air pollution is also a massive problem from fuels that use in boilers. Fossil fuels like natural gas, coal, and oil are mainly caused by air pollution. Because of that, many industries try to reduce the environmental impact by using alternative fuels which are not pushed to air pollution.

Boilers burn a wide variety of solid, liquid, and gaseous fuels. Combinations of powers may occasionally be utilized to cut emissions or enhance boiler efficiency. In addition to various fuels and fuel mixtures, fossil, biomass, and RDF fuels are frequently used in boilers. In ICI boilers, fossil fuels like coal, petroleum-based oils, and natural gas are commonly burned. However, this category occasionally includes various types of liquid, gaseous or solid, fuel derived from these fossil fuels. Biomass is a different term for

fuel used in boilers. Renewable organic matter is biomass. Fast-growing plants and trees, wood and wood waste, crops and byproducts, aquatic plants and algae, animal wastes, and organic municipal and industrial wastes are a few examples of biomass.

Worldwide demand for alternative energy is rising, and numerous research projects are now being conducted to identify alternatives to finite fossil fuels. These alternatives are meant to alleviate worries about the depletion of fossil fuels because we cannot use them indefinitely, and they will ultimately run out, notwithstanding the increase in the human population. People on earth are eating up resources that cannot be replenished quickly, and if something is not done, fuels like coal and oil will run out for future generations. Therefore, it is necessary to develop substitute fuels. Many companies employ multi-fuel power boilers to generate on-site electricity and deliver cost-effective steam for use in processes. It is typical for these units to be fed with alternative fuel sources in addition to fossil fuels (gas, oil, and coal), such as biomass, waste wood, waste liquids, refinery off-gases, biogas, surplus hydrogen, coke oven gas (COG), or blast furnace gas (BFG). Multi-fuel boiler operation must be optimized to produce steam for the lowest cost possible in today's cutthroat business environment.

2 OVERVIEW OF INDUSTRIAL BOILERS

A boiler is a closed vessel that produces steam through a heat transfer process. A process receives heat transfer from pressured hot water or steam. Basically, boilers are used domestically and industrially. Although household boilers and industrial boilers have different purposes, the operational aspects are like each other. So, these industrial boilers are played a major role in the industrial production processes. Most industries have at least one industrial boiler. The steam generated is used for: [1] • **Power generation • Heating • Utilization occurs in industries** like chemical industries, sugar mills, etc.

So, these boilers are especially used in varieties of industrial functions within the industries, such as boiler-based power generation, heating applications such as water heating, central heating, and other uses. So, these boilers are assembled as package one, or those boilers are available in massive sizes.

3 ENVIRONMENTAL POLLUTION

It should keep up its industrial operations as a nation that is developing globally. Steam is used in a variety of sectors for production purposes. The majority of enterprises used various types of boilers to create steam. Some companies use hot water instead of steam, likewise produced by hot water generators. These sectors can be divided into,

- Plantation (Tea, Rubber, Coconut, Palm oil).
- Food and beverage (Rice, confectionery, soft drinks, alcohol, meat, desiccated coconut, sugar, milk powder)
- Rubber and plastic (Tire, leather products, plastic household manufacturing, carpets, Styrofoam, water tanks, PVC products, nylon ropes)
- Pulp and Paper (Paper, corrugated, printing)
- Cement and concrete (cement, cement products, tiles)
- Wood and timber
- Textile (garment, elastic, yarn, buttons and zippers, yarn and fabric dyeing)
- Hotels and Hospitals

- Metal and steel
- Health care and cosmetics
- Medicine and Ayurveda drugs

All of the sectors mentioned above of the economy support one another. In addition to producing household products, helping the growth process, and, most significantly, serving as the foundation of the global trade economy, they offer a sizable number of work possibilities to the populace. Most industries mentioned above use steam boilers and hot water generators for their manufacturing operations. Biomass, furnace oil, and diesel boilers are a few of them [2].

However, air pollution is a serious problem that arises with using boilers. But as mentioned above, the boiler has become indispensable for all industries. Accordingly, we should be concerned about getting a comprehensive understanding of the air pollution caused by these boilers, which is an integral part of almost every industry, and finding possible solutions for it. Following are the primary air pollutants released into the atmosphere by using boilers [3].

- Carbon Oxides
- Nitrogen Oxides
- Sulphur Oxides
- Hydrocarbons
- Particular matter

The amount of pollution emitted by these boilers depends on the amount of fuel used, the type of fuel used and the method of combustion used. In focusing on the air pollution caused by these fuels for the various types of fuel used for boilers in the world today,

Coal-

Air pollution from quarries is caused by gases and solid waste emitted from coal. CO_2 and S_2O are examples of gaseous wastes. These gases release into the atmosphere is the cause of the greenhouse effect and acid rain. The soil contaminant that pollutes the air is the soot from coal burning. In addition to air pollution, it is seen that animal health is also strongly affected. This air pollution is caused by using cheap and cheap low-quality coal boilers [4]. Different stones with other properties contribute to air pollution at different levels.

Lignite –

Lignite is coal still in the early stages of coalification, with qualities midway between bituminous coal and peat. The particulate particles (PM) here are smaller than or equal to 10 micrometers in diameter (PM 10). Apart from that, condensable particular matter (COM), Sulphur oxides, nitrogen oxides, carbon monoxide and total organic compounds etc., can be pointed out as substances added to the environment during this combustion lignite.

Bituminous and Subbituminous-

Bituminous coals are the most common type, with higher volatile matter than anthracite and lower fixed carbon. The amount of moisture, volatile matter and Sulphur contained in this sub-bituminous coal is higher than that of bituminous coal. Therefore, it is also used as an alternative fuel for some boilers. Here, in the study of pollutants harmful to the atmosphere emitted by the combustion of bituminous and sub-bituminous coal, particular matter, Sulphur oxides and nitrogen oxides etc., can be seen. Especially even under optional boiler operating conditions, sure unburned combustibles, such as carbon monoxide and various organic compounds, are generally released. These can indicate that the change in the atmosphere's composition causes multiple problems.

Anthracite –

Anthracite coal has more fixed carbon and less volatile matter than bituminous, sub-bituminous or lignite. Accordingly, it can be seen that by burning anthracite coal, particular matter, Sulphur oxide, nitrogen oxides and carbon monoxide and a trace amount of organic compounds and trace elements are added.

Fuel oil/ diesel oil –

Two types of fuel oil are mainly used. This fuel is used primarily for domestic and small commercial boilers. That is kerosene and diesel fuel. These typically contain less than 0.3% Sulphur, minimal nitrogen, and ash by weight. And residual oil is created from residuals left after removing the lighter fractions of fuel oil from crude oil. These contain high amounts of ash, nitrogen and Sulphur [5]. Sulphur dioxide and particular matter are the primary substances emitted during combustion. The amount of these pollutants released depends on the grade of the oil. Here it can be seen that air pollution caused by the contaminants added by the combustion of fuel oil/diesel oil contributes to acid rain and health problems.

Natural gas –

Natural gas has a very high percentage of methane and a varying amount of ethane, propane, butane and inert gases (often nitrogen, carbon dioxide, and helium). Nitrous oxides, Volatile Organic Compounds (VOC), trace amounts of Sulphur dioxides and particulate matter can be pointed out [5]. Especially during the combustion of this natural gas, a significant amount of greenhouse gas emission occurs in addition to carbon dioxide. Also, Methane and Nitrous oxide form when burning natural gases under low temperatures or incomplete combustion.

Biomass (wood/wood residue) –

Nowadays, biomass material is used as a popular boiler fuel. By burning this biomass, heat energy and various residue particles are created. Hogged wood, bark, sawdust, shavings, chips, mill rejects, sander dust, or wood trim can be pointed out as the world's most commonly used biomass fuel for boilers [5].

Although this biomass is used for its easy availability, it causes severe air pollution by residue particles and **flue** gases. Particulate matter, CO, CO_2, NO_x, SO_x, VOC and trace species, including polyaromatic hydrocarbons, can be pointed out as pollutants harmful to the environment. This residue is detrimental to the human respiratory system and causes various diseases. CO gas can also be pointed out as a gas that is harmful to living things and contributes to increasing the greenhouse effect [6].

A large amount of particulate matter is released by burning biomass (wood). These directly affect living things. That is, respiratory illness and even cancer can be affected. Diesel and fuel can release a lot of Sulphur, and this Sulphur can cause acid rain. Natural gas and LPG etc., emit significant amounts of NOx.

This affects the development of acid rain, photochemical smog and the greenhouse effect. But the release of SO2 by this natural gas boiler can be considered relatively minimal. Air pollution by industrial boilers can be analyzed thoroughly. Through this report, we focus on alternative fuel sources that can bring this air pollution to a very minimum level, thereby providing high efficiency to the boiler.

4 ALTERNATIVE FUEL SOURCES FOR BOILERS.

Every industry has a fundamental goal in mind regarding environmental pollution reduction. The most crucial raw resources in any sector, without exception, are fuel sources. Multi-fuel power boilers produce steam or hot water for industrial processes, as mentioned in the above sections. In today's industrial boilers, fossil fuels, natural gas, crude oil, and coal are the most prevalent fuel kinds. Alternative fuel streams can be used in furnaces in addition to fossil fuels to provide heat.

Various solid, liquid and gaseous fuels are burned in the boiler. Boilers frequently burn fuels, including biomass, fossil fuels, and other fuel kinds and sorts. Fossil fuels generally burnt in boilers include natural gas, coal, and oils made from petroleum. However, this category occasionally includes various solid, liquid, or gaseous fuels generated from these fossil fuels. Another fuel option for boilers is biomass. Biomass is an organic, renewable resource. Examples of biomass include trees, plants, agricultural waste, and crops.

Industries have been encouraged to use solid fuel-fired and alternative fuel steam boilers to lower operational costs and long-term pollution. Several boiler types that are built to burn alternate fuels exist throughout the world. And today, there is access to current technology, such as fluidized bed design, a different way to burn solid fuels (coal). As a result, businesses must add more air pollution control technology to their current steam-generating boiler systems. Costs go up as a result of that procedure. Companies search for alternate fuels to run their boilers as a result [7].

So, biomass boilers are mainly used in many industries as a good solution for air pollution. The basic design of waste-burning, wood-burning, and biomass-burning boilers is the same for industrial boilers, utility radiant boilers, and boilers that consume coal. The type of biomass (vine clipping, leaves, grasses, bamboo, sugar cane, or bagasse) changes according to the season or time of year, the geographical location, and the region in which it is situated.

Three primary parameters influence wood's calorific value (CV) when choosing it for burning. The species used, the wood's density, and the wood's moisture level all significantly impact the quantity of heat produced per unit of fuel. The CV varies a little bit depending on the species selected. For various types of wood, a varied CV is available. It is approximately 18.4 MJ/kg if rubber wood is taken into account. Rubber wood (Hevea Brasiliensis) has become a crucial agricultural source for biomass production in tropical nations. Rubber wood is the most promising source of biomass from the standpoint of utilizing it as fuel.

A well-known and popular fuel for a biomass boiler is rubber wood. Deforestation is thus being widely used to meet the need for biomass. It is crucial to provide alternative biomass sources to reduce the excessive demand for rubber wood. These include sawdust, paddy husk, rice hulls (husks), rubber seeds, bagasse, coconut shell, and Dendro.

RICE HUSKS & STRAW

Interestingly, rice straw (Fig. 1) and husk (Fig. 2) are essential for bioenergy. However, there is currently very little energy produced from rice husks. Its calorific value ranges from 13 to 19 MJ/kg.

According to the data, rice production generates 30% of rice straw and 20% of rice husk after harvest [3]. Rice straw, which remains after harvesting paddy fields, is considered agricultural waste. Once properly managed, this agrarian waste may be used as a fuel source for industrial steam boilers. This has a positive impact on farmers' revenue in addition to significantly reducing environmental pollutants. Rice straw is typically somewhat dry biomass. It is rich in silica, alkali metals (such as potassium), alkali earth metals (such as calcium), and other elements like Cl, Mg, P, and S. The ash being produced is volatile and has a low melting point. The result is that the ash produced during combustion evaporates in the furnace and condenses to create slag layers on colder surfaces [8].

There are many benefits related to rice straw as an alternative fuel. With compared to other biomass fuels, it is cheaper; Energy efficiency is high in rice straw-fired boiler systems. It results in reduced steam costs, minimizing overall input costs; because rice straw-based steam boilers and power plants are carbon neutral and environmentally friendly. Government agencies grant better incentives and tariffs, It is highly available in local areas of rice farming countries such as India, China, Indonesia, Bangladesh, and the fore.

Fig. 1. Rice straw

Fig. 2. Rice husk

The covering on rice seeds known as rice husk shields the embryo from extremes in temperature, humidity, and weather during the developing season. In general, opaline silica and lignin are the rigid ingredients used to make rice husk. Each kilogram of milled white rice produces around 0.28 kilos of rice husk as a byproduct, with a normal moisture level of between 5-12%. Additionally, it is claimed that 1 ton of rice crop typically produces 220 kg of rice straw. By applying densification methods, rice husk briquettes and pellets are produced that increase the density of the material and the combustion performance [9]. The covering on rice seeds, known as rice husk, shields the embryo from extremes in temperature, humidity, and weather during the developing season. In general, opaline silica and lignin are the rigid ingredients used to make rice husk. Each kilogram of milled white rice produces around 0.28 kilos of rice husk as a byproduct, with an average moisture level of 5-12%. Additionally, it is claimed that 1 ton of rice crop typically produces 220 kg of rice straw. By applying densification methods, rice husk briquettes and pellets are created that increase the density of the material and the combustion performance [10].

This densified rice husk works well in industrial boilers to replace fossil fuels. Since rice husk has a high calorific value between 13 and 19 MJ/kg, rice mills in the Polonnaruwa region of Sri Lanka are now utilizing part of it as an alternative fuel for their biomass boilers. To reduce fuel consumption at the INSEE

cement Puttalam in Sri Lanka, a small amount of rice husk is also partially used to replace coal demand [5]. Since rice straw and husk are biomasses, virtually, those are considered Carbon neutral and environmentally friendly fuels. Because, Carbon Dioxide which is released when Biomass fuel is burned is taken in again by plants

BAGASSE

The byproduct bagasse is utilized as an alternative fuel for these industrial boilers. Sugarcane is a well-known raw material for the sugar and ethanol industries worldwide. Bagasse is typically fed with 50% moisture content. With the development of bagasse dryers, a boiler fuel substitute. Because it usually has a 9.6MJ/kg energy potential. But because it is already used in the sugar industries to generate electricity, it cannot replace all the fuel sources for boilers [5].

DENDRO PLANT

Dendro plantations have established themselves as a well-known sustainable biomass source for the production of biomass power in the form of short rotation coppice. It has generated interest as an energy source for a number of reasons. For instance, the medium-sized leguminous tree *Gliricidia sepium*, which has a short growth season and the potential to be used as a cheap local energy source. It ranks behind tea, rubber, and coconut as the country of Sri Lanka's fourth national plantation crop. The table below displays the various Dendro plantations in Sri Lanka those are available on each type of terrain.

There are many advantages from this Dendro plant.

- The leaves of *Gliricidia sepium* are effective as animal feed, mulch for other crops, and suitable material for compost production.
- No need for replanting for around 20 years of period.
- soil enrichment & specially Dendro plantation, avoid soil erosion.
- Free from pest and plant diseases.
- It has a high growth rate as well as high coppicing ability.
- Because it is a short-term cropping species, it needs around six months.

Cashew nut shells

Cashew nut shells are frequent forms of tropical biomass waste that may be utilized for energy generation. The cashew nut tree (Western Anacardium) grows naturally due to intentional agricultural practices in subtropical countries like Brazil, Nigeria, and Ghana.

70% of cashew is the shell, and 30% is the nut. Although cashew nuts are consumed worldwide, their incredibly rigid bodies, which are between 1 and 2 mm thick, are typically discarded. Cashew shells typically include 10.8% water and 2.6% ash. With a net calorific value of 18.9 MJ/kg, cashew shells are well in the middle of the biomass fuel mean range (14 - 21 MJ/kg) [11].

Corn cob

Corn cobs burn more effectively than other crop waste (figure 12). Consequently, this fuel may compete with woody fuels more successfully while striving to reduce harmful combustion side effects. The moisture content of corn cobs falls to about 12% after drying and threshing the grains, or 2% less than the moisture content of the grains. Compared to the range of 0.9 to 1.2 for woody biomass, the average ash content is more significant at 1.4%. Even so, it has a lower ash level than other agricultural waste, such as wheat straw, which has a lower average ash content of 5.7% and maize stover, which has an ash content of 6.7%. Corn cobs have a gross calorific value (GCV) of 18.3 to 18.8 MJ kg-1 and a net calorific value (NCV) of 15.7 MJ kg-1 with a moisture content of 11.5% [12].

Coconut shells

In Sri Lanka, there are 60 coconut mills. There are 720,000 acres utilized for coconut plantations, the bulk of which are smaller than 5 acres. For an average mill to produce 60,000 nuts daily and run 180 days a year, 12,000 acres of coconut farms are required. Recycled coconut shells from a typical plant (figure 13) contain adequate calorific content to provide a 12 MW power plant's needs. Because they utilize less energy, coconut mills have extra coconut shells to trade. Some are marketed for use in cement mills and other industrial thermal applications. Future biomass plants may only sometimes be able to purchase coconut shells from coconut farms, but they increase the plant's security of fuel supply.

Saw dust

A semi-gasification technique used to burn sawdust results in a high-temperature fire. Waste created during the processing of trees or timber is referred to as "sawdust." (Figure 15) A sawdust-fired burner may turn waste sawdust into energy, saving manufacturer money. Sawdust is a biomass fuel that is safe for the environment. If sawdust is utilized as a supplementary raw material after wood processing, its moisture content must be considered. It is advised to send sawdust as soon as possible for burning into a boiler or heat source at low humidity levels of 20 to 30 per cent.

Regarding carbohydrates, sawdust includes 27% lignin and up to 70% cellulose and hemicellulose. By weight, sawdust comprises 50% carbon, 6% hydrogen, 44% oxygen, and 0.1% nitrogen [13].

Palm fresh fruit bunch

Energy may be recovered from the by-product of palm fresh fruit bunch (PFFB), converted into palm oil, as an alternative to fossil fuels. Empty fruit bunch (EFB) is an incredibly affordable alternative fuel for burning in boilers because the only cost is shipping. A small proportion is often used on plantations for internal use, but a significant portion is saved and occasionally burnt to prevent losing storage space or decomposing into compost. Because of this, a large amount of EFB still needs to be used. Many companies have switched from utilizing fossil fuel in their steam boilers to raw, shredded EFB, which has allowed these companies to save money. Shredded EFB can be used as a solid fuel for steam boilers. Exploiting such a significant volume of feedstock for power generation offers a very alluring potential and must be fully utilized [13].

Bio-Briquettes

Bio-briquettes were created to solve these problems since biomass is susceptible to moisture during storage and transportation. Biomass and other fuel ingredients are combined to create composite products known as "bio-briquettes." Bio briquettes may include up to 30% biomass in various forms. A precise amount of lime-based desulfurization agents (DSA), such as CaCO3 and Ca(OH), may reduce SO2 emissions by roughly 80–90% when applied to the briquettes. Briquette fuels, in contrast, often have higher calorific values than raw biomass and have better physical and mechanical properties for burning than coal or lignite.

Refuse-Derived fuel

Residential, commercial, and industrial solid waste transported to a landfill for disposal can be used as fuel in waste-to-energy boilers. MSW that includes mixtures of paper, wood, yard wastes, food wastes, plastics, leather, and rubber can exhibit wood-like characteristics. However, processing is typically required before it can be appropriately burnt. Mass burning or using MSW as-received fuel are also options for using MSW as a fuel. To shred the waste and remove non-combustible components, MSW that has undergone size-reduction and material recovery operations is referred to as RDF. The very variable nature of 18 MSW makes it challenging to design a combustion system that can burn this high-ash, low-sulfur fuel.

5 CONCLUSION

To decrease air pollution in industrial boilers, fuel switching, the installation of air pollution control equipment, and the use of energy-saving measures It's feasible. Finding answers to the general problems of pollutant generation, including the production of nitrogen oxides (NOx), sulfur oxides (SOx), particulate matter (PM), hydrocarbons, and carbon oxides, was the goal of this investigation (CO and CO2). The usage of alternative fuels to lower air pollution was looked at in this article. As an illustration, cutting SO2 emissions in half by moving from coal to natural gas or biomass is possible because these fuels often contain minimal S. Less non-biogenic CO2 and NOX emissions were a side effect of replacing fossil fuels with biomass. SCR emission control technology can cut NOX emissions from wood by around 75% and from coal, natural gas, and residual oil by about 90%. These solutions are typically technically possible and affordable and may significantly contribute to addressing present and future needs.

6 REFERENCES

[1] Sajath S.H.M, Industrial Boiler Operation, Journal of Research Technology and Engineering, 1(3), 89, 2020

[2] Udara SPR Arachchige, Sakuna Sandupama PW; “Alternative fuel for biomass boilers in Sri Lanka”; International Journal of Chemical Studies 2019; 7(3): 729-733.

[3] U. S. P. R. Arachchige, “Boiler Operations and Maintenance Technology.” Colombo: Multidisciplinary Research Publishers, 2022.

[4] H. Bian, “Analysis on flue gas pollution of coal-fired boiler and its countermeasures,” IOP Conference Series: Earth and Environmental Science, vol. 450, no. 1, p. 012028, 2020.

[5] USEPA (US Environmental Protection Agency).; “Compilation of air pollution emission factors”; AP-42, 5th ed., vol. I/1.6, Minor rev. Office of Air Quality Planning and Standards. Research Triangle Park, NC; 2003.

[6] “Guidance.” [Online]. Available: http://iaqm.co.uk/guidance/ [Accessed: 24-Oct-2022].
[7] National Insulation Association; “A Different Perspective: Going Green with Alternative Fuel Burning Boilers”; March 1, 2012;[online] Available at: https://insulation.org/io/articles/a-different-perspective-going-green-with-alternativefuel-burning-boilers/ ; [accessed 25th October 2022]
[8] ZHENGZHOU BOILER(GROUP) CO., LTD; “Rice Husk Application As Fuel In Boiler” ; 2019-01-04; [online] Available at: https://www.zgindustrialboiler.com/info/biomassfiredboiler/rice-husk-application-asfuel-in-boiler.html; [accessed 27th October 2022].
[9]“Cashew Nut Shells as Fuel.”Energypedia, energypedia.info/wiki/Cashew_Nut_Shells_as_Fuel#:~:text=The%20Cashew%20Nut%20Shell%20Gasifier,are%20still%20a%20viable%20alternative..
[10] “Developing Bio-Energy Projects.” Venture Renewable Energy (VRE), www.venturerenewable.com/our-services/developing-bio-energy-projects. [Accessed on: 20/03/2023].
[11] Olisa, Y. P., and K. W. Kotingo. "Utilization of palm empty fruit bunch (PEFB) as solid fuel for steam boiler." European Journal of Engineering and Technology 2.2 (2014).
[12] Singh, Ramesh Man, et al. "Biobriquettes-an alternative fuel for sustainable development." Nepal Journal of Science and technology 10 (2009): 121-127
[13] Ramesh Man Singh, Hee-Joon Kim, Mistsushi Kamide, Toran Sharma; “Biobriquettes an Alternative Fuel for Sustainable Development.”; Nepal Journal of Science and Technology 10 (2009) 121-127.