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Engr. Ch. Muhammad Arif, President Pakistan Engineering Congress is a distinguished civil engineer with an illustrious career spanning over five decades. After completing his early education at Govt. Central Model High School and Govt. College Lahore, he pursued a B.Sc in Civil Engineering from the University of Engineering and Technology (U.E.T.) Lahore. Throughout his career, he has excelled in planning and executing complex infrastructure projects, particularly in the construction of highways, major river bridges, and other prestigious developments both within Pakistan and abroad. His expertise in executive and management control has earned him a reputation for handling challenging projects with remarkable efficiency.

He retired as Chief Engineer from the Communication & Works Department, Punjab, after years of exemplary service. His extensive knowledge in contract law, administration, and arbitration has made him a respected figure in dispute resolution, acting as an arbitrator for major inland and international contracts of the National Highway Authority (NHA), Water and Power Development Authority (WAPDA), and the Communication & Works Department Punjab. His contributions to academia include serving as an external examiner for U.E.T. and as a visiting faculty member at the Punjab Engineering Academy, where he has imparted his expertise on contract administration and arbitration.

Beyond his professional endeavors, Ch. Muhammad Arif has actively participated in various engineering associations. He has held prestigious positions such as President of the Punjab Highways and Building Engineers Welfare Association, Member of the Board of Governors of the Govt. Engineering Academy Punjab, and Executive Council Member and Vice President of the Pakistan Engineering Congress. His contributions to the field have been widely recognized, receiving appreciation from the Chief Minister of Punjab, the Minister for Communication & Works Punjab, and the Secretary of the C&W Department for his meritorious services on several occasions.

Currently, he serves as the Chief Executive of a renowned consulting engineering firm, where he has been leading the design and supervision of major infrastructure projects, including highways, buildings, water supply, and sewerage schemes, for the past sixteen years. His expertise, leadership, and dedication continues to shape the engineering landscape in Pakistan.



Engr. Ch. Muhammad Arif
President
Pakistan Engineering Congress
(78th Session)

EDITOR'S NOTE

As the world marks World Water Day on March 22 and World Environment Day on June 5, 2025, we stand at a critical juncture in the ongoing narrative of sustainability. This year's themes "Glaciers Preservation" and "Ending Plastic Pollution" are not just evocative slogans; they are urgent calls to action that speak to both global responsibility and localized resilience.

In Pakistan, where water scarcity is no longer a distant threat but a lived reality, the symbolism of water as a peace-building resource carries profound relevance. With transboundary waters shaping the region's socio-political landscape, there is a pressing need for collaborative frameworks that prioritize equitable sharing, responsible usage, and ecological stewardship. Water must no longer be an instrument of discord, it must be a shared currency of peace.

Equally, World Environment Day's focus on restoring ecosystems provides a fitting counterbalance. In a country rich in biodiversity yet vulnerable to deforestation, urban sprawl, and climate volatility, restoration is not merely environmental, it is economic, social, and generational. Initiatives such as wetland revitalization, reforestation, and circular urban planning are no longer luxuries but necessities. We must shift our orientation from extraction to regeneration.

Together, these two observances underscore a shared truth: sustainability is a mosaic built from shared commitment, scientific foresight, and moral clarity. Whether through integrated water management policies or community-led green restoration projects, the path forward requires adaptive, inclusive, and transparent governance.

In 2025, let our journals, platforms, and voices reflect not just analysis, but aspiration. Let our debates yield direction. Let our data inspire design. Because the future is not to be endured, it is to be shaped.

Let us commit ourselves to embracing innovation, collaboration, and solidarity in our efforts to restore our lands, enhance our resilience, and combat desertification. Together, we can make a meaningful difference and leave a positive legacy for the planet and future generations.

NUCLEAR POWER GENERATION TECHNOLOGY: CONCEPTS, EVOLUTION, AND ITS ROLE IN A SUSTAINABLE ENERGY SUPPLY SYSTEM

Dr. Noor Jamal,
Mr. Mansoor Hassan Khan Lodhi

NUCLEAR POWER GENERATION TECHNOLOGY: CONCEPTS, EVOLUTION, AND ITS ROLE IN A SUSTAINABLE ENERGY SUPPLY SYSTEM

By:

Dr. Noor Jamal[1], Mr. Mansoor Hassan Khan Lodhi[1]

Abstract

Nuclear power plants (NPPs) operate much the same way that other thermal steam power plants (SPPs) do, to generate electricity. The major difference is the source of thermal energy for steam generation, that spins turbine(s), coupled with a generator. Since its inception in the early 1950s, nuclear energy is recognized as an important source of commercial energy supply for sustainable development. Consequently, many developed countries-initiated efforts to develop nuclear power technology and today, there are several variants/types of nuclear power reactors.

These variants are being evolved, aimed at enhancing and improvement of NPP technology and its safe operation. Currently, in the world, most of the under construction commercial NPP are Generation-III and are mostly Pressurized Water Reactor (PWR) by technology type. Likewise, more than two-third out of the total 442 operational NPPs are PWR.

In Pakistan, all five operational (2,430 MWe) and one under-construction (1,100 MWe) nuclear reactors are PWR type. In these, one operational (1,100 MWe) and the one under-construction (1,100 MWe) are Generation-III (i.e., latest generation). These NPPs of the country operate under International Atomic Energy Agency (IAEA) safeguards and periodically review by the World Association of Nuclear Operators (WANO) to maintain rigorous safety standards. Locally, the implementation of these standards is assured by the government through Pakistan Nuclear Regulatory Authority (PNRA). Established in 2001 through an act, PNRA is a statutory body that functions independently, with 24/7 presence of their experts at the Country's NPPs. Since 1971, Pakistan total nuclear generation is 111 billion kWh, that has avoided more than 69 million $CO_{2\text{-eq}}$ greenhouse gases (GHG) emissions in the country.

1. Introduction

Historically, the development of modern power system is rooted in the invention of steam engine in 1769. Using abundantly available coal, this invention triggered the development of large-scale industry by replacing humane and animal muscular power (Caineng & al., 2016). The industrial growth and scientific research/inventions of almost 100 years helped in developing the world first direct current (DC) power plant in 1875 in France. This plant was based upon steam engine and dynamo. In 1884, alternating current (AC) generator was invented, that triggered the initiatives of hydropower plant technology. Till 1900, hydropower plant had marked several milestones[2]. Thus, by the time, coal and hydropower had been established as source of energy for electricity generation (Power Magzine, 2007).

Later, the technology development aided in the exploration of mass scale oil and gas resources. Compared to coal, these two resources were expensive and were used for

[1] Applied Systems Analysis Division, PAEC

[2] In Pakistan (as a part of United India by the time), 1 MWe hydropower plant near Renala Khurd was built in 1923 by Sir Ganga Ram

powering automobiles[3]. But later, their production cost reduced by virtue of scale of economy and turned into options for power generation. During this period, steam turbine was also being developed, and General Electric (GE) made the world first 500 kWe and 5 MWe steam turbine in 1901 and 1903, respectively. With the passage of time, steam turbine size (capacity) and efficiency improved (Power Magzine, 2007). In the late 1940s, nuclear energy emerged as a new energy option for power generation. Relatively clean and densest energy contents within fuel made the nuclear energy an attractive power generation option, particularly in industrial countries. They embarked individually upon development of nuclear reactor technology for power generation. Consequently, different variants of nuclear reactor technology emerged, that prevailed in the next 20-25 years across the globe. Today, nuclear energy meets around 10% of the world electricity requirements.

This paper presents the concept of nuclear power reactor technology & its operation and discusses variants of the nuclear reactor technology. The paper likewise highlights the development of the technology and management approach to ensure safety of NPP operation. In the later sections, the paper briefly presents information regarding NPP current status around the world as well as in Pakistan and highlights the technology recognized role in a sustainable development of energy system.

2. Advent of Nuclear Energy

In 1954, Russia's APS-1 Obninsk[4] of 6Mwe capacity was the world first nuclear reactor that supplied electricity to the Country's grid system. Almost two years later, in 1956, two nuclear reactors[5] - each of 60 MWe - in the UK were connected to the country grid system. The USA first nuclear reactor 68 MWe Shipping-port[6] - came online by the end of 1957. It is noteworthy that the NPPs of all these three countries were based upon different concepts of NPP technology. By the late 1960s, nuclear energy was well established power generation option in Europe (including Russia) and the USA. However, during 1970s and 1980s, nuclear power generation capacity expanded most rapidly in the developed countries (see Figure-2) and prevailed in many developing countries, including Pakistan (IAEA (c), 2021). Pakistan first NPP – KANUPP 137 MWe - was commissioned in 1971 and its commercial operation started the next year.

[3] In 1886, the invention of internal combustion engine triggered the initiatives of automobile industry

[4] The reactor produced electricity till 1959 and was based on Russian Light Water Graphite moderated Reactor (LWGR) technology, discussed later in the paper

[5] These two reactors were Gas Cooled Reactor (GCR) and is discussed later in the paper

[6] The USA first reactor was Pressurized Water Reactor (PWR), that is to be discussed later in the paper

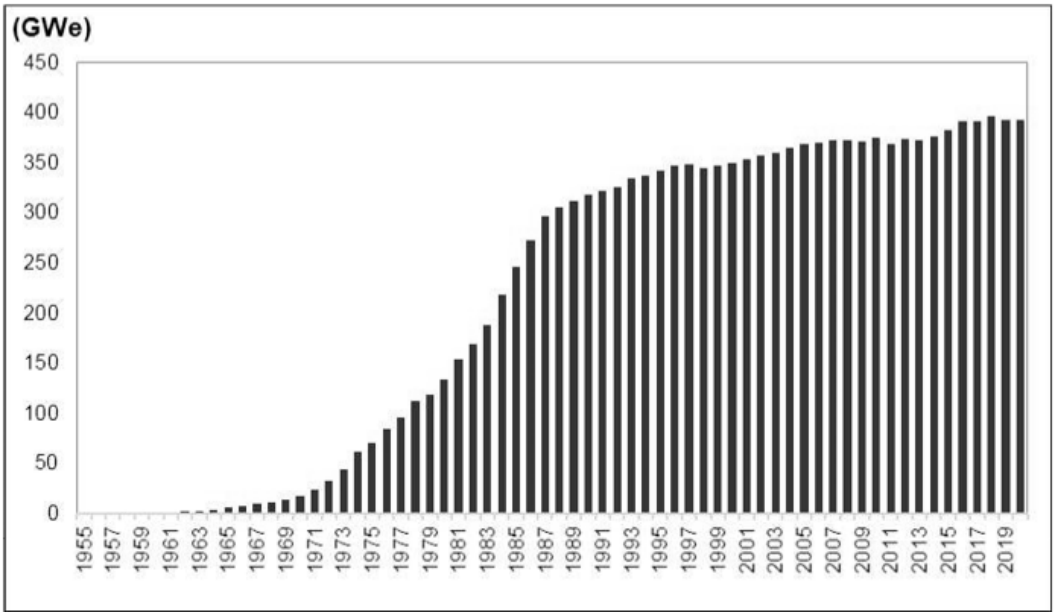


Figure-1: World Installed NPP Capacity by Year 2020 (IAEA (c), 2021)

3. NPP Basic Concepts

In case of both SPP and NPP, steam is produced to spin turbine(s) that is coupled with a generator through a shaft to generate electricity. However, in case of NPP, the heat (i.e., energy) source to produce the steam is nuclear fuel (i.e., uranium) instead of fossil fuel. Compared to fossil fuel, the energy density of nuclear fuel is substantially high. This fuel, as a whole, with some other auxiliaries is termed as the reactor core of an NPP. The reactor core is kept in a steel or steel reinforced concrete confinement, depends upon technology variant and accordingly termed as reactor pressure vessel, calendria or just confinement. Reactor core occupies a fraction of the vessel volume and the rest of the vessel is occupied/filled by moderator and primary coolant.

In a nuclear reactor core (i.e. nuclear fuel), a sustainable fission reaction takes place to produce thermal energy (i.e., heat). The production of thermal energy is proportional to the fission reaction rate, and this rate is controlled through chemicals, employed in the form of solid rods and liquid. In a fission reaction, a neutron enters (or is absorbed by) the nucleus of fissionable atom isotope (e.g., U-235), that split the atom into two atoms of light elements[7] (e.g., U-235 into Kr-89, Ba-144). Each fission/splitting process generates thermal energy (i.e., heat) of about 200 MeV (3.2044e-11 Joule) as well as 2-3 neutrons. For a sustainable chain fission reaction, one of these neutrons must enter into the nucleolus of target atom (U-235). In almost all currently operating reactor types, slowing down of these neutrons to a certain energy level is required to maximize the probability of fission reaction. This slowing down of neutrons is achieved through a medium, called moderator of the reactor (The Open University, 2019).

Ideally, the moderator should not absorb neutrons. However, all the three well-established moderator medium – light water, heavy water, and graphite – absorb fraction of the neutrons. These mediums can be ranked by least neutron absorption (i.e., efficient moderator) as; heavy water, graphite, and light water. Consequently, when needed, the ratio of fissionable isotopes (e.g., U-235) must be increased in the reactor fuel to compensate for the neutron absorption. Naturally, the ratio of this isotope in the reactor fuel is only 0.7% and is sufficient to be used as fuel with heavy

[7] The light element further decay into other elements

water as moderator. In the case of the other two moderator medium, the isotope U235 percentage is increased during fuel fabrication process, generally 3.0% to 4.0% (The Open University, 2019), (Hewitt & Collier, 1997).

NPP primary coolant is in fluid[8] form (e.g., water, gas, etc.,), that transports heat from the reactor core to heat exchanger (HX)[9]. The HX is like a boiler - filled with water - but having internal tubes grid/arrangement. When the hot primary coolant from the reactor core/vessel passes through these tubes of the HX, the heat transfers to the HX filled water, that boils and converts into steam. Consequently, the primary coolant temperature drops and this relatively cold coolant is pumped back into the vessel, thus forming a closed loop. This closed loop is called primary loop of the NPP (The Open University, 2019), (Hewitt & Collier, 1997).

The difference in the designs of nuclear reactor is mainly due to the arrangement as well as choice of moderator and coolant. Obviously, these choices affect the fuel enrichment requirements as mentioned earlier. Additionally, differences can be found in the mechanism of thermal energy transportation from reactor core. In the following section, these differences in the well-known reactor designs are briefly elaborated.

4. NPP Technology Variants

4.1 Pressurized Water Reactor (PWR)

Pressurized Water Reactor (PWR) technology was initially developed by the USA. Currently, in addition to the USA, China, France, South Korea, and Russia are the lead developers of PWR based NPP. In the current total operating reactors across the globe, more than 73% share by capacity belongs to PWR technology that operates in 28 different countries. Pakistan's all five operational nuclear reactors and the under-construction one are PWR. In the installed PWR capacity across the globe, the leading shareholders are France, the USA and China with share around 22%, 21%, and 17%, respectively. In the under-construction nuclear reactors, around 88% capacity is PWR, that is being constructed in 19-different countries (IAEA (c), 2021) (IAEA, 2020).

In PWR, the primary loop (including pressure vessel) is filled by light water (i.e., common water), that functions as moderator as well as coolant, and the fuel is obviously enriched. For a sustainable fission reaction, the primary loop is highly pressurized typically 15-16 MPa - to avoid any steam or bubble formation at the operating temperature of 300^{o} C and is, therefore, called PWR. A schematic diagram of a typical PWR is presented in Figure-2 (Hewitt & Collier, 1997) (CAMECO, 2017); (WNA, 2021).

[8] Depends upon technology type, the fluid can be gas, water, or even molten metal or salt at the working temperature

[9] In Boiling Water Reactor (BWR) case, coolant water converts into steam directly within reactor vessel and required no HX

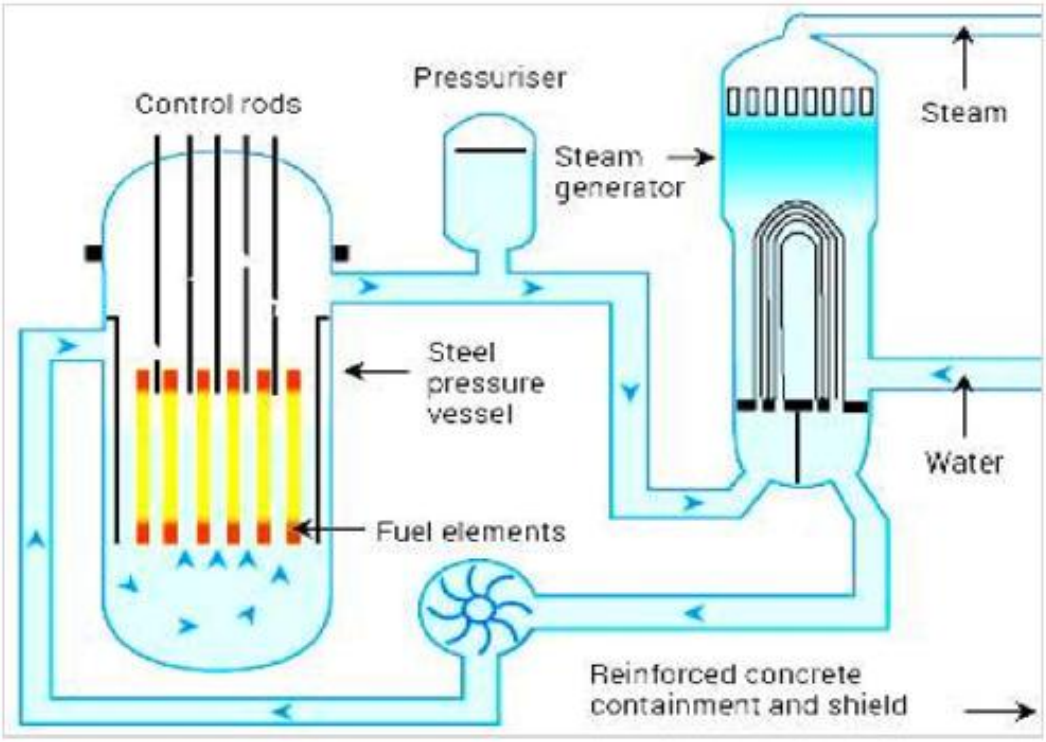


Figure-2: Schematic of Pressurized Water Reactor (PWR) Nuclear Island

4.2 Boiling Water Reactor (BWR)

In addition to PWR, the USA early efforts also resulted in the development of Boiling Water Reactor (BWR) technology. Currently, the USA has the highest number (i.e., 31) of BWR reactors followed by Japan (i.e., 17 reactors). However, regarding future development, the efforts by Japan are most significant and they are the only country constructing new BWRs (2x1326.5 MWe) capacity. In the current operating reactor in the world, the share of BWR by capacity is around 16% that operates in 09-different countries (IAEA (c), 2021); (Hewitt & Collier, 1997).

In BWR, like PWR, light water is used both as moderator and as coolant, with enriched fuel. However, BWR operates at around 7 MPa pressure, consequently, 12%-15% of the total water in the vessel is converted into steam at typical operating temperature of 285^{o} C. The steam exists in the top part of the vessel, that is treated for moisture separation before channelling to steam turbine for spinning. This approach of the design eliminated the requirement of HX (Figure-3). However, to compensate for the boiled water, the reactor core (i.e., fuel) and vessel volume are to be more than PWR (CAMECO, 2017); (WNA, 2021); (Hewitt & Collier, 1997).

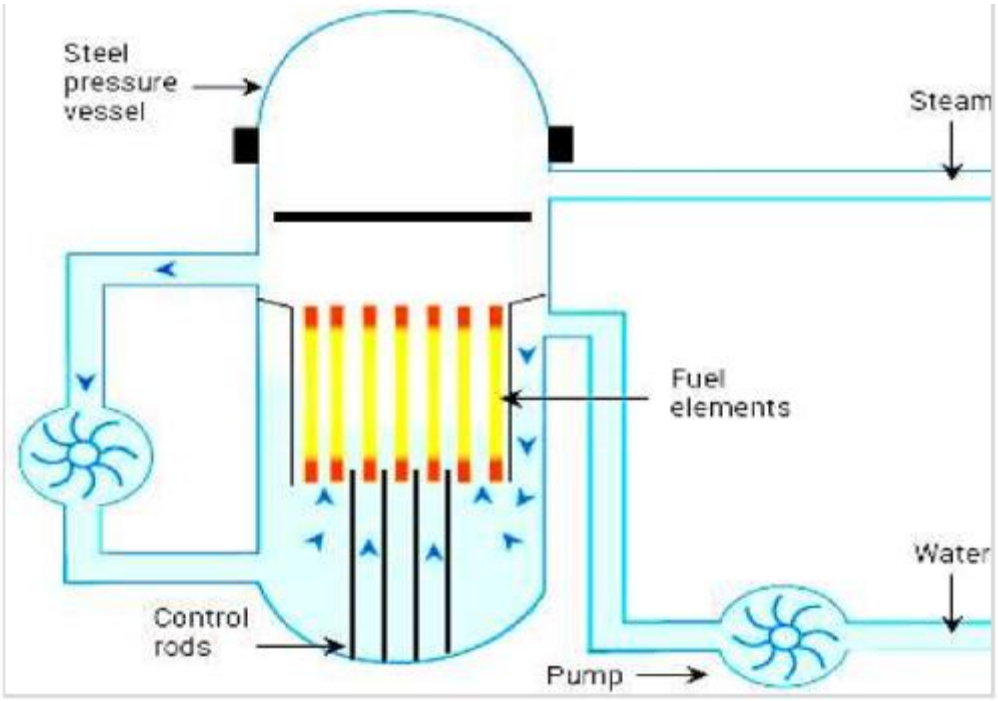


Figure-3: Schematic of Boiling Water Reactor (BWR) Nuclear Island (WNA, 2021)

4.3 Pressurized Heavy Water Reactor (PHWR)

The USA and Sweden were the countries, that initiated the early efforts of Pressurized Heavy Water Reactor (PHWR) development. However, the real development of this technology belongs to Canada, that has developed CANDU-6, a Generation-III[10] PHWR. Recently, India also claimed 100% indigenous capability of PHWR design and construction, but this yet to be demonstrated/confirmed. In the existing operation reactors, PHWR share is around 6% by capacity, with highest capacity share in Canada (~58%) and India (~16%). Currently, India's four under-construction PHWRs are the world only under-construction PHWR (IAEA, 2020).

Pakistan's first NPP - Karachi Nuclear Power Plant (KANUPP) - was also based upon PHWR technology. This plant was commissioned in 1971 and permanently shut down in August 2021 for decommissioning.

In the case of PHWR, the vertical vessel is replaced with a horizontal drum like structure, called Calandria. The Calandria encapsulates dozens of channels for holding nuclear fuel, giving advantage of online fueling i.e., inserting new fuel bundle and removing/collecting the used one. The rest of the calendria volume is filled of heavy water to moderate neutrons. Commonly, the reactor coolant is also heavy water but of low grade by purification. Therefore, without mixing with the moderator, the coolant passes through annular - formed over each fuel channel - to transport heat from the reactor. The heavy water moderator as well as coolant allow to use natural uranium as fuel i.e., required no enrichment for a sustainable fission reaction. Typically, PHWR coolant pressure at reactor exit is 9-10 MPa and temperature is 310^{o} C. In the following (Figure-4), a typical PHWR schematic diagram is presented for more clarification (CAMECO, 2017); (WNA, 2021); (Hewitt & Collier, 1997).

[10] The Generations are discussed later in the paper

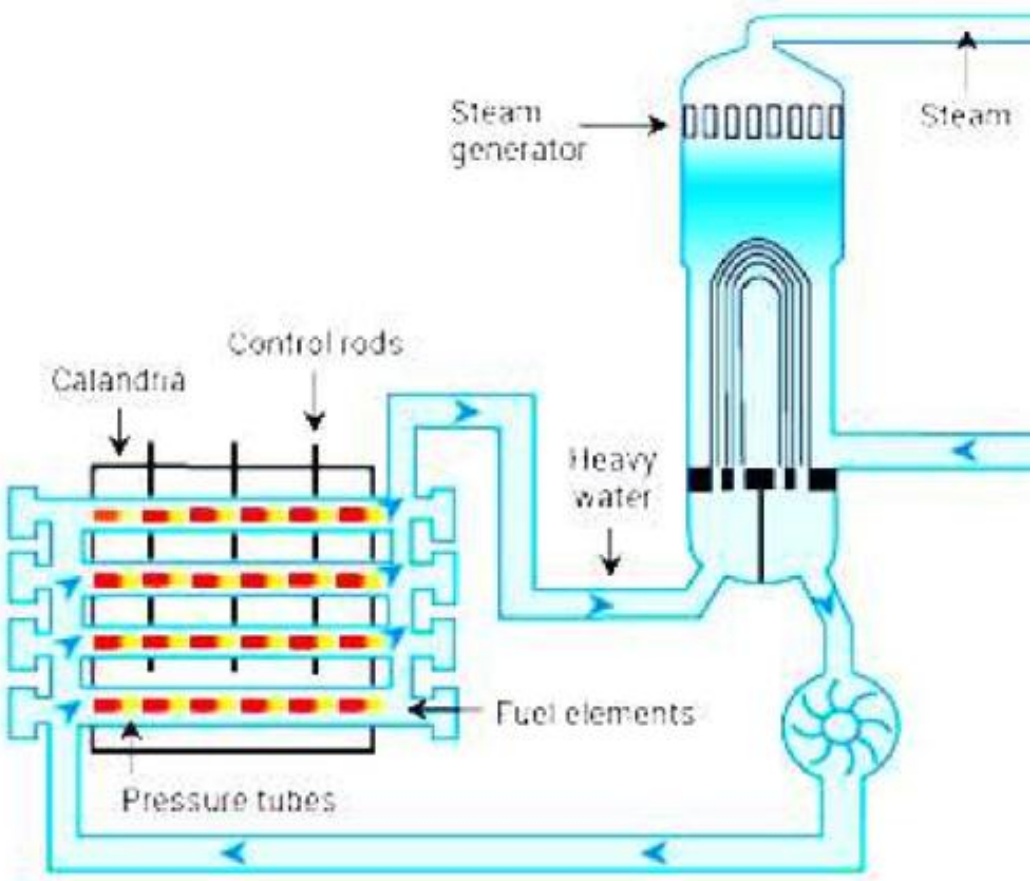


Figure-4: Schematic of a Typical Pressurized Heavy Water Reactor (PHWR) Nuclear Island (WNA, 2021)

4.4 Gas Cooled Reactor (GCR)

The UK initiated the development of Gas Cooled Reactor (GCR) in early 1950s, and currently all operational GCRs (i.e., 14) are in the UK. This operational capacity makes less than 2% of the world operating NPP capacity. However, many countries including Japan, China, etc., are working on the advanced version of the GCR technology. China recently connected the country high temperature gas cooled reactor (HTGR) based NPP to the national grid for demonstration of the technology. This NPP is consisted of 2x100 MWe unit of the HTGR (IAEA, 2020); (CNNC, 2021).

In this type of reactors, solid graphite is used as moderator and gas as coolant. Since graphite is solid, therefore, compartments and channels are formed within the graphite volume for fuel placement and gas flow. The gas is typically carbon-dioxide or helium, that removes heat generated by the reactor core (i.e., within fuel) and transports it to the HX for steam production (Figure-5). Since GCR coolant (i.e., gas) is superheated, therefore, it operates at extremely high temperature (450-600^{o} C). The coolant temperature of the future advanced version of the technology (i.e., HTGR) is expected to be around 850^{o}C (CAMECO, 2017); (WNA, 2021); (Hewitt & Collier, 1997).

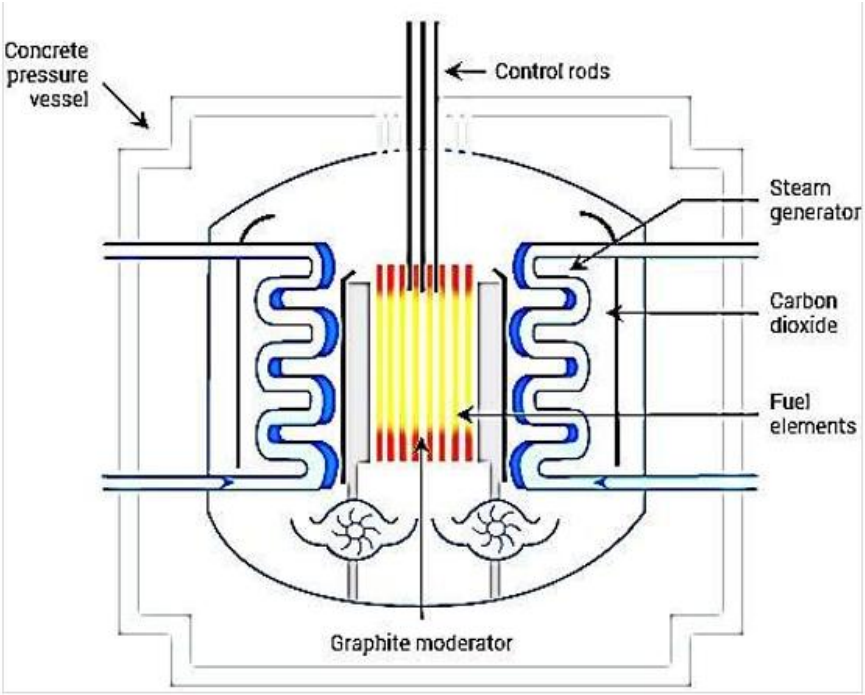


Figure-5: Schematic of a Typical Gas Cooled Reactor (GCR) Nuclear Island (WNA, 2021)

4.4 Light Water Graphite Reactor (LWGR)

LWGR was developed by the former USSR and had been built only in Russia or in USSR former states. Outside Russia (i.e., USSR), the technology did not receive much consideration. The existing operational 12-LWGR are in Russia, that constitute around 2% of the world NPP capacity.

In this type of reactor, the moderator is graphite and long pressure tubes pass throug it for fuel placement and water (light water) flow as shown in Figure-6. The operating pressure of the LWGR is around 7 MPa and temperature is 290ºC, that permits partial boiling of the water as in BWR (Hewitt & Collier, 1997).

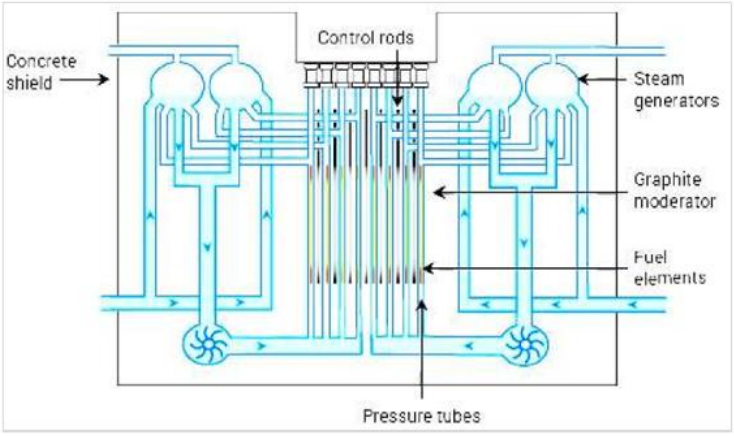


Figure-6: Schematic of a Typical Gas Cooled Reactor (GCR) Nuclear Island, (WNA, 2021)

4.5 Fast Breeder Reactor (FBR)

In addition to above, the fast reactor breeder reactor is another well-known design category of the nuclear reactor. The design is well-proven and has been demonstrated in many countries, however, the high construction and

operating/maintenance costs are major hurdles to commercialize the design. Russia's two fast fast reactors of total 1,380 MWe capacity, are only commercially operated reactors in the world, with China's 25 Mwe demonstration FBR (WNA, 2021); (Hewitt & Collier, 1997).

For comparison, shares of different reactor technologies in the total operating 413.7 GW capacity are presented in the following (Figure-7).

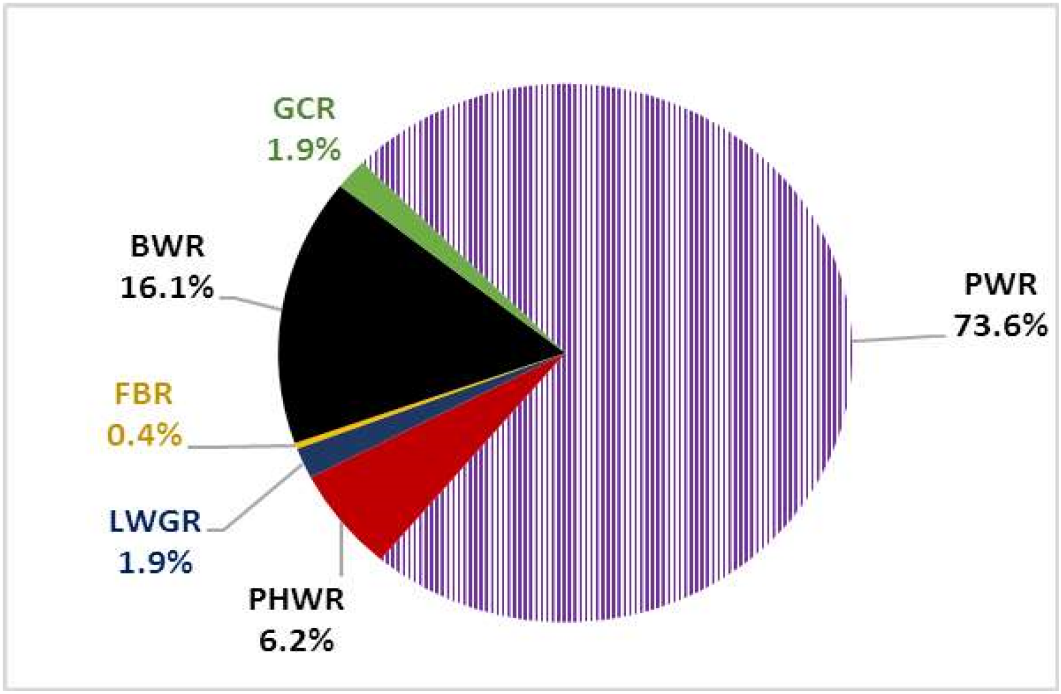


Figure-7: Share of Different Reactor Type in the Installed NPP Capacity (IAEA (c), 2021)

5. Evolution of NPP Technology

All variants of NPP technology perpetually improve and evolve with aim of enhancing performance, safety, and economics. For convenience, this enhancement in the technology is classified and each class is termed as Generation. Currently, Generation-III technology is commercially available for development and Generation-IV technology is in the early phase of design. Since the installation of NPPs and improvement/enhancement in the technology continue side by side, therefore, temporal-overlapping of different generations can be found in the installed capacity across the world. In the following, different Generation of the technology are briefly presented.

5.1 Generation-I

Generation-I (Gen-I) of nuclear power technology included early (1950s) prototype reactors, that were developed in Europe and in the USA. These prototype nuclear reactors were derivatives of the reactors, that were designed and developed for military purposes (e.g., submarine propulsion). Relatively small in size[11], these demonstration reactors had no or limited arrangements (i.e., dedicated systems) for a safe commercial operation (i.e., electricity generation) (Goldberg & Rosner) (Haas, Mez, & Ajanovic, 2019).

[11] The size of Gen-I most reactors ranges 5 MWe to 70 MWe. However, few later installed reactors of the generation in the USA and the UK were quiet big one

Consequently, most reactors of the Gen-I technology served to generation electricity for some period (i.e., 5-25 years) and Gen-II reactors started to replace them in 1960s. However, the UK's Wylfa-1 Gen-I reactor continued electricity production until recent. This reactor of 530 MWe (i.e., GCR) was permanently shutdown in

2019, after operating for almost 50-years. Pakistan's KANUPP-I of 137 MWe is categorized by some experts as Gen-I technology. However, the plant had relatively better arrangements and dedicated safety systems. KANUPP-I is permanently shut down in August 2021 after almost 50 years of operation (Goldberg & Rosner) (Haas, Mez, & Ajanovic, 2019).

5.2 Generation-II and China's Generation-II Plus

Gen-II reactors were designed and developed specifically for commercial use. Therefore, these reactors have more arrangements and design features for a safe operation. The safety systems of these reactors sense any abnormal condition – whether internal (e.g., pressure, temperature, etc.,) or external situation (e.g., seismic activity, grid fluctuation, etc.,) - and if any such condition comes about, the reactor shut down automatically. For the safe shutdown, dedicated active safety systems are installed. To implement the concept of defense in-depth, these systems are redundant as well as diverse in their function (Goldberg & Rosner) (Haas, Mez, & Ajanovic, 2019).

Gen-II started to prevail in 1960s and dominate the NPP new-builds market across the globe until recent (i.e., 2010 or even later). In 2000, China added up some safety features of Generation-III in their Generation-II reactors, that resulted in Generation II+ version of the technology (NEI-Magzine, 2013). The same Generation II+ reactors were then exported to Pakistan, that operate at Chashma Nuclear Power Generation Station (CNPGS).

Typically, the capacity of these reactor ranges from few hundreds up to 1,600 MWe. In most cases, the design life of Gen-II reactors is 40-year that can be extended. In the USA, life extension up to 40-year of some Gen-II reactors is planned. Today, more than 98.0% of the world installed nuclear power capacity is Gen-II or Gen-II plus (Goldberg & Rosner) (Haas, Mez, & Ajanovic, 2019).

5.3 Generation-III

The design of Gen-III reactor technology emerged in the late 1980s and most of these designs are evolutionary i.e., developed from Gen-II design. Among others, the prominent improvements in this new generation of the reactor technology are following (Goldberg & Rosner) (Haas, Mez, & Ajanovic, 2019);

i) Gen-III reactor design incorporated passive safety systems/features i.e., reactor does not require active controls or operator intervention to mitigate the impacts of any abnormal event. These systems work automatically under all conditions using gravity, fluid buoyant forces, and natural convection.

ii) Reactor containment is double in most designs, that increased the containment strength and helped in the implementation of the above-mentioned passive safety system.

iii) The design life of Gen-III reactors is 60-year, that improved the plant economics.

iv) In some designs of the generation, standardization and modularization in the design of Gen-III reactors is conceived, that help in licensing and construction of the plant.

Currently, only few reactors of the generation are in operation, that included Pakistan's 1,100 Mwe KANUPP-2 (K-2) plant. However, around 35 Gen-III reactors - including Paki -3 (K-3) - are worldwide under construction (IAEA, 2020); (Haas, Mez, & Ajanovic, 2019).

In addition to above, the concept of Small Modular Reactor (SMR) is also under development. The SMR designs have incorporated safety features of Gen-III technology, and aimed to achieve the following objectives (IAEA (d), 2020):

- Construction of the NPP as modules in a factory, that are to be installed in sequence. This will improve construction quality and will reduce construction time, resulting in improvement of the NPP economics.
- Construction of different size (i.e., capacity) NPP, by installing multiple SMR, that shares different systems and resources. The flexibility in size will facilitate to adjust the NPP capacity according grid system size.
- The smaller size and construction efficiency will lead to easier financing, even for developing countries.
- To use nuclear energy for power generation as well as industrial application, including hydrogen production, desalination, etc.

NuScale Power, a private US firm, has designed an SMR, and based upon that design, an NPP is currently under development in the USA. This NPP will be consisted of 06 to 12 SMR, each of 60 MW capacity.

5.4 Generation-IV

Gen-IV covers a range of different design concepts to further improve nuclear reactors safety & economics, reduce waste, and make the technology proliferation resistant. In the year 2000, Generation-IV International Forum (GIF) was formed, that consisted of 14-member countries, including the USA. Out of some 100 conceptual designs, the GIF has selected six of them for research and development (R&D). These designs are mostly revolutionary and required substantial crosscutting R&D. Therefore, it will take years, if not decades for the Gen-IV reactors to be available on commercial basis (Goldberg & Rosner) (Haas, Mez, & Ajanovic, 2019).

6. IAEA, WANO Role in Maintaining Safety of NPPs

The International Atomic Energy Agency (IAEA) was established in 1957 and the same year, Pakistan became member of the IAEA. The IAEA functions under the umbrella of United Nations (UN) as the focal point for development/ expansion and peaceful use of nuclear power & radiation in the world. For this purpose, the IAEA assists member states and provides services in the form of trainings, knowledge sharing, technology transfer, and expansion planning. The IAEA also provides guidelines and standards regarding each phase of NPP development and operation i.e., from site selection till de-commissioning. Pakistan comply these guidelines and apply the standards through internal monitoring and verification mechanism. Nevertheless, Pakistan Nuclear Regulatory Authority (PNRA) – established in 2001- is the sole independent authority to validate and certify the implementation of these standards in Pakistan. Therefore, as a regulatory authority, PNRA is involved in the process of NPP development, operation, and decommissioning (PNRA, 2021) (IAEA(b), 2021).

Pakistan is also member of the World Association of Nuclear Operator (WANO), that was established in 1989 to maximize NPP safe and reliable operation by working

together. WANO is independent of any government or regulatory influence. For the safe and reliable operation of NPP around the world, they do independent assessment, share information, and emulate best practices across the member states. WANO main services included (WANO, 2021);

i) In-depth Peer Review of member state NPPs operation by external experts, at four-year frequency, with a follow up after two years.

ii) Performance Analysis by collecting and analyzing operating experience, particularly data related to an event, that is shared among member states.

iii) Member Support Programme, that is carried out at the request of member state.

iv) New Unit Assistance, that support an NPP during project phase and its transition from project phase to safe and reliable operation.

7. Nuclear Energy: World and Pakistan Outlook

Nuclear power has been an important part of the world as well as Pakistan power system. Currently, around 442 nuclear reactors are operating in 32 different countries, including Pakistan as shown below (Figure-8). In the year 2020, the share of nuclear energy in the world total electricity generation was 10%[12], with highest share in the national electricity generation of France. In Pakistan's power system, the contribution of nuclear energy in electricity supply during 2020 was around 7.0%. This share is expected to grow further up to 11.0% in the next year - as K-2 (i.e., 1,100 MWe) has started commercial operation in May, 2021 (IAEA (c), 2021).

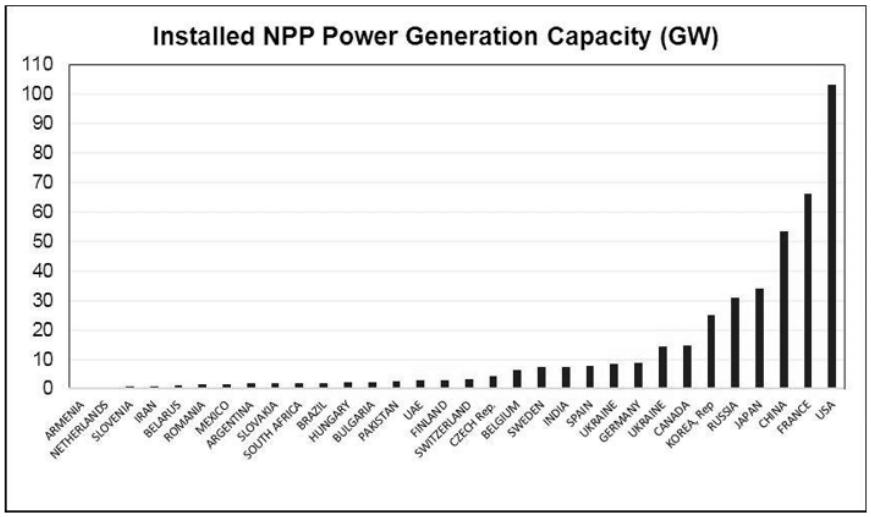


Figure-8: Installed NPP Power Generation Capacity (GW) in Different Countries (IAEA (c), 2021)

In addition, around 59 GW nuclear capacity is under-construction. In this total, more than 50% is in Asia, that included Pakistan's 1,100 MWK-3 NPP.

8. Identified Future Role of Nuclear Energy

8.1 Firm Base Load Supply Option

Nuclear power fuel cost and variable operating cost is the least among all thermal power generation option. Therefore, an NPP is generally designed to operate as base-load plant and once fuelled, it operates for 14 - 18 months non-stop. This constant

[12] The total generation is around 25 trillion kWh

continuous supply increases the power supply system reliability. In addition, it helps in stabilizing the supply system prices as the share of fuel price is less than 15% in the cost of generation. Among others, these two attributes are essential for economic growth, particularly large-scale industry expansion. Like any developing country, a perpetual and significant economic growth potential is foreseen in the case of Pakistan. Hence, the country will require substantial and sustainable firm base-load supply, that can be guaranteed through development of nuclear power capacity expansion.

8.2 Climate Change Mitigation

Climate change owing to anthropogenic greenhouse gases (GHG) emission is a known challenge. Currently, the total annual anthropogenic GHG emission is more than 50 billion tonnes CO_2 equivalent and expected to grow by more than 20% by 2050 (IPCC, 2021); (University of Michigan, 2021). In this annual GHG emission, 65%75% comes from burning of fossil fuel for energy (including ~25% of electricity sector) production (United Nations, 2015). According to IPCC (2021), the energy related emissions should be neutralized by 2050 to avoid rise in the earth surface mean temperature by 1.5^{o} C above pre-industrial (1850-1900) temperature by the end of this century. In other case, there will be proportional severe impacts of climate change in the form of; long warm weather, rapid glacier melting, irregular rainy seasons, flood, drought, etc., that will be hard to cope, particularly by developing countries.

Nuclear energy is a recognized energy generation option to achieve the sector GHG emission neutrality. Therefore, IPCC as well as other well-known organizations included nuclear power in almost all prospective solutions for handling the climate change. In 2050, therefore, nuclear power is expected to be doubled as of current capacity (IAEA, 2020).

Since Pakistan is among the 10 most prone countries, that are facing the severity of climate change, therefore, the country has always supported the international efforts of GHG emission mitigation. In this regard, in 2016, Pakistan ratified the Paris Agreement of GHG emission mitigation. For effective mitigation, therefore, nuclear power will be essential for the country to reduce the country energy sector GHG emissions, that currently constitutes around 45% of the Country's total around 490 million tonne $CO_{2\text{-eq}}$ emissions (GoP, 2021). Since 1971, nuclear energy has avoided 69 million tonne $CO_{2\text{-eq}}$ GHG emissions, that are equivalent to burning of around 28.7 million tonne coal in an open field.

8.3 Security of Energy Supply

Security of energy supply is essential for a sustainable energy system. Since nuclear fuel contains densest contents of energy as mentioned earlier, therefore, any disruption of fuel supply resulting from international politics or other issue - does not affect an NPP operation for months, even years. Once fueled, a nuclear reactor can operate more than 18 months as mentioned above. In addition, fuel for two years can be stored conveniently without extra cost.

9. Conclusion

NPP is well-proven power generation technology and several variants of the technology are available in the world. The technology is being evolved for the last 70-years, aiming to improve operational safety and economics. Currently, 442 nuclear reactors are operating in the world, mostly PWR designs of Gen-II. However,

Pakistan's nuclear reactors at Chashma Nuclear Power Generation Station (CNPGS) reactors are Generation II+ (i.e., plus) PWR, and the recently commissioned K-2 and the under-construction K-3 are Gen-III PWR. Gen-III designs are relatively safer that use natural convection, buoyancy, and gravity to perform the safety operation, without humane intervention.

Nuclear power contributes well in the energy supply system of several developed and emerging developing countries. In the world, the share of nuclear energy in the energy supply system is 10% and an increase in the capacity of the nuclear reactor is acknowledged to handle the climate change issue and for a reliable power supply.

In Pakistan, nuclear energy has been part of the Country's power system from 1971, and its current share is more than 9%.

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EFFICIENCY ANALYSIS OF JET PULSING DUST COLLECTOR TO CONTROL AIR POLLUTANTS

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EFFICIENCY ANALYSIS OF JET PULSING DUST COLLECTOR TO CONTROL AIR POLLUTANTS

By

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Abstract

A Jet Pulsing Dust Collector (bag house) was installed on a 6-ton heavy fuel oil boiler at a shoe manufacturing industry in Batapur, Lahore. The unit, comprising 30 imported glass fiber bags, operates at 0.4–1 m³/min gas velocity to purify flue gases. Monitoring showed reductions in O_2 (3.3%→1.62%), CO_2 (13.32%→6.48%), NOx (223.17→135.21 mg/Nm³), and SOx (2597.22→1926.06 mg/Nm³), with temperature dropping from 196.9°C to 135.7°C. CO levels remained largely unchanged, typical of older boilers. Removal efficiencies were highest for SOx (74.16%), followed by NO (62.79%) and NOx (60.59%).

Keywords: *Bag house Filter, Boiler emissions, Heavy Fuel Oil, Jet Pulsing Dust Collector*

1. Introduction

Numerous industrial activities result in the discharge of air pollutants, and among these, particulate matter stands out as a significant concern due to its detrimental impact on both the environment and human well-being. Effectively curtailing the release of dust into the atmosphere is of paramount importance. In recent decades, the drive for enhanced methods of dust reduction has been spurred by increasingly stringent regulations, as highlighted by Ginestet et al. 2022. Undoubtedly, the significance of industrial development in driving economic growth cannot be overstated. However, industries also stand as significant contributors to global air pollution (Liu et al., 2019). These emissions from industrial activities encompass a range of air pollutants, including particulate matter, carbon oxides, nitrogen oxides, volatile organic compounds (VOCs), and persistent organic pollutants. These pollutants pose substantial threats to both human health and the environment (Geng et al., 2019).

In recent times, there has been notable concern surrounding fine particulate matter primarily because of its substantial health hazards (I. Manisalidis et al., 2020). An efficient strategy for eliminating fine particles from the air involves the utilization of dust collection technology (C.H. Zheng et al., 2018), where bag filters have gained extensive adoption for industrial air purification due to their effectiveness in capturing a broad spectrum of particle sizes (R. Burnett, et al., 2018).

Electrostatic precipitators (ESPs) and bag filter systems are extensively employed for the elimination of solid particulates from manufacturing process gases. ESPs are recognized to exhibit collection efficiencies ranging from 99.5% to 99.9% for larger particles with diameters spanning between 2.5 and 10 micrometers (μm), designated as PM10. However, ESPs tend to exhibit diminished collection efficiency for finer particles (Y. Cuiping et al., 2013). In contrast, bag filters, constructed from fabric materials, not only exhibit exceptional separation efficiency (exceeding 99.99%) but

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also possess commendable capability for collecting fine. This technology finds widespread application in various industrial settings to capture solid particulate matter present in process gas streams (Y. Cuiping et al., 2013). For instance, fabric filters have emerged as a viable alternative for dust collection, effectively capturing fly ash from flue gas (Ortiz. F.J.G et al., 2007). Bag filters have demonstrated their utility in diverse scenarios, such as the removal of fly ash (Y. Cuiping et al., 2013), polychlorinated dibenzo-p-dioxins (dioxins) (Y.H. Wang et al., 2009), and carbon particles suspended in flue gas (D. Fino et al., 2009).

Throughout the filtration procedure, particles progressively accumulate on the filter bag's surface, forming a layer of powdery cake. This accumulation results in an escalation of the pressure drop across the filtration process (D. Thomas et al., 2001). To circumvent a decline in the flow of dusty gas and a subsequent surge in energy consumption, periodic regeneration of the filter becomes necessary (X. Simon et al., 2010). Consequently, the swift buildup of a compact filter cake necessitates more frequent cleaning cycles, leading to increased instances of process downtime. Furthermore, frequent cleaning also contributes to the reduced longevity of the filter bag (S.J. Park et al., 2003). Hence, a primary objective in air filtration using bag filters remains the reduction of resistance imposed by the cake layer. Various factors influence the resistance exhibited by filter cakes, encompassing operational conditions like filtration velocity and dust concentration (T.C. Hsiao et al., 2018), as well as the characteristics of the dust, including particle size (M. Hennemann et al., 2021) and sphericity (R. Deshpande et al., 2020). The resistance attributed to the filter cake is primarily governed by factors such as the mass loading and cake porosity (Y.S. Chen et al., 2009). Enhancing particle deposition efficiency (Y. Fan et al., 2013) or fostering the formation of a less compact filter cake can aid in mitigating cake resistance (Guangyu Zhou, 2023).

Research on pulse-jet cleaning systems (Morris, 1984; Sievert & Löffler, 1987) highlights key parameters—air pressure, injection duration, pipe geometry, distance to filter elements, and venturi use—as critical to effective dust-cake removal and uniform cleaning. Studies emphasize the importance of hole diameter (Simon et al., 2007; Andersen et al., 2016; Thumbe et al., 2017; Li et al., 2019). Empirical and computational work further examined airflow, pressure, mass flow, and jet angle in injection pipes (Thumbe et al., 2017).

Thumbe et al. (2017) noted that uniform cleaning in pulse-jet baghouses requires equal mass flow through injection pipe holes. However, even with identical diameters, mass flow and jet angles vary by hole position: those nearer the tank show lower flows and larger inclinations. Such variations likely cause differences in cleaning efficiency among filter bags beneath the same pipe.

Simon et al. (2007) identified an optimal nozzle diameter for pulse-jet cleaning, noting that larger diameters increase pulse pressure only up to a threshold, beyond which performance declines. Fu and Ger (1999) modeled uniform mass flow distribution by adjusting nozzle sizes, while Hemerka and Doubek (2002) proposed guidelines for uniform air distribution, designing hole diameters based on pipe dimensions, hole count, and nominal diameter.

Li et al. (2019) investigated an experimental pulse-jet baghouse with five pleated cartridge filters, introducing the concept of 'composite pressure' to assess cleaning efficiency. Composite pressure increased along the injection pipe, with the fifth cartridge 1.73 times higher than the first. A modified pipe design, with decreasing

orifice diameters, produced a more uniform profile (fifth cartridge 1.09 times the first), reducing residual pressure drop, extending cleaning cycles, and lowering average dust emissions—though peak emissions immediately after cleaning rose. The study aimed to evaluate boiler flue gas data and baghouse efficiency in controlling emissions.

2. Methodology

The automatic Jet Pulsing Dust Collector type bag house is studied which is installed on boiler of capacity 06 ton at shoes manufacturing industry, Batapur, Lahore. Process flow diagram of shoes manufacturing industry is shown in figure 1. The said industry used natural gas and furnace oil as a fuel in boiler. 06 to 07 months natural gas is used as a fuel or on its availability whereas furnace oil is used in winter. The bag filter contained 30 bags made of imported glass fiber. There are 05 lines and in one line there are 6 filters each. They are suspended with open ends attached to a manifold. The Bag Filter separates dust from the exhaust gas by collecting them with the filter media. Dust accumulates on filter media, with the hopper collecting particles. Incoming gas strikes a baffle plate, dropping larger particles by gravity, while finer particulates form a cake on bag surfaces. Filtration efficiency rises once the pre-coat forms, but dust buildup increases air resistance, requiring periodic cleaning by pulse or reverse jet airflow. Gas velocity through bags is 0.4–1 m^3/min, and moisture prevents operation. The system comprises bag filters, nozzles, fan, and tube sheets (Figures 2–3; Table 1).

Pulse-jet cleaning uses high-pressure blasts of compressed air through venturies to flex filter fabric, dislodging dust cake into the hopper. Cleaning cycles, controlled by an adjustable timer, are critical for efficiency. The system has no moving parts and cleans on demand.

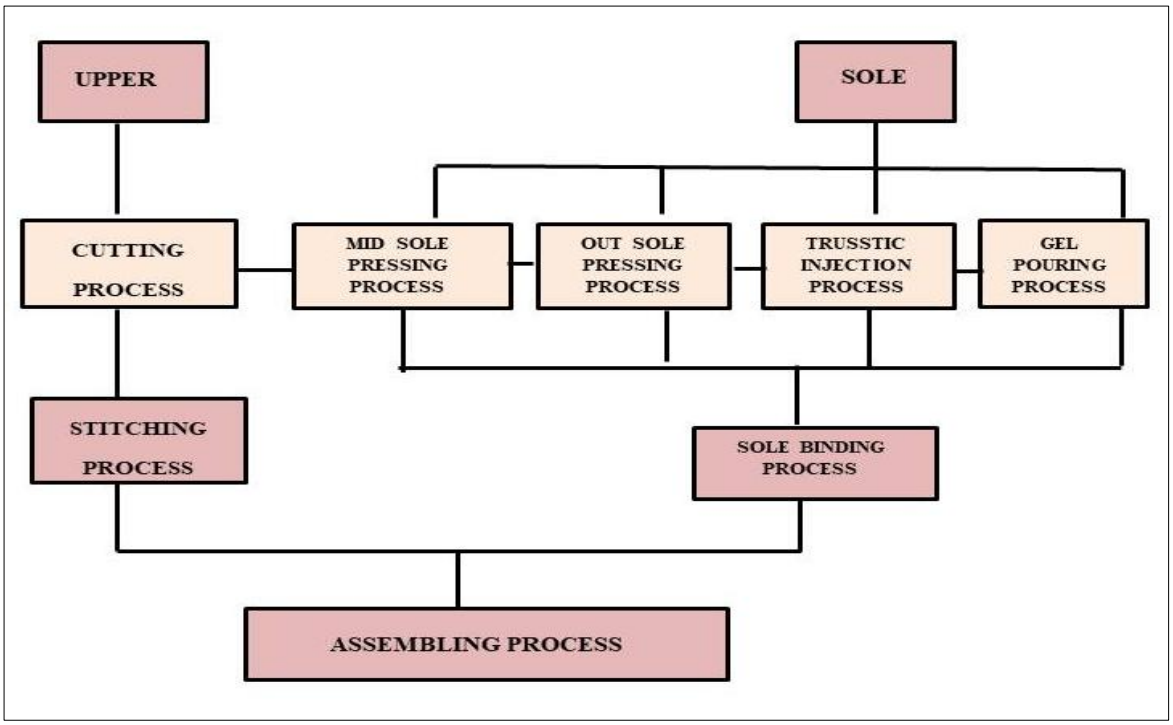


Fig-1: Process flow diagram of shoes manufacturing industry

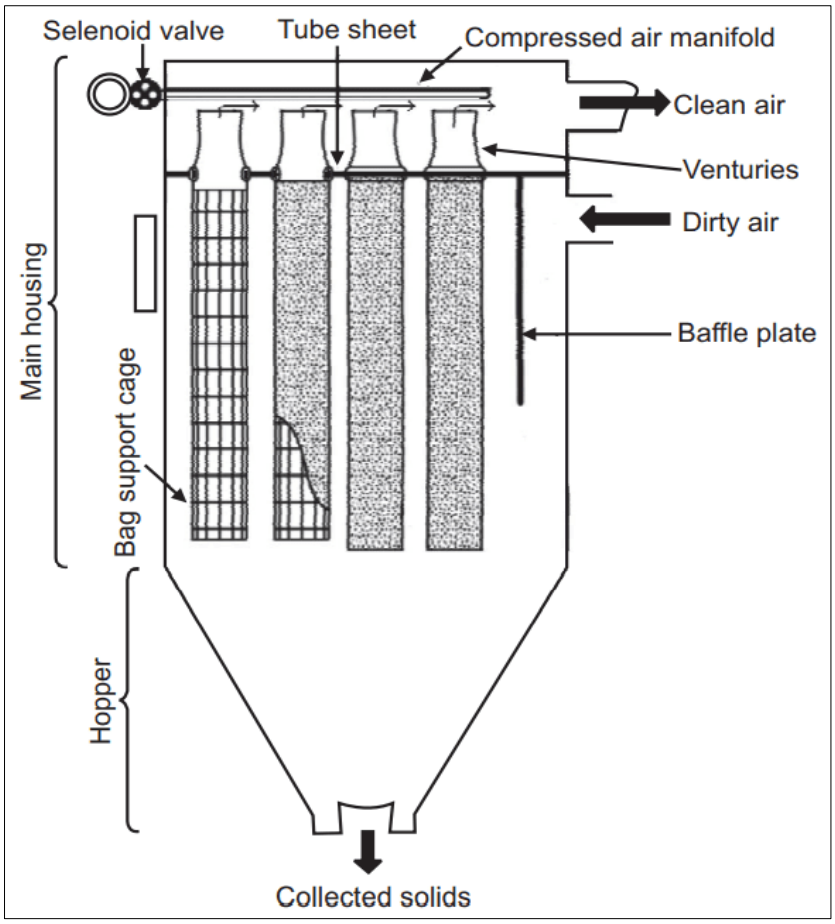


Fig-2. Schematic diagram of the pulse jet bag house

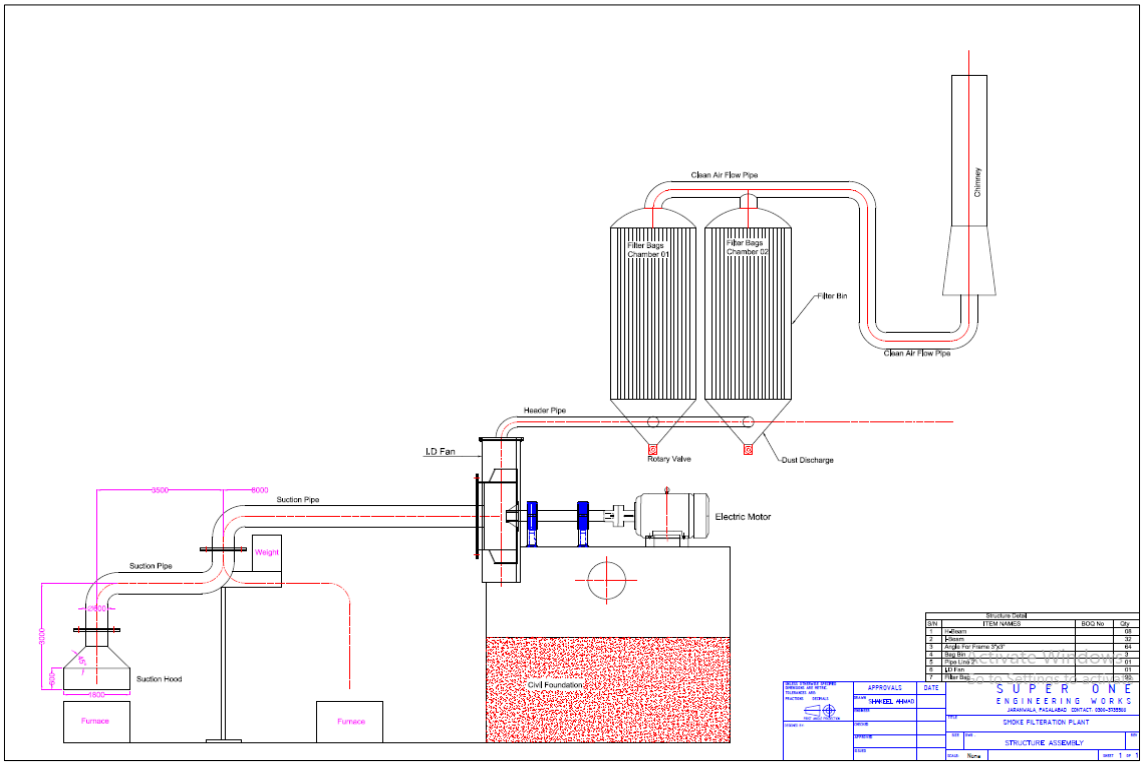


Fig-3. Layout diagram of the pulse jet baghouse installed at shoes manufacturing industry

Table-1: Design of Bag House and Physical Properties of Bag Filter Material

Specifications of installed Bag House (Dust Collector)	
Total Height	18 feet
Plant height without collection system	12 feet
Hopper length	06 feet
Width x Depth	6x6 feet
Electricity consumption	11KW/hour
Height of main duct	25 feet
Bag Filter Material	Glass Fibre
Diameter of Bag	6 inches
Bag length	3.3 meter
Height of Bag	10 feet
No. of Bags	30
Physical properties of Glass Fibre (Bag Fabric)	
Maximum Continuous Operating Temperature	290 ^{o}C
Acid Resistance	Good
Alkali Resistance	Good
Alkali Resistance	Good
Flex abrasion resistance	Fair
Tensile Strength (kg/cm^2)	14,060

3. Results

Table 2 shows emission data of boilers having capacity of 06 tons with heavy furnace oil used as a fuel, the monitoring parameters are CO, NO, NO_x, SO_x and Temperature, O_2, CO_2, NO_2 and Smoke. Values depict that O_2 is 3.3%, CO_2 is 13.32%, CO is 388.68 mg/Nm^3, emission of NO is 192.72 mg/Nm^3, NO_2 is 30.45 mg/Nm^3, NO_x 223.17 mg/Nm^3, SOx 2597.22 mg/Nm^3, Smoke 20% and Temperature is 196.9 ˚C. Gas velocity through bags is 0.4–1 m³/min. PEQS provides no limits for O_2, CO_2, NO, NO_2, or temperature, but sets standards for CO (800 mg/Nm³), NOx (600 mg/Nm³), SOx (1700 mg/Nm³), and smoke (40%). Monitoring values remained below these limits.

After installation of bag house filter results show that values of O_2 (1.62%), CO_2 (6.48%), NO (121 mg/Nm$^{3)}$, NO_2 (14.21 mg/Nm^3), NO_x (135.21 mg/Nm^3), SO_x (1926.06 mg/Nm^3)and Temperature (135.7 ˚C)decreases but there is no significant change in smoke and CO is observed after installation as shown in Table 3. Percentage removal efficiency of pollutants after installation of bag house filter is calculated in Table 4. It shows that NO removal efficiency is 62.79%, NO_x 60.59% whereas highest removal efficiency of SO_x is observed which is 74.16%. Removal efficiency of O_2, CO_2 and NO_2 is less than 50%.Figure 5 also shows that maximum peak of CO and Smoke because value of smoke remain same and there is less difference in CO value before and after installation of bag house filter. Comparison between before and after installation of bag house filter is shown in Figure 4(a) and (b) which shows that after installation of bag house filter there is significant reduction in SO_x and NO_2 emissions.

Table-2. Boiler emissions before installation of Bag House Filter

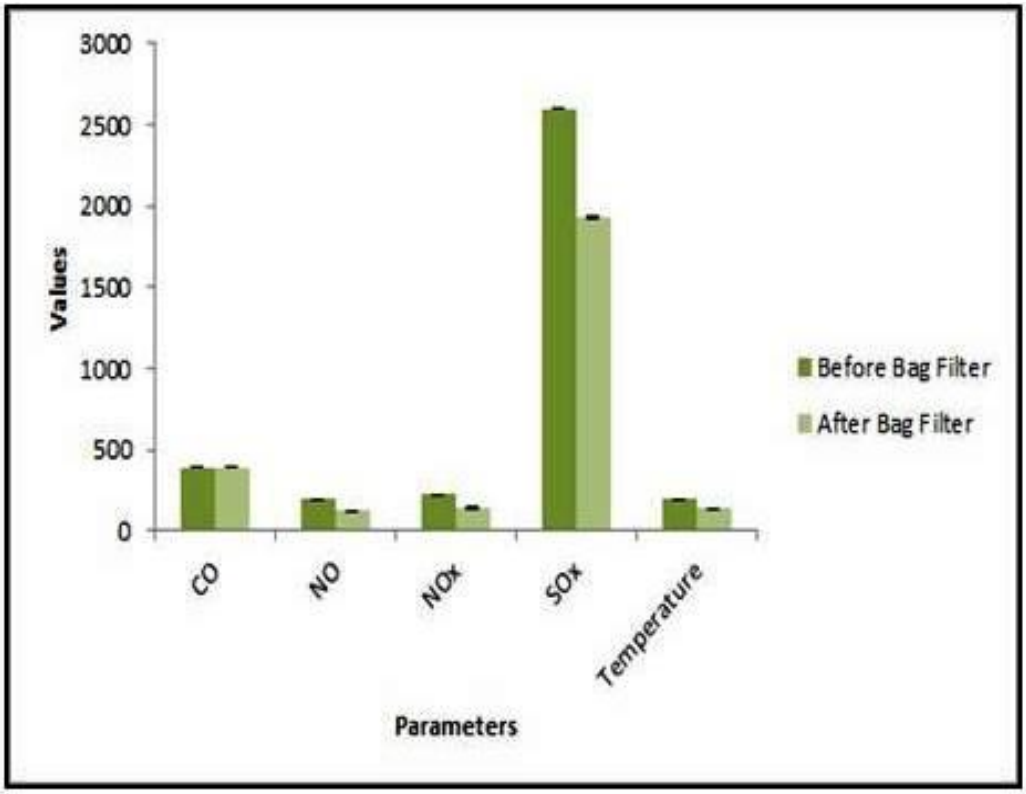
Sr. No	Parameters	Units	Methods	Reading 1	Reading 2	Reading 3	Average	Standard Deviation
1.	O_2	%	Electrochemical	3.3	3.31	3.3	3.3	0.01
2.	CO_2	%	NDIR Method 10	13.32	13.32	13.31	13.32	0.01
3.	CO	mg/Nm^3	OTM-39	391.1	391.1	391.21	391.14	0.06
4.	NO	mg/Nm^3	OTM-39	192.72	191.4	194.04	192.72	1.32
5.	NO_2	mg/Nm^3	OTM-39	30.45	32.48	28.42	30.45	2.03
6.	NOx	mg/Nm^3	OTM-39	223.17	223.88	222.46	223.17	0.71
7.	SOx	mg/Nm^3	USEPA Method 8	2597.22	2600.04	2594.40	2597.22	2.82
8.	Smoke	%	Ringelmann Scale	20	20	20	20	0.00
9.	Temperature	°C	-	197.6	196.2	196.8	196.9	0.70

Table-3. Monitoring of boiler emissions after installation of Bag House Filter

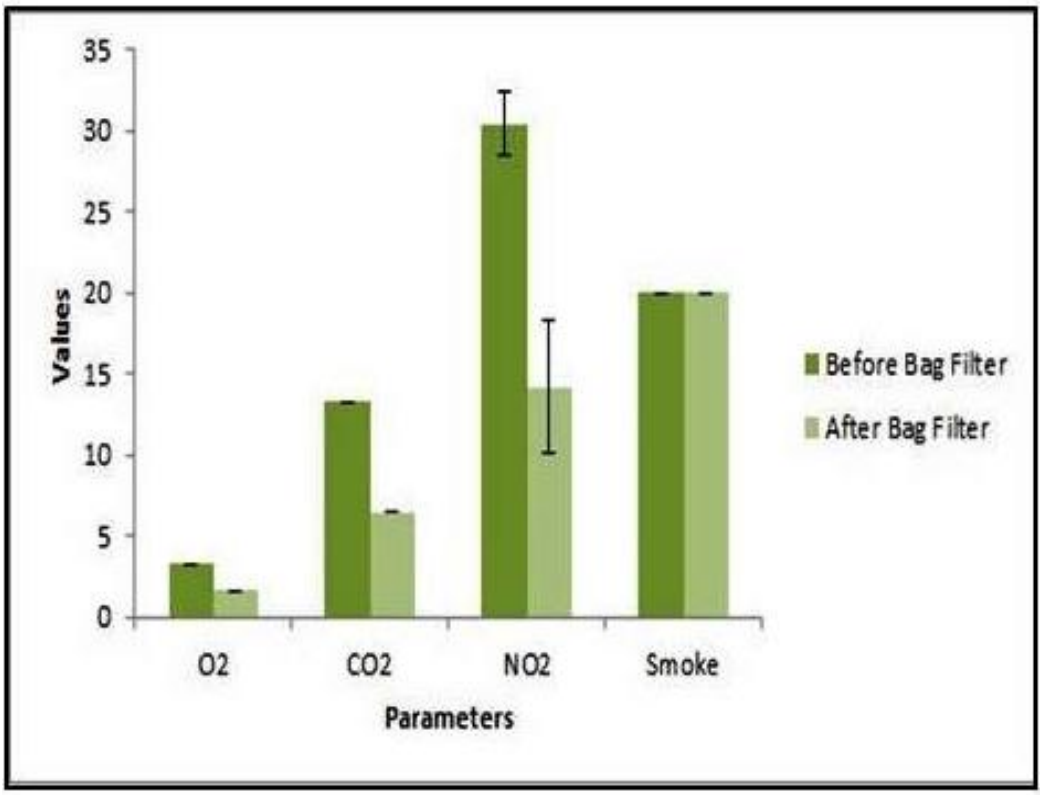
Sr. No	Parameters	Units	Methods	Reading 1	Reading 2	Reading 3	Average	Standard Deviation
1.	O2	%	Electrochemical	1.61	1.615	1.616	1.62	0.00
2.	CO2	%	NDIR Method 10	6.45	6.49	6.5	6.48	0.03
3.	CO	mg/Nm3	OTM-39	386.22	388.68	391.14	388.68	2.46
4.	NO	mg/Nm3	OTM-39	117.48	121.44	124.08	121	3.32
5.	NO2	mg/Nm3	OTM-39	10.15	14.21	18.27	14.21	4.06
6.	NOx	mg/Nm3	OTM-39	127.63	135.65	142.35	135.21	7.37
7.	SOx	mg/Nm3	USEPA Method 8	1917.6	1928.88	1931.7	1926.06	7.46
8.	Smoke	%	Ringelmann Scale	20	20	20	20	0.00
9.	Temperature	°C	-	135.4	135.8	135.9	135.7	0.26

Table-4. Removal Efficiency calculation of Bag House Filter

S. No	Parameters	Units	Before Installation	After Installation	%age efficiency
1.	O_2	%	3.3	1.62	49.09
2.	CO_2	%	13.32	6.48	48.65
3.	CO	mg/Nm^3	388.68	388.68	99.37
4.	NO	mg/Nm^3	192.72	121	62.79
5.	NO_2	mg/Nm^3	30.45	14.21	46.67
6.	NO_x	mg/Nm^3	223.17	135.21	60.59
7.	SO_x	mg/Nm^3	2597.22	1926.06	74.16
8.	Smoke	%	20	20	100.00
9.	Temperature	°C	196.9	135.7	68.92



(a)



(b)

Fig-4 (a) Calculated values of CO, NO, NO_x, SO_x and Temperature (b) O_2, CO_2, NO_2 and Smoke before and after installation of Bag House Filter

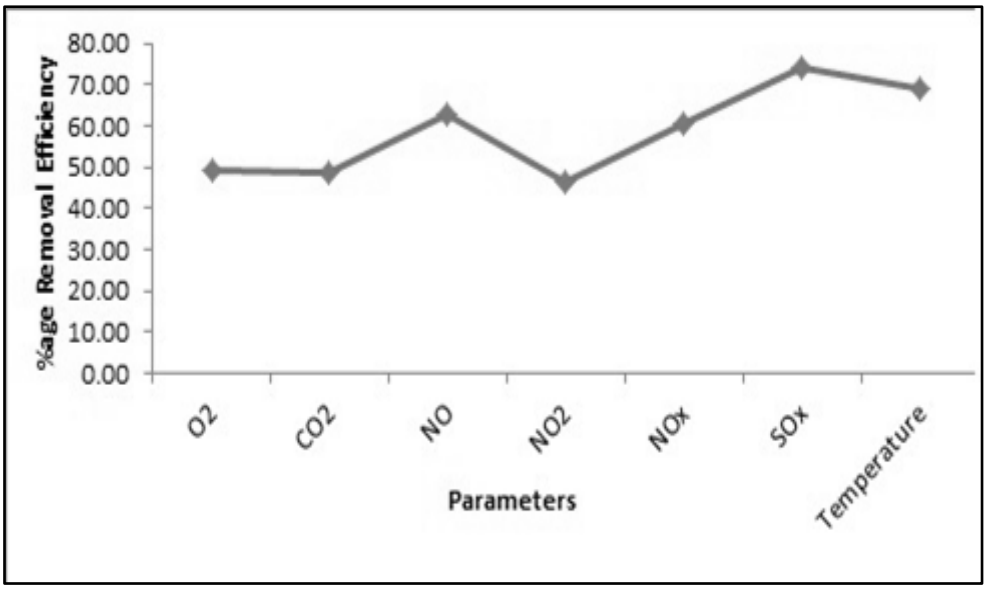


Fig-5. Percentage Removal Efficiency of parameters O_2, CO_2,, NO, NO_2, NO_x SO_x and Temperature of Bag House Filter

4. Discussion

In a study conducted by S. R. Malik et al. in 2009, it was observed that opting for natural gas as a fuel source could substantially reduce emissions. Natural gas primarily consists of methane, resulting in carbon dioxide and water vapor as the main byproducts during combustion similar to what we exhale when we breathe. In contrast, coal and oil are composed of more intricate molecules with higher carbon ratios, as well as elevated levels of nitrogen and sulfur. Consequently, the combustion of coal and oil leads to heightened emission levels of pollutants, including increased carbon emissions, nitrogen oxides (NOx), and sulfur dioxide (SO_2). Furthermore, coal and fuel oil release ash particles into the atmosphere, which are not combustible and contribute to environmental pollution. In contrast, using natural gas as a fuel produce less amount of sulfur dioxide and nitrogen oxide emissions negligible amount of ash or particulate matter and less quantities of carbon dioxide, carbon monoxide and other reactive hydrocarbons.

The most efficient approach for diminishing CO_2 levels involves a fuel transition. When utilizing natural gas for combustion, carbon dioxide emissions are notably reduced, with nearly a 30% decrease compared to oil and just under 45% decrease compared to coal (S.R.Malik et al. in 2009).

During the process of combustion, the carbon present in the fuel undergoes a series of reactions to ultimately form carbon dioxide (CO2). However, achieving complete conversion of carbon to CO2 is seldom accomplished in real-world scenarios, often resulting in partial oxidation to an intermediary stage, namely carbon monoxide.

CO levels tend to be higher in older boilers compared to newer ones, mainly due to the relatively recent recognition of CO as a significant issue. Older burner designs were not initially aimed at achieving low CO emissions. In this study, elevated carbon monoxide emissions largely stem from incomplete combustion, which can be attributed to inadequate burner design, suboptimal firing conditions (such as improper air-to-fuel ratio), or even potential furnace leaks. By adhering to proper burner upkeep, conducting regular inspections, appropriate operational procedures, and considering equipment upgrades or the incorporation of oxygen control mechanisms, it is possible

to manage and maintain carbon monoxide emissions at an acceptable threshold. (Energy Solution Centre Organization) .

Numerous experiments were undertaken to assess the impact of baghouse temperature on the removal of NOx. The baghouse temperature was adjusted within the range of 675°F to 850°F (357°C to 454°C) to identify the optimal operating conditions for effective NOx removal. The outcomes of the conducted tests indicated that, in conjunction with the employed catalyst, higher baghouse temperatures led to improved NOx removal it was deduced that achieving the project's objective of 90% NOx removal required a baghouse temperature within the range of 800°F to 850°F (425°C to 454°C). (Kudlac, G. A., 1992)

Sangras, R., et al in 2005 discovered that elevating temperatures within fuel-rich environments and prolonging the duration during which fuel-bound nitrogen is present can lead to a decrease in NOx emissions. This process involves the conversion of nitrogen into a molecule resembling CN, which subsequently transforms into N2, all occurring within fuel-rich conditions.

The group of nitrogen oxides, known as NOx, encompasses nitrous oxide (N2O), nitric oxide (NO), nitrogen dioxide (NO2), nitrogen trioxide (N2O3), and nitrogen pentoxide (N2O5). Among these, the main focus in relation to air pollution revolves around nitric oxide (NO) and nitrogen dioxide (NO2). Nitric oxide (NO), a colorless gas, acts as a precursor to NO2 and plays an active role in photochemical reactions that lead to the formation of smog. Nitrogen dioxide (NO2), which has a reddish-brown appearance, imparts the color to smog and can contribute to the visibility obstruction of flue gas plumes emitted from stacks.

Boilers are operated with an extra supply of air, known as excess air, to ensure complete combustion and safety. Among the factors impacting the generation of nitrogen oxides (NOx) within a boiler, the level of excess air is noteworthy. Elevated excess air levels can lead to heightened NOx production because the surplus nitrogen and oxygen from the combustion air combine within the flame, forming thermal NOx. The control of excess air intake is achieved through burner design and can be optimized using oxygen trim controls. For most boilers, adopting a strategy of firing with lower excess air is feasible and typically brings about a reduction of 5-10% in overall NOx emissions when natural gas is the chosen fuel (S.R.Malik et al. in 2009)

For industrial boiler operators, the most economically efficient approach to reducing SOx emissions involves the use of low sulfur fuels. Given that the levels of SOx emissions are predominantly tied to the sulfur content within the fuel, opting for fuels with lower sulfur concentrations (such as distillate oil) can lead to diminished SOx output. This reduction can be achieved without the necessity of installing and upkeeping costly equipment. The burning of sulfur-containing fuels, mainly oils and coals, produces pollutants in the forms of sulfur dioxide (SO2) and sulfur trioxide (SO3), collectively known as sulfur oxides (SOx). The quantity of SOx released is directly influenced by the sulfur content in the fuel. The emission levels of SOx are unrelated to the size of the boiler or the design of the burner. Typically, around 95% of the fuel's sulfur content is emitted as SO2, with 1-5% as SO3, and 1-3% as sulfate particulate. It's important to note that sulfate particulate is not considered within the overall assessment of total SOx emissions.

In contrast to NOx, SOx, and CO2, which exhibit reactivity and acidity, carbon monoxide is inert in nature. It possesses minimal dipole and quadrupole moments.

Standard adsorbents like activated charcoal, zeolites, and earth materials fail to comprehensively adsorb carbon monoxide due to its rapid desorption rate. When coexisting with other constituents of flue gas, the adsorption of carbon monoxide on these conventional adsorbents is insignificant. (Puranik and Puranik, 2019).

5. Conclusion

Air pollution is exerting detrimental effects on both human health and the environment. The emissions data obtained from boilers at shoes manufacturing industry underscores that notable amount of air emissions released when heavy furnace oil is used in boilers. The primary focus regarding air pollution revolves around primary pollutants i.e SO_X, NO_X, CO_2 and CO which pose risks not only individually but also contribute to the development of hazardous secondary pollutants such as ozone and acid rain. The simplest approach to mitigate pollution involves adopting eco-friendly fuels like natural gas and installation of air pollution control devices like bag house. The study shows that bag house plays an important role in highest removal efficiency of SO_x i.e 74.16% followed by NO 62.79% and NO_x 60.59%.

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PHYSICO-CHEMICAL AND MICROBIOLOGICAL WATER QUALITY ASSESSMENT OF MEHMOOD BOOTI DRAIN IN LAHORE CITY

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PHYSICO-CHEMICAL AND MICROBIOLOGICAL WATER QUALITY ASSESSMENT OF MEHMOOD BOOTI DRAIN IN LAHORE CITY

By:

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Abstract

In this case study water quality assessment of Mehmood Booti Drain in Lahore city was carried out on the basis of major physico-chemical and microbiological parameters. The pH values (ranging from 6.65 to 7.34) of all samples collected from two sites of the drain were found to be within the safe limits of NEQS guidelines. EC values varied from 825 to 1266 μS/cm suggested low contamination of major cations and anions in drain water while the sulphate ions concentration was well below the permissible limits. Total Suspended Solids (TSS) values of all water samples were higher than permissible limit of 200 mg/L (473 to 2675 mg/L). Very low average value of dissolved oxygen (0.29mg/L), showed that drain water contain high quantity of organic matter. BOD values (146-432 g/L) were also found to be much higher than the permissible NEQS limit i.e. 80 mg/L. Relatively higher COD values were detected which ranged from 210 to 705 mg/L. The value of nitrates was in the range of 4.2 to 21.8 mg/L. The value of ammonium varied from 12.5 to 36.21 mg/L. The total Kjeldahl nitrogen of these samples ranged from 28.4 to 50.4 mg/L and found 38.3 mg/L on average. Bacteriological analysis showed that water samples were heavily contaminated with total and fecal contamination. The maximum count of total coliform was noted $9.6x10^7$ and the minimum count was $9×10^4$. Maximum Fecal coliform count was $8.8×10^6$ and the minimum count was $2.0×10^4$.

Keywords: Water Quality Assessment, Physico-Chemical Parameters, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Mehmood Booti Drain

Introduction

Pakistan's growing population and depleting reserves are intensifying pressure on its water resources, pushing the country towards shortage and famine. In 2006, per capita water availability for irrigation was 1,100 cubic meters—barely above the 1,000 cubic meters minimum required to avoid being classified as water-short [1]. Water shortage has meant that access to potable drinking water is limited in many areas. The problems are exacerbated in the major cities by over extraction of groundwater and resulting in falling water tables. As a result, groundwater quantity has traditionally been a priority over quality issues in Pakistan. While this disaster demands to safe the quality of this small quantity of water [2].

Lahore is second largest city of Pakistan, lies in the upper Indus plain near the Indian border, at 31°34′N 74°20′E (31.560000 North, 74.35000 East). Ravi River is smallest of the five rivers of Punjab. Just above the Lahore city, the course of stream is carefully directed by the Mahmood Buti Bund, which keeps it to one channel and protect the city from the havoc of the floods. As much as 1,307.08 tones hazardous and untreated waste, mostly industrial, is going into the Ravi on a daily basis, making it poisonous [3]. As per the study, share of district Lahore in polluting the Ravi is 56 percent i.e. is 728.75 tons per day. About 10 drains and pumping stations and five industrial

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wastewater drains were throwing over 2,000 cusec municipal sewage and toxic industrial effluents into the river. It revealed that according to international standards, the level of biological official demand (BOD) in the river water should be 80 mg/L whereas the level of BOD in the water of 10 drains and pumping stations ranged between 129 mg/L and 430 mg/L. Likewise, BOD in the water of five drains throwing toxic industrial waste into the river ranged between 24 mg/L and 360 mg/L [4].

The EPA conducted a study of drains which are discharging municipal and industrial water in the Ravi. According to the study Babu Sabu Drain, Lahore, is discharging 270.7 cusec waste water per second in the river, Furukhabad Drain 219 cusec, Main Out Fall Drain193 cusec, Gulshan-e-Ravi Drain 243.5 cusec , Hudiara Drain 535.7 cusec, Shahbagh Drain 139 cusec, Sukhnehr Drain 313.6 cusec, Buda Ravi Drain 41.9 cusec, Foresh Colony Drain 15.37 cusec, Muhmood Booti Drain 20.87 cusec, Shahdra Town Drain 21.87 cusec, Summundari Drain, Faisalabad, 400 cusec, Deg Nullah/Jaranwal Drain, Faisalabad, 100 cusec, Gojra Drain, Toba Tek Singh, 45 cusec, and Sukhrawa Drain, Shiwal is discharging 53 cusec liquid waste per second in the river [5]. The toxicity of water and plankton in the River Ravi stretchfromLahore siphon to Baloki head works and related effluent discharging tributaries has been studied. [6]. It was reported that there is the serious groundwater issue which is influencing health metabolic system [7]. The residue of hydrocarbons, organic and inorganic pollutants, moving along fault, leaching and seepage are contaminating the ground water aquifer which can be the source of drinking water [8].

In present study a survey was conducted in Lahore for waste water quality assessment from two identified sites of Mehmood Booti Drain. The aim of this study was to record different physico-chemical parameters and microbiological parameters like pH, Temperature, Total Suspended Solids, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Relative Humidity (rH), Sulphate, Total Hardness, Nitrate as N, Ammonium as N, Total Kjeldhal Nitrogen and Microbiological contamination. This study uniquely combines detailed water quality profiling with a focus on the linkage between urban wastewater discharge and downstream riverine health. The data aim to enhance understanding of pollutant sources, assess compliance with environmental standards, and provide actionable insights for wastewater management strategies. This research will be valuable for environmental scientists, policymakers, and water resource managers as it helps identify the main sources of pollution

Materials and Methods

The water quality assessment of Mehmood Booti Drain in Lahore, a densely industrialized area, was conducted following the Standard Operating Procedures (SOPs) set forth by the American Public Health Association (APHA) for wastewater sampling and analysis [9]. Sampling was carried out at two key sites along the drain to represent different points of possible industrial discharge. Each sample was collected in sterilized glass bottles and immediately preserve to maintain integrity until analysis.

Location of Sampling Points

Mehmood Booti drain was selected for the study. First sampling point (site-1) is located near the Lahore Compost at Band Road Lahore at Latitude 31°36’35”, Longitude 74°22’38” and at 204m elevation, whereas the second point (site-2) is near the Rani

Chowk of Village Bhamma at Latitude 31°37’10”, Longitude 74°20’04”and at 200m elevation The Locations of both sampling points are marked in the figure (1).

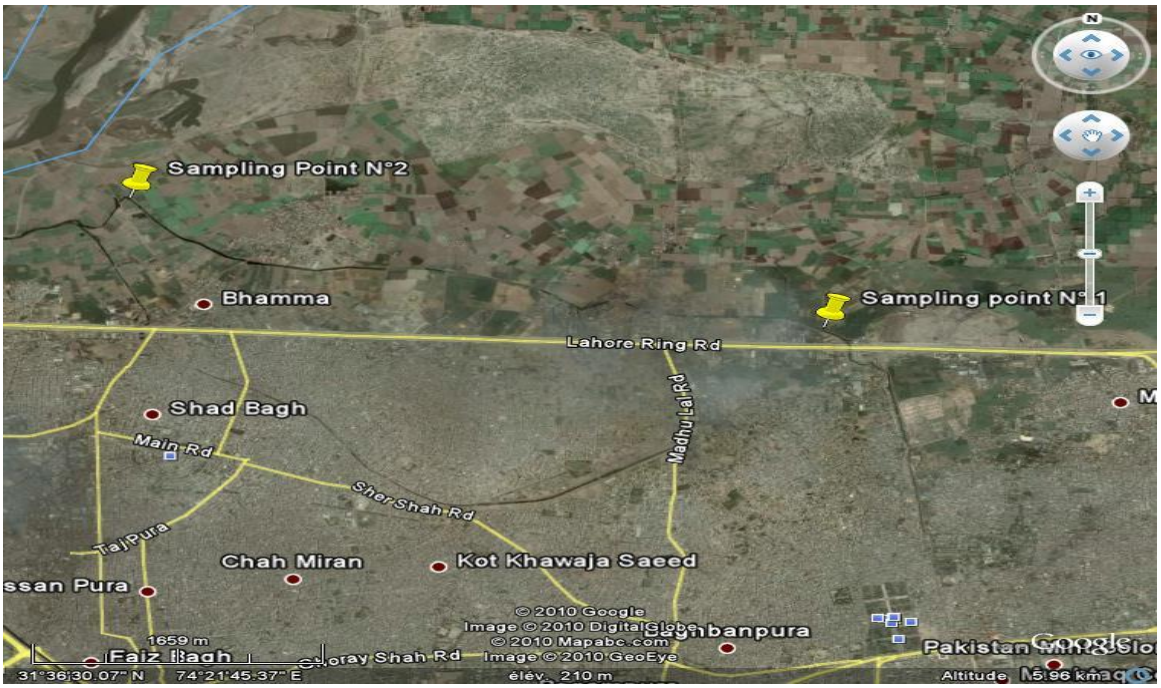


Figure-1 Sampling sites of Mehmood Booti drain

Sample Collection

The waste water sampling was made for continuous five days from 1st June to 5th June 2020. Two water samples were collected daily from each site (one in morning and other in evening time). In morning session water samples were collected round about 10 O’clock. This time maximum effluent flow was observed in the sewage drains of the city. In evening session, the samples were taken about 6 O’clock.

The samples were collected from the representative points with the help of the auto-sampler at depth of about 1.5 feet from surface. The sample of each shift and date was given a specific identified detailed code, showing the sample number and site identification, e.g. 7-S-1 means sample number 7 and site number 1. (Table 1)

Table-1: Sampling Information and weather conditions

Serial No.	Site No.	Time	Sample ID	Temper-ature °C	General Weather condition*	Relative Humidity (Percent)
1	1	10:15	1-S-1	39.3	Dry and sunny	24
2	2	10:35	2-S-2	42.0	Dry and sunny	27
3	1	18:04	3-S-1	39.4	Dry and sunny	20
4	2	18:22	4-S-2	36.2	Dry and sunny	22
5	1	10:10	5-S-1	39.0	Dry and sunny	20
6	2	10:35	6-S-2	45.4	Dry and sunny	22
7	1	18:10	7-S-1	38.3	Dry and sunny	24
8	2	18:32	8-S-2	41.6	Dry and sunny	20
9	1	10:00	9-S-1	30.3	Sunny and airy	29
10	2	10:38	10-S-2	29.9	Sunny and airy	28
11	1	18:05	11-S-1	39.2	Cloudy and dry	26
12	2	18:40	12-S-2	32.8	Cloudy and airy	45
13	1	9:50	13-S-1	36.6	Cloudy and dry	40
14	2	10:30	14-S-2	33.4	Cloudy and airy	49
15	1	17:30	15-S-1	36.8	Cloudy and airy	36
16	2	18:15	16-S-2	28.4	overcast	59
17	1	9:53	17-S-1	36.4	Sunny and airy	33
18	2	10:25	18-S-2	41.5	Sunny and airy	26
19	1	17:55	19-S-1	35.9	Sunny and airy	28
20	2	18:15	20-S-2	33.7	Sunny and airy	28
Minimum				**28.4**		**20**
Maximum				**45.4**		**59**

The parameters (subject to change during storage and shifting to laboratory) such as pH, electrical conductivity, temperature, dissolved oxygen, weather temperature, sample temperature and relative humidity were determined at the site in the field. For rest of the parameters the samples were preserved in good conditions according to the requirements of each parameter. The detail of the preservation is summarized in the table 2.

Table-2 Types of water samples & Preservative

Type	Sites	Parameter	Preservative	Quantity added
A	All	Microbiology	1.8% solution of sodium thiosulfate as dechlorinating agent	0.1 mL/100mL
B	All	COD, Total Kjeldahl Nitrogen (TKN)	Conc. H_2SO_4 to maintain pH less than 2	1mL/500mL
C	All	Nitrate (N)	1M Boric acid	5mL/500mL
D	All	Hardness, pH, EC,	No Preservative added	None
E	All	BOD	Allyl Thiourea	1mL/500mL
F	All	Stored at 0°C as	No Preservative added	Not required
G	All	Ammonium (N)	Hydrochloric Acid to	1mL/500mL

The samples collected from the site were transferred to the lab in ice box to keep the chemical and microbial constituents as stable as possible. All the collected samples were analyzed in the laboratory by MPN dilution method for the waste water samples. Dilutions were made with sterilized peptone water.

Analysis of Water Samples

The water samples were analyzed for major parameters namely Temperature, Total Suspended Solids, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Relative Humidity (rH), Sulphate, Total Hardness, Nitrate as N, Ammonium as N, Total Kjeldhal Nitrogen and Microbiological contamination. Some necessary parameters were tested at site, while the others were analyzed in the laboratory. For quality assurance the blank and certified reference materials were run on the instruments before the analysis of the samples. The samples were analyzed for the committed parameters using the test methods given in Table 3.

Table-3 Water Quality Parameters and Standard method of Analysis [10]

S. #	Water Quality Analysis Parameters	Test Methods
1.	Hardness (mg/L)	EDTA Titration, Standard Method (1992)
2.	TSS (mg/L)	Colorimeter DR2800
3.	Sulfate (mg/L)	4500 SO_4, Standard Method (1992).UV-Visible Spectrophotometer, SPECORD 200, Analytikjena
4.	Nitrate-N (mg/L)	4500 NO_3, Standard Method (1992), UV-Visible Spectrophotometer, SPECORD 200, Analytikjena

5. Microbiological Analysis	APHA (1992 Edition) 9221B, Multiple Tube Fermentation Technique for Colform Group (MPN Method)
6. NH_4^+ -N	Salicylate Method, 10031Colorimeter DR2800
7. Water Temperature	Thermometer, Immersion GH Zeal England N2 Filled
8. BOD	5-Day BOD method
9. COD	Reactor Digestion Method 8000, Colorimeter DR-2800
10. DO	DO Meter, Model 970; Jenway
11. Total Nitrogen	Total Kjeldahl Nitrogen Method (TKN)
12. Relative Humidity (rH)	With Relative Humidity Meter
13. pH	pH Meter, Hanna Instrument Model HI 991301, Italy

Bacteriological Parameter (with dilution method for waste water analysis

Bacteriological analysis of water samples was conducted using the multiple fermentation technique, following APHA, AWWA, and WEF standards. Seven tubes each of MacConkey Broth (for total coliforms) and Brilliant Green Lactose Bile Broth (for fecal coliforms) were inoculated with varying volumes of water and incubated at 35°C and 44°C respectively for 48 hours. Gas and acid production indicated positive presumptive tests, and results were reported as Most Probable Number (MPN) per 100 mL.

Results and Discussion

Weather Conditions at the Time of Sampling

The lowest temperature (28.4°C) was recorded on 4th June 2020 at site 2 but the highest temperature (45.4°C) was observed on 2nd June 2020. The average temperature during the whole monitoring remained 36.80°C. Hot air flows with sunny days prevailed during most of the days but in some sessions cool and cloudy conditions were also prevailed. The humidity on the average remained about 30% but it was noted 59% in a single case due to airy and overcast condition [Table 1] A line graph illustrates the daily temperature variations, with indicators highlighting the extreme temperatures on June 2 and June 4, and a reference line for the average temperature. The humidity levels are presented on the same graph using a bar graph, showing fluctuations against the temperature trends. This visual presentation highlights the inverse relationship between temperature and humidity, especially on days with notable weather shifts as shown in figure 2.

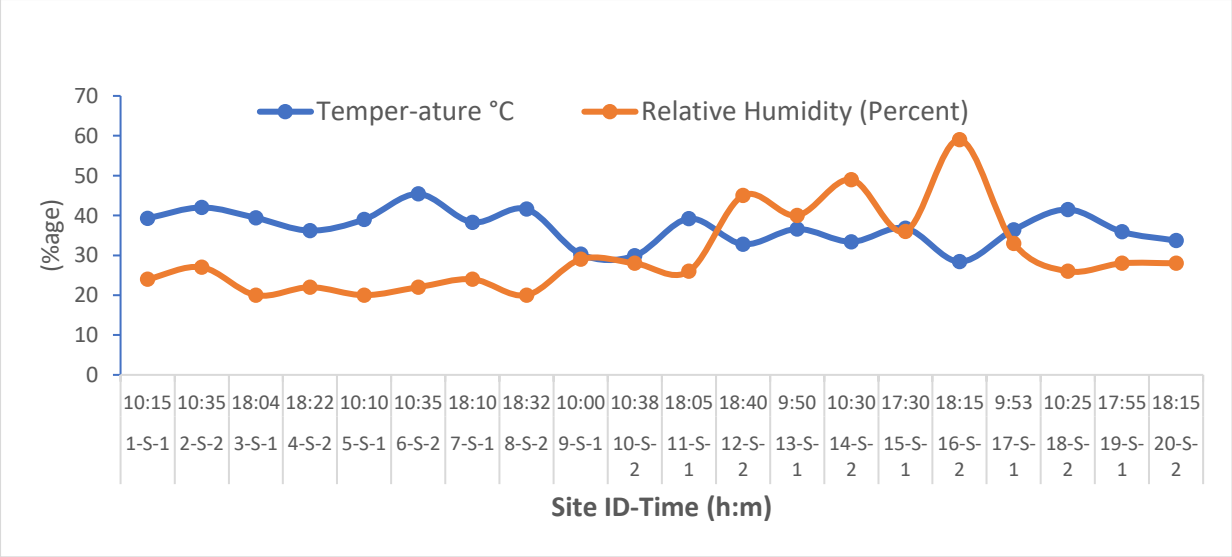


Figure-2 Temperature (ºC) and humidity (% age)

Physico-Aesthetic Parameters

Table 4 presents analytical data for physical parameters (pH, EC, DO, TSS, and temperature). The pH, governed by the carbonate–bicarbonate–CO_2 system, ranged from 6.65 to 7.34, indicating all samples fall within the safe limits of NEQS guidelines (6-9).

EC of the water samples was 825 to 1266 μS/cm and on average to 1065 (Table 4). As EC indicates the concentration of salts in water sample, so it can be inferred that there is a low contamination of major cations and anions in drain water.

Table-4: Physico-Aesthetic Parameters

Serial No.	Sample ID	Sample Temperatu	EC (μS/c	TSS (mg/	pH	DO (mg/	BOD (mg/ L)	COD (mg/
Permissible limits		**=<3°C**	**NGVS**	**200**	**6-9**	**<4**	**80**	**150**
1	1-S-1	36.0	1136	558	7.1	0.41	190	241
2	2-S-2	34.7	1070	705	7.1	0.42	179	210
3	3-S-1	32.5	1266	2215	6.6	0.36	212	267
4	4-S-2	32.3	1179	1010	7.1	0.32	218	287
5	5-S-1	33.3	1128	743	7.2	0.35	235	332
6	6-S-2	33.4	966	473	7.2	0.26	267	309
7	7-S-1	35.3	1073	828	7.1	0.13	432	705
8	8-S-2	33.8	1110	898	7.1	0.25	261	318
9	9-S-1	29.6	1018	756	7.2	0.21	238	405
10	10-S-2	32.6	980	782	7.1	0.19	365	591
11	11-S-1	33.4	1061	980	7.2	0.20	272	402
12	12-S-2	30.2	1055	996	7.0	0.27	250	337
13	13-S-1	31.6	1057	872	7.1	0.23	273	442
14	14-S-2	32.5	902	784	7.1	0.39	225	296
15	15-S-1	32.7	1071	924	7.2	0.25	290	413
16	16-S-2	29.0	825	2675	7.0	0.18	367	529
17	17-S-1	31.1	1060	540	7.3	0.23	261	334
18	18-S-2	32.1	1015	1254	7.0	0.38	176	266

19	19-S-1	32.9	1213	2410	6.8	0.42	146	250
20	20-S-2	33.4	1109	1785	7.0	0.38	161	270
Minimum		**29.0**	**825**	**473**	**6.6**	**0.13**	**146**	**210**
Maximum		**36.0**	**1266**	**2675**	**7.3**	**0.42**	**432**	**705**
Average		**32.6**	**1065**	**1109**	**7.1**	**0.29**	**146**	**210**

Total Suspended Solids (TSS) in the all collects water samples were found crossing the permissible limits of 200 mg/L (Table 4). The TSS value ranges from 473 to 2675 mg/L in these samples. The high values of TSS, results in increase of temperature and depletion of dissolved oxygen [10].

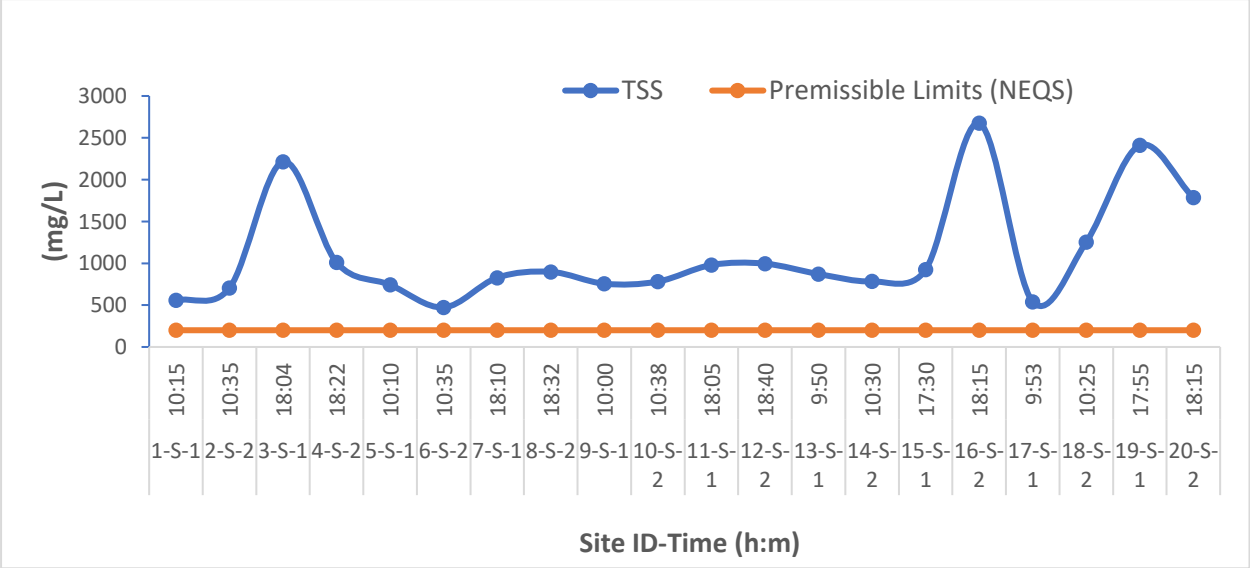


Figure-3 Total suspended solids

The graph as shown in figure 3 illustrates the TSS variations across the samples, clearly showing the degree to which each sample surpasses the permissible threshold. This visual highlight the potential impact of high TSS on water quality, temperature, and oxygen availability, underscoring the need for intervention to control suspended solids in these water sources

The dissolved oxygen (DO) levels in the drain water samples were notably low, ranging from 0.13 to 0.42 mg/L, with an average of 0.29 mg/L. These values fall significantly below the minimum recommended level of 2 mg/L necessary to sustain aerobic conditions and prevent harmful effects on aquatic life. [12]. The figure 4 visually emphasizes this trend, displaying DO levels for each sample, all of which are far below the threshold. The low DO levels reflect high organic matter content in the water, likely leading to anaerobic conditions that produce bad odors. This graphic underline the urgent need for interventions to reduce organic load and improve oxygenation to protect aquatic ecosystems and environmental quality

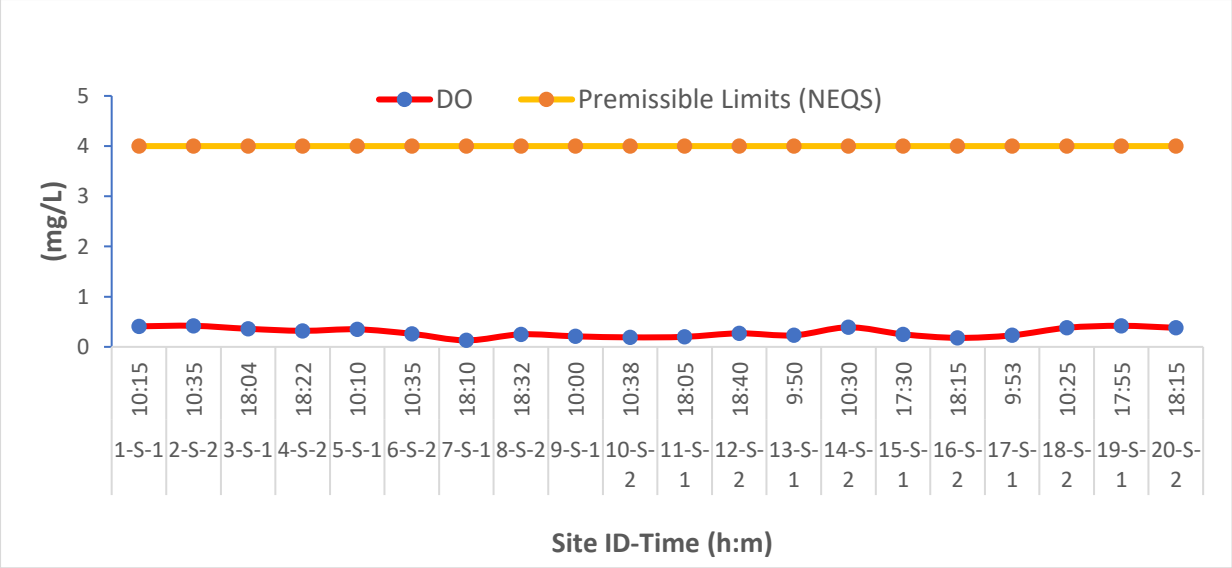


Figure-4 Dissolved Oxygen (DO)

Biological Pollutants

Biological oxygen demand (BOD) of the collected samples found in the range of 146 to 432 mg/L. These values are much higher than the permissible NEQS limit i.e. 80mg/L. So, these values show that the water dumping in the River Ravi requires treatment for the safety of the River Ravi and the environment. The Biological Oxygen Demand (BOD) levels in the collected water samples ranged from 146 to 432 mg/L, significantly exceeding the NEQS permissible limit of 80 mg/L (Table 4). The graph illustrates (Figure 5) these elevated BOD levels across samples, each far surpassing the threshold. Such high BOD values indicate a substantial presence of organic pollutants, highlighting the urgent need for treatment before discharging this water into the River Ravi. Reducing BOD is critical to protect the river's ecological balance and prevent further environmental degradation [13]. This graphical representation emphasizes the severity of pollution and the necessity for wastewater management

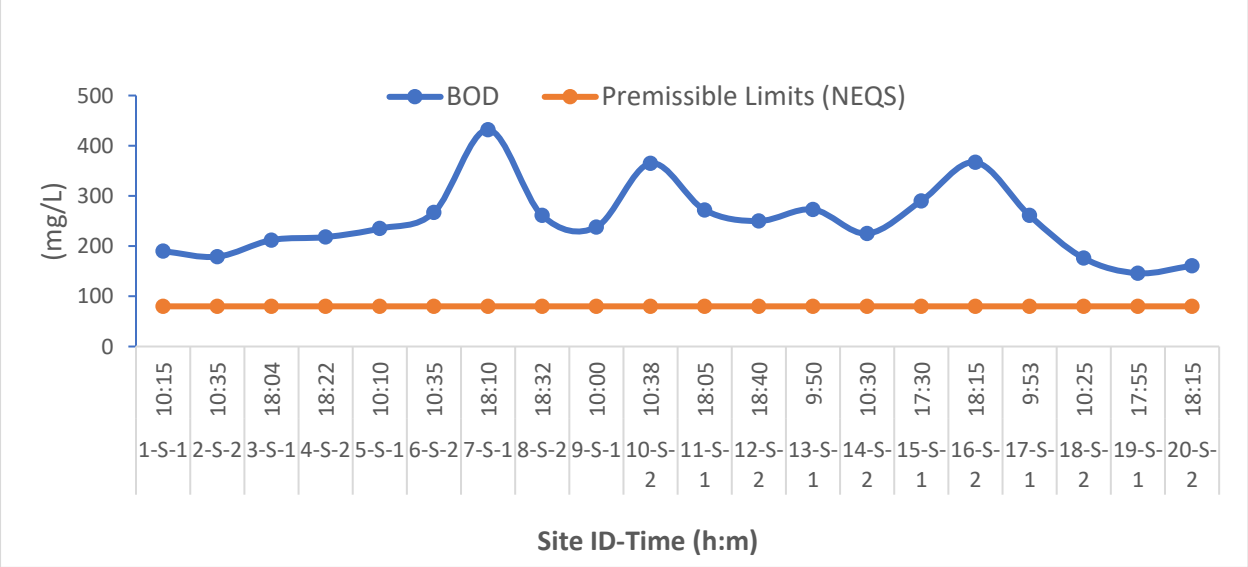


Figure-5 Biological oxygen demand (BOD)

Chemical Oxygen Demand (COD), closely linked with BOD and DO, serves as an indicator of organic and chemical pollution. COD values in the drain ranged from 210 to 705 mg/L, providing strong evidence of biological contamination (Table 4).

The Chemical Oxygen Demand (COD) levels in the drain water samples ranged from 210 to 705 mg/L, reflecting substantial organic and chemical contamination. The graph demonstrates (Figure 6) these elevated COD values, underscoring the drain's high levels of biological pollution. Since COD is closely linked to Biochemical Oxygen Demand (BOD) and Dissolved Oxygen (DO), the high COD values further corroborate the findings of low DO levels and elevated BOD, indicating an environment rich in organic matter. These conditions are detrimental to water quality, signaling the need for treatment to reduce organic pollution and prevent negative impacts on aquatic life

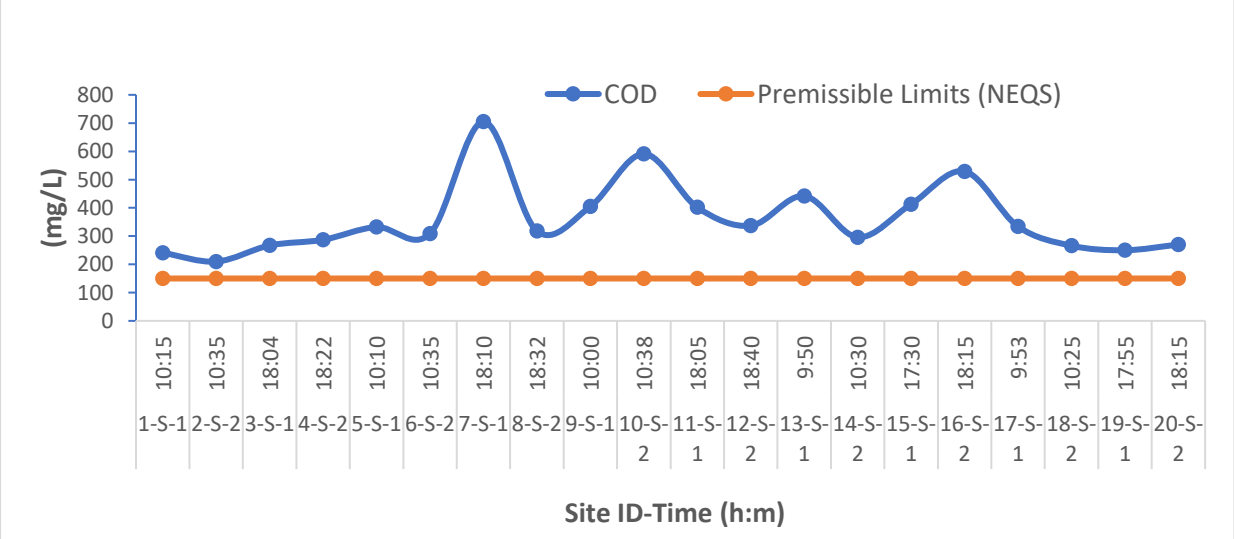


Figure-6 Chemical oxygen demand (COD)

Nitrogen Contamination

Nitrogenous contaminants in water samples included nitrates (4.2–21.8 mg/L), ammonium (12.5–36.21 mg/L), and total Kjeldahl nitrogen (28.4–50.4 mg/L; avg. 38.3 mg/L). Nitrates mainly originate from biological oxidation, while high ammonia levels cause foul odor and are toxic to freshwater organisms at 0.53–22.8 mg/L. Detailed data are presented in Table 5.

Table-5: Nitrogen Contamination

Sample ID	Nitrate (mg/L)	Ammonium (mg/L)	Total Kjeldahl Nitrogen	Sulphate (mg/L)	Total Hardness (mg/L)	Total Coliform	Fecal Coliform
Permissible	**NGVS**	**40**	**NGVS**	**600**	**NGVS**	**MPN/100 mL**	**MPN/100 mL**
1-S-1	10.5	32.25	44.4	10	235	$2.0x10^7$	$5x10^6$
2-S-2	10.7	36.21	50.4	8	235	$8.8x10^6$	$2.2x10^6$
3-S-1	4.2	24.65	30.2	40	230	$3.8x10^5$	$2.0x10^5$
4-S-2	6.5	31.57	38.8	9	230	$2.4x10^6$	$3.8x10^5$
5-S-1	12.9	36.02	49.6	16	235	$2.1x10^7$	$7.6x10^6$
6-S-2	8.7	19.51	32.2	47	215	$3.8x10^7$	$8x10^6$
7-S-1	16.2	29.47	46.2	17	230	$9.6x10^7$	$8.8x10^6$
8-S-2	21.8	27.68	49.9	25	240	$3.8x10^7$	$7x10^6$

Sample ID	Nitrate (mg/L)	Ammonium (mg/L)	Total Kjeldahl Nitrogen	Sulphate (mg/L)	Total Hardness (mg/L)	Total Coliform	Fecal Coliform
9-S-1	17.1	15.1	33	13	235	$2.1x10^7$	$5x10^6$
10-S-2	18.8	12.5	32.6	14	215	$1.4x10^7$	$7.6x10^6$
11-S-1	19.6	22.24	43.8	19	230	$1.1x10^7$	$2x10^6$
12-S-2	12.2	22.78	36.2	39	235	$8.8x10^6$	$2x10^6$
13-S-1	15.9	19.2	36.2	14	225	$9x10^6$	$2.2x10^6$
14-S-2	8.9	18.58	28.4	18	220	$3.8x10^7$	$7.6x10^6$
15-S-1	13.5	17.2	31	20	230	$1.5x10^5$	$5x10^4$
16-S-2	21.4	18.9	41.6	67	240	$1.2x10^5$	$8.8x10^4$
17-S-1	19.7	14.6	35.8	6	225	$9.6x10^5$	$8.8x10^4$
18-S-2	18.1	15.74	34.9	9	230	$9x10^4$	$2.0x10^4$
19-S-1	21.4	12.86	35.8	124	230	$3.8x10^5$	$9x10^4$
20-S-2	15.6	18.9	35.6	55	240	$1.5x10^5$	$2.2x10^4$
Minimu	**4.2**	**12.5**	**28.4**	**6**	**215**	**$9x10^4$**	**$2.0x10^4$**
Maximu	**21.8**	**36.21**	**50.4**	**124**	**240**	**$9.6x10^7$**	**$8.8x10^6$**
Average	**14.7**	**22.30**	**38.33**	**28.5**	**230**	**$4.4x10^6$**	**$5.3x10^5$**

Chemical Contamination

Water hardness, imparted by calcium and magnesium ions, ranged from 215 to 240 mg/L. Sulphate concentrations varied from 6 to 124 mg/L, remaining well below NEQS permissible limits. Detailed chemical data are presented in Table 5.

Microbiological Contamination

The maximum count of total coliform was noted in sample is $9.6x10^7$ and the minimum count was $9x10^4$. Maximum fecal coliform count was $8.8x10^6$ and the minimum count was $2.0x10^4$. The analytical values of Total Coliform and Fecal Coliform (E. coli) are presented in Table-5.

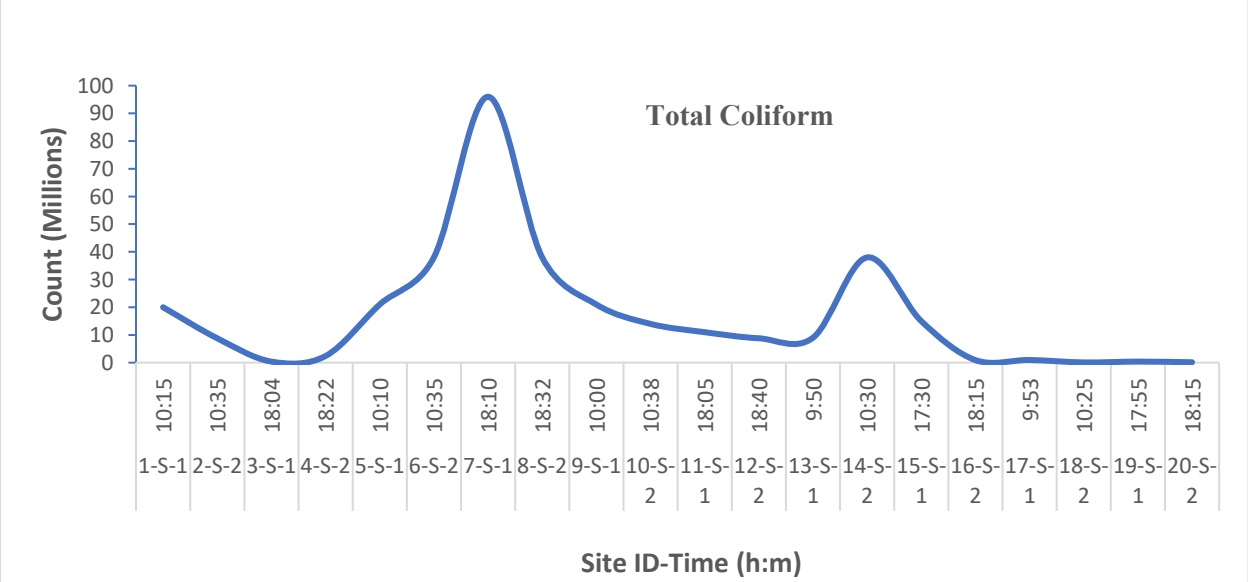


Figure 7 Total Coliform

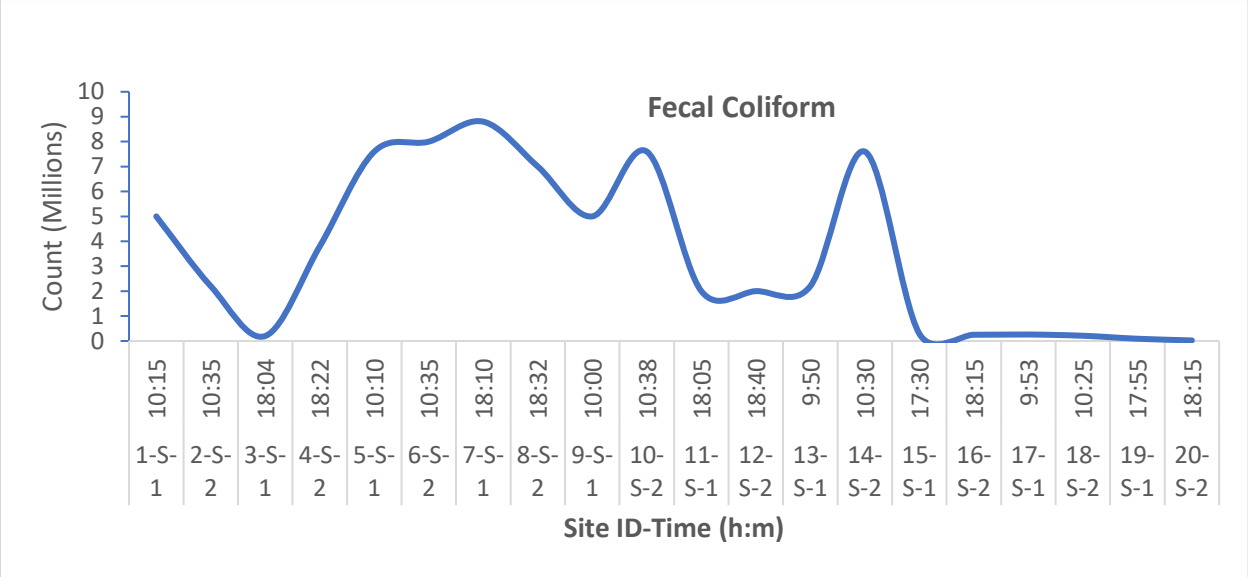


Figure-8 Fecal Coliform

Coliform presence indicates biological pollution, with drain water heavily contaminated by total and fecal coliforms. Figures 7 and 8 show counts exceeding safe limits. Untreated organic matter containing fecal coliforms can deplete dissolved oxygen during aerobic decomposition, threatening fish and aquatic life [12].

Conclusion

The water quality assessment of the Mehmood Booti Drain in Lahore reveals significant contamination, particularly in terms of organic and suspended solids content. While pH values (6.65–7.34) were within the NEQS guideline, indicating overall acidity/alkalinity stability, other parameters exceeded permissible limits. Elevated Electrical Conductivity (EC) levels (825–1266 µS/cm) suggest moderate ionic contamination. High levels of Total Suspended Solids (473–2675 mg/L) surpass the NEQS limit, indicating considerable particulate pollution. Dissolved oxygen (DO) levels were critically low (0.29 mg/L), reflecting high organic load, with Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) levels (146–432 mg/L and 210–705 mg/L, respectively) far above the acceptable standards, further confirming organic pollution. Nitrate levels (4.2–21.8 mg/L) and elevated ammonium and Total Kjeldahl Nitrogen (TKN) values reveal nutrient loading, which can lead to eutrophication if discharged untreated into waterways.

Recommendations

1. **Treatment Interventions**: Establishment of wastewater treatment facilities is essential to reduce organic load, TSS, BOD, and COD levels before the water is discharged into the River Ravi.
2. **Aeration Techniques**: Implementing aeration systems can increase dissolved oxygen levels, which would help reduce the impact of organic pollution and improve conditions for aquatic life.
3. **Nutrient Control**: Reducing nutrient concentrations (nitrates and ammonium) is crucial to prevent eutrophication. This could involve adopting nutrient-removal techniques in treatment processes.

4. **Regular Monitoring**: Continuous monitoring of physico-chemical and microbiological parameters is recommended to detect pollution trends and assess the effectiveness of treatment interventions over time.
5. **Public Awareness and Policy Enforcement**: Raising awareness about the impacts of untreated waste discharge and enforcing regulatory compliance with NEQS can encourage industrial and municipal entities to take responsibility for their effluents.
6. **Green Buffer Zones**: Establish green buffer zones with vegetation along the drain to naturally filter runoff, potentially reducing suspended solids and nutrient concentrations through bio-filtration

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REAL-TIME & PREDICTIVE ANALYSIS OF SEA SURFACE TEMPERATURE VARIABILITY IN EL NINO AND LA NINA WEATHER CYCLE ALONG PAKISTAN COAST

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REAL-TIME & PREDICTIVE ANALYSIS OF SEA SURFACE TEMPERATURE VARIABILITY IN EL NINO AND LA NINA WEATHER CYCLE ALONG PAKISTAN COAST

By

Rizwan Akhtar[1], Tahreem Zafar[1], Bassam Nasir[1], Ibrahim Zia[1]

Abstract

This study observes sea surface temperature (SST) trends in the Arabian Sea near the Pakistan Coastline. It explores how SST anomalies may arise from global warming, climate change, and impacts on coastal ecosystems. Identifying these trends is important for climate science for ocean and marine ecosystems. SST may significantly impact coastal erosion by increasing storms, raising sea levels, and changing wave patterns. To analyze SST, this research uses Google Earth Engine (GEE) and machine learning techniques. GEE is a cloud-based platform for processing remote sensing data. It provides advanced capabilities for analyzing satellite imagery. The in-situ Data provided by National institute Of Oceanography Pakistan. Particularly, this study uses Ocean Color SMI: Standard Mapped Image MODIS Aqua Data Level 3.the Comparative analysis of the Hybrid Coordinate Ocean Model (HYCOM) provides global ocean data with a spatial resolution of 0.08 degrees (approximately 9 km) from 2003 to the present. The HYCOM data subset available in GEE includes variables such as salinity, temperature, velocity, and elevation. This data durations over 18 years (2003-2022) and focuses on regions like the Arabian Sea. GEE data showed two distinct periods of increasing sea surface temperature (SST) from 2003 to 2022. The first period was from 2003 to 2010, and the second was from 2011 to 2022. Both periods had positive SST anomalies. In June 2007 and 2010, significant changes in sea surface temperature observed near Pakistan Coastline. These changes happened during the Guno and Phet cyclones. The temperatures ranged observed from 31.72°C to 33.9°C and in The Phet cyclone period the temperatures ranged from 30.8°C to 30.9°C. respectively. The increasing SST trend may continue if no intensive measures are taken to address this issue. The analysis aims to improve our understanding of SST dynamics and their effects on climate and marine environments.

Keywords: Sea Surface Temperature anomalies, MODIS, HYCOM, Google Earth Engine, Cloud base processing, Coastal Ecosystem, Global Warming, Climate Science, Coastal Erosion.

Introduction

Increasing the sea surface temperatures (SST) and the absorption of carbon dioxide in the Ocean, along with alternative greenhouse gas emissions might change the sea surface temperature in the Arabian Sea causing the impact of global warming.SST directly impacts the melting of ice glaciers. As a result of this phenomenon, higher sea level rise can affect the coastal zone. The effect of sea surface temperature is not only the Sea level rise but other climate changes such as long-term drought, cyclone or storm surges, heat waves and flash floods in low-lying coastal areas that may cause Sea water intrusion.[1][2]. Sea water intrusion is due to natural and anthropogenic processes. Sea level rise associated with climate change by way of changes to atmospheric pressure, expansion of oceans/seas as the warm, melting of ice sheets

[1] National Institute of Oceanography

and glaciers is one significant process that plays a role in sea water intrusion. The SST had risen from 0.1 to 0.6 °C at the coastal area of Pakistan, in the early of 90's. The number of research shows that an increasing trend of 0.2 °C per decade on the Coastal region of Pakistan. However, the rate observed a higher SST rate near the Karachi coast due to the instant industrial development and higher air temperature[3]. SST trend analysis could use historical data, representing an annual increase of 0.0138 °C. It anticipates the SST for the next 25 years based on these historical figures. Up to 2045, the predicted SST indicates a higher value of 0.35 °C.[1].

According to The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5), The mean ocean surface temperature increased by 0.88°C [0.68–1.01°C] from 1850–1900 to 2011–2020 and with 0.60°C [0.44–0.74°C] of this increase appearing since 1980. Under the Shared Socioeconomic Pathways (SSP1-2.6) scenario, the estimates suggested that the sea surface temperature will rise by an average of 0.86°C [0.43–1.47°C, range] from 1995–2014 to 2081–2100. In the SSP5-8.5 scenario, the temperature is expected to increase by 2.89°C [2.01–4.07°C, range]. The Indian Ocean, as well as Western Boundary Currents, have shown the greatest rapid anomaly of surface warming since the 1950s, while ocean circulation in the Southern Ocean, equatorial Pacific, North Atlantic, and coastal upwelling systems has resulted in slower warming or cooling of the surface (extremely high confidence). At least 83% of the ocean surface is expected to increase warm very much over the 21st century in all SSP scenarios.[4]. The biodiversity of marine environments is impacted by variations in sea surface temperature (SST). SST variations may boost biodiversity in some areas such as the Gaeta Gulf, but they can also be detrimental to marine life. According to research, temperature affects ecosystem diversity, and colder SSTs can increase the number of some species such siphonophores. SST variations can also boost marine productivity and phytoplankton abundance, as well as increase the number of species like Ommastrephes bartramii in the northwest Pacific [5]. the relationship between mean annual sea surface temperatures (SST) along Pakistan's coast and the Multivariate EL Nino Southern Oscillation (ENSO) Index (MEI). It finds significant variability in SST affected by Southern Oscillations. Noticeable samples are observed during El Niño and La Niña spells. SSTs normally start lower at the beginning of El Niño occurrences. They rise during the event and peak at the start of La Niña events. Past data from El Niño episodes (1986-1987, 1991-1992, 1997-1998) and La Niña events (1988-1989, 1998-1999, 2000-2001) show that SST peaks relate with ENSO phases. However, exact one-to-one connection is less clear after 1999[6].

Multitemporal SST analysis is now easy for Google Earth Engine (GEE) Cloud platfrom.it is a recent technology for the processing the remote sensing data. GEE is more efficient at processing the big data of remote sensing and stores it more efficiently at Cloud storage.[7].In modern era machine learning algorithms is powerful tools for analysis the real time data and projected data with outperformance accuracy.[8] [9].The numerical model with data driven approach, that is Gray model is also accord great future projections based on the historical long term data of SST [10].

Literature Review

The variability of sea temperature in the Arabian Sea Warm Pool (ASWP), with an emphasis on the seasonal development and degradation of the ASWP before the Indian Ocean summer monsoon, as well as its wider climatic impacts, was examined in a study. The effects of vertical entrainment, advection, and sea surface heat flux on ASWP temperature variations using recent SODA reanalysis data was investigated.

The results demonstrated that ASWP forms in April and decays by June, with the decay occurring more quickly than the development. While vertical entrainment predominated during decay, sea surface heat flux had the biggest effect on mixed-layer temperature during development. Additionally, the study discovered that ASWP fluctuation is significantly linked to the Indian Ocean Dipole and ENSO. The ASWP is more apparent in the year following an El Niño event and weaker following a La Niña. These findings highlight the ASWP's critical role in regional and global climate dynamics [11].

In another study, it was discussed how the cold sea surface temperature (SST) bias in climate models for the Arabian Sea impacts the Indian monsoon, which is a major source of water vapor. The researchers (unspecified) conducted the investigation to better understand how mesoscale oceanic variability effects SST and monsoon precipitation. By comparing climate model experiments with non-eddying and eddy-permitting ocean components, researchers discovered that mesoscale variability, such as warm water advection around the Gulf of Aden and Oman, elevates SST in the western Arabian Sea. This action also lessens the cooling caused by coastal upwelling during the monsoon season. Sensitivity experiments revealed that accurate SST modeling relies mostly on resolving mesoscale eddies, with the Persian Gulf and Red Sea playing a secondary role. The findings showed that, in relation to SST variations in the western Arabian Sea, the eddy-permitting model enhanced precipitation over western and northern India while decreasing it over the southeastern Arabian Sea. The results highlight how crucial ocean resolution is to accurately representing the Indian monsoon system in climate model [12].

With an emphasis on cyclone activity variations during the pre-monsoon (April–June) and post-monsoon (October–December) seasons, the study investigated the historical evolution of tropical cyclones (TCs) in the Arabian Sea. The study, which was carried out by unidentified academics, sought to evaluate patterns in the distribution and intensity of TC. Stronger TCs (>34 knots, including severe cyclonic storm categories) have significantly increased, according to the results, whereas weaker TCs (<34 knots), including depressions, have only slightly increased. TC activity spread throughout time, especially during the post-monsoon season, from the eastern Arabian Sea (1982–2001) to the southwest (2002–2021). According to environmental studies, past decades (1982–2001) supported enhanced TC activity by exhibiting concentrated positive relative humidity anomalies at 500 hPa (RH–500 hPa) and negative outgoing longwave radiation (OLR) on the eastern side. Weak vertical wind shear and improved convection developed throughout the basin in the subsequent decades (2002–2021), facilitating more frequent and stronger TCs, particularly post-monsoon. In both seasons, storm activity was continuously sustained by a sea surface temperature of at least 26.5°C. The results highlight how changing atmospheric conditions are affecting the Arabian Sea's cyclone patterns and severity[13].

Approach/Methodology

Step #	**Detail**
Define Region of Interest (ROI)	a) Define window size the geographic area or area of interest. b) Set the area want to analyze in earthengine
Load SST Dataset	a) Dataset is filtered to include only the relevant data by applying ROI

Step #	Detail
	b) Filterd the calendar date range (2003-2023)
Select SST Band	From the filtered dataset, the Sea Surface Temperature (SST) band is selected for analysis
Setting Visualization parameters and variables	a) Visualization settings are established b) Taking the mean SST c) Clipping it to the ROI d) Applying a color palette for the SST range.
Display Data on Map	SST data layer is displayed with the defined visualization.
Create and Apply Time Series Chart for data visulization.	a) A time series chart is generated to display how the SST changes over time within the ROI b) Chart settings like labels, title, and plot points are applied
Result /Output	The final output consists of the displayed map and time series chart, providing visual insights into the SST trends for the specified period

Table-1 : Algorithm to analysis of Sea Surface Temperature.

Experiments & Results

The geospatial and time series analysis of SST the region of Arabian sea by using GEE technology can better big SST data analysis. In this research, GEE was capable of comparative trend analyze 20 years daily SST data. field surveying, which needs to measure SST directly in the sea, was challenging. It would necessitate significantly more expenses, resources, and working hours. The JavaScript programming language can used by GEE to execute and produce custom scripts, enabling efficient data processing and analysis for large-scale environmental monitoring tasks.

There were two Satellite imagery dataset compare HYCOM and MODIS, the comparison of variation of SST in the region of Arabian sea near Pakistan coastline. The daily SST from 2003 to 2023 was generated by the GEE scripts and displayed as a graphical representation and break down into five years graphs chunks.

Comparative trend analysis HYCOM and MODIS and variation of SST From 2003 to 2007

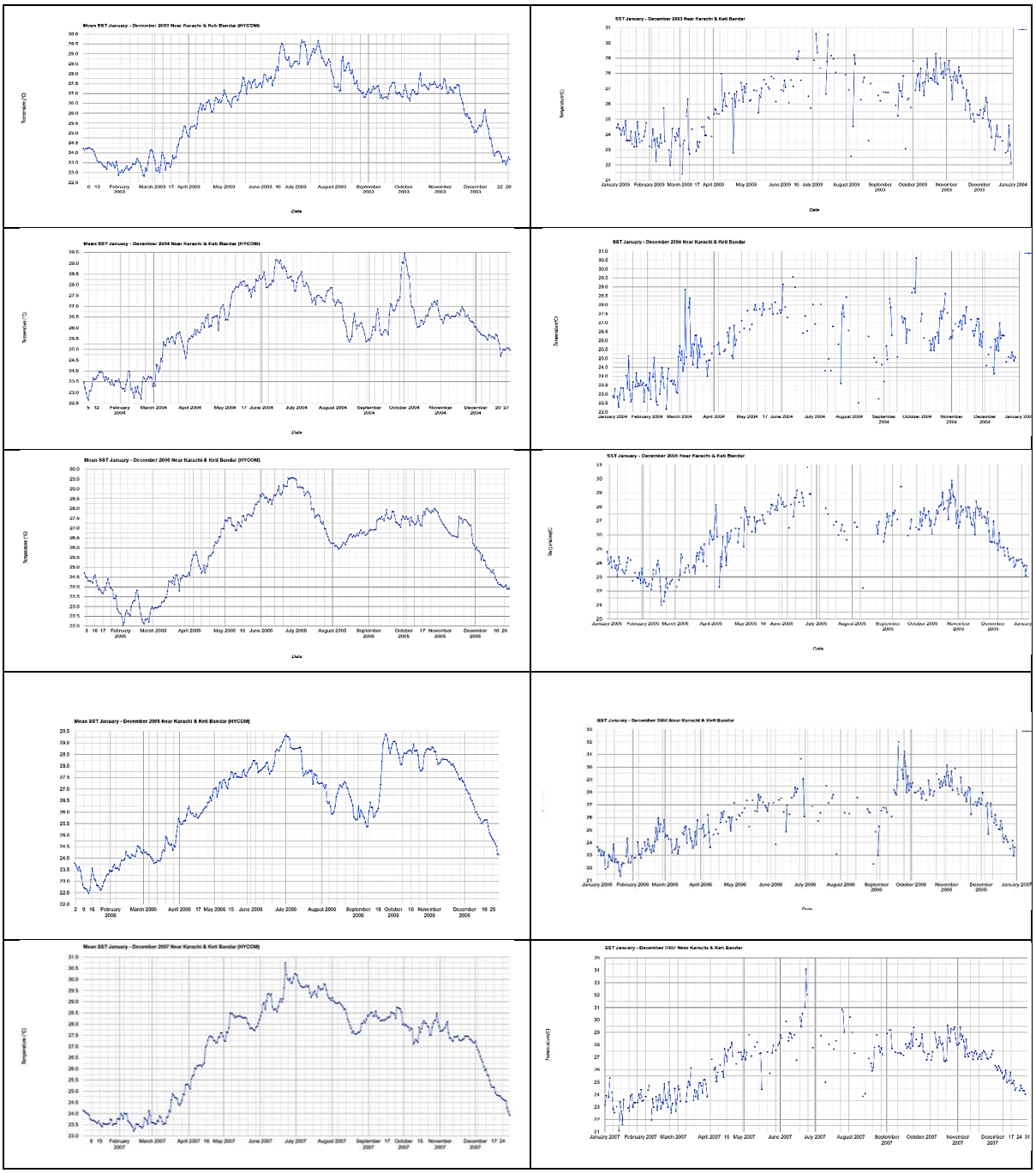


Figure-1: Comparative trend analysis HYCOM and MODIS and variation of SST From 2003 to 2007

Comparative trend analysis HYCOM and MODIS and variation of SST From 2008 to 2012

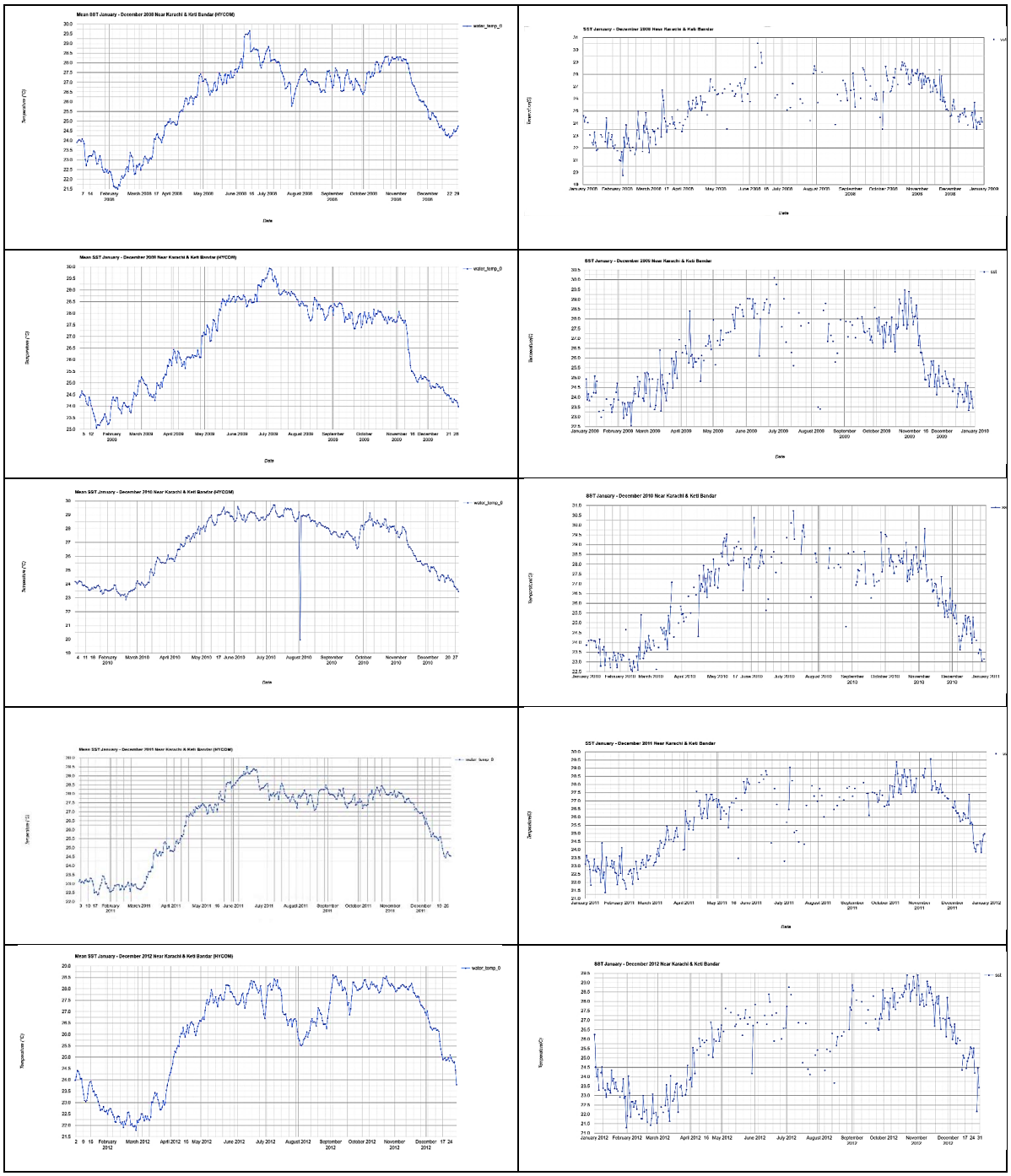


Figure-2: Comparative trend analysis HYCOM and MODIS and variation of SST From 2008 to 2012

Comparative trend analysis HYCOM and MODIS and variation of SST From 2013 to 2017

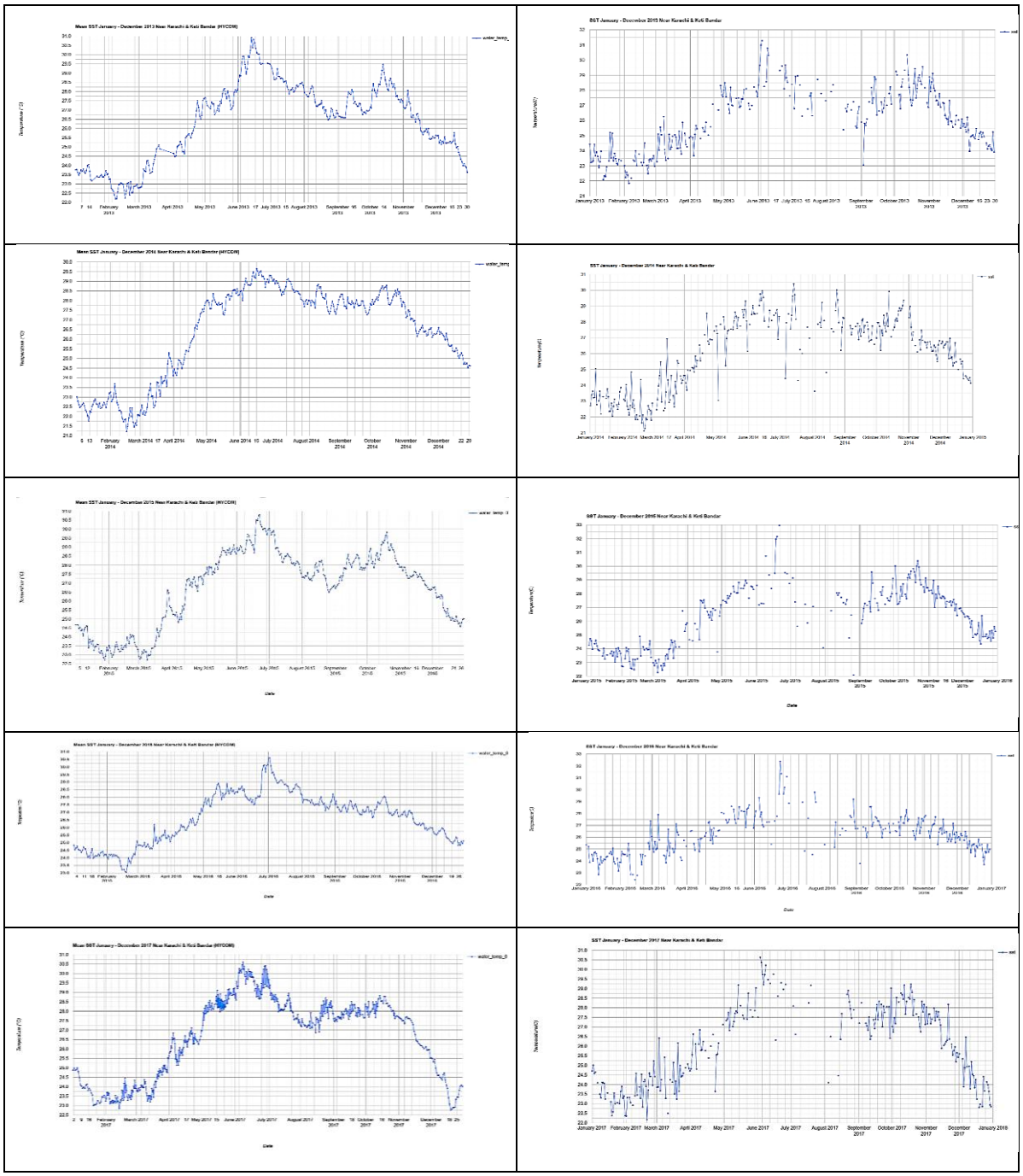


Figure-3: Comparative trend analysis HYCOM and MODIS and variation of SST From 2013 to 2017

Comparative trend analysis HYCOM and MODIS and variation of SST From 2018 to 2023

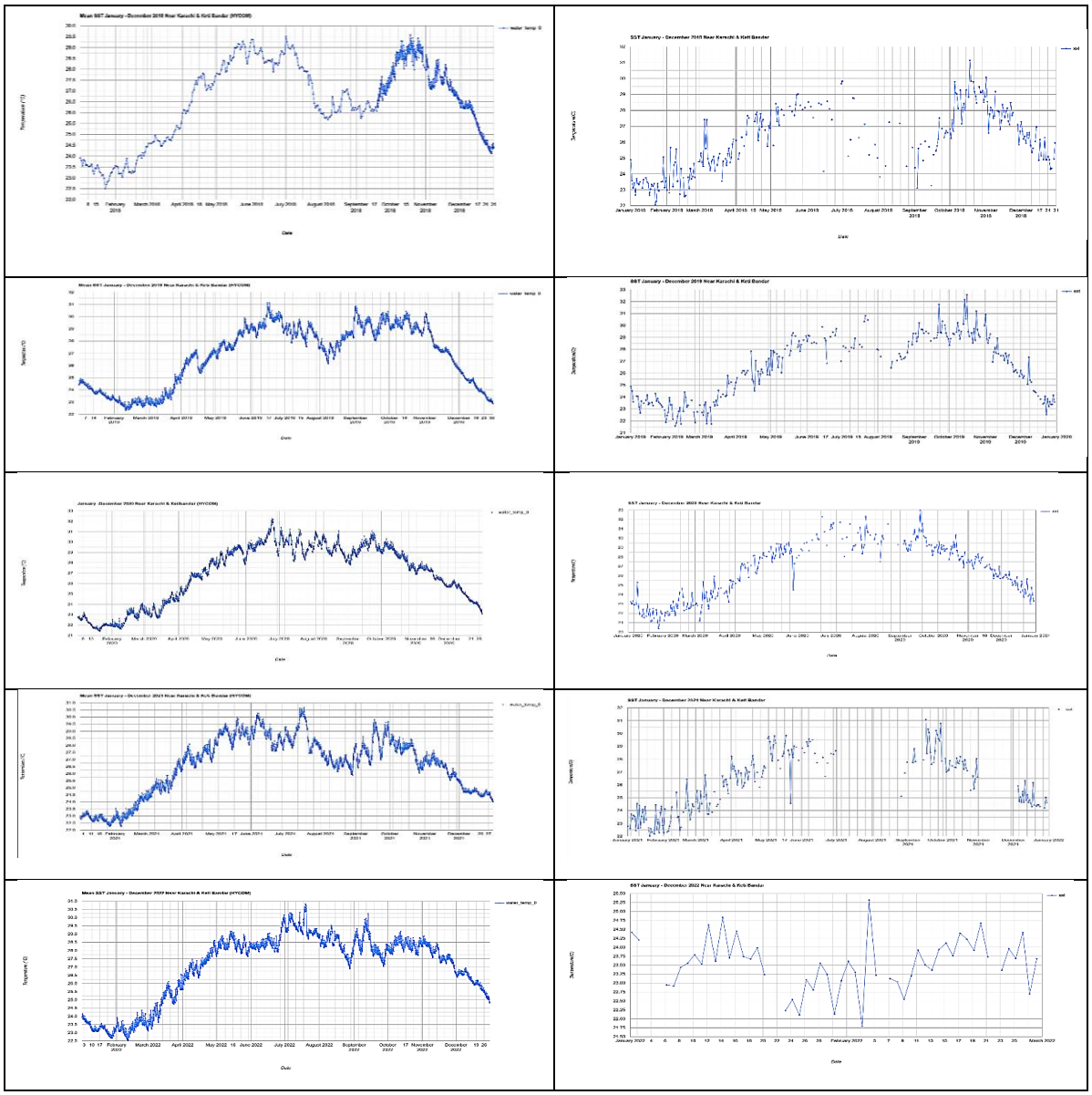


Figure-4: Comparative trend analysis HYCOM and MODIS and variation of SST From 2018 to 2023

The 20 years graph showed daily SST variability during the years period of 2003-2023.The observation of Arabian sea near Pakistan coastline experiences distinct seasonal temperature patterns. During the summer monsoon (May to August) The SST became warmer since monsoon wind patterns over south Asia influenced it. Those season, higher sun radiation intensity caused higher evaporation intensity followed by higher water vapor concentration during condensation process. It contributes to higher rainfall intensity and also increased SST contributes to the intensity and frequency of tropical cyclones in the Arabian Sea. The SST was about 28^{o}C to 30^{o}C.in south Asia of Arabian sea.

In 2009 to 2010 moderate El Nino event and 2015 to 2016 major El Nino event was observed the SST Reaches to 33 to 34 ^{o}C and weak monsoon pattern in south Asian side of Arabian sea.

In September, October, November and December, SST tended to be intermittent because of season changes from rainy season to dry season that is transition season. The comparative warmer SST was about 26 ^{o}C to 30 ^{o}C.

The temperature changes were starting to be identified in the graph clearly in mid of December, during the winter season along the coastline of Pakistan in Arabian sea. The general wind direction is forming from the northeast to southwest. since there was influences of northeast monsoon.

During the winter months (Mid December, January, February and mid of March), the northeast monsoon brings cool, dry winds from the land to the sea, mostly originating from the Himalayas and Central Asia. These winds blow across Pakistan’s coastline, affecting areas like Karachi and the surrounding regions along the Arabian Sea.

In January to mid of march air pressure had been changed in south Asia. High and low air pressure occurred in Asia. It started northeast wind from to originate from the Himalayas and central Asia. It contained lower rainfall. SST tended to be cooler since of low sun radiation intensity and low ambient air temperature followed by low evaporation. It caused low rainfall intensity. The SST was about 22°C to 26°C in those months.

Mean Sea Surface Temperature 2003 to 2022

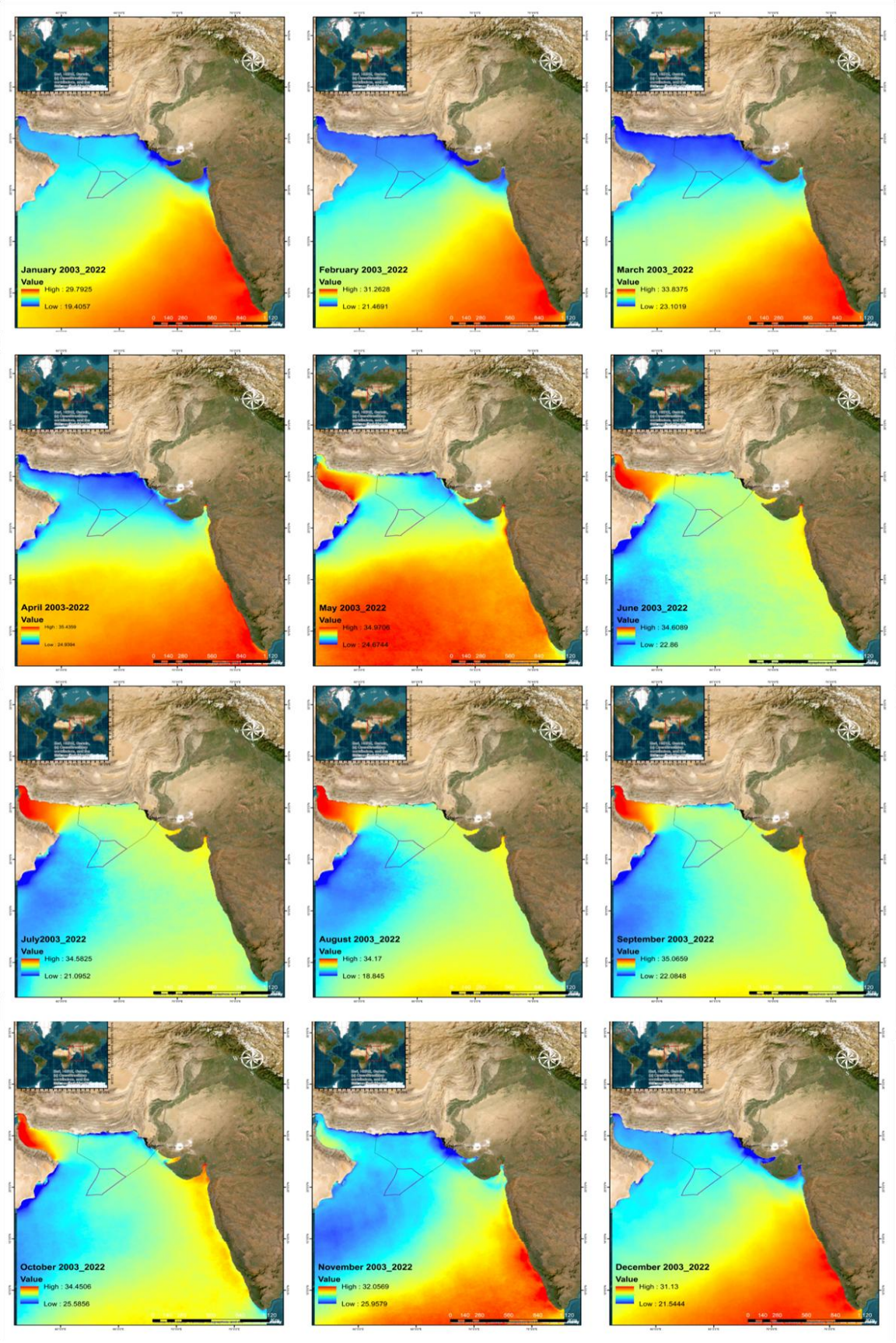


Figure-5: Mean Sea Surface Temperature 2003 to 2022

Table-2: Max and Min Mean Sea Surface Temperature from 2003 to 2022 in Arabian Sea

S.NO	Month	Maximum Temperature (C)	Minimum temperature (C)
1	Mean SST of January	29.7	19.4
2	Mean SST of February	31.2	21.4
3	Mean SST of March	33.8	23.1
4	Mean SST of April	35.4	24.9
5	Mean SST of May	34.9	24.6
6	Mean SST of June	34.6	22.8
7	Mean SST of July	34.5	21.0
8	Mean SST of August	34.1	18.8
9	Mean SST of September	35.0	22.0
10	Mean SST of October	34.4	25.5
11	Mean SST of November	32.0	25.9
12	Mean SST of December	31.1	21.5

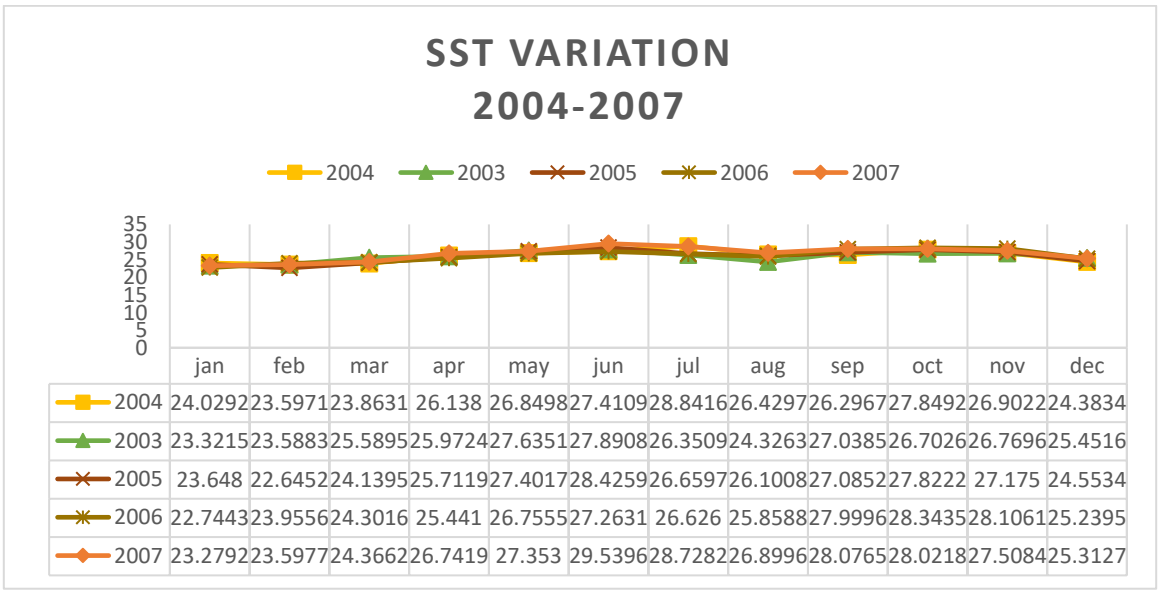
Table-2. The Arabian Sea's Mean Sea Surface Temperature (SST) data from 2003 to 2023 shows a distinct seasonal temperature variation throughout the region. April observed the highest temperatures, reaching a maximum of 35.4°C. May and June see a minor cooldown, with the SST still over 34°C. The cooler months usually observed a drop in temperature, with August noticing the lowest SST of 18.8°C. The general pattern shows a minor period from October to February. The warm season is from March to September, with highs of about 34°C to 35°C.

In terms of hotspot direction, the western and northern regions of the Arabian Sea, near the coastline of Pakistan is typically experienced higher SSTs, notably in the months of April and May. This can be qualified to the normal wind patterns during the northeast monsoon. it brings cooler winds from the land towards the sea and allowing the surface temperatures to be slightly lower down in the eastern parts. The highest SST hotspots are often located along the southern coast extend towards the central Arabian Sea. This temperature circulation plays a key role in regional oceanography, marine ecosystems, and climate patterns, with warmer waters influencing monsoon patterns and tropical cyclone activity in the Arabian sea.

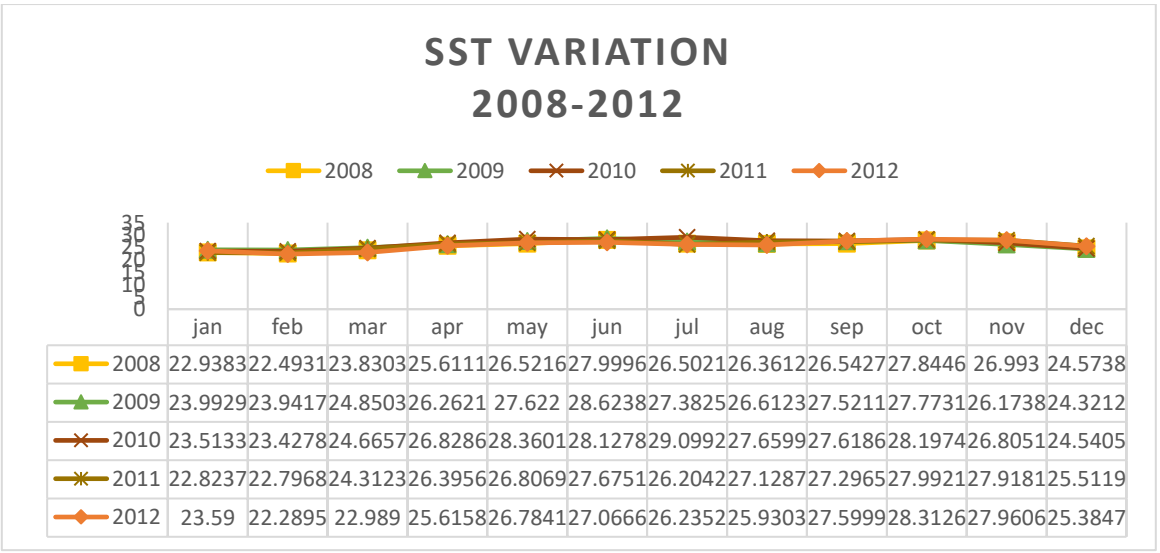
The Mean Sea Surface Temperature (SST) data from January to December across the Arabian Sea shows discrete seasonal patterns in temperature, which are influenced by both the time of year and regional wind and ocean current dynamics.

the hotspots for SST along the Pakistan coastline are most prominent from April to September. When temperatures tend to be highest, mostly in the southern and central parts of the Arabian Sea. The colder period from October to March is influenced by the northeast monsoon winds, which lower temperatures, especially in the northern and eastern parts of the Arabian Sea.

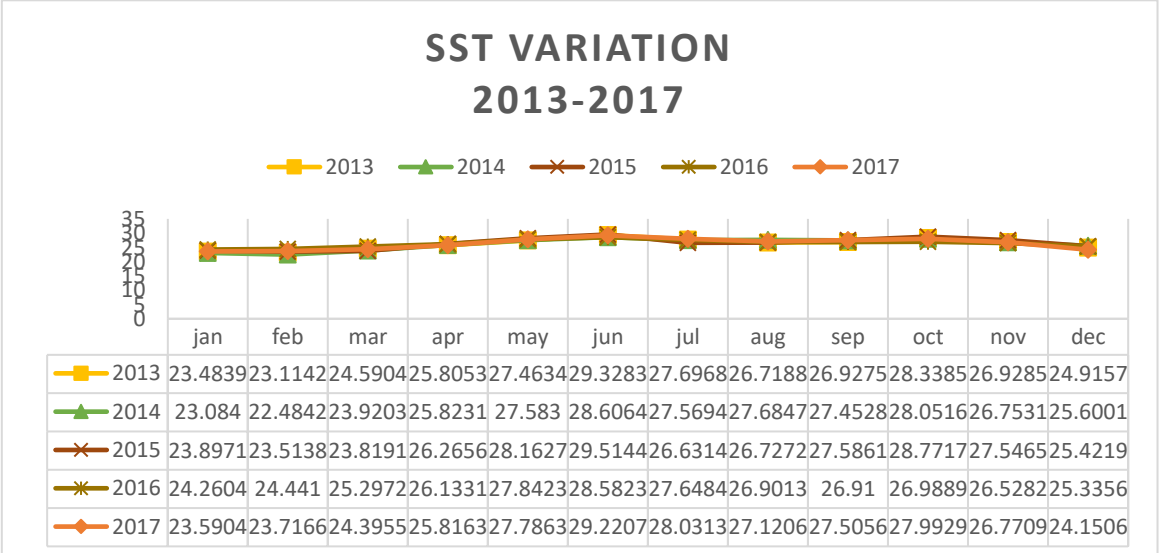
SST Variation from 2003 to 2021 Arabian Sea near Karachi coast.



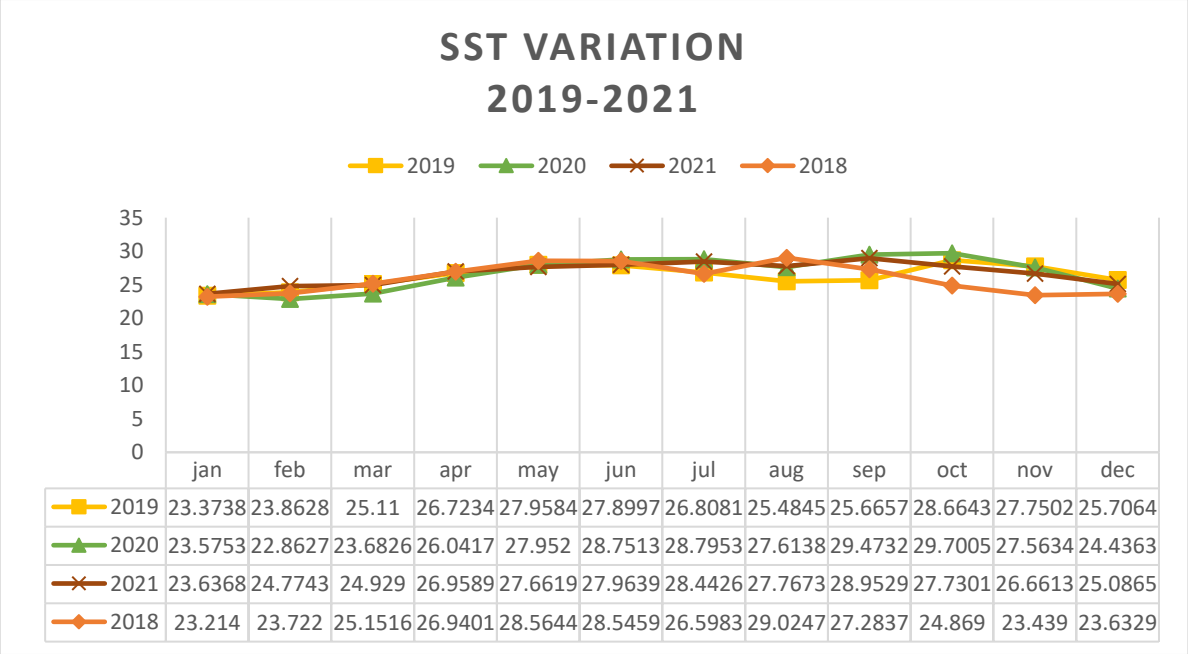
	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
2004	24.0292	23.5971	23.8631	26.138	26.8498	27.4109	28.8416	26.4297	26.2967	27.8492	26.9022	24.3834
2003	23.3215	23.5883	25.5895	25.9724	27.6351	27.8908	26.3509	24.3263	27.0385	26.7026	26.7696	25.4516
2005	23.648	22.6452	24.1395	25.7119	27.4017	28.4259	26.6597	26.1008	27.0852	27.8222	27.175	24.5534
2006	22.7443	23.9556	24.3016	25.441	26.7555	27.2631	26.626	25.8588	27.9996	28.3435	28.1061	25.2395
2007	23.2792	23.5977	24.3662	26.7419	27.353	29.5396	28.7282	26.8996	28.0765	28.0218	27.5084	25.3127



	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
2008	22.9383	22.4931	23.8303	25.6111	26.5216	27.9996	26.5021	26.3612	26.5427	27.8446	26.993	24.5738
2009	23.9929	23.9417	24.8503	26.2621	27.622	28.6238	27.3825	26.6123	27.5211	27.7731	26.1738	24.3212
2010	23.5133	23.4278	24.6657	26.8286	28.3601	28.1278	29.0992	27.6599	27.6186	28.1974	26.8051	24.5405
2011	22.8237	22.7968	24.3123	26.3956	26.8069	27.6751	26.2042	27.1287	27.2965	27.9921	27.9181	25.5119
2012	23.59	22.2895	22.989	25.6158	26.7841	27.0666	26.2352	25.9303	27.5999	28.3126	27.9606	25.3847



	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
2013	23.4839	23.1142	24.5904	25.8053	27.4634	29.3283	27.6968	26.7188	26.9275	28.3385	26.9285	24.9157
2014	23.084	22.4842	23.9203	25.8231	27.583	28.6064	27.5694	27.6847	27.4528	28.0516	26.7531	25.6001
2015	23.8971	23.5138	23.8191	26.2656	28.1627	29.5144	26.6314	26.7272	27.5861	28.7717	27.5465	25.4219
2016	24.2604	24.441	25.2972	26.1331	27.8423	28.5823	27.6484	26.9013	26.91	26.9889	26.5282	25.3356
2017	23.5904	23.7166	24.3955	25.8163	27.7863	29.2207	28.0313	27.1206	27.5056	27.9929	26.7709	24.1506



	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
2019	23.3738	23.8628	25.11	26.7234	27.9584	27.8997	26.8081	25.4845	25.6657	28.6643	27.7502	25.7064
2020	23.5753	22.8627	23.6826	26.0417	27.952	28.7513	28.7953	27.6138	29.4732	29.7005	27.5634	24.4363
2021	23.6368	24.7743	24.929	26.9589	27.6619	27.9639	28.4426	27.7673	28.9529	27.7301	26.6613	25.0865
2018	23.214	23.722	25.1516	26.9401	28.5644	28.5459	26.5983	29.0247	27.2837	24.869	23.439	23.6329

In 2009 to 2010 moderate El Nino event and 2015 to 2016 major El Nino event was observed the SST Reaches 2009 and 2010 to 28.6 to 29 ^{o}C and weak monsoon pattern in south Asian side of Arabian sea. Similarly in 2015 and 2016 28 to 29.5 ^{0}C was observed near the Karachi coast.

Conclusion

SST may significantly impact coastal erosion by increasing storms, raising sea levels, and changing wave patterns. To analyze SST, this research uses Google Earth Engine (GEE) and machine learning techniques. GEE is a cloud-based platform for processing remote sensing data. It provides advanced capabilities for analyzing satellite imagery. The in-situ Data provided by National institute Of Oceanography Pakistan. Particularly, this study uses Ocean Color SMI: Standard Mapped Image MODIS Aqua Data Level 3.the Comparative analysis of the Hybrid Coordinate Ocean Model (HYCOM) provides global ocean data with a spatial resolution of 0.08 degrees (approximately 9 km) from 2003 to the present.

The geospatial and time series analysis of SST the region of Arabian sea by using GEE technology can better big SST data analysis. In this research, GEE was capable of comparative trend analyze 20 years daily SST data. field surveying, which needs to measure SST directly in the sea, was challenging.

During the summer monsoon (May to August) The SST became warmer since monsoon wind patterns over south Asia influenced it. Those season, higher sun radiation intensity caused higher evaporation intensity followed by higher water vapor concentration during condensation process. It contributes to higher rainfall intensity and the also increased SST contributes to the intensity and frequency of tropical cyclones in the Arabian Sea. The SST was about 28^{o}C to 30^{o}C.in south Asia of Arabian sea.

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Limitations & Future Work

Data set extract by using google earth engine programing script and analyze GEE Cloud platform. The Data gap, bands, cloud Cover, spatial and temporal resolution sufficient for global scale studies. This may possibly not be fine enough for specified analysis of local or small-scale kinds like coastal changes, urban areas, or small water bodies.

Credit authorship contributions statement.

Rizwan Akhter: Conceptualization, Methodology, Software, Formal analysis, Data curation, Writing – original draft, Investigation.

Dr. Ibrahim Zia: Conceptualization, Validation, Formal analysis, Writing – review & editing.

Tahreem Zafar: Validation, Writing – review & editing.

Declaration of competing interest

The authors state that none of the work described in this study could have been influenced by any known competing financial interests or personal relationships.

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Glossary

Term Used	Description Terminology
GEE	Google Earth Engine
SST	Sea Surface Temperature
HYCOM	Hybrid Coordinate Ocean Model
MODIS	Moderate Resolution Imaging Spectroradiometer
IPCC	Intergovernmental Panel on Climate Change
AR5	Fifth Assessment Report
SSP	Shared Socioeconomic Pathways

Term Used	Description Terminology
ENSO	El Nino Southern Oscillation
ASWP	Arabian Sea Warm Pool
SODA	Simple Ocean Data Assimilation
TCs	Tropical Cyclones
OLR	Outgoing Longwave Radiation
ROI	Region Of Interest
SLR	Sea Level Rise

El Nino and Lanina

El Niño is a Spanish word that means 'Little Boy'. It refers to a climate phenomenon that impacts global climate patterns. Normally, easterly winds, known as the Trade Winds, blow west along the equator in the Pacific Ocean. The trade winds carry warm water from South America towards Asia. During an El Niño event, these trade winds are weak, and warm water is pushed back east toward the west coast of the Americas and disrupting weather patterns. The entire period the trade wind is weak.

La Nina

La Niña is a Spanish word that means 'Little Girls'. La Niña has the opposite effect of El Niño. During La Niña events, trade winds become stronger than usual. These stronger winds push more warm water toward Asia. This impact lead to cyclone activity, monsoon strength and temperature variation in South Asia.

ENSO Phase

El Niño is part of a much larger global variation in the atmosphere called ENSO (El Niño/Southern Oscillation). The Southern Oscillation describes changes in air pressure patterns in the Southern Pacific Ocean between Tahiti, in the middle of the Southern Pacific Ocean, and Darwin, Australia, to the west. The El Niño refers to the warm episode of ENSO, while La Niña refers to the cool episode of ENSO.

Non-eddying and Eddy-permitting

Non-eddying and eddy-permitting are the climate ocean model experiments that shows ocean flows are known to currents. Sometimes, these currents can form circular loops of water, known as eddies, when they slice sections. Non-eddying models make easier fluid dynamics, while eddy-permitting models interpret some of the effects of eddies.

UP-Welling

Upwelling is a process where cold, deep ocean water rises to the surface. This happens when winds push surface water away, and the water below replaces it. Upwelling can occur near coastlines or in the open ocean On the other hand, downweling is the opposite process.

ROI

A Region of Interest (ROI) refers to a specific region that someone is focused on or interested in. On a map, it's the location or area that is being studied, observed, or analyzed.

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RESPONSE OF OPTIMIZED SELF-COMPACTING CONCRETE USING PARTICLE PACKING CONCEPTS AND SUPPLEMENTARY CEMENTITIOUS MATERIALS (SCMS)

Syed Ali Rizwan,
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RESPONSE OF OPTIMIZED SELF-COMPACTING CONCRETE USING PARTICLE PACKING CONCEPTS AND SUPPLEMENTARY CEMENTITIOUS MATERIALS (SCMs)

By

Syed Ali Rizwan[1], Sufian Ahmad[2], Qamar uz Zaman[3] and Hamza, Ali[4]

Abstract

This research reports the effect of varying packing density on the flow and mechanical characteristics of Self Consolidating Concrete Systems (SCC) made with and without Secondary Raw Materials (SRMs) or supplementary cementitious materials (SCMs). The ratio of fine to coarse aggregate ratios was varied in the 20-80% range as a trial process to see the effect on the degree of packing of aggregates in the SCC mixes. Then it was compared with that based on the modified Anderson and Andreason (MAA) approach. The packing density and compressive strengths were found to be optimum when the fine-to-coarse aggregate ratio was 50:50 in terms of weights in trial mixes, while based on the MAA approach, this ratio was around 51:49 with distribution modulus "q" equal to 0.25. Fly Ash (FA) and Limestone Powder (LSP) were used in the same proportions by weight to partially replace 30% cement based on an earlier published study [1]. Theoretical results using the MAA approach and EMMA software were compared with the experimental response of SCC formulations. Results showed that SCC prepared on the basis of the MAA approach was more economical and showed better response in terms of flow, volume stability, heat of hydration and compressive strength. Using the MAA approach for SCC mix design saves the time and materials needed in the trial process of SCC design. EMMA software was utilized to adjust the mix proportion to achieve an optimized particle size distribution for a mix with the fewest voids. A modified A&A (MAA) formulation at q = 0.25 and a binder-to-aggregate ratio of 1:3.89 was attained using EMMA as optimised mixes.

Keywords: Packing Density, Self-Compacting Concrete, Fly Ash, Limestone Powder, Secondary Raw Materials, Modified Andreassen and Andersen.

1. Introduction

Self-compacting concrete (SCC) is characterized by two contradictory requirements of high deformation without bleeding and segregation. It usually requires either higher paste content or using a viscosity enhancing agent (VEA) or both to improve segregation resistance and aid in its placement, especially through the pumping process [2]. The use of Secondary Raw Materials (SRMs/SCMs) like FA and LSP can enhance the properties of SCC in terms of flow, volume stability, heat of hydration, durability, and strength due to their synergic effect [3]. Encouraging the use of SRMs in SCC translates into an indirect reduction of the CO_2 footprint and results in environment-friendly concrete [4]. Another approach for SCC mix design was proposed by Su and Miao, popularly known as the Chinese method [5], which starts with packing aggregates and then filling the voids of aggregates with paste. This

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method results in more economical concrete by reducing the amount of paste required to fill the voids. The largest possible volume of aggregates is also beneficial in terms of strength, volumetric stability, creep, permeability, and stiffness. Several packing models have been proposed that can be utilised to alter the particle size distribution (PSD) of aggregates to make the mix densely packed with minimum space between the aggregate particles. Computer software like EMMA [6] can be utilised to design the mixed composition of SCC using particle packing concepts.

1.1. Packing Models

Particle packing models have been in use for quite some time now; several researchers have contributed to them, starting from Furnas to Fuller & Thompson (F&T) and then to a more recent model proposed by Funk and Dinger, also known as the Modified Andreasen and Andersen Model (MA&A). Details and the differences between these models can be found elsewhere [7-13]. Since naturally occurring materials cannot be mono-sized and contain particles up to infinitely small size. Funk and Dinger considered it, and they incorporated both minimum and maximum sizes of particles in their model to make the mixture have the least content of voids. Mathematically MAA model can be written as:

$$CPFT = \frac{d^q - d_{min}^q}{d_{max}^q - d_{min}^q} \times 100 \qquad (1)$$

Here, CPFT means cumulative percentage finer than the diameter of particle “d” having distribution modulus “q”, d_{min} and d_{max} are the minimum and maximum sizes of particles used, respectively.

Generally, a mix with more fines results in a lower distribution modulus (q) value to have a mix of optimum packing density. However, the value of q also depends on several factors like particle density, particle porosity, particle shape, and maximum & minimum size of particles used [7]. Sajjad et al. [14] used the Modified A&A model to reduce voids in fine aggregates for Self-Compacting Mortar systems (SCMs) and found 0.35 as the optimum q value to have a mix of the highest packing density. Similarly, Qamar et al. [15] suggested a lower value of q (i.e., 0.205) when SRMs are incorporated into SCM systems to increase the degree of packing in SCMs. This is because of the inclusion of finer content in the mixture. Later, it will be known that by the inclusion of coarse aggregates, the value of q raised to 0.25 for optimised packing density of SCC systems incorporating SRMs (see Fig 5).

2. Experimental

2.1. Materials

Ordinary Portland Cement of grade 53, type-1 conforming to EN-197-1 manufactured by “Bestway”, Class F Fly Ash (FA) imported from Germany, Limestone Powder (LSP) manufactured locally from Margalla crush, 3rd generation, PCE-based liquid superplasticizer Viscocrete - 20 HE produced by Sika and Master Matrix 110, a Viscosity Modifying Agent (VMA), was used to prepare Self-Compacting Concrete (SCC) having a target flow of 70 ± 1cm using Abraham’s cone confirming to EN 12350. All the materials used in the research were kept in air-tight containers before use to protect them from any type of moisture contact.

The chemical composition of powders was determined using X-ray fluorescence (XRF) analysis. Physical characteristics were analyzed using SEM images and Particle size distribution (PSD) by Laser granulometry. The results are shown in Table 1.

Table-1: Chemical and Physical Analysis of Powders

Samples	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Particle Size (D_{50})
OPC	19.19	0.29	4.97	3.27	0.04	2.23	65.00	0.58	0.51	0.08	3.84	16.4
FA	59.06	1.58	27.58	5.14	0.05	1.27	1.66	0.54	1.59	0.15	1.38	11.0
LSP	3.00	0.04	0.69	0.27	0.01	0.67	52.67	0.30	0.10	-	42.24	8.63

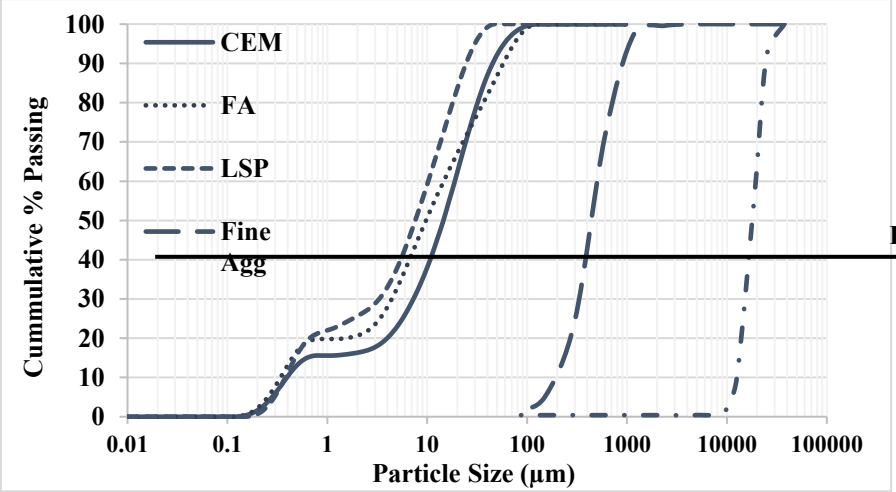


Figure-1: Particle size distribution of Materials (Powders and Aggregates)

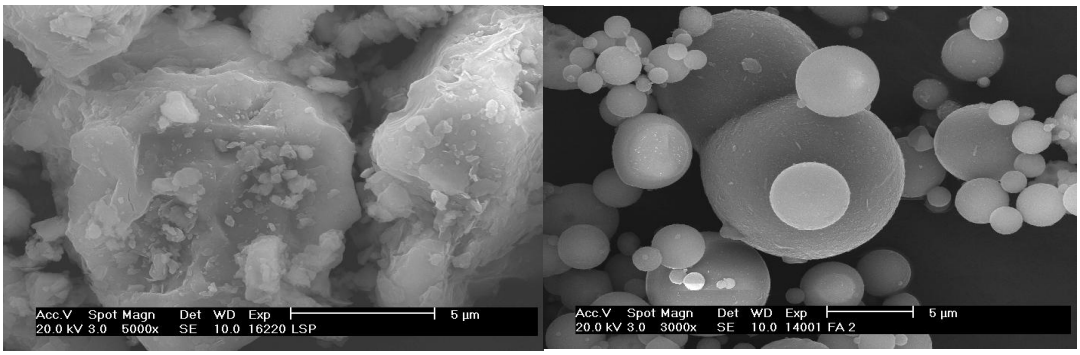


Figure-2: SEM images of LSP and FA Powders, respectively Rizwan, 2006[4]

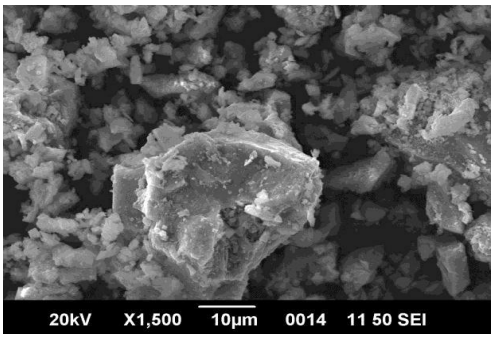


Figure-3: SEM image of OPC Powder [7]

2.2. Packing Density of Aggregate

Naturally occurring fine and coarse aggregate were mixed in ratios of 20/80, 30/70, 40/60, 50/50, 60/40, 70/30, and 80/20 to determine the optimum packing density

mixture by following the standard guidelines of BS-812. Results showed that maximum packing density can be achieved by using a fine/coarse aggregate ratio of 50/50 when naturally occurring aggregates are used, as shown in Figure 4. This also reconfirms the work done by Brouwers [16]. It is suggested that for the density of aggregates, the maximum particle size should be 10 times smaller than the internal diameter of the container to avoid the wall effect [17, 18]. Mathematically packing density can be written as

$$\alpha = 1 - e$$

$$e = \frac{100*[Gs*62.4]-BulkDensity}{Gs*62.4}$$

Here α is packing density, e is the percentage of voids in aggregates (coarse and fine), and Gs is the specific gravity of aggregates.

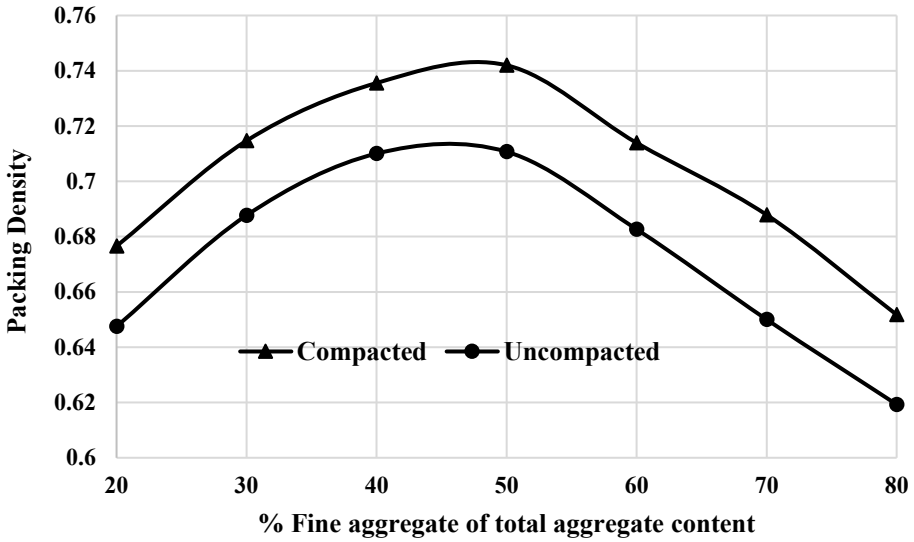


Figure-4: Packing Density of Mixes with varying Fine Aggregate content

Fig.5 shows the void ratio versus sand to coarse aggregate ratio, as reported [16].

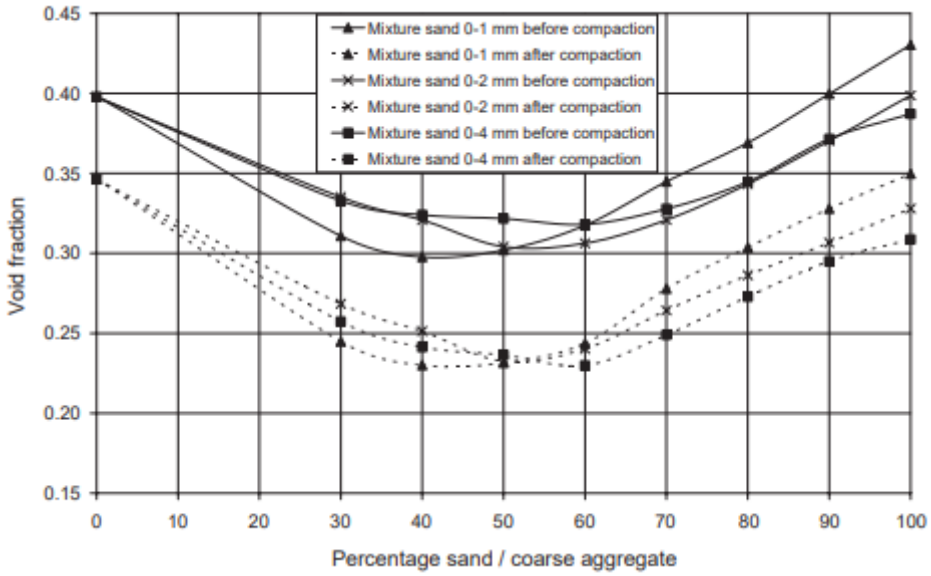


Figure-5 Void Ratio and sand to coarse aggregate ratio relation [16]

A modified A&A model was also utilized to increase the degree of packing of aggregate mixes. Different distribution modulus (q) values ranging from 0.22 to 0.28 were used to determine its relationship with packing density, which was found to be optimum at q = 0.25, as shown in Figure-6. The particle size distribution (PSD) curve of the Modified A&A Model with different values of q is shown in Figure-7, which shows an increase in % passing of material with a decrease in the value of q for a particular size of the particle.

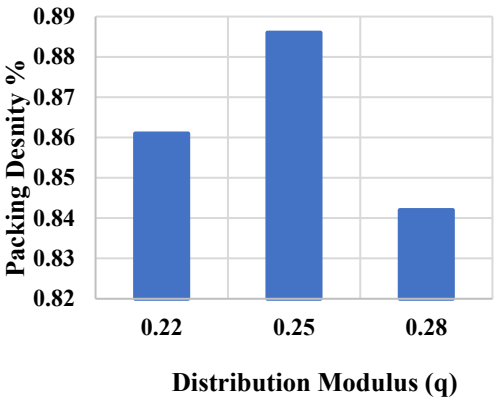


Figure-6: Packing Density of Mixes with varying Distribution Modulus (q)

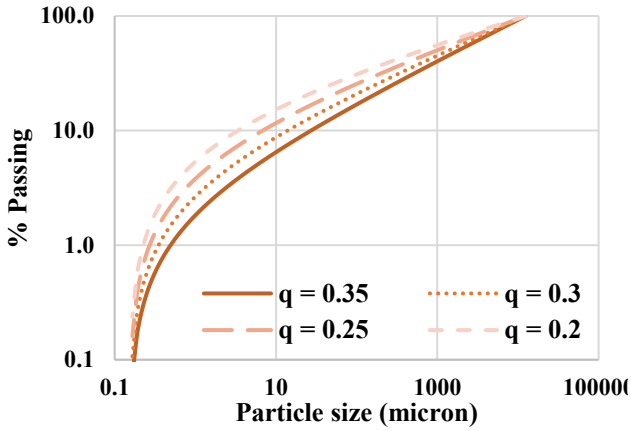


Figure-7: Particle Size Distribution for varying Distribution Modulus (q)

Three out of seven (with untailored aggregates) and one out of three (MAA model-based) optimised formulations showing greater theoretical packing density were selected for further experimental investigation on flow and other mechanical properties by varying the constituents, as given in Table-2. Figure-8 shows the packing density of the above four optimised theoretical formulations. The formulation based on the Modified A&A approach shows an 18% greater degree of packing than the one with a fine/coarse aggregate ratio of 50/50.

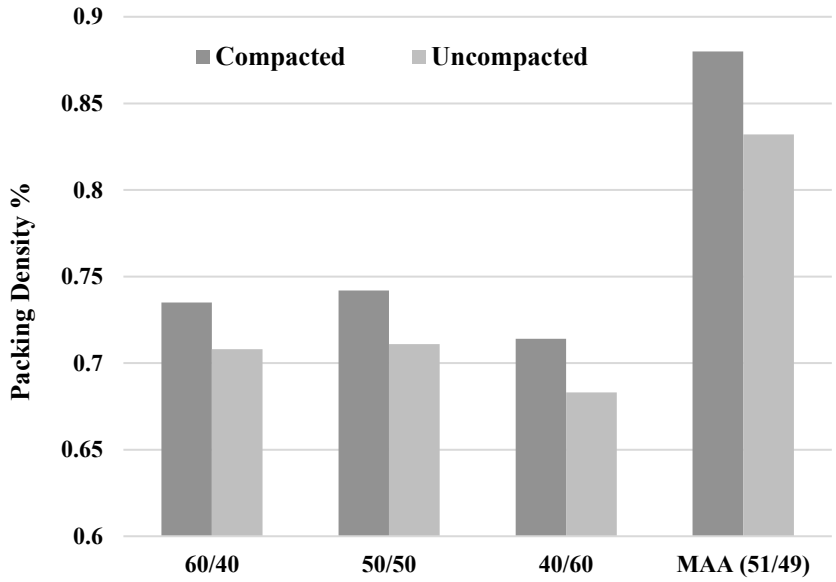


Figure-8: Theoretical Packing Density of optimized formulations

2.3. SCC Formulations Designed for Optimum Packing

To study the effect of packing density on properties of experimental SCC along with partial replacement of OPC with blends of FA and LSP (15% each by weight of cement), a total of seven mixtures were investigated, as shown in Table 2. Considering the mix design proposed by Brouwers and the practical experience of the Principal author [4,14,16], binder to aggregate ratio of 1:3 and w/c ratio = 0.42 was maintained for all the formulations. The amount of SP was adjusted for each formulation to attain a target flow of 70 ± 1cm, while VEA was used to avoid any segregation/bleeding in the control mixes without SRMs. SCC Formulations without mineral admixtures are designated as “CM” (Control Mixes), while those having SRMs/SCMs are defined as “MM” (Modified Mixes), and digits show the percentages of fine and coarse aggregate, respectively; for example, a mix CM 64 means that there are 60% fine aggregates (of the total aggregates) and 40% are coarse aggregates. Other mixes can be understood on similar lines.

The SCC mix was optimized based on the Modified A&A particle packing model. EMMA software was utilized to adjust the mix proportion to achieve an optimized particle size distribution for a mix with the fewest voids. A modified A&A (MA&A) formulation at q = 0.25 and a binder-to-aggregate ratio of 1:3.89 was attained using EMMA; details are shown in Table 2.

2.4. Mixing Regime

A 50-liter capacity pan mixer was used, and a total of 5 minutes of SCC mixing was done. Starting with dry mixing of materials for a minute at 65 rpm, followed by adding 70% water and mixing it for 1 more minute before the addition of chemical admixtures along with the remaining 30% water, mixing was continued for 3 further minutes to ensure SP activation, resulting in a uniform mix of self-compacting concrete.

Table-2: Details of SCC Formulations

Materials/ Mixes	Fine/coarse aggregate ratio	Binder to Aggregate ratio	OPC (Kg)	FA (15%) (Kg)	LSP (15%) (Kg)	Fine Agg (Kg)	Coarse Agg (Kg)	w/c=0.42 (Kg)	SP (%)	VEA %
CM64	60/40	1:3	10	-	-	18	12	4.2	1.15	-
CM55	50/50	1:3	10	-	-	15	15	4.2	1	0.4
CM46	40/60	1:3	10	-	-	12	18	4.2	1.4	0.6
MM64	60/40	1:3	7	1.5	1.5	18	12	2.94	1.7	-
MM55	50/50	1:3	7	1.5	1.5	15	15	2.94	1.59	-
MM46	40/60	1:3	7	1.5	1.5	12	18	2.94	1.65	-
MA&A (51/49)	51/49	1:3.89	5.4	1.156	1.156	15.3	14.7	2.268	1.61	-

3. Results

3.1. Flow Response of SCC Formulations

To investigate the flow response against packing density, seven SCC formulations with different packing densities were subjected to routine SCC flow tests, including slump flow spread, L-box, V-funnel, and J-Ring test, as per the EN 12350 standard.

3.1.1. SP Demand and Slump Flow Spread of SCC Formulations

Abraham's slump cone with a narrow end-up was utilized to determine the SP demand of SCC for a target flow of 70 ± 1 cm, as shown in Figure 9. Plastic Viscosity and deformability, in terms of T50 cm time and T70 cm time, respectively, were also evaluated for the mixes, and the results are shown in Figure 10.

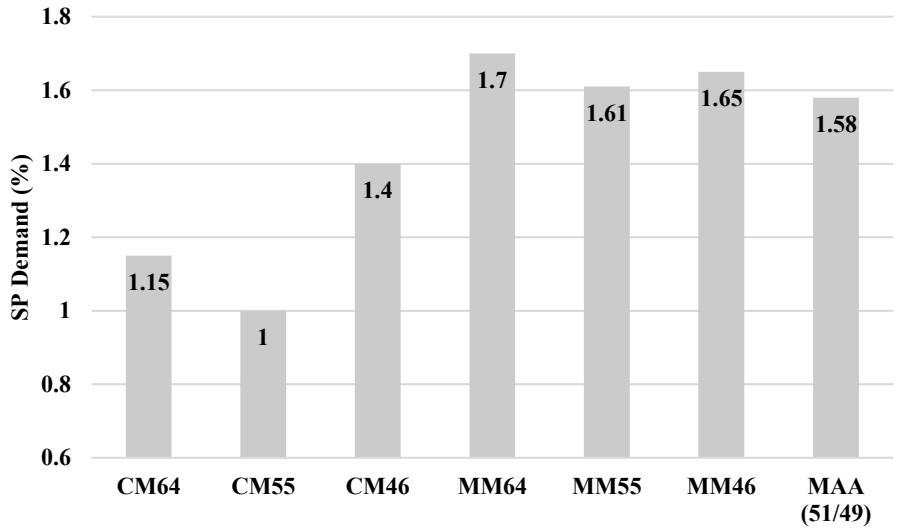


Figure-9: SP Demand of SCC Formulations

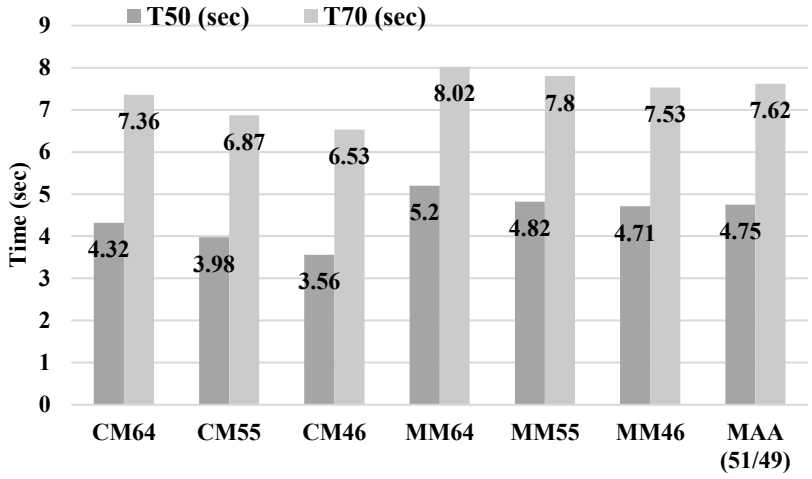


Figure-10: T50 and T70 cm flow times of SCC

3.1.2. V-Funnel Test on SCC Formulations

The formulations' viscosity was evaluated using a V-funnel apparatus. The concrete was allowed to pass through an opening of the funnel until the light appeared at the bottom, and the time required was noted, representing the viscosity of SCC as shown in Fig.11

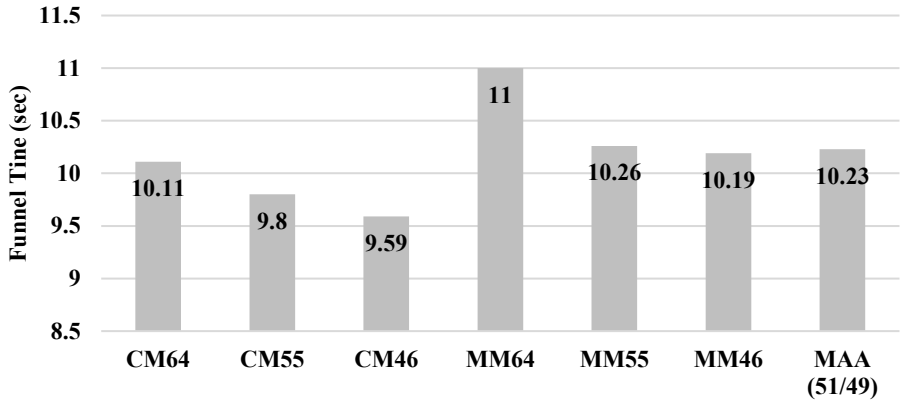


Figure-11: V-Funnel Time of SCCs

3.1.3. L-Box Test on SCC Formulations

The L-box apparatus replicates the field conditions for SCC to pass through the steel reinforcements, which shows its passing ability. The time required (T20, T40, and T60) for SCC to cover the distance of 20cm, 40cm, and 60cm at the horizontal section of L-Box after passing through reinforcements were reported. Also, the ratio of height (H2/H1) of SCC before and after passing through reinforcements is shown in Figure 12.

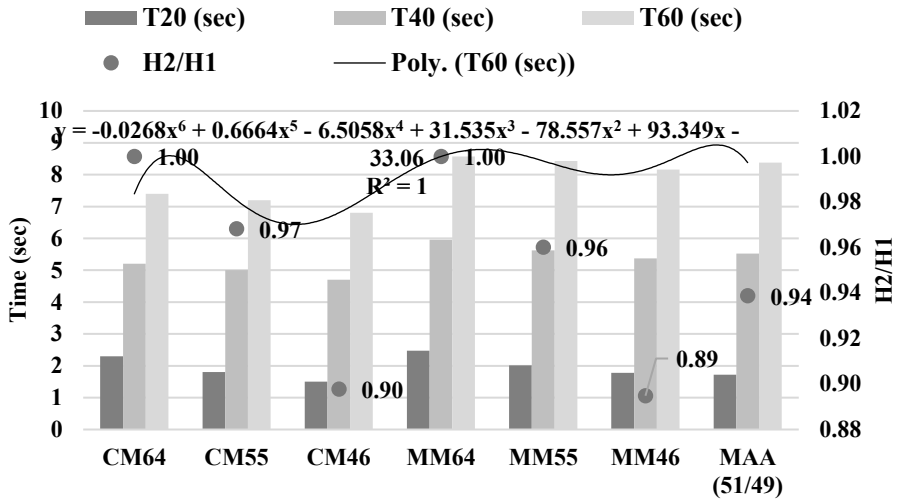


Figure-12: Flow Time for L-Box (T20, T40, T60 and H2/H1)

3.1.4. J-Ring Test on SCC Formulations

The total spread time of SCC, T50cm time, and height difference (Bj) of concrete before and after passing through the J-Ring were noted. The J-Ring response of SCC formulations is shown in Figures 13 and 14.

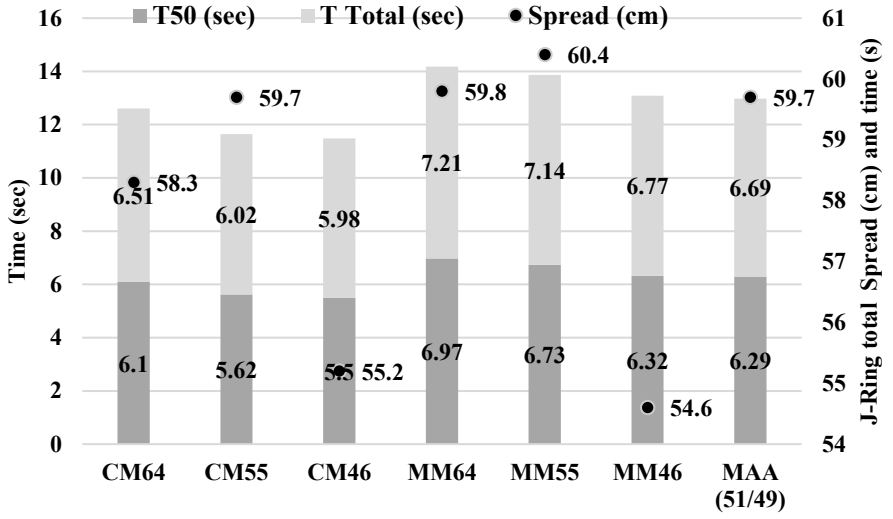


Figure-13: Flow Time for J-Ring (T50, T total and Total Spread)

Bingham number Bj can be used to characterize the rheological behavior of SCC under varying rates, and shear stresses between 1-5 indicate the non-Newtonian flow behaviour of SCC, while its value between 5-10 indicates the non-Newtonian flow behaviour of SCC with slow flows through J Ring and moderate yield stress indicating passing ability and filling ability of SCC as reflected in J-Ring test.

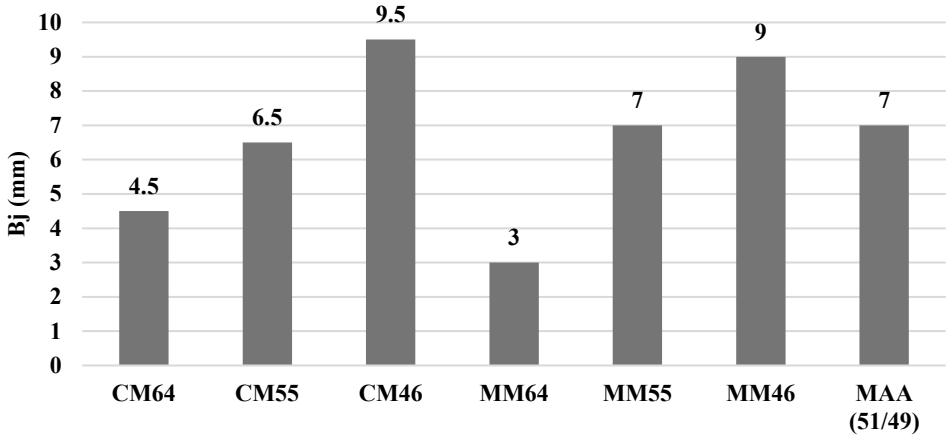


Figure-14: J-Ring Passing Ability Results (Bj)

3.1.5. Approximate Shrinkage Response of SCC Formulations

Early age shrinkage response was measured using Modified German Schwindrinne apparatus 4x6x25 cm^3 capable of measuring linear shrinkage up to 31 microns sensitivity. Schwindrinne channel was filled with the fresh SCM obtained after passing SCC through a 2mm sieve, and the channel was then covered with a plastic sheet to avoid any exchange of moisture with the environment. The shrinkage response of studied formulations is shown in Figure-15.

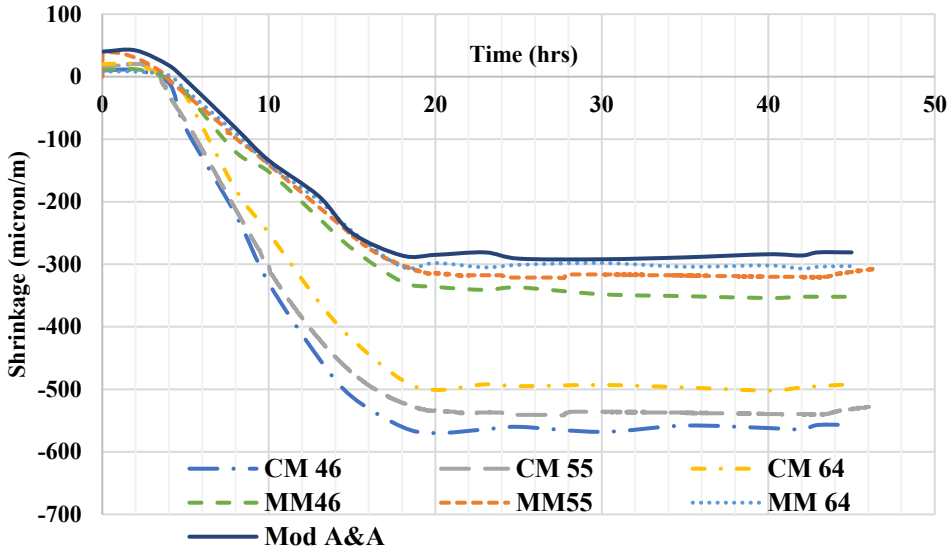


Figure-15: Simulation of Shrinkage Response of SCC formulations

Packing was highest at 50-50 % fine: coarse aggregates both in experimental investigation and as reported in [16] as shown in Figures 4 and 5, and it decreased on both sides of this ratio. The lowest shrinkage was shown by the Modified Andersen and Andreason formulation. The same was the trend in Calorimetry.

3.1.6. Approximate Calorimetry of SCC Formulations

The hydration kinetics of SCC formulations were studied using an F-CAL 8000 field Calorimeter. A sample of fresh concrete was obtained from SCC by sieving it through a 2 mm sieve. The sample was then filled in polythene bags and placed in the apparatus for 48 hours. Figure 16 shows the calorimetric response of SCC formulations, which was, in fact, that of SCM systems. Increasing sand content

reduced the exothermic temperature. Modified Anderson and Andreason formulation gave the least temperature.

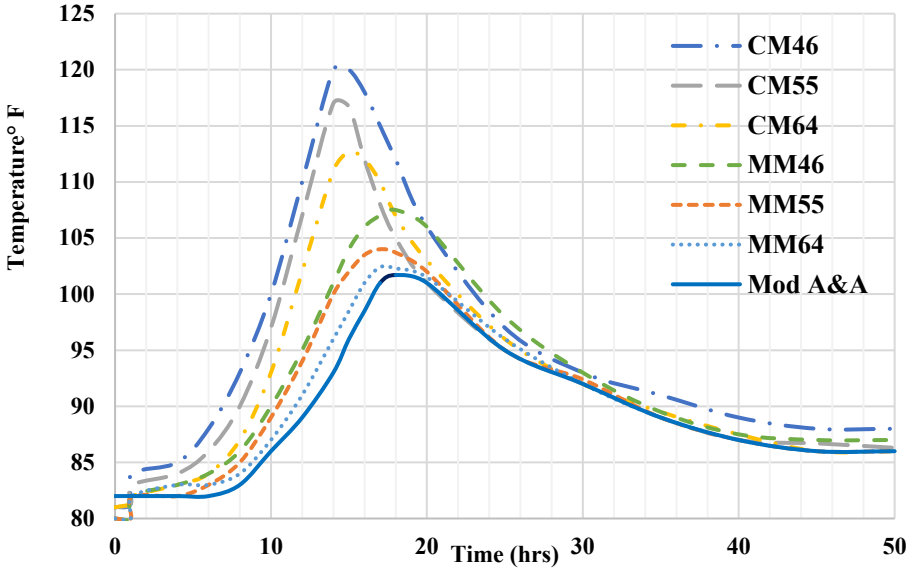


Figure-16: Calorimetry of SCC Formulations

3.1.7. Compressive Strength of SCC Formulations

The compressive strength of concrete samples dimensioning 4x4x4 inch^3 was determined according to EN 12390 standard guidelines. Samples were water-cured and were tested in SSD conditions at 1, 7, 14, and 28 days, and the results are shown in Figure-17.

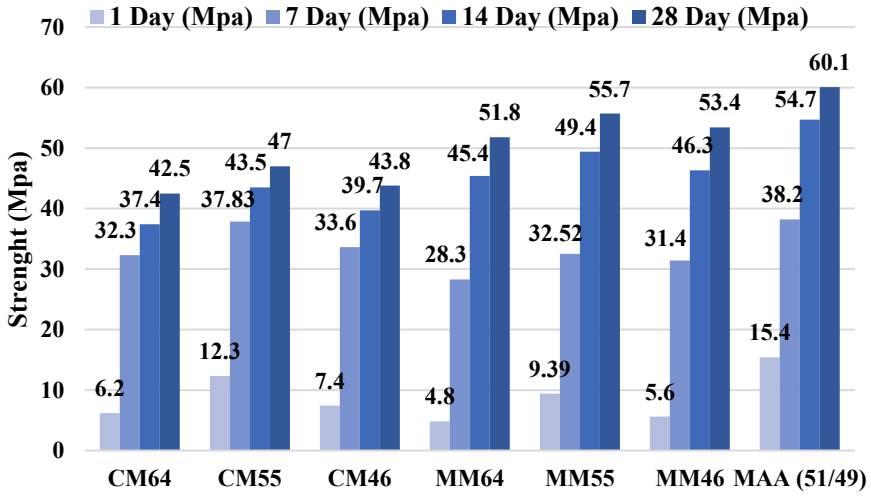


Figure-17: Compressive Strength of SCCs

4. Discussion

4.1. Flow response of SCC

Replacement of OPC by FA and LSP reduced the clinker content in SCC. By introducing SRMs/SCMs in modified SCC mixes increased the SP demand. It is thought that with higher fine aggregates, the SP demand should increase due to increased friction and reduced effective water available for hydration, as seen in Figure 9. The same is said about T50 cm and T 70 cm flow times. Funnel times decrease by decreasing sand content due to reduced internal friction. The same is true for L-box

times and J-Ring results. T50 and T70 show the viscosity and yield stress of the mixture, respectively [19, 20].

4.2. Shrinkage response of SCC

Approximate Linear early shrinkage of SCC slightly increased with reduction of sand content. This looks surprising, but remember that it was, in fact, the shrinkage of (self-compacting mortars) SCM systems as SCC was sieved through a 2 mm sieve, and the absence of coarse aggregates resulted in this response. Another factor may be increased effective water. Mod A&A formulation shows the least amount of shrinkage caused due to the hydration reaction

4.3. Calorimetric Response of SCC

The exothermic nature of the hydration reaction is investigated through calorimetry, as shown in Figure 16, which indicates the delay in the hydration reaction due to the presence of FA as a retarder and LSP as an inert material that does not take part in the hydration reaction but just encourages the growth of hydration products. Formulations having a greater amount of fine aggregate show a lower intensity of hydration reaction due to the presence of the lesser amount of OPC in the mix obtained after passing through a 2mm sieve. Figure 16 shows the calorimetric response of SCC formulations, which was, in fact, that of SCM systems. Increasing sand content reduced the exothermic temperature. Modified Anderson and Andreason formulation gave the least temperature.

4.4. Compressive strength of SCC

Figure-17 shows the compressive strength results of SCC formulations, and it appears that by introducing SRMs/SCMs, the compressive strength increased as expected for obvious reasons. However, pozzolanic activity and nucleation sites offered by FA and LSP, respectively, caused the increment in strength at 28 days of age. CM55 and MM55 formulations, possibly due to higher packing density, showed greater compressive strength at all ages. Similarly, the formulation modeled using Modified A&A (MAA) showed maximum strength, clearly showing sand's role in theoretical formulations, which is again close to a 50:50 ratio of fine and coarse aggregates by weight. However, the packing effect seems to be more dominant in the early stages.

4.5. SEM Analysis

Hydration of SCC samples was stopped by keeping them in Acetone for 24 hours followed by submerged in isopropanol for another 24 hours. Samples were then prepared for SEM analysis. Figure 19a shows the hexagonal CH crystals, slightly different sizes and morphology. Figure 19b shows the Interfacial Transition Zone (ITZ) between aggregate and paste, considered the weakest link in the reinforced concrete. The material engineers should try to make ITZ strong by using their knowledge and experience. The concrete is examined at micro-scale and the results are interpreted at macro-scale.

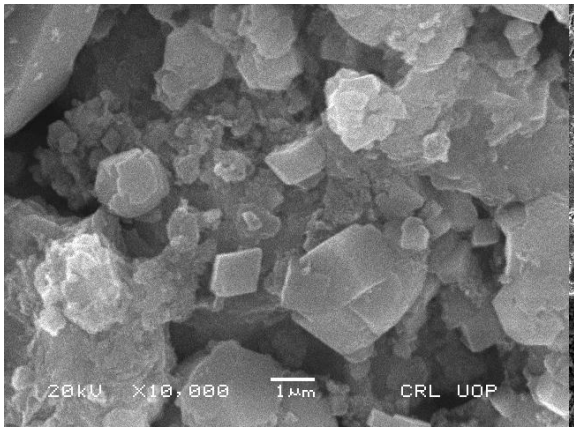


Figure-19(a): SEM Image of SCC

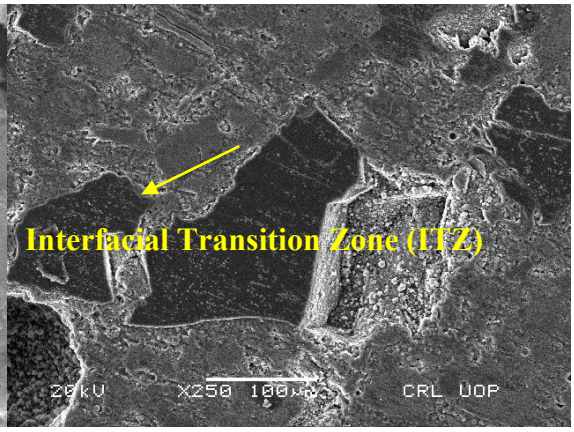


Figure-19(b): SEM Image of SCC

5. General Concluding Remarks

In the following lines, general conclusions are given which should be useful for the end users having some basic knowledge. It is hoped that researchers all over the world will benefit from this work when this paper is uploaded to the digital library of the Pakistan Engineering Congress.

Packing density is usually maximum at 50:50 of fine and coarse aggregates in both loose and compacted aggregate states, which is in agreement with [16]. Increased sand content also increases the SP demand for a given target workability in self-compacting cementitious systems. The addition of SCM also increases the SP demand. Shrinkage, Calorimetry, Strength, and micro-structural investigations also favor a 50:50 ratio of fine to coarse aggregates. Based on the results obtained, it can be concluded that the packing density of SCC directly influences the properties of concrete, like flow, SP demand, volume stability, heat of hydration, and strength. Also, blends of FA and LSP can be used as a partial replacement of cement up to 30% by weight to enhance the properties of concrete. The use of SRMs/SCMs to have environmentally friendly concrete is also recommended.

6. Acknowledgements

The authors are grateful to Mr. Haider Ali Malhi, Regional Head of SIKA Pakistan, for providing chemical admixtures used in this research free of cost.Thanks are also due to the post-graduate students of the Principal author who worked tirelessly on this rather complex issue involving both theoretical work and the experimental validation

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Address of Welcome

By

Engr. Najam Waheed, President
Pakistan Engineering Congress

at

77th Annual Session (Proceedings)
December 26, 2024

WELCOME ADDRESS BY PRESIDENT PAKISTAN ENGINEERING CONGRESS 77th ANNUAL SESSION

Honorable Chief Guest

Distinguished Delegates

Members of Pakistan Engineering Congress

Ladies & Gentlemen!

Aslamoalaikum

It gives me immense pleasure to welcome you all to this auspicious occasion of 77th annual session of Pakistan Engineering Congress. It is a great honour that His Excellency Dr. Asad Majeed Khan, Secretary General of the ECO, acceded to our request to inaugurate this annual session. Excellency, we highly value and appreciate your presence keeping in view your extremely busy schedule.

Ladies and Gentlemen

I avail this opportunity to mention the rich legacy of this esteemed organization; its contributions to the field of engineering, and its unwavering commitment to societal development.

Pakistan Engineering Congress, was founded over a century ago in 1912, it stands today as a testament to the vision and dedication of engineers, who sought to build a better future for our nation. From a very humble beginning, it has attained a recognized status of being the oldest professional engineering organization in the country.

Over the decades, the Congress has been a beacon of knowledge and its activities are devoted solely to the advancement of engineering knowledge and practice.

It has the unique honour of having on its rolls all the eminent engineers who have lived and worked in this part of the sub-continent that now constitutes Pakistan. The scientific contributions and the engineering made from the platform of this organization have won world recognition. Some of the most important advances made in the field of irrigation engineering were first presented before the congress in the form of scientific papers. It also provides platform for engineers to enhance their knowledge and skill sets through exchange of ideas, sharing best practices; for contributing in the growth and development of Pakistan.

Ladies and Gentlemen

Pakistan Engineering Congress continually strives to provide opportunities to its members for sharing of practical knowledge & experiences

by arranging technical sessions, seminars, workshops and lectures on vital issues in addition to technical study tours of significant engineering projects.

It also collaborates and fosters the exchange of technical knowledge through participation and invitation to international technical forums such as the International Commission on Large Dams (ICOLD), international commission on irrigation and drainage ICID where congress members also served on important committees such as the Permanent Committee on Technical Activities. Also, the congress has the unique honour of having 2 vice presidents who also served as presidents of the congress. In addition to active participation of its members in ASCE USA.

It is a matter of great honor and pride that highly qualified engineers and top experts of the country in their respective fields of engineering are part of the fraternity of Pakistan Engineering Congress. The objective is to promote engineering knowledge and practices, to help the engineers in raising their standards for providing their services to the people of Pakistan. It also aims at promoting self-reliance and ethical standards for the engineering community, and to provide a forum for discussing and investigating different technical and management problems.

Furthermore, Computer Center of Pakistan Engineering Congress established in 1994 offers IT courses for engineers, executives, and the general public, including advanced programming and designing. Thousands of young engineers and students have already been trained at nominal fees.

Ladies and Gentlemen

Pakistan Engineering Congress holds seminars and symposia on current issues such as water scarcity, climate change, and environmental degradation. The Congress actively participates in events like World Water Day and World Environment Day to highlight these important issues and also raising awareness about pollution control, renewable energy, and sustainable practices.

Additionally, Engineering News, a quarterly journal published by the Congress since 1958, features professional papers on various engineering topics. These papers are available for reference and consultation at the Congress Head Office library and are also distributed free of cost to various institutions, engineering universities and to the libraries.

Ladies and Gentlemen!

The Congress also spends a major part of its resources to encourage talented youth through offering of scholarships to under-graduate as well as post graduate engineering students of accredited public as well as private engineering universities. In this context, I would also like to mention that in this age of information technology, where the world has squeezed to a global village, Congress is also looking for avenues to have arrangements with various foreign universities & institutions for updation of the knowledge & improvement in skill

sets of our engineering students / researchers. Accordingly, availing this opportune moment, may I also request our worthy Chief Guest of the day, for his support through his high office in joining this effort with Congress.

Ladies and Gentlemen

The Congress also aims to bring together talented individuals from academia, industry, and government to exchange their expertise and experiences, address implementation challenges, and collaborate on creative and effective solutions for future research that connects to real-life applications. For this, at every annual session, technical papers are presented and discussed.

Excellency,

During this session, which you have very kindly consented to inaugurate, technical papers are being-presented covering various important subjects. A symposium on the subject of "Air Quality Management in Pakistan" is also being held as part of this Annual Session.

Ladies and Gentlemen

As we look ahead, the Pakistan Engineering Congress remains steadfast in its mission to inspire innovation, foster collaboration, and drive progress. Our engineers are the backbone of Pakistan’s development, and it is through their expertise and dedication that we can overcome challenges and seize opportunities.

In the end His Excellency, I extend sincere gratitude on behalf of the Executive Council of the Congress, Engineering Community in general and on my own behalf in particular for your presiding over this in-augural session despite your pressing engagements.

Together, let us continue to uphold the legacy of this organization and work towards a brighter, more sustainable future for Pakistan.

Thank you, and may Allah (SWT) bless us with success in our efforts.

-: Pakistan Paindabad :-

Inaugural Address

By

The Chief Gust
His Excellency, Amb. Dr. Asad Majeed Khan,
Secretary General Economic Cooperation Organization

at

77th Annual Session
December 26, 2024

Pakistan Engineering Congress
77th Annual Session

Inaugural Address

By

His Excellency, Amb. Dr. Asad Majeed Khan,

Secretary General Economic Cooperation Organization

President Pakistan Engineering Congress

Eminent Scholars of Engineering Fraternity,

Members of Pakistan Engineering Congress

Distinguished Delegates

Ladies & Gentlemen!

Assalam o Alaikum!

I feel great honor to address such a gathering of luminaries of engineering profession on this auspicious occasion of 77th Annual Session of Pakistan Engineering Congress. The Congress is a formidable institution engaged in the noble cause of facilitating in a robust way, the spread of engineering studies at undergraduate and post graduate level instituting 200 scholarships for undergraduate / post graduate engineering studies and disbursing Rupees 200 Million every year. The effort of the Congress ought to be vociferously lauded.

Ladies & Gentlemen!

Researchers, students of engineering disciplines, project planners have an awesome technical output of **790** papers on myriad concepts, engineering policies, mega completed development projects in addition to **346** papers read at symposiums on theme of National and International context readily available at its website for consultation at ease. No mean achievement. The Computer College of the Congress is also imparting professional I.T courses at extremely subsidized economical rates both foreign & domestic students and professional engineers and is further expanding its cooperation. This augurs well for the socio-economic advancement of the country.

Ladies & Gentlemen!

Leave aside America, Euro-Country & peep at the gigantic achievements of “Hong Kong (China) Singapore, South Korea, Taiwan etc., in the economic field. It would emerge that it is due to the strenuous efforts of their private sector, public-private collaboration. And the advanced economies. The cataclysmic achievements in the field of science, technology, cloud computing, satellite engineering, robotics and artificial intelligence all are in the private sector of these Countries who are making huge sponsorship investment in research, innovation and inventions.

Grant of already embarked upon the programme of facilitating the private sector, providing start-up capital to the young professional for setting-up small and medium Industries. Industrial Zones are being established at appropriate places turning Gawader Port and Gawader as an industrial and commercial hub under CPEC.

Government is also cognizant of the looming of water-scarcity (being water short Country). Action at warfooting is underway for the construction of Mega Diamer Hydro Power Project, Mohmand Dam as well as small Dams at various sites.

The Government has also started a number of Schemes for providing better standard of living for the marginalized people through financial assistance, importing technical education, health insurance coverages, food package distribution etc. We are stire sure to emerge as a fast-growing welfare state.

Glimpses of

77th Annual Session
December 26-28, 2024

77th Annual Session – Pakistan Engineering Congress





Group Photo of 77th Executive Council of Pakistan Engineering Congress with **Dr. Asad Majeed Khan, Chief Guest** 77th Annual Session



(From Left) Engr. Najam Waheed President PEC, Dr. Asad Majeed Khan Chief Guest, Engr. Nayyar Saeed Secretary Pakistan Engineering Congress



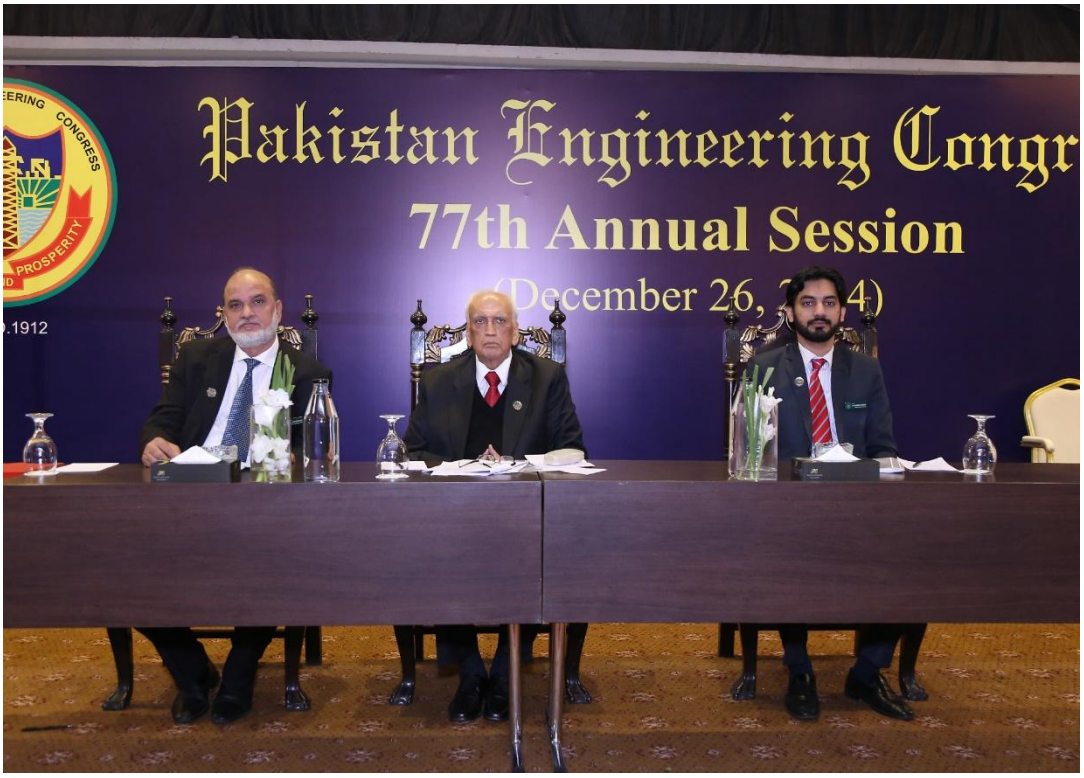
Engr. Najam Waheed President-PEC Presenting Welcome Address at the event



Chief Guest Dr. Asad Majeed Khan delivering Concluding Remarks at the event



Engr. Najam Waheed President-PEC presenting Congress Shield to Dr. Asad Majeed Khan, Chief Guest 77th Annual Session



(From Left) Engr. Dr. Muhammad Riaz, Engr. Zubair Imran Khawaja Chairman Technical Session, Engr. Muhammad Ammar Joint Secretary-PEC



Engr. Zubair Imran Khawaja, Chairman Technical Session, delivering his remarks



Engr. Riaz Nazir Tarar presenting his paper on “What Next After Diamer Basha Dam”



(From Left) Engr. Dr. Muhammad Riaz Co-Chairman Technical Session, Engr. Zubair Imran Khawaja Chairman Technical Session presenting Congress Shield to Engr. Sohail Kibria for his paper on “Evaluation of Scour Depth in Soils and Rocks-State of the Art Guidelines”



(From Left) Engr. Dr. Muhammad Riaz Co-Chairman & Engr. Zubair Imran Khawaja Chairman Technical Session, presenting Congress Shield to Prof. Dr. Ingr. Syed Ali Rizwan for his paper on “Response of Optimized Self-Compacting Concrete using Particle Packing Concepts and Supplementary Cementitious Materials (SCMS)”



(From Left) Engr. Dr. Muhammad Riaz Co-Chairman & Engr. Zubair Imran Khawaja Chairman Technical Session, presenting Congress Shield to Mr. Abdul Rehman Ch. for his paper on “Construction of Railway Bridge on River Indus at Taunsa Barrage”



Engr. Najam Waheed President-PEC presenting Congress Shield to
Engr. Dr. Muhammad Riaz, Co-Chairman of the Session



Engr. Najam Waheed President-PEC presenting Congress Shield to
Engr. Zubair Imran Khawaja, Chairman of the Session



(From Left) Engr. Safdar Ali Khan Co-Chairman, Mr. Shahid Hameed Chairman of the Session & Engr. Muhammad Ammar Joint Secretary-PEC



(From Left) Engr. Safdar Ali Khan Co-Chairman & Mr. Shahid Hameed Chairman Technical Session presenting Congress Shield to Mr. Jehanzeb for his paper on “An Overview of Diamer Basha Dam Project”



(From Left) Engr. Safdar Ali Khan Co-Chairman & Mr. Shahid Hameed Chairman Technical Session presenting Congress Shield to Mr. Mazhar Hussain Mahu for his paper on "Experiments of Archimedes Screw Turbine on Main Line Lower at Fall Rd 19+850



(From Right) Engr. Capt. (R) M. Qadir Khan Vice President-PEC, Mr. Shahid Hameed Chairman Technical Session, Engr. Najam Waheed President-PEC, presenting Congress Shield to Engr. Safdar Ali Khan Co-Chairman Technical Session



(From Left) Engr. Safdar Ali Khan, Engr. Najam Waheed President-PEC, presenting Congress Shield to Mr. Shahid Hameed Chairman Technical Session



(From Left) Engr. Shariq Ahmad Co-Chairman, Engr. Dr. Javed Iqbal Chairman Technical Session, Engr. Muhammad Ammar Joint Secretary-PEC



(From Left) Engr. Shariq Ahmad Co-Chairman & Engr. Dr. Javed Iqbal Chairman Technical Session, presenting Congress Shield to Engr. Dr. Ahsan Bela for his paper on “Waste Generation and Characterization”



(From Left) Engr. Shariq Ahmad Co-Chairman & Engr. Dr. Javed Iqbal Chairman Technical Session, presenting Congress Shield for paper on “Real Time & Predictive Analysis of Sea Surface Temperature Variability in El Nini and La Nina Weather Cycle along Pakistan Coast”



(From Left) Engr. Shariq Ahmad Co-Chairman of the Session, Engr. Dr. Javed Iqbal Chairman of the Session, presenting Congress Shield to Dr. Habib ur Rehman for his paper on “Physico-Chemical and Microbiological Water Quality Assessment of Mehmood Booti Drain in Lahore City“



(From Left) Engr. Shariq Ahmad Co-Chairman & Engr. Dr. Javed Iqbal Chairman Technical Session, presenting Congress Shield to Ms Maryam Khan for her paper on “Efficiency Analysis of Jet Pulsing Dust Collector to Control Air Pollution”



(From Right) Engr. Dr. Javed Iqbal Chairman Technical Session, Engr. Ch. Muhammad Arif Vice President-PEC & Engr. Muhammad Ibrahim Malik, presenting Congress Shield to Mr. Shariq Ahmad Co-Chairman Technical Session



Engr. Shariq Ahmad Co-Chairman Technical Session, Engr. Muhammad Ibrahim Malik & Engr. Ch. Muhammad Arif Vice President-PEC presenting Congress Shield to Dr. Javed Iqbal Chairman Technical Session

Glimpses of Audiences





Glimpses of Audiences





Keynote Address
By
Engr. Husnain Ahmad,
Convener Symposium Committee
Pakistan Engineering Congress
on the eve of
Annual Symposium on the theme of
"Air Quality Management in Pakistan"

77th Annual Session
December 27, 2024

PAKISTAN ENGINEERING CONGRESS
ANNUAL SYMPOSIUM (DECEMBER 12, 2024)
ON THE THEME OF
AIR QUALITY MANAGEMENT IN PAKISTAN
KEYNOTE ADDRESS

By

ENGR. HUSNAIN AHMAD[1]

Honorable Chief Guest – Dr. Jahanzeb Khan Sahib,

Distinguished delegates,

Fellow Engineers,

Ladies and Gentlemen:

Assalam-o-Alaikum and a very Good morning!

Air quality management is a crucial element in safeguarding public health, preserving the environment, and promoting sustainable development. As urbanization and industrialization continue to accelerate, the degradation of air quality has emerged as one of the most pressing challenges faced by many nations.

Current State of Air Quality in Pakistan

In Pakistan, this issue has reached alarming levels, with major cities consistently experiencing hazardous air pollution. In the recent years especially during the last decade, Pakistan has witnessed a significant decline in air quality, with pollutants frequently exceeding acceptable limits. According to the Pakistan Environmental Protection Agency (Pak-EPA) and various research institutions, the average annual concentration of PM2.5— a dangerous particulate matter that poses serious health risks—has consistently remained alarmingly high. In 2021, studies highlighted that major urban areas like Lahore recorded average PM2.5 levels of around 95 μg/m³, markedly higher than the World Health Organization's (WHO) safe limit of 10 μg/m³annually and25 μg/m³ daily. Unfortunately, Pakistan's air pollution levels have fallen significantly short of these standards. During, 2023 the average PM2.5 concentration in Pakistan rose to 160: 14.7 times the WHO annual air quality guideline value.

Lahore and Karachi often rank among the most polluted in the world, with particulate matter (PM2.5) and other harmful pollutants exceeding the World Health Organization’s recommended safe limits. For instance, during the winter months, Lahore frequently records some of the worst air quality indices (AQI) in the world. The AQI during smog episodes in winter often surpasses 300, a level classified as hazardous. Poor air quality not only contributes to respiratory illnesses and

[1] Convener Symposium Committee / Vice President Pakistan Engineering Congress

cardiovascular diseases but also imposes significant economic burdens due to increased healthcare costs and reduced labor productivity.

In 2020, a report from the State of Global Air indicated that approximately 125,000 deaths in Pakistan were attributable to air pollution, emphasizing a severe public health crisis.

Comparatively, countries in South Asia and across the globe are also facing with air quality issues, but Pakistan's urban centers have consistently reported some of the highest levels of pollution. While some nations are making strides towards cleaner air, efforts in Pakistan are hindered by regulatory challenges and insufficient awareness regarding the health impacts of poor air quality.

Sources of air pollution

The multifaceted nature of air quality issues in Pakistan is influenced by various factors, including vehicular emissions, industrial discharge, burning of solid waste, and agricultural practices.

Understanding the sources of air pollution is critical to devising effective management strategies. In Pakistan, several key contributors have been identified:

1. Industrial Emissions: Rapid industrial growth, especially in urban areas, has led to increased emissions from factories. The lack of adherence to environmental standards has resulted in the release of harmful substances, including heavy metals, particulate matter, and volatile organic compounds.

2. Vehicular Emissions: With a rapidly growing urban population, the number of vehicles on the roads has surged. The transportation sector contributes significantly to air pollution, particularly in major cities where traffic congestion is common. According to estimates, vehicular emissions contribute over 60% of urban air pollution, especially from old and poorly maintained vehicles.

3. Household Activities: The use of cheap fuels, such as wood and coal, for cooking and heating in many households contributes to indoor and outdoor air pollution. Reports suggest that around 70% of rural households rely on solid fuels, impacting air quality and exacerbating health issues.

4. Agricultural Practices: Stubble burning is a significant environmental concern in agriculture. Farmers often set fire to crop residues postharvest to clear fields for the next planting season. This practice releases vast amounts of smoke and particulate matter

Health Impacts of Poor Air Quality

Air pollution leads to an estimated 128,000 premature deaths annually in Pakistan (Lancet Countdown, 2021). Common health issues include asthma, chronic obstructive pulmonary disease (COPD), and ischemic heart disease. Children and the elderly are particularly vulnerable.

Poor air quality in Pakistan poses a significant threat to public health, contributing to respiratory and cardiovascular diseases, reducing life expectancy, and imposing a substantial economic burden. Addressing this issue requires a multi-faceted approach, including stricter enforcement of environmental regulations, public awareness campaigns, and investment in cleaner technologies. Improving air quality

is essential for protecting the health and well-being of the population and ensuring sustainable development in Pakistan.

Environmental Consequences of Poor Air Quality in Pakistan

Air pollution is also a critical issue in Pakistan, with respect to its significant environmental consequences. The country's rapid industrialization, urbanization, and reliance on fossil fuels have led to deteriorating air quality, impacting the environment with consequences on ecosystems including forests, rivers and agricultural lands. It also contributes significantly to climate change, emissions of greenhouse gases (GHGs) such as carbon dioxide (CO2), methane (CH4), and black carbon that also affect health of flora and fauna.

Economic Consequences

Air pollution imposes a heavy economic burden, with estimated annual losses of $20 - 22 billion USD, equivalent to 5.9% to 6.5% of Pakistan’s GDP (World Bank, 2023). These costs arise from healthcare expenditures, lost labor productivity, and decreased agricultural yields.

Regulatory Framework and Policies in Pakistan

Pakistan's regulatory framework and policies have evolved significantly over the years to address various economic, social, and environmental challenges. The regulatory environment in Pakistan encompasses a wide range of sectors, including finance, industry, environment, and public health. Environmental protection is a critical aspect of Pakistan's regulatory framework. The Pakistan Environmental Protection Agency (Pak-EPA) is responsible for enforcing environmental laws and regulations to ensure sustainable development and protect natural resources.

Pakistan's regulatory framework and policies play a crucial role in promoting economic growth, ensuring environmental sustainability, and protecting public health. While significant progress has been made, there is a need for continuous improvement and adaptation to address emerging challenges. Strengthening regulatory institutions, enhancing enforcement mechanisms, and promoting transparency are essential for achieving sustainable development in Pakistan.

Technological Innovations and Best Practices for Air Quality in Pakistan

Technological innovations and best practices are essential to mitigate air pollution and improve air quality. Some of the key technological advancements and best practices in air quality management those may help in air quality in Pakistan includes the following;

1. Smart Air Quality Monitoring Systems using advanced sensors and data analytics to provide real-time information on air quality parameters such as particulate matter (PM2.5 and PM10), nitrogen dioxide (NO2), sulfur dioxide (SO2), and ozone (O3) to identify pollution hotspots and take timely action to mitigate pollution.

2. Catalytic Converters: Catalytic converters to reduce harmful emissions in vehicles can significantly reduce vehicular emissions, which are a major source of air pollution in urban areas.

3. Renewable Energy Technologies help reduce the reliance on fossil fuels. Pakistan has made significant investments in renewable energy projects, such as the

Quaid-e-Azam Solar Park and the Jhimpir Wind Corridor, to promote sustainable energy production.

4. Electrostatic Precipitators: Electrostatic precipitators to remove particulate matter from exhaust gases. This technology is highly effective in reducing industrial emissions and improving air quality.

5. Bio-filtration and Bio-remediation: Biofiltration and bioremediation are innovative technologies to clean up contaminated environments. These technologies offer sustainable and cost-effective solutions for air pollution control.

Best Practices for Air Quality Management

Technological innovations and best practices are essential for addressing the air quality challenges in Pakistan. By adopting smart air quality monitoring systems, catalytic converters, renewable energy technologies, electrostatic precipitators, and biofiltration, Pakistan can significantly reduce air pollution. Implementing air quality standards, promoting public awareness, enhancing regulatory frameworks, encouraging research and innovation, and integrating green infrastructure are key best practices for effective air quality management. International collaboration and cooperation are also crucial for achieving sustainable air quality improvements. By embracing these innovations and best practices, Pakistan can create a cleaner and healthier environment for its citizens.

Strategic Recommendations for Improving Air Quality in Pakistan

Air pollution is a pressing issue in Pakistan, with significant health, environmental, and economic impacts. To address this challenge, it is crucial to implement strategic measures that enhance public awareness and education, as well as strengthen regulatory enforcement. Here are some detailed recommendations:

Enhancing Public Awareness and Education

Conduct awareness programs to educate citizens about air pollution's health impacts and their role in mitigation.

Strengthening Regulatory Enforcement

Improving air quality in Pakistan requires a multifaceted approach that combines public awareness and education with strong regulatory enforcement. By implementing comprehensive public awareness campaigns, integrating air quality education into school curricula, engaging communities, and collaborating with NGOs, Pakistan can raise awareness and foster a culture of environmental responsibility. Strengthening environmental regulations, enhancing monitoring and reporting, building the capacity of regulatory agencies, promoting compliance through incentives and penalties, and improving interagency coordination are essential steps to ensure effective enforcement and sustainable air quality improvements. With a rapidly growing population and urban infrastructure, the challenge of managing air quality becomes even more critical. Addressing these issues is essential for ensuring the health of citizens and the sustainability of the environment. These strategic recommendations can help Pakistan address its air pollution challenges and protect the health and well-being of its citizens.

The objective of this symposium is also to bring together experts, policymakers, researchers, and stakeholders to engage in meaningful dialogue surrounding air

quality management in Pakistan. This event aims to share knowledge, discuss innovative strategies, and develop actionable plans to combat air pollution. By fostering collaboration and creating a platform for the exchange of ideas, we aspire to pave the way for effective policies and practices that will lead to improved air quality and a healthier future for all citizens of Pakistan.

I am confident that with papers covering significant aspects of Air Quality Management, starting from analysis of the existing situation with a review on Air Pollution control Technologies, GIS based Health Risk Assessment, along with meaningful pollution Governance Strategies in Pakistan shall help us in understanding and better management of Air Quality in Pakistan. Papers in this Symposium also include case studies on Seasonal Variability of Air Quality in Lahore and Spatial and Temporal Analysis aimed at highlighting implications of PM2.5 in Lahore for Public Health and Policy Making. Likewise, another paper highlights the importance and need of Scientific Framework for Clean Air in Karachi. The effort of the authors deserve not only due audience but a great appreciation for their painstaking work and efforts for presenting there work in this Symposium.

Finally, it is important to understand that together we can drive change and create a cleaner, more sustainable environment for generations to come.

-: Pakistan Paindabad :-

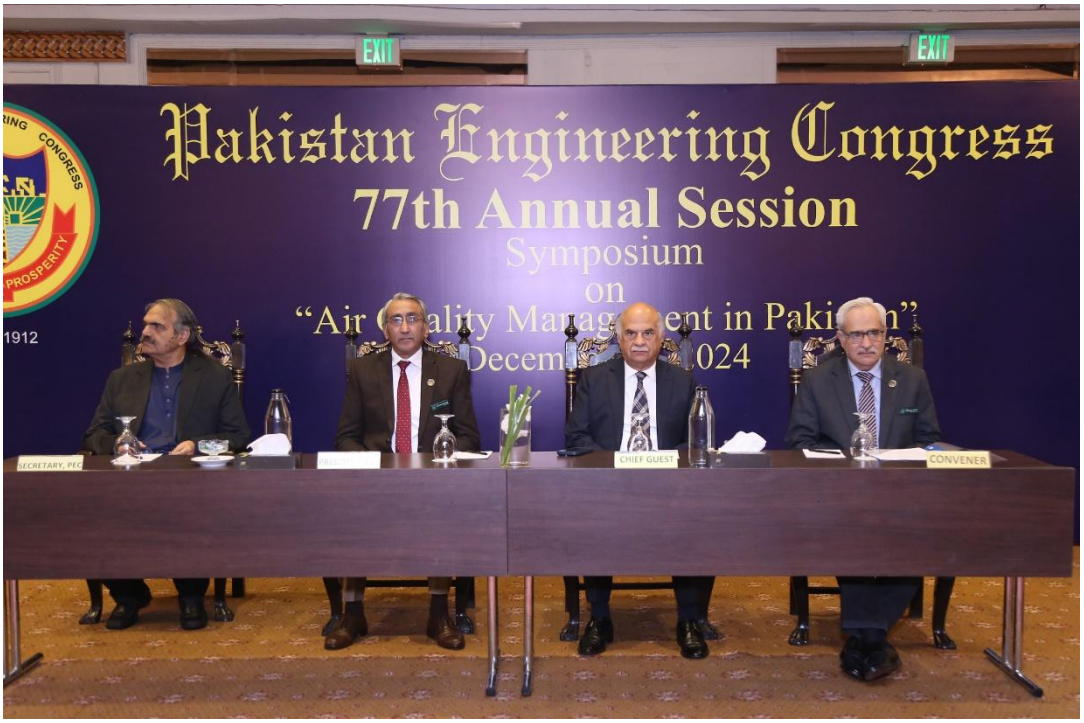
Glimpses of Annual Symposium

(77th Annual Session)
December 27, 2024

Annual Symposium on the theme of "Air Quality Management in Pakistan"



(From Left) Engr. Husnain Ahmad, Vice President PEC,
Mr. Muhammad Jehanzeb Khan, Chief Guest, Engr. Najam Waheed, President PEC,
Engr. Iftikhar Ahmad & Engr. Muhammad Ibrahim Malik



(From Left) Engr. Nayyar Saeed Secretary-PEC, Engr. Najam Waheed President-PEC, Mr. Muhammad Jehanzeb Khan Chief Guest,
Engr. Husnain Ahmad Vice President-PEC



Engr. Husnain Ahmad Convener Symposium Committee delivering Key Note Address at 77th Annual Symposium



Chief Guest Mr. Muhammad Jehanzeb Khan delivering Concluding Remarks at the event



(From Right) Engr. Husnain Ahmad Vice President-PEC / Convener Symposium Committee, Engr. Najam Waheed President-PEC, presenting Congress Shield to Mr. Muhammad Jehanzeb Khan, Chief Guest



Engr. Nayyar Saeed Secretary-PEC Conducting the Proceedings



(From Right) Engr. Dr. Javed Iqbal Chairman of the Session, presenting Congress Shield to Ms Tayyaba Gulzar for her paper on “A Review on Air Pollution Control Technologies Commonly Employed in the Industrial Sector“



(From Right) Engr. Dr. Javed Iqbal Chairman of the Session, presenting Congress Shield to Dr. Irfan Jalees for his paper on “GIS-Based Health Risk Assessment of Ambient Air Quality Due To Rapid Urbanization in Lahore, Pakistan”



(From Right) Engr. Dr. Javed Iqbal Chairman of the Session, presenting Congress Shield to Mr.M. Ali Amjad for his paper on “A Study on the Seasonal Variability of Air Quality in Lahore City”



(From Right) Engr. Dr. Javed Iqbal Chairman of the Session, presenting Congress Shield to Mr. Syed Tehzeeb ul Hassain for his paper on “Towards More Effective Air Pollution Governance Strategies in Pakistan: A Systematic Review of the Literature”



(From Right) Engr. Dr. Javed Iqbal Chairman of the Session, presenting Congress Shield to Ms Masooma for her paper on “Understanding the Relationship Between Air Pollution and Meteorological Conditions and Finding Solutions to Air Pollution Problems at the Community and Individual Level”



(From Right) Engr. Najam Waheed President-PEC, presenting Congress Shield to Engr. Dr. Javed Iqbal Chairman of the Session.

Glimpses of Audiences





Glimpses of 78th Annual General Meeting

(77th Annual Session)
December 28, 2024

78th Annual General Meeting 2024
Pakistan Engineering Congress



Engr. Muhammad Ammar Member Executive Council Conducting the Proceedings



Engr. Nayyar Saeed presenting Secretary Report at the 77th Annual General Meeting



Engr. Sh. Mushtaq Ahmed



Engr. Khalid Zia Cheema

Glimpses of Audiences





Glimpses of Audiences





Seminar on

"Dispute Avoidance and Dispute Resolution: Best Practices"

&

"Legal Dimensions of Adverse Subsoil Conditions"

Held on April 10, 2025 at Husnain Hall of Pakistan Engineering Congress

SEMINAR ON "DISPUTE AVOIDANCE AND DISPUTE RESOLUTION: BEST PRACTICES" & "LEGAL DIMENSIONS OF ADVERSE SUBSOIL CONDITIONS" HELD ON 10-04-2025 AT HUSNAIN HALL OF PAKISTAN ENGINEERING CONGRESS HQ

Pakistan Engineering Congress organized a Seminar on 10-04-2025 wherein following papers were presented by the foreign specialists with lifelong knowledge and vast experience:

I. "Dispute Avoidance and Dispute Resolution: Best Practices" by Prof. Allione Romano

Brief introduction of Prof. Allione Romano

Mr. Allione is a Professional Engineer and Project Management Consultant, internationally recognized for his expertise in dispute resolution and infrastructure development. A Member of the FIDIC President's List of Approved Adjudicators and Charter Member—and Past President—of the Dispute Resolution Board Foundation (DRBF), he received the DRBF's prestigious Al Mathews Award for outstanding contribution.

With over 30 years at Impregilo S.p.A., Italy's largest contractor, he played pivotal roles in landmark projects across Africa, Asia, and Latin America—including the Tarbela Dam in Pakistan, El Cajon Dam in Honduras, and Katse Dam in Lesotho. He was a pioneer in launching the first DRB outside the United States and continues to promote DRB/DAB mechanisms globally through training and thought leadership.

Post-retirement, he remains active in arbitration, serving as Chair or Member on numerous boards including ICC Combined Dispute Boards and Italy's CCT for the Bologna High-Speed Train Station. As a lecturer at Milan Polytechnic, he specializes in contract, claims, and delay management.

II. "Legal Dimensions of Adverse Subsoil Conditions" by Mr. Julian Bailey

Brief introduction of Mr. Julian Bailey

Prof. Julian Bailey advises on international construction and infrastructure projects globally. He has represented sovereign governments, developers, and contractors in construction and engineering projects and disputes.

Prof. Julian has represented in an International Chamber of Commerce (ICC) arbitration concerning a port project in Iraq, a solar EPC contractor in an ICC arbitration concerning a project in Egypt, a gas pipeline interconnector project in south east Europe, a port project in Moracco, in UK Supreme Court concerning a Hydroelectric Power Project, in High Court litigation in northern Ireland an arbitration concerning a sub-sea electrical interconnector, in an arbitration in Qatar concerning delay and disruption to the construction and commissioning of a gas-fired power station and in a dispute concerning onshore infrastructure for a LNG facility.

Mr. Julian was chairman of the Society of Construction Law (UK) from 2015 to 2016, the leading industry body for construction law. He is also author of Construction Law, a three-volume general text as it applies in

England, Australia, Hong Kong, and Singapore, with an international outlook.

Julian is a visiting professor at the Dickson Poon School of Law, King's College, London and is an adjunct professor of law at Hamad bin Khalifa University, Doha, Qatar.

Both presenters delivered insightful and well-structured lectures that were rich in technical depth and practical relevance. Their sessions drew a substantial and engaged audience, reflecting the significance of the subject matter and the stature of the speakers. A dynamic question-and-answer session followed each presentation, marked by thoughtful queries and comprehensive responses, fostering meaningful dialogue between the speakers and participants.

The event concluded with remarks by Engr. Ch. Muhammad Arif, President of the Pakistan Engineering Congress, who acknowledged the speakers' valuable contributions and the enthusiastic participation of attendees. As a token of appreciation, Pakistan Engineering Congress shields were conferred upon the distinguished speakers. The event emerged as a profoundly stimulating and intellectually rewarding occasion.

GLIMPSES OF SEMINAR ON "DISPUTE AVOIDANCE AND DISPUTE RESOLUTION: BEST PRACTICES" & "LEGAL DIMENSIONS OF ADVERSE SUBSOIL CONDITIONS"

GLIMPSES OF SEMINAR ON "DISPUTE AVOIDANCE AND DISPUTE RESOLUTION: BEST PRACTICES" & "LEGAL DIMENSIONS OF ADVERSE SUBSOIL CONDITIONS"



Chief Guest Prof. Allione Romano being received by Engr. Ch. Muhammad Arif, President PEC along with members of Executive Council (78th Session)



Engr. Ch. Muhammad Arif President PEC, delivering Welcome Address

Prof. Allione Romano delivering lecture on "**Dispute Avoidance and Dispute Resolution: Best Practices**"





Glimpses of the Audience










Reserve


PEC
Abdur Rahman



Engr. Ch. Muhammad Arfi President PEC & Engr. Dr. Javed Iqbal Secretary PEC,
Presenting Pakistan Engineering Congress Shield to Prof. Allione Ramano



Engr. Sheikh Moeen receiving Pakistan Engineering Congress Shield on behalf of
Mr. Julian Bailey from Engr. Ch. Muhammad Arif President PEC &
Engr. Dr. Javed Iqbal Secretary PEC

World Water Day 2025
On the theme of
"Glacier Preservation"
Held on April 12, 2025

World Water Day 2025
On the theme of
"Glacier Preservation"
Held on April 12, 2025

World Water Day 2025 centered on the urgent theme of **Glacier Preservation**, spotlighting the global significance of glaciers in sustaining freshwater resources for drinking, agriculture, clean energy, and ecosystem stability. The event emphasized the accelerating retreat of glaciers due to climate change, underscoring the imperative to reduce greenhouse gas emissions and implement sustainable meltwater management strategies.

Speakers highlighted the profound impacts of glacial melt—ranging from unpredictable water cycles to increased risks of floods, droughts, and sea-level rise. The call to action was clear: protecting our frozen water reserves is a survival strategy for humanity and the planet.

The Pakistan Engineering Congress convened a distinguished panel of experts specializing in water conservation and application. Following nine research papers were presented, contributing valuable insights into innovative approaches, technological interventions, and policy frameworks to safeguard water resources in the face of climatic challenges.

- "GMRC-WATER'S CONTRIBUTION TO GLASIER MONITORING IN PAKISTAN"
- "CLIMATE CHANGE & FRESH WATER SUPPLY OF PAKISTAN"
- "VULNERABILITY CHALLENGES TO HIGH ALTITUDE WETLANDS AND ITS FEEDING GLACIERS IN PAKISTAN REGARDING CLIMAGTE CHANGE"
- "ROLE OF DIAMER BASHA DAM (DBD) ON FOOD, ENERGY SECURITY AND CLIMATE CHANGE MITIGATION OF PAKISTAN"
- "INDUS TELEMETARY PROJECT – A PROJECT FOR TRANSPARENT DISTRIBUTION OF PROVINCIAL SHARES"
- "GLACIAL MILTING IN PAKISTAN AND THE CONSEQUENT TRIBULATIONS FOR THE COUNTRY'S EXPOSED POPULATION"
- "USING RAW GROUND WATER FOR THE DEVELOPMENT OF ORGANIC MINERAL WATER"
- "HEAVY METAL POLLUTION IN MANAGROVES STANDS ALONG PAKISTAN COASTLINE"
- "DECADAL TREDS IN SNOW COVER DYNAMICS ACROSS THE INDUS BASIN: INSIGHTS FROM MODIS NDSI ANALYSIS (2008-2018)"

Honorable Mr. Kazim Ali Pirzada, Minister for Irrigation, graced the occasion as Chief Guest. Following the presentation of research papers, an engaging question-and-answer session unfolded, fostering thoughtful dialogue between speakers and attendees. The event concluded with insightful remarks by the Chief Guest, after which commemorative shields from the Pakistan Engineering Congress were presented to the distinguished speakers.

Address of Welcome

By

Engr. Ch. Muhammad Arif, President Pakistan Engineering Congress

On the eve of

World Water Day 2025

On the theme of

“Glacier Preservation”

Welcome Address

By

Engr. Ch. Muhammad Arif

President Pakistan Engineering Congress

On World Water Day, 2025

On the theme of "Glacier Preservation"

Honorable Chief Guest
Distinguished Delegates,
Executive Council Members,
Fellow Engineers, Ladies & Gentlemen,

Assalam-o-Alaikum!

It is truly an honor and privilege to welcome you all here today as we come together to commemorate World Water Day 2025 which infact falls on 22nd March but has been rescheduled for today due to Holy Ramdan.

Since 2005, Pakistan Engineering Congress has been proudly observing this important day, adopting global themes that call for attention to fundamental water issues. This year, the theme is "Glacier Preservation," a pressing subject that highlights the sustainable management of water resources, the promotion of conservation, and the protection of these vital reserves.

Ladies & Gentlemen!

Glaciers, known as "rivers of ice," are not only awe-inspiring natural wonders but also significant to the planet's ecological balance. They serve as one of the largest reservoirs of freshwater on Earth, storing an astounding 69% of the world's freshwater. Communities living downstream of glacier-fed rivers rely heavily on these melting glaciers during warmer months for agriculture, drinking water, and hydropower. Glaciers are found in all major mountain ranges around the globe. The biggest glaciers are found in Alaska and Patagonia. As we talk of Pakistan, there are over 7,000 glaciers in the northern regions of Pakistan in Gilgit-Baltistan and Khyber Pakhtunkhwa.

Ladies & Gentlemen!

Glaciers play an imperative role in regulating the Earth's climate through the albedo effect, reflecting sunlight and helping to cool the planet. However, global warming has placed these icy giants under severe threat, accelerating their melting and creating a feedback loop of rising temperatures. This loss poses serious risks, from water scarcity and disrupted ecosystems to sea-level rise and intensified climate change impacts.

But glaciers are more than just environmental treasures; they hold profound economic, cultural, and even spiritual value. They attract millions of tourists and are deeply woven into the traditions and beliefs of many communities worldwide.

Ladies & Gentlemen!

I would say, the fight to preserve glaciers is a fight for life on Earth. These icy giants are more than a symbol of nature's beauty—they are critical to sustaining our planet's ecosystems, economies, and communities. As we witness their alarming

decline, the time for complacency is over. Every individual, organization, and nation has a role to play in safeguarding these natural treasures for future generations.

On this occasion, let us pledge to take meaningful actions—big and small—to combat climate change and protect our glaciers. Whether it is advocating for sustainable practices, supporting conservation efforts, or simply making environmentally conscious choices in our daily lives, every step counts to safeguard this precious resource for future generations.

Kindly remember, protecting glaciers is not merely an environmental responsibility; it is an investment in humanity's future. Together, we can preserve these majestic rivers of ice and ensure that their legacy endures for generations to come

Ladies & Gentlemen!

Today, I am pleased to share that the Pakistan Engineering Congress has curated 9 insightful papers by distinguished speakers to address this important theme. I extend my heartfelt appreciation to the authors for their dedication and contributions, which will advance our understanding and inspire action for this cause.

On this World Water Day, let us pledge to do our part—working together to preserve our glaciers and ensure clean water access for all.

Thank you!

-: Pakistan Paindabad :-

Address

By

The Chief Guest
Honorable Mr. Kazim Ali Pirzada,
Minister for Irrigation, Punjab

On the eve of

World Water Day 2025

On the theme of

“Glacier Preservation”

Address

By

The Honorable Mr. Kazim Ali Pirzada,
Minister for Irrigation, Punjab

On World Water Day, 2025

On the theme of "Glacier Preservation"

Respected members of the Pakistan Engineering Congress,

Esteemed Guests,

Ladies, and Gentlemen!

Assalam-o-Alaekum!

Good Morning and thank you for the honor of being here as your Chief Guest on this remarkable occasion of World Water Day 2025. Today, we gather not only to celebrate the irreplaceable resource that sustains all life "The Water", but to also shine a spotlight on an important issue that demands our collective action, that is Glacier Preservation.

As we look around the room, we are reminded of Pakistan's unique geographical blessings, home to the mighty Karakoram, Himalayas, and Hindu Kush ranges, boasting some of the world's largest glaciers outside the polar regions. These "Water Towers" of Asia serve as the lifeblood for our rivers, agriculture, industries, and, indeed, for millions of lives downstream. Yet, these glaciers, our natural reservoirs of fresh water are under severe threat.

Climate change has unleashed unprecedented challenges. Rising global temperatures have accelerated glacial melt, causing erratic water supplies, increased risks of glacial lake outburst floods (GLOFs), and threatening the delicate ecosystems that depend on these icy giants. For a water-stressed nation like Pakistan, the consequences are dire, as we face growing water scarcity, reduced hydropower potential, and challenges to food security.

Ladies and gentlemen!

This is a call to action—urgent, collective action. We cannot control nature, but we can control our response to its changes. The preservation of glaciers demands a multi-faceted approach. It starts with "mitigation, adaptation, and awareness". Allow me to outline a few key priorities:

Ladies & Gentlemen!

To slow glacier melt, we must act decisively to curb greenhouse gas emissions. This requires transitioning toward renewable energy sources, promoting energy efficiency, and reforestation efforts. Pakistan's own initiatives are commendable in this direction.

Efficient use of our water resources is vital. Engineers, scientists, and policymakers must work together to modernize our irrigation systems, develop water storage infrastructure, and minimize waste. Every drop saved upstream means resilience downstream.

Communities living near glacier-fed regions must be empowered through knowledge and tools to manage and adapt to the risks of glacial melt. Public awareness campaigns can foster environmental stewardship at all levels.

Ladies & Gentlemen!

Glacier preservation is a global challenge that transcends borders. Pakistan must strengthen partnerships with neighboring countries, leveraging shared knowledge and resources to protect the Himalayas, Karakoram, and beyond.

As engineers, policymakers, and citizens, you hold the expertise, resources, and influence to spearhead this mission. Pakistan Engineering Congress, with its rich legacy of driving innovation and progress, is uniquely positioned to lead the charge in glacier preservation. Together, we can turn challenges into opportunities—developing sustainable technologies, fostering innovation, and leaving a legacy of resilience for future generations.

Ladies and gentlemen!

The fate of our glaciers is intertwined with the future of our nation. Let us make a solemn commitment today—a commitment to act, to innovate, and to safeguard the lifelines of our rivers, our agriculture, and our people. Let us be the torchbearers of change in preserving the icy wonders that fuel our world.

On this World Water Day 2025, let us not just celebrate water but take a stand to protect its very source “our majestic glaciers”. For in their preservation lies the promise of life, prosperity, and hope.

Thank you.

-: Pakistan Paindabad :-

Glimpses
Of
World Water Day 2025

World Water Day 2025 on the theme of "Glacier Preservation" Commemorated at Pakistan Engineering Congress Headquarter on Saturday April 12, 2025



Engr. Muhammad Ammar Member Executive Council Conducting the Proceedings



(From Left) Engr. Dr. Javed Iqbal Secretary-PEC, Engr. Ch. Muhammad Arif President-PEC, Chief Guest Honorable Mr. Kazim Ali Pirzada, Minister for Irrigation Punjab, Engr. Muhammad Ammar Joint Secretary-PEC



Engr. Ch. Muhammad Arif President-PEC Presenting Welcome Address



Chief Guest Honorable Mr. Kazim Ali Pirzada, Minister for Irrigation Punjab addressing the audience

Glimpses of Audiences





Glimpses of Audiences





Glimpses of Audiences





Questions / Answers Session











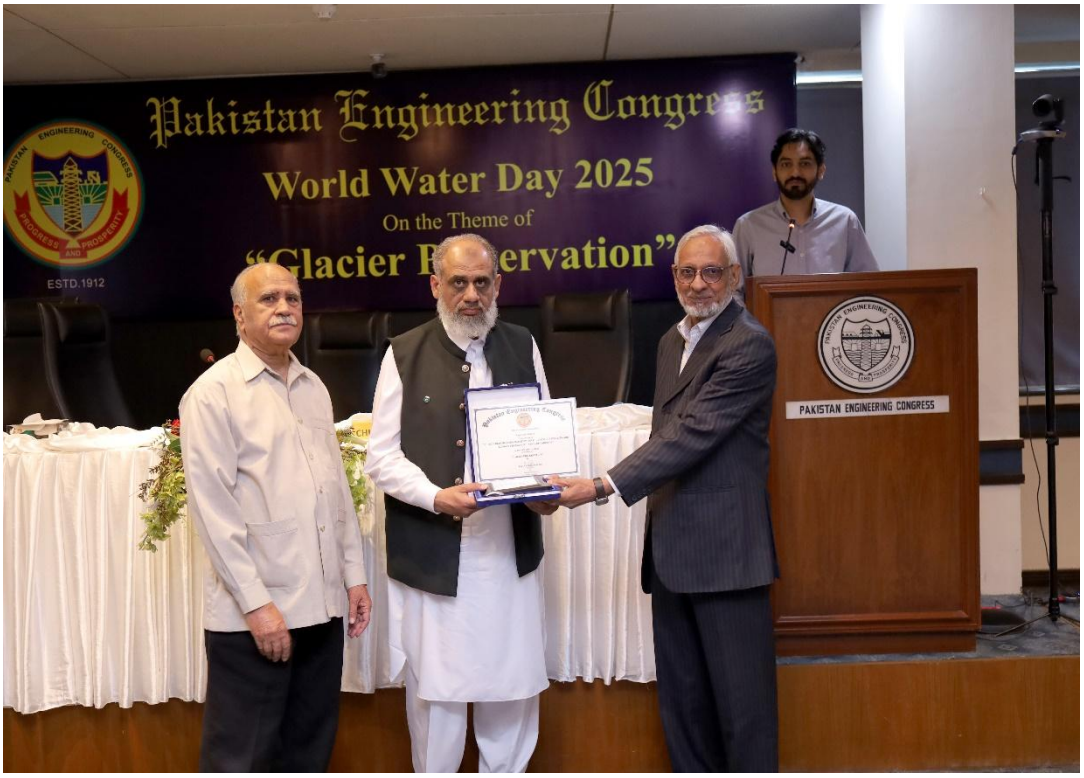
(From Right) Engr. Ch. Muhammad Arif President-PEC, Chief Guest Honorable Mr. Kazim Ali Pirzada presenting Pakistan Engineering Congress Shield to Syed Hammad Ali for his paper on “GMRC-WAPDA’s Contribution to Glacier Monitoring in Pakistan”



(From Right) Engr. Dr. Rana Akhtar Ali Chairman Technical Session and Engr. Riaz Ahmad Khan Co-Chairman of the Technical Session presenting Congress Shield to Engr. Riaz Nazir Tarar for his paper on “Climate Changes & Fresh Water Supply of Pakistan”



(From Right) Engr. Dr. Rana Akhtar Ali Chairman Technical Session and Engr. Riaz Ahmad Khan Co-Chairman Technical Session presenting Congress Shield to Ms. Javeria Faisal for her paper on "Vulnerability Challenges to High Altitude Wetlands and its Feeding Glaciers in Pakistan Regarding Climate Change"



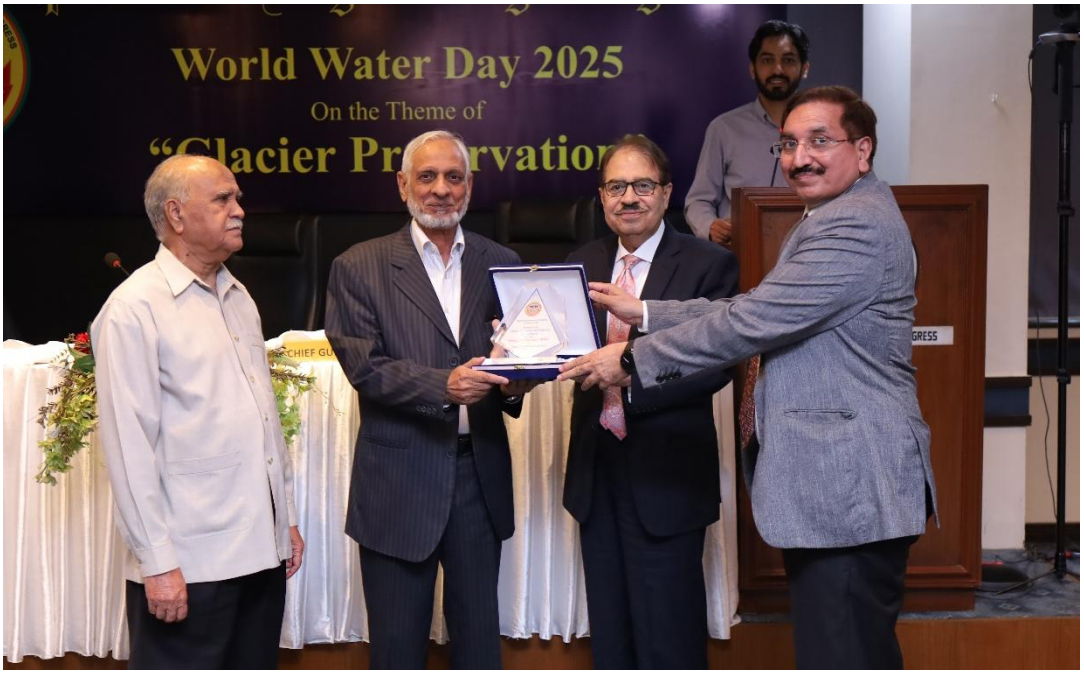
(From Right) Engr. Dr. Rana Akhtar Ali Chairman Technical Session and Engr. Riaz Ahmad Khan Co-Chairman Technical Session presenting Pakistan Engineering Congress Shield to Engr. Zahid Majeed for his paper on "Role of Diamer Basha Dam (DBD) on Food, Energy Security and Climate Change Mitigation of Pakistan"



(From Right) Engr. Dr. Rana Akhtar Ali Chairman Technical Session and Engr. Riaz Ahmad Khan Co-Chairman Technical Session presenting Congress Shield to Engr. Dr. Muhammad Riaz for his paper on “Indus Telemetry Project – A Project for Transparent Distribution of Provincial Shares”



(From Right) Engr. Dr. Rana Akhtar Ali Chairman Technical Session and Engr. Riaz Ahmad Khan Co-Chairman Technical Session presenting Pakistan Engineering Congress Shield to Mr. Khurram Saleem for his paper on “Glacial Melting in Pakistan and the Consequent Tribulations for the Country’s Exposed Population”



(From Right) Engr. Dr. Javed Iqbal Secretary-PEC, Engr. Ch. Muhammad Arif President-PEC and Engr. Riaz Ahmad Khan Co-Chairman of the Technical Session, presenting Pakistan Engineering Congress Shield to Engr. Dr. Rana Akhtar Ali Chairman Technical Session



(From Right) Engr. Dr. Javed Iqbal Secretary-PEC, Engr. Ch. Muhammad Arif President-PEC presenting Pakistan Engineering Congress Shield to Engr. Engr. Riaz Ahmad Khan Co-Chairman of the Technical Session, Dr. Rana Akhtar Ali Chairman of the Technical Session

SEMINAR ON "INDUS WTER TREATY"

HELD ON May 10, 2025

SEMINAR ON "INDUS WATER TREATY" HELD ON MAY 10, 2025

The **Indus Waters Treaty (IWT)** is a landmark water-sharing agreement signed between **India and Pakistan** on **September 19, 1960**, with the **World Bank** acting as a broker. The treaty governs the use of waters from the **Indus River system**, which includes six major rivers: the Indus, Jhelum, Chenab, Ravi, Beas, and Sutlej.

Under the treaty:

- **Pakistan** was granted exclusive rights over the **three western rivers**—Indus, Jhelum, and Chenab.
- **India** retained control over the **three eastern rivers**—Ravi, Beas, and Sutlej.

The agreement also established a **Permanent Indus Commission** to facilitate cooperation and resolve disputes. Despite geopolitical tensions, the IWT has endured for over six decades and is widely regarded as one of the most successful examples of transboundary water management.

In recent years, the treaty has faced challenges due to climate change, infrastructure development, and regional security concerns, prompting calls for modernization and enhanced dialogue.

On May 10, 2025, the Pakistan Engineering Congress organized a highly insightful seminar addressing multidimensional aspects of the Indus Waters Treaty, drawing an impressive turnout from professionals, academics, and policymakers. The event featured two distinguished lectures by subject-matter experts, offering legal and technical perspectives on one of South Asia's most critical transboundary water agreements.

Key Lectures Delivered

- **"Legal Aspects of Indus Waters Treaty" by Mr. Ahmer Bilal Soofi**

Mr. Soofi, a leading legal authority and Founding President of RSIL, shared his expertise on treaty interpretation, international dispute resolution, and Pakistan's legal standing in water-sharing frameworks. His extensive experience—spanning appearances at ICJ and ICSID—provided participants with a robust understanding of how international law interfaces with regional water diplomacy.

- **"Technical Aspects of Indus Waters Treaty" by Mr. Mirza Asif Baig**

As a former PCIW Commissioner and infrastructure leader, Mr. Baig discussed engineering challenges, hydrological nuances, and the strategic importance of data and infrastructure in managing the western rivers allotted to Pakistan under the treaty. His insights reinforced the role of technical expertise in shaping policy responses and future water negotiations.

Special Participation

The seminar was graced by Mr. Muhammad Mohsin Khan Leghari as Guest of Honor, whose remarks underscored the intersection of water governance, policymaking, and institutional resilience. With notable experience as a legislator and provincial minister, Mr. Leghari emphasized the need for integrated approaches to water sustainability.

Closing & Recognition

A vibrant Q&A session enabled meaningful interaction between speakers and attendees, fostering a deeper understanding of Pakistan's water landscape. The

President of Pakistan Engineering Congress, Engr. Ch. Muhammad Arif, delivered the Concluding Remarks, appreciating the speakers' contributions and affirming the Congress's commitment to addressing national challenges through expert discourse. Shields were formally conferred upon the speakers as a gesture of acknowledgment.

The seminar served as a dynamic platform for exchanging knowledge and reinforcing multidisciplinary collaboration on water issues central to Pakistan's future.

GLIMPSES OF THE SEMINAR
ON
"INDUS WTER TREATY"

LECTURE ON THE INDUS WATER TREATY ON 10-05-2025



Engr. Ch. Muhammad Arif President-PEC along with Engr. Dr. Javed Iqbal, Secretary-PEC, Rana Imran Arshad Manager-PEC, Welcoming the Chief Guest Mr. Bilal Ahmer Soofi



(From Right) Engr. Ch. Muhammad Arif President-PEC with Engr. Dr. Javed Iqbal Secretary-PEC, Rana Imran Arshad Manager-PEC & Mr. Rana Ross Masood



Engr. Ch. Muhammad Arif President-PEC with Engr. Dr. Muhammad Riaz Member Executive Council, Engr. Dr. Javed Iqbal Secretary-PEC, Welcoming the Guest of Honor Mr. Muhammad Mohsin Leghari, Ex-Minister for Irrigation, Punjab



Engr. Muhammad Ammar Member Executive Council Conducting the Proceedings



Engr. Ch. Muhammad Arif President-PEC delivering Address of Welcome



Mr. Ahmer Bilal Ahmer Soofi presenting Lecture on “Legal Aspects of Indus Waters Treaty”



Mr. Rana Ross Masood presenting his remarks



Mirza Asif Baig presenting Lecture on “Technical Aspects of Indus Waters Treaty”



Mr. Muhammad Mohsin Laghari presenting his remarks





Engr. Ch. Muhammad Arif President-PEC with Engr. Dr. Javed Iqbal Secretary-PEC, Presenting Congress Shield to Mr. Ahmer Bilal Soofi for his lecture of “Legal Aspects of Indus Water Treaty”



Engr. Ch. Muhammad Arif President-PEC with Engr. Dr. Javed Iqbal Secretary-PEC, Presenting Congress Shield to Mirza Asif Baig for his lecture of “Technical Aspects of Indus Water Treaty”



Engr. Ch. Muhammad Arif President-PEC with Engr. Dr. Javed Iqbal Secretary-PEC, Presenting Congress Shield to Rana Ross Masood Advocate



Engr. Ch. Muhammad Arif President-PEC with Engr. Dr. Javed Iqbal Secretary-PEC, Presenting Congress Shield to Mr. Muhammad Mohsin Laghari

World Environment Day 2025
On the theme of
"Ending Plastic Pollution"
Held on June 14, 2025

WORLD ENVIRONMENT DAY 2025 HELD ON JUNE 14, 2025 ON THE THEME OF ENDING PLASTIC POLLUTION

On June 14, 2025, the Pakistan Engineering Congress hosted a thematic seminar in observance of World Environment Day 2025, dedicated to the pressing global challenge of Ending Plastic Pollution. The event attracted a broad spectrum of attendees including engineers, researchers, environmental professionals, and students, underscoring widespread commitment to sustainable development.

Technical Sessions & Presentations

The seminar featured the presentation of **ten research papers** focused on innovative strategies, policy frameworks, and engineering solutions aimed at eliminating plastic pollution. Each paper offered practical insights aligned with the seminar's environmental mandate. The following papers were presented at the event:

- "IRREVERSIBLE ENVIRONMENTAL IMPACTS OFPLASTI USE AND ITS MITIGATION STRATEGIES"
- "MANAGING PLASTI WASTE"
- PRODUCTION AND EVALUATION OF BRIQUETTES FROM MIXED ORGANIC FRACTIONS AND PLAXTI WASTE STREAMS"
- RECYCLING OF PLASTIC WASTE BY PRODUCING PRODUCTIVE CONSTRUCTION MATERIAL"
- POLLUTION REDUCTION THROUGH ALTERNATIVES TO USE OF PLASTICS – PAKISTAN CONTEXT"
- DETERMINING HEAVY METALS AND MICROPLASTIC IN DIFFERENT ENVIRONMENTAL COMPARTMENTS OF MANGLA LAKE"
- PLASTIC POLLUTION – A CHALLENGE FOR OPERATION OF CANAL IRRIGATION & DRAINAGE NETWORK IN PUNJAB PAKISTAN"
- ECO-FRIENDLY PAPER MANUFACTURING: MARBLE WASTE AND PLASTIC IN MAKING AN ECO-FRIENDLY STONE PAPER"
- MICROPLASTICS POLLUTION: DO THEY HAVE CONSEQUENCES FOR SOIL MULTIFUNCTIONALITY AT ECOSYSTEM SCALE?"
- MICROPLASTICS FROM PAINT INDUSTRIES: AN EMERGING THREAT TO ENVIRONMENT AND ITS TREATMENT POSSIBILITIES:

Interactive Segment & Closing Remarks

A vibrant Question & Answer session followed the technical presentations, fostering constructive dialogue and exchange of ideas among participants and speakers. The session was chaired by Engr. Ali Habib, former Director General WWF-Pakistan and Chairman of the Technical Session, who provided concluding remarks emphasizing the urgency of collaborative action and policy integration in combating plastic pollution.

Recognition & Acknowledgment

To honor the contributors, Pakistan Engineering Congress Shields and Certificates were formally conferred upon the speakers. The ceremony recognized their valuable input and reaffirmed the Congress's role in promoting thought leadership on environmental challenges.

This widely attended seminar served as a dynamic platform for knowledge sharing, advocacy, and commitment to sustainability, marking a meaningful contribution to Pakistan's environmental discourse.

Address of Welcome

By

Engr. Ch. Muhammad Arif, President
Pakistan Engineering Congress

On the eve of

World Environment Day 2025

On the theme of

“Ending Plastic Pollution”

Welcome Address
Engr. Ch. Muhammad Arif,
President Pakistan Engineering Congress
at the eve of
World Environment Day, 2025
On the theme of
"Ending Plastic Pollution"

Honorable Chief Guest,
Distinguished Delegates,
Executive Council Members,
Fellow Engineers, Ladies & Gentlemen,

Assalam-o-Alaikum !

Ladies & Gentlemen!

Today, as we gather to mark World Environment Day 2025, we are united by a shared purpose—a commitment to protect and nurture our planet for future generations. This year, the theme that calls us to action is *Ending Plastic Pollution*. It is a theme that resonates deeply, for plastic pollution is a crisis that touches every corner of the Earth, every living creature, and every human being. It is time for us to face this challenge head-on, armed with determination, innovation, and compassion.

Let us first reflect on the magnitude of the problem. Plastic, once hailed as a miraculous invention for its versatility and convenience, has become an emblem of environmental destruction. Every year, over 400 million metric tons of plastic are produced, and a significant portion of it is single-use—destined to be discarded within minutes of its use, yet haunting our ecosystems for centuries to come. Our oceans are choking under the weight of nearly 12 million tons of plastic waste annually. Marine life is entangled in a web of microplastics and debris, and human health is at risk as plastics infiltrate our food chain.

Ladies & Gentlemen!

The staggering scale of plastic pollution may seem insurmountable, but despair is not an option. Today is a reminder of the power of collective action—of what we can achieve when we come together with a shared vision. Ending plastic pollution is not merely an environmental imperative; it is a moral duty, a social responsibility, and an opportunity to transform our world for the better.

It begins with awareness. We must confront the reality of our choices and understand the true cost of convenience. Each item we discard—a plastic straw, a food wrapper, or a water bottle—has a story, and that story doesn't end in the trash bin. Instead, it continues in landfills, rivers, and oceans, creating a legacy of harm. By educating ourselves and others, we can ignite a spark of change that grows into a flame of transformation.

But awareness alone is not enough. We need action—bold, decisive, and sustained action at every level of society. Governments must enact and enforce policies that curtail the production and use of single-use plastics, while encouraging innovation in biodegradable alternatives. Businesses must take responsibility for their environmental footprint, adopting practices that prioritize sustainability over profit. Communities must come together to clean up plastic waste and demand change from the authorities and corporations. And as individuals, we must embrace the principles of reduction, reuse, and recycling, making conscious choices that reflect our commitment to the planet.

Ladies & Gentlemen!

Innovation will be a key ally in our fight against plastic pollution. The bright minds of today are designing solutions that inspire hope—from creating edible packaging and advanced recycling technologies to developing methods to extract microplastics from water bodies. We must support and invest in these innovations, fostering a culture where sustainability is the driving force behind progress.

As we look ahead, let us also honor the resilience and beauty of nature. Despite the scars of pollution, our planet continues to sustain us, offering breathtaking landscapes, vibrant biodiversity, and resources that fuel our lives. We owe it to Earth to be stewards of its care—to tread lightly and live mindfully.

Ladies & Gentlemen!

In the end, I urge each of you to reflect on your role in this journey. The challenge of ending plastic pollution is immense, but so too is our collective power to overcome it. Together, we can rewrite the story of plastic—not as a tale of waste and destruction, but as a conquest of human ingenuity and responsibility.

Let this World Environment Day be a turning point—a moment where we pledge to act with courage and urgency. For the sake of our oceans, our wildlife, our health, and our future, let us rise to the challenge. Let us end plastic pollution and let us do so with unwavering resolve.

Thank you.

-: Pakistan Paindabad :-

Address
By
Engr. Riaz Nazir Tarar

Chief Guest
World Environment Day 2025

Address by the Chief Guest Engr. Riaz Nazir Tarar at the eve of World Environment Day, 2025 On the theme of "Ending Plastic Pollution"

Distinguished Delegates,
Executive Council Members,
Fellow Engineers, Ladies & Gentlemen,
Assalam-o-Alaikum!
Ladies & Gentlemen!

It is with great humility and an unwavering sense of purpose that I address you today as both a policymaker and your chief guest on this World Environment Day 2025. Today, we stand united under a singular and pressing theme: *Ending Plastic Pollution*. This theme is not just a call for change; it is a resounding demand for decisive and immediate action. The responsibility is ours to shoulder, the challenge ours to overcome, and the legacy ours to create.

Ladies & Gentlemen!

Let us reflect for a moment on the magnitude of the crisis we face. Plastic pollution has become one of the most formidable threats to our planet. It is an invisible intruder in our food, air, and water, and a glaring scar on our landscapes, rivers, and oceans. Over the past century, what began as a revolutionary invention has spiraled into an environmental catastrophe.

As mentioned by Mr. President in his address, Each year, we produce over 400 million metric tons of plastic, and a significant proportion of this finds its way into our environment. Marine ecosystems are choking with 12 million tons of plastic waste annually, and microplastics are now present in the bodies of fish we consume and even in the rain that falls from the sky.

These statistics are staggering, but behind them lies an even greater tragedy. Plastic pollution knows no boundaries. It affects every community, every country, and every ecosystem on Earth. It threatens marine life, suffocates wildlife, and undermines the health of humans across the globe. This is a challenge that cannot be ignored, a battle we cannot afford to lose.

Ladies & Gentlemen!

We stand at a crossroads. The decisions we make today will shape the future of our environment and define our legacy. Ending plastic pollution requires bold leadership, courageous action, and unwavering commitment. We cannot continue with business as usual. We must rethink, redesign, and reform.

Our first responsibility is to enact robust policies that address the root causes of plastic pollution. This means introducing and enforcing bans on single-use plastics, incentivizing the development and adoption of sustainable alternatives, and setting ambitious reduction targets across all sectors. It also means holding corporations accountable through extended producer responsibility, requiring them to manage the life cycle of the plastic they produce.

Second, we must invest in innovative solutions and infrastructure. Recycling systems in many parts of the world are inefficient and underdeveloped. We must modernize these systems, making them more accessible and effective. Moreover, we must support the research and development of groundbreaking alternatives to conventional plastics, such as biodegradable materials and advanced recycling technologies. These solutions have the potential to revolutionize the way we consume and manage resources.

Third, international collaboration is essential. Plastic pollution is a global crisis that transcends borders. To tackle it effectively, we need collective action and global cooperation. This includes establishing international agreements to reduce plastic waste, sharing knowledge and resources, and committing to a shared vision for a sustainable future.

Fourth, let us empower communities and individuals. Education and awareness are the cornerstones of change. By informing citizens about the impacts of plastic pollution and equipping them with practical solutions, we can inspire a groundswell of action. From reducing personal plastic use to participating in cleanup campaigns, every small action contributes to the larger mission.

But let us also remember that this fight for our planet must be grounded in equity and justice. Vulnerable communities often bear the brunt of plastic pollution, from living near landfills to facing polluted waterways. Our policies must prioritize these communities, ensuring that environmental justice is at the heart of our efforts.

Ladies & Gentlemen!

As your chief guest today, I am moved by the passion and commitment I see in this room and beyond. There are countless stories of hope and resilience—students mobilizing plastic cleanup drives, entrepreneurs pioneering eco-friendly innovations, and activists pushing for stronger laws. Together, these efforts remind us that change is not only possible but inevitable when we work together.

Ladies & Gentlemen!

The theme of this year's World Environment Day—*Ending Plastic Pollution*—is both a challenge and an opportunity. It is an opportunity to reimagine our relationship with plastic and redefine what progress means in a sustainable world. It is an opportunity to leave behind a legacy of stewardship and responsibility for our children and grandchildren.

So let us take this moment, this gathering, this World Environment Day 2025, as a pivotal point. Let us reaffirm our commitment to ending plastic pollution—not tomorrow, not someday, but starting now. Let us lead with purpose, act with determination, and inspire with vision.

Together, we can and will create a future where our rivers run clean, our oceans thrive, and our Earth flourishes. Let us rise to the challenge, united in our mission and guided by hope.

Thank you.

-: Pakistan Paindabad :-

Glimpses
Of
World Environment Day 2025

WORLD ENVIRONMENT DAY 202 ON THE THEME OF "ENDING PLASTIC POLLUTION" AT PAKISTAN ENGINEERING CONGRESS HEADQUARTER ON SATURDAY JUNE 14, 2025



Engr. Muhammad Usman Rasheed Member Executive Council Conducting the Proceedings



Engr. Ch. Muhammad Arif President-PEC delivering Address of Welcome



Chief Guest Engr. Riaz Nazir Tarar Addressing the Audience



(From Left) Engr. Ali Hassan Habib Chairman of the Technical Session, Engr. Husnain Ahmad Vice President-PEC, Engr. Muhammad Usman Rasheed Member Executive Council

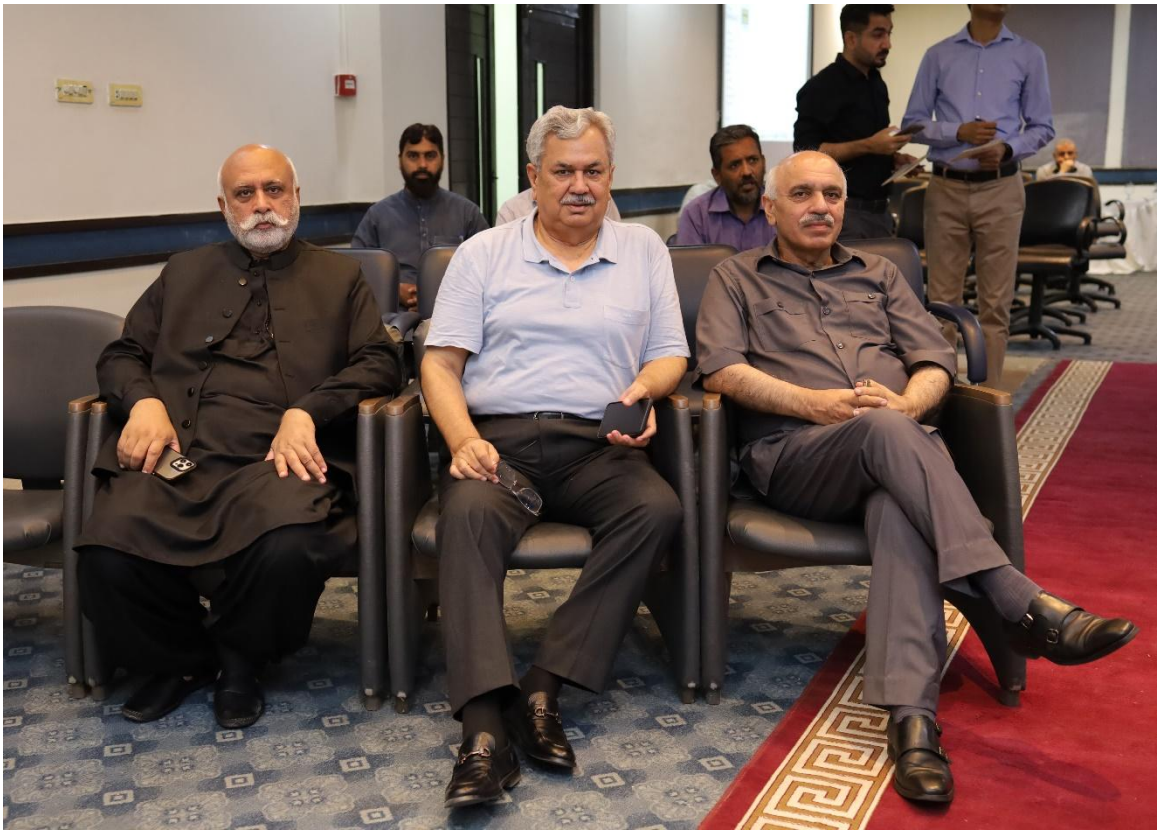
GLIMPSES OF AUDIENCES





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QUESTIONS / ANSWERS SESSION





QUESTIONS / ANSWERS SESSION





Chairman of the Session Mr. Ali Hassan Habib, responding to the Questions of the Audience



(From Right) Engr. Ch. Muhammad Arif President-PEC, Mr. Ali Hassan Habib Chairman of the Session, Engr. Riaz Nazir Tarar Chief Guest, and Engr. Husnain Ahmad Co-Chairman of the Session presenting Pakistan Engineering Congress Shield to Engr. Shariq Ahmad
Presenting paper on “Irreversible Environmental Impacts of Plastic Use and its Mitigation Strategies”



(From Right) Engr. Ch. Muhammad Arif President-PEC, Mr. Ali Hassan Habib Chairman of the Session, Engr. Riaz Nazir Tarar Chief Guest, and Engr. Husnain Ahmad Co-Chairman of the Session presenting Pakistan Engineering Congress Shield to Engr. Ahsan Iqbal Bela
Presenting paper on “Managing Plastic Waste”



(From Right) Engr. Ch. Muhammad Arif President-PEC, Mr. Ali Hassan Habib Chairman of the Session, Engr. Riaz Nazir Tarar Chief Guest, and Engr. Husnain Ahmad Co-Chairman of the Session presenting Pakistan Engineering Congress Shield to Ms. Rimsha Azhar Presenting Paper on " Ending Plastic Pollution in Pakistan: A Review of National Progress, Alternatives to Plastic, and Sustainable Waste Management Practices"



(From Right) Engr. Ch. Muhammad Arif President-PEC, Mr. Ali Hassan Habib Chairman of the Session, Engr. Riaz Nazir Tarar Chief Guest, and Engr. Husnain Ahmad Co-Chairman of the Session presenting Pakistan Engineering Congress Shield to Ms. Amina Shahbaz Presenting Paper on "Determining Heavy Metals and Microplastic indifferent Environmental Compartments of Mangla Lake"



(From Right) Engr. Ch. Muhammad Arif President-PEC, Mr. Ali Hassan Habib Chairman of the Session, Engr. Riaz Nazir Tarar Chief Guest, and Engr. Husnain Ahmad Co-Chairman of the Session presenting Pakistan Engineering Congress Shield to Engr. Dr. Tahir Anjum Qureshi Presenting Paper on “Plastic Pollution – A Challenge for Operation of Canal Irrigation & Drainage Network in Punjab Pakistan”



(From Right) Engr. Ch. Muhammad Arif President-PEC, Mr. Ali Hassan Habib Chairman of the Session, Engr. Riaz Nazir Tarar Chief Guest, and Engr. Husnain Ahmad Co-Chairman of the Session presenting Pakistan Engineering Congress Shield to Ms. Sumbal zaheer Presenting Paper on “Microplastics from Paint Industries: An Emerging Threat to Environment and its Treatment Possibilities”



(From Right) Engr. Ch. Muhammad Arif President-PEC, Mr. Ali Hassan Habib Chairman of the Session, Engr. Riaz Nazir Tarar Chief Guest, presenting Pakistan Engineering Congress Shield to Engr. Husnain Ahmad Co-Chairman of the Session



(From Right) Engr. Ch. Muhammad Arif President-PEC, Engr. Riaz Nazir Tarar Chief Guest, Engr. Husnain Ahmad Co-Chairman of the Session presenting Pakistan Engineering Congress Shield to Mr. Ali Hassan Habib Chairman of the Session



(From Right) Engr. Riaz Nazir Tarar Chief Guest, , Mr. Ali Hassan Habib Chairman of the Session, Engr. Husnain Ahmad Co-Chairman of the Session presenting Pakistan Engineering Congress Shield to Engr. Ch. Muhammad Arif President-PEC



(From Right) Engr. Ch. Muhammad Arif President-PEC, Mr. Ali Hassan Habib Chairman of the Session, Engr. Husnain Ahmad Co-Chairman of the Session presenting Pakistan Engineering Congress Shield to Engr. Riaz Nazir Tarar Chief Guest