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(Research Article)

Utilization of treated wastewater dry sludge for lightweight concrete and the use of treated waste water as a curing medium

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Abstract

The increasing generation of sludge from wastewater treatment plants and the growing concerns over sustainable waste management have led to a demand for innovative and eco-friendly approaches. This abstract presents a novel approach that addresses two significant environmental challenges: the utilization of dry sludge as a partial replacement for cement in concrete production and the use of wastewater as a curing medium for concrete. Concrete, being the most widely used construction material worldwide, has a significant environmental impact due to its extensive consumption of natural resources and high carbon emissions. To address these challenges, researchers have explored various sustainable alternatives, one of which is incorporating sludge, a byproduct of wastewater treatment plants, into concrete production. This abstract presents a comprehensive overview of the utilization of sludge as supplementary cementations material (SCM) in concrete, highlighting itspotential benefits and challenges. Sludge, rich in organic and inorganic compounds, possesses properties that can enhance the performance of concrete. As a SCM, It can partially replace cement thereby reducing its demand and minimizing the carbon footprint associated with cement production. Additionally, sludge in corporation in concrete promotes waste management and offers a sustainable solution for the disposal of this abundant by product. The abstract examines the effects of sludge on various concrete properties, including workability, strength development, durability and environmental impacts. Studies have shown that sludge addition can enhance the workability of fresh concrete, leading to improved cohesiveness and reduced water demand. Furthermore, the pozzolanic and filler effects of sludge contribute to the strength development of hardened concrete, with potential improvements observed in both early age and long-term strengths. Moreover, the inclusion of sludge in concrete can enhance its durability performance, such as resistance to chloride ion penetration, sulfate attack and alkali-silica reaction. The abstract also discusses the potential environmental benefits, including reduced carbon emissions, energy saving and conservation of natural resources, resulting from sludge utilization in concrete production. Overall , in corporation sludge into concrete presents a promoting opportunity to enhance the sustainability of the construction industry; further research and development efforts are required to fully understand the long term performance and environmental implication of sludge-based concrete and to overcome the associated challenges. By embracing sludge as valuable resources, the construction sector can move towards a more circular economy and contribute to a greener and more sustainable future.

Keywords: Dry Sludge; Supplementary Cementations Material; Concrete Production; Wastewater; Curing Medium; Sustainability; Circular Economy; Resource Efficiency.

1. Introduction

Concrete is the most widely used construction material globally, providing the backbone for countless infrastructure projects. However, the production of concrete has significant environmental consequences, including the depletion of

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natural resources and high carbon emissions. In recent years, there has been a growing interest in finding sustainable alternatives to conventional concrete production method. One such alternative is the utilization of sludge, a by-product generated from wastewater treatment process, as a supplementary material in concrete. Sludge, often considered a waste material, contain a mixture of organic and inorganic Substances it composition varies depending on the source and treatment process, but it typically includes fine particles, organic matter and trace elements. Instead of disposing of sludge in landfills or incineration facilities, researchers and engineers have been exploring ways to incorporate it into concrete, there by transforming it into valuable resources. The incorporation of sludge in concrete offers several potential benefits. Firstly, it can serve as a partial Replacement for cement, which is the primary binder in concrete production. Concrete production is energy –intensive and accounts for a significant portion of carbon dioxide emissions by partially replacing cement with sludge ,the demand for cement can be reduced, leading to a decrease in carbon emissions associated with it production. Additionally, the use of sludge in concrete production can help solve the problem of sludge disposal wastewater treatment plants. Generate massive amount of sludge, which often poses a challenge in terms of appropriate disposal, incorporating sludge into concrete provide an environmentally friendly a sustainable solution by diverting it from landfills and incinerators. Moreover, sludge can potentially enhance the performers of concrete. Due to its fine particles and chemical composition, sludge can exhibit pozzolanic and filler properties. These properties contribute to improved workability, strength development, and durability of the resulting concrete. Furthermore, the incorporation of sludge has the potential to enhance the resistance of concrete to various aggressive agents, such as chloride ions, sulfates and alkali – silica reaction. Despite the potential advantages, the utilization of sludge in concrete does present same challenges. These include addressing concerns regarding heavy metal content, ensuring consistent quality of sludge, and establishing guidelines and standards for its safe and effective use in concrete production. Research and development efforts are ongoing to overcome these challenges and to fully understand the long – term performance and environmental implications of sludge –based concrete.

Sewage sludge is a semi-solid material that is generated during the treatment of wastewater. It is composed of organic matter, nutrients, and some contaminants, including heavy metals and pathogens. Traditionally, sewage sludge has been disposed of in Landfills or incinerated, but these methods can be expensive and can leave negative environmental impacts. In recent years, there has been growing interest in using Sewage Sludge as construction materials due to its unique properties and low cost. This paper provides an overview of the current state of knowledge on the use of Sewage Sludge as a construction material, including its applications and environmental impacts

2. Materials and Methods

2.1. Potable Drinking Water

Potable tap water is water that is safe for human consumption and is supplied to households and businesses through a network of pipes. Potable tap water should meet the standards set by regulatory authorities for safe consumption. The specific properties of tap water can vary depending on the source of the water and the treatment process used by the water treatment plant. The physical and chemical property of portable water is shown in

Table 1 Physical and Chemical Properties of Potable Water

Test	**Results**	**Units**	**Indian Standards as per IS 10500:2012**	
			Desirable	Permissible
Colour	<5.0	Hazen	5	15
Odour	Agreeable	-	Agreeable	Agreeable
Turbidity	1.02	NTU	1	5
pH	7.22	-	6.5-8.5	No Relax
Total Dissolved Solids as TDS	378.0	Mg/I	500	2000
Alkalinity as CaCO 3	152	Mg/I	200	600
Total Hardness asCaCO3	160.0	Mg/I	200	600
Calcium	38.4	Mg/I	75	200
Magnesium	15.55	Mg/I	30	100

Copper	BDL	Mg/I	0.05	1.5

2.2. Cement

My Cem Cement, Grade: OPC 43 .It have various concrete tests not limited to slump test, Cone Test, Cube Test etc. For Ensuring, strong Concrete slabs it have high strength, low heat of hydration, low alkali, low chloride, Low sulphate, highly consistent etc.

2.3. Treated wastewater

Treated wastewater, also known as reclaimed water, is wastewater that has been treated to remove pollutants and contaminants and can be reused for non-potable applications such as irrigation, industrial processes, and toilet flushing. Treated wastewater can be a valuable resource for non-potable applications such as irrigation and industrial processes. The specific properties of treated wastewatercan vary depending on the treatment process used and the intended use of the water. Careful monitoring and testing are necessary to ensure that the treated wastewater meets the required standards for the intended application. The physical and chemical properties of treated wastewater are shown in table 2.

Table 2 Physical and chemical analysis of waste water samples

Test	Results	Desirable Limits	Units
pH	7.40	6.5-9.0	-
Total Suspended Solid	44.0	100.0	Mg/I
Total Dissolved Solid	512.0	-	Mg/I
Biochemical Oxygen Demand asBOD	18.0	30.0	Mg/I
Chemical Oxygen Demand asCOD	58.0	250.0	Mg/I
Oil & Grease	BDL	10.0	Mg/I
Phosphate as PO4	0.88	5.0	Mg/I
Silica as SiO2	12.4	-	Mg/I

2.4. Wastewater Dry sludge

The Dry sludge used for this research was collected from Bharwara STP, Gomtinagar, Lucknow. The environmental friendliness of the Dry sludge was also considered to promote its use in lightweight concrete. The sludge was air-dried and was crushed until it could pass through the 4.75 mm sieve.

2.5. fine and coarse aggregates

Fine aggregates: Sand is a naturally occurring granular material that is used in a variety of construction applications. Theproperties of sand make it an important component in a wide range of construction materials, including concrete, mortar, and plaster. The specific properties of sand can vary depending on its source and processing, and careful selection and testing are important to ensure that the sand used meets the requirements for the specific construction application.

Coarse aggregates are an essential component of concrete, are typically made up of materials such as crushed stone, gravel, andrecycled concrete. The properties of coarse aggregates play an important role in the strength, durability, and workability of concrete. Careful selection and testing are important to ensure that the aggregates used meet the requirements for the specific construction application.

2.6. Design Strength of concrete

M25 is a concrete mix designation used in India, which specifies the compressive strength of concrete after 28 days of curing. M25 grade concrete means that the concrete has a characteristic strength of 25 MPa (megapascals) at 28 days, asmeasured by crushing a cylindrical concrete sample in a compression-testing machine.

Step 1: Determine the target strength the target compressive strength of M25 grade concrete is 25 MPa (N/mm2) at 28 days.

Step 2: Determine the water-cement ratio the water-cement ratio is taken as 0.50. However, this can be adjusted based onthe workability and strength requirements of the concrete.

Step 3: Determine the cement content The cement content is calculated by using the following formula: Cement content =(Target strength / (1.65 x sqrt(fck))) x (1 / w/c ratio)

Where, fck = Characteristic compressive strength of concrete at 28 days = 25 N/mm2 w/c ratio = Water-cement ratio = 0.50Cement content = (25 / (1.65 x sqrt(25))) x (1 / 0.50) = 340 kg/m3

Step 4: Determine the water content the water content is calculated by using the following formula: Water content = Cement content x w/c ratio

Water content = 340 x 0.50 = 170 liters/m3

Step 5: Determine the aggregate proportions the aggregate proportions are determined based on the total volume of concrete and the assumed dry-rodded bulk density of aggregates. The assumed dry-rodded bulk density of 20mm aggregateis 1550 kg/m3 and that of sand is 1600 kg/m3.

The aggregate proportions are calculated as follows: Volume of coarse aggregate = (0.62 / 1.55) = 0.4 m3 Volume of fine aggregate = (1 - 0.4) = 0.6 m3

Weight of coarse aggregate = Volume x Bulk density = 0.4 x 1550 = 620 kg/m3 Weight of fine aggregate = Volume x Bulk density = 0.6 x 1600 = 960 kg/m3

Step 6: Determine the mix proportions The mix proportions are calculated by dividing the weights of each material by thetotal weight of the mix.

Cement: 340 / (340 + 620 + 960) = 0.252 Fine Aggregate (Sand): 960 / (340 + 620 + 960) = 0.355 Coarse Aggregate

(20mm): 620 / (340 + 620 + 960) = 0.393

Therefore, the mix proportions for M25 grade concrete are: Cement: 1 Fine Aggregate (Sand): 1.41 Coarse Aggregate (20mm): 1.56

2.7. Mixing casting and curing of cubes

Mixing, casting, and curing are essential steps in the process of creating concrete cubes for testing and quality control. Here's a brief overview of each step:

2.7.1. Mixing

Start by gathering the necessary materials: cement, aggregates (usually sand and gravel), water, and any additivesor admixtures required for the specific concrete mix design. Use a concrete mixer to combine these materials thoroughly. The mixing process should ensure a uniform distribution of all components, resulting in a consistent mixture.

2.7.2. Casting

Prepare the cube molds, which are typically made of steel or plastic and come in standard sizes (e.g., 150mm x 150mm x 150mm or 100mm x 100mm x 100mm).Clean and lubricate the inside surfaces of the molds to prevent concrete from sticking. Fill the molds with the freshly mixed concrete, making sure to compact the concrete properly to remove any air voids. This can be done using a vibrating table or a compaction rod. After filling, strike off the excess concrete from thetop of the molds to create a smooth, level surface.

2.7.3. *Curing*

Curing is the process of maintaining adequate moisture and temperature conditions to allow the concrete to gain strength and durability. Cover the filled molds with wet burlap, plastic sheeting, or curing blankets to retain moisture. This prevents the concrete from drying out too quickly, which can lead to cracking and reduced strength. Maintain a suitable curing temperature, typically around 68-73°F (20-23°C). Curing in a controlled environment helps the concrete develop itsfull strength. The curing period may vary depending on the concrete mix and its intended use, but it typically lasts for a minimum of 7 days.

2.8. Scanning electron microscope (SEM) and energy dispersive X-ray (EDX)

SEM (Scanning Electron Microscopy): Scanning Electron Microscopy is a technique that uses a focused beam of electrons to create high-resolution images of the surface of a sample. It provides detailed information about the sample's topography, morphology,and composition. The electron beam scans the sample, and the interactions between the beam and the sample produce signals that are detected and used to generate an image. SEM is widely used in materials science, nanotechnology, and various fields of research to study the microstructure and surface features of samples at a magnification ranging from tens to hundreds of thousands of times.

EDX (Energy-Dispersive X-ray Spectroscopy): Energy-Dispersive X-ray Spectroscopy is an analytical technique used in conjunction with SEM to analyze the chemical composition of a sample. EDX measures the characteristic X-rays emitted by the sample when it isbombarded with an electron beam. These X-rays carry information about the elements present in the sample and their relative concentrations. By detecting and analyzing the emitted X-rays, EDX can provide qualitative and quantitative elemental analysis of thesample. It allows researchers to identify elements and map their distribution within a sample, aiding in material characterization and identification.

2.9. Compressive strength of cured concrete

Compressive strength of cured concrete is a critical property used to assess the quality and durability of concrete. It measures the maximum amount of axial load (force applied in the direction of the axis) a concrete specimen can withstand without failing.

Concrete is often categorized into different grades based on its compressive strength. Common grades include 20 MPa (2,900 psi), 25 MPa (3,600 psi), 30 MPa (4,400 psi), and so on. Higher-grade concrete generally has higher compressive strength.

The cubes were weighted in order determine the effect of the dry sludge on the overall weight of the concrete, and the value was recorded before crushing the concrete cubes. A compression load of 180 kN/min was applied without shock and the load was increased automatically until the concrete cube failed. Article DOI

Table 3 Sample composition for one cubic of concrete

Sample	Stone (kg/m3)	Cement (kg/m3)	Sand (kg/m3)	Dry sludge (kg/m3)	Water (L/m3)
Control	1233	320	788	0	191.58
C1	1233	320	704	18	191.58
C2	1233	320	635	32	191.58
C3	1233	320	593	44	191.58
C4	1233	320	539	54	191.58
C5	1233	320	491	61	191.58

3. Result and discussion

The results confirm the feasibility and benefits of utilizing dry sludge in concrete production and wastewater as a curing medium. The incorporation of dry sludge in concrete contributes to reduced cement consumption, improved workability, and enhanced durability. The utilization of wastewater for concrete curing provides a sustainable alternative to freshwater, promoting resource conservation and minimizing water-related environmental concerns. The combination of these approachescontributes to the development of environmentally friendly and economically viable practices in the construction industry, fostering sustainability and the circular economy.

3.1. Physical and chemical properties of Dry sludge

The physical properties of WWDS in shown in Table

Table 4 Physical and Chemical properties of Wastewater Dry sludge

Test	Results	Units
pH	6.52	-
Moisture	29.34	(%)
Volatile Matter	27.2	(%)
Ash	41.4	(%)
Organic Matter	8.22	(%)
Calcium as CaCO3	154.0	(Mg/Kg)
Magnesium as MgCO3	80.0	(Mg/Kg)
Silica as SiO2	22.2	(Mg/Kg)
Phosphate as P2O5	7.66	(Mg/Kg)
Potash as K2O	56.5	(Mg/Kg)

3.2. Physical and chemical properties of fine and coarse aggregate

3.2.1. Fine aggregates

Table 5 Lab Test results of fine aggregate

Sample Description	Fine Aggregate
Test:	Particle size distribution , Fineness modulus.
Test method	I.S. 2386 (Part -1) : 1963

Sample taken 1000gResult

Table (a)

s.no	**I.S. sieve**	**Retained weight in g**	**Cumulative retained Weight in g**	**Cumulative retained %**	**Passing %**	**% passing according to I.S. 383-2016**			
						Zone 1	Zone 2	Zone3	Zone 4
1	10mm	0.00	0.00	0.00	100	100	100	100	100
2	4.75mm	33.00	33.00	3.30	96.70	90-100	90-100	90-100	95-100
3	2.36mm	184.00	217.00	21.70	78.30	60-95	75-100	85-90	95-10
4	1.18mm	328.50	545.50	54.55	45.45	30-70	55-90	75-100	90-100
5	600μm	252.70	798.20	79.82	20.18	15-34	35-59	60-79	80-100

6	300µm	112.80	911.00	91.10	8.90	5-20	8-30	12-40	15-50
7	150µm	64.00	975.00	97.50	2.50	0-10	0-10	0-10	0-15

(B) Fineness Modulus =3.4794 Final Result =Zone I

3.2.2. Coarse aggregates

Table 6 Lab test results of coarse aggregates

S.no	**test**	**Result**	**unit**
1	Material finer than 75µ is Sieve		
A	Coarse aggregate	……	%
B	Fine aggregate	1.65	%
2	Combined Flakiness Index & Elongation Index		
A	Flakiness index	21.76	**%**
B	Elongation index	21.42	**%**
3	**Specific gravity and water absorption**		
A	Specific gravity	2.66	**-**
B	Apparent specific gravity	2.68	**-**
C	Water absorption	0.23	**%**
4	**Bulk Density**		
A	Compact	1.59	Kg/lt.
B	Loose	1.54	Kg/Lt.
5	**Mechanical property**		
A	Impact value	18.00	**%**
B	Crushing value	17.00	**%**
c	Abrasion value	18.00	**%**

3.2.3. SEM of dry sludge

The Micro Structure of dry sludge is shown in fig 1

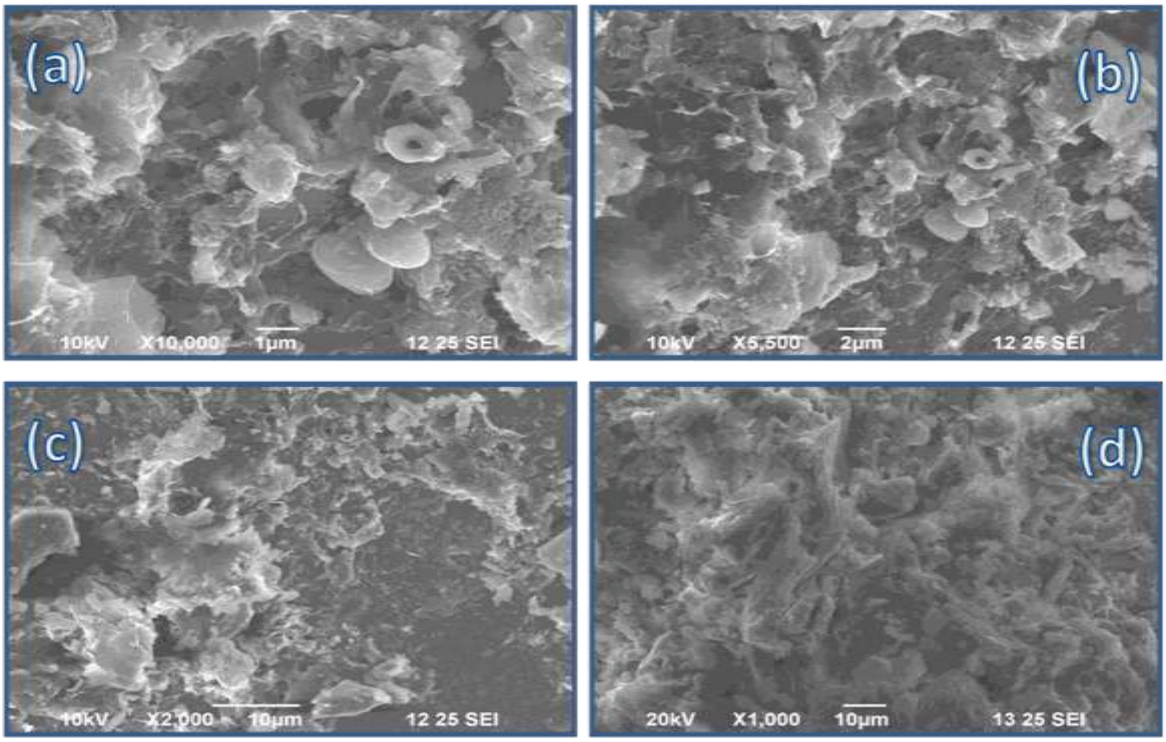

Figure 1 SEM of dry sludge at (a) x10000 ,(b) x5500,(c)x2000,(d)x1000

3.3. Energy dispersive X-Ray (EDX) of dry sludge

The elemental contents of the sludge sample are presented in fig 2 and table 4

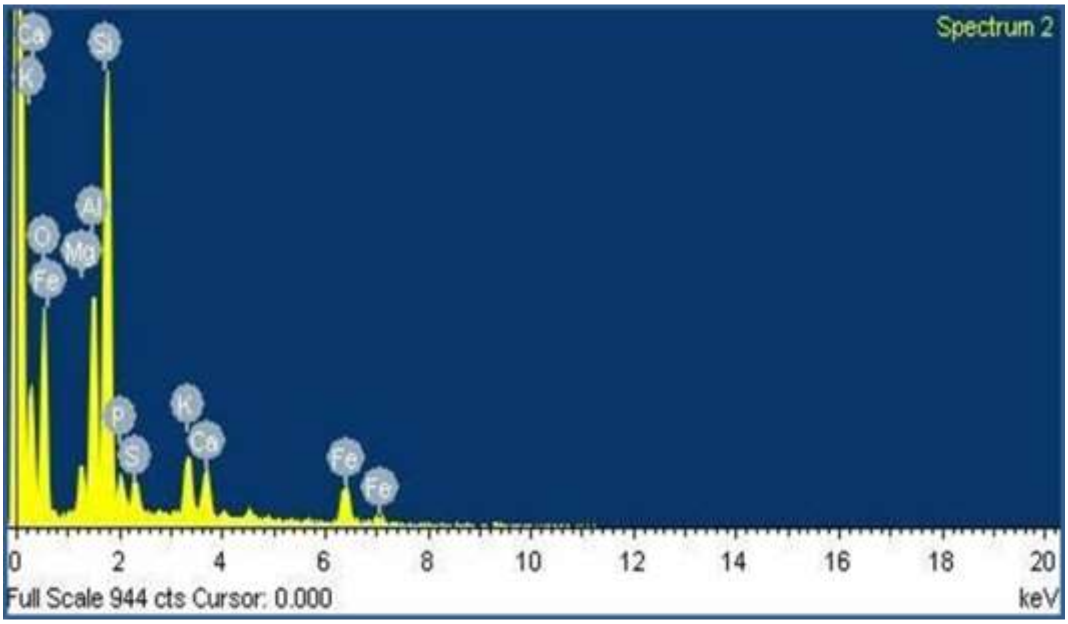

Figure 2 EDX chemical composition analysis of wastewater dry sludge from Barware STP, Gomti Nagar Lucknow

Table 7 EDX quantitative percentage of elements in dry sludge

Element	Weight%	Atomic%
O K	48.22	64.27
Mg K	2.56	2.24
Al K	9.85	7.79
Si K	21.98	16.69
P K	2.30	1.59
S K	1.88	1.25
K K	4.31	2.35
Ca K	2.86	1.52
Fe K	6.04	2.31
Totals	100.00	

3.3.1. Microstructure of sludge based concrete composite

Sludge-based concrete composites, often referred to as sustainable or eco-friendly concrete, incorporate sludge or waste materials into the mix to reduce environmental impact and enhance sustainability. The microstructure of these composites can vary depending on the type and proportion of sludge and other materials used. The binder phase in sludge-based concrete composites typically consists of cementations materials such as Portland cement. The microstructure of this phase involves the formation of calcium silicate hydrates (C-S-H) and other cementations compounds during hydration. Sludge particles, which are often finely ground and incorporated into the mix, can have a heterogeneous distribution within the concrete. The microstructureof sludge particles depends on their composition, size, and shape. They may contain organic matter, minerals, and other contaminants. To fully understand the microstructure of sludge-based concrete composites, researchers often use techniques such as scanning electron microscopy (SEM), X-ray diffraction (XRD), and other advanced imaging methods. These methods provide insights into the distribution and interaction of various components at the micro scale.

3.3.2. Compressive Strength of concrete cured in wastewater and portable water

Compressive strength of cured concrete is a critical property used to assess the quality and durability of concrete. It measures the maximum amount of axial load (force applied in the direction of the axis) a concrete specimen can withstand without failing. The concrete specimens must be properly cured under controlled conditions before testing to ensure accurate results. This involves maintaining adequate moisture and temperature levels for a specified curing period, as mentioned in the previous response. Concrete is often categorized into different grades based on its compressive strength. Common grades include 20 MPa (2,900 psi), 25 MPa (3,600 psi), 30 MPa (4,400 psi), and so on. Higher-grade concrete generally has higher compressive strength.

3.3.3. Effect of wastewater on concrete cubes (Compressive strength) as curing medium.

The specimen was immense in the wastewater for 7, 14, 21 and 28 days to establish the effect on the compressive strength of the concrete. Based on the results, It was found that only sample containing 12.5% sludge did not meet the design strength on 25 MPa after 28 days. The addition of sludge into concrete has significant adverse effects on the compressive strength [3,17]. However, the concrete 12.5% sludge composition can be used for maintenance and non-structural concrete work in wastewater treatment plants.

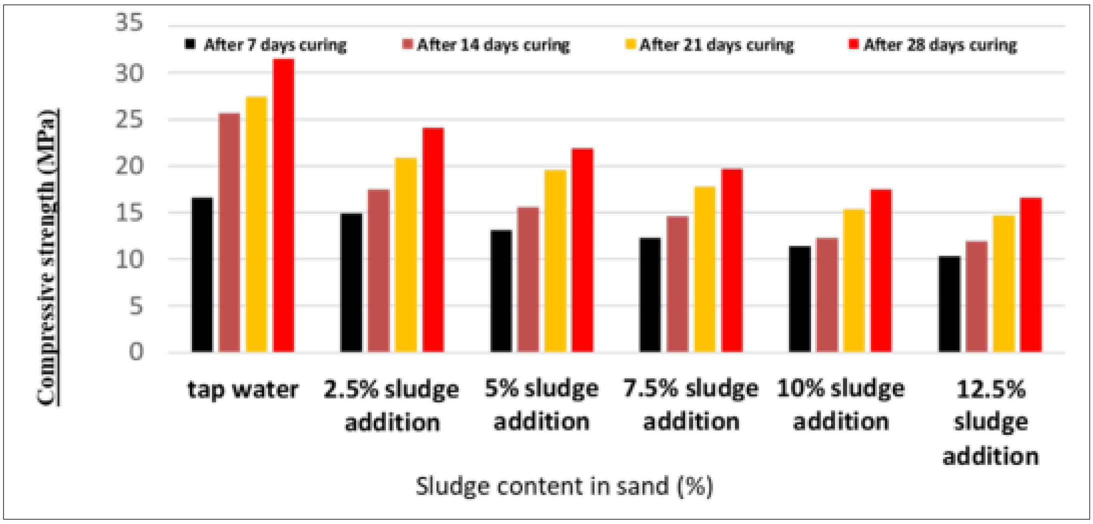

Figure 3 Compressive strength of concrete samples cured in tap water

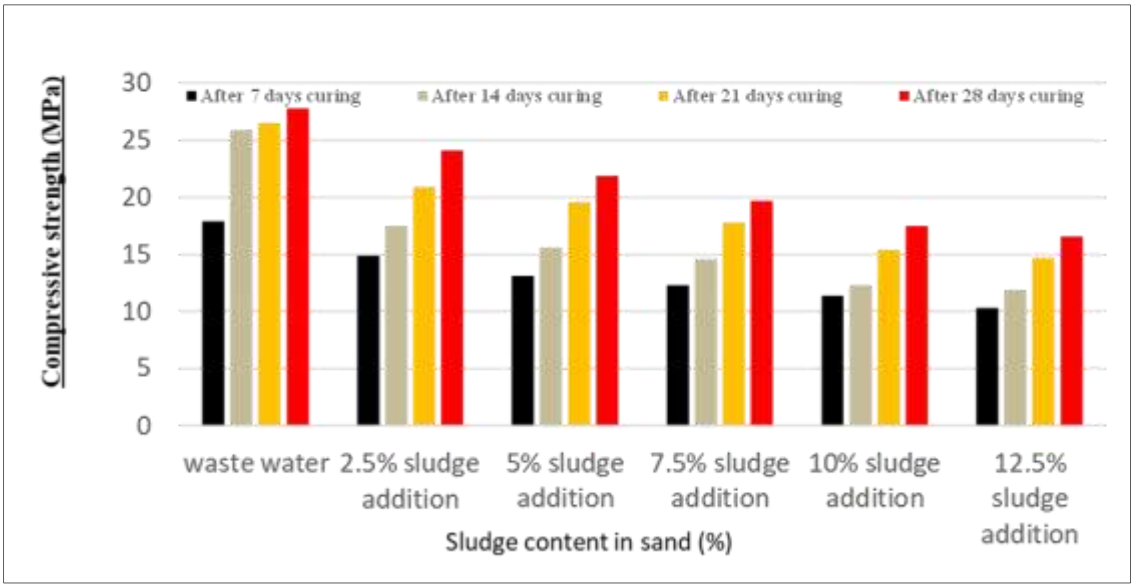

Figure 4 Compressive strength of concrete samples cured in wastewater Allowable matter limits for bharwara STP wastewater sludge

Table 8 Allowable metal limits for Bharwara STP wastewater Sludge.

Heavy Metals	Allowable limit (mg/kg)	Results (mg/l)
Zinc as Zn	<2800	7.5
Nickel as Ni	<420	0.58
Copper as Cu	<1500	0.31
Total Chromium	<1200	0.26
Arsenic as As	<40	0.13
Cadmium as Cd	<40	0.06
Mercury as Hg	<15	BDL
Lead as Pb	<300	0.10

3.4. Environmental impact of using sewage sludge as a construction material

The used of Sewage Sludge as a construction material can have both positive and negative environmental impacts. On the one hand, it can reduce the amount of waste that is sent to Landfills or incinerators, which can help to conserve Landfills space and reduce greenhouse gas emissions. It can also provide a low cost alternative to traditional construction materials, which can help to reduce construction costs. On the other hand, Sewage Sludge can contain contaminants that can pose environmental andhealth risks if not handled property. These contaminants can leach into Soil and water, potentially contaminating ground water and Surface water. Furthermore, the transportation and handling of Sewage Sludge can generate greenhouse gas emissions, which can contribute to climate change.

4. Conclusions

The utilization of dry sludge in concrete production and wastewater as a curing medium offers promising solutions for sustainable waste management and resource utilization in the construction industry. The research findings demonstrate the feasibility, benefits, and potential challenges associated with these approaches. Incorporating dry sludge as a partial replacement for cement in concrete production helps reduce the environmental impact of cement production. The resulting concrete exhibits satisfactory mechanical properties, durability, and resistance to environmental degradation. The use of dry sludge as a supplementary cementations material enhances the microstructure of concrete, reduces permeability, and contributes to long-term durability. Furthermore, utilizing wastewater as a curing medium for concrete provides an environmentally friendly alternativeto freshwater. The wastewater, obtained from treatment plants, contains nutrients and moisture that promote cement hydration and contribute to the development of concrete strength. The cured concrete exhibits comparable or improved mechanical properties and enhanced resistance to shrinkage and cracking. The combination of these approaches promotes the circular economy by utilizing waste materials and conserving natural resources. The utilization of dry sludge and wastewater contributes to reducing waste generation, minimizing environmental pollution, and optimizing water resource management in the construction industry. However, the successful implementation of these approaches requires careful consideration of various factors such as the chemical composition of dry sludge and wastewater, potential contaminants, and their effects on concrete properties. Adherence to relevant regulations and safety guidelines is essential to ensure the environmental safety and structural integrity of the concrete. Overall, the utilization of dry sludge in concrete production and wastewater as a curing medium presents a viable pathway towards sustainable and eco-friendly construction practices. Continued research, field studies, and technological advancements are necessary to optimize these approaches, address potential challenges, and promote their widespread adoption in the construction industry. By doing so, we can contribute to a more sustainable future, where waste materials are effectively managed, and resources are efficiently utilized.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] "Use of Sewage Sludge in Construction Materials" by D.C. Morton and R.K. Dhir.

[2] "Utilization of Sludge in Civil Infrastructure Construction" by K. P. Ananthapadmanabhan and M. Santhanam.

[3] "Sewage Sludge Ash in Concrete" by A. M. L. Ferreira and J. Castro-Gomes.

[4] "Recycling of Sludge in Construction Materials: A Review" by P. Chindaprasirt et al.

[5] "Reuse of Treated Wastewater in Concrete Production" by N. B. Singaravelan and V. Murugesan.

[6] "Use of Treated Wastewater for Curing of Concrete" by M. L. Gambhir and M. Neha.

[7] "Reuse of Treated Wastewater in Concrete Mixing and Curing" by C. Maravelis et al.

[8] "Effect of Treated Wastewater on Concrete Properties" by I. Abu-Safa and R. Abu-Dabous.

[9] "Effect of Treated Wastewater on Concrete Properties" by I. Abu-Safa and R. Abu-Dabous. Sulaimani.

[10] Title: Wastewater Treatment and Reuse: Theory and Design Examples: Authors: Syed R. Qasim, Guang Zhu, and Pervez Ahmed,Publisher: Wiley,Year: 2018.

[11] Title: "Utilization of wastewater in the production of lightweight concrete" Authors: Farid Debieb and Said Kenai Journal: Cement and Concrete Research Year: 2006 Volume: 36 Issue: 3 Pages: 449- 457

[12] Title: "Utilization of sewage sludge as lightweight aggregate in production of lightweight concrete" Authors: Xiangming Zhou, Srinivasan Chandrasekaran, and Jie Li Journal: Journal of Cleaner Production Year: 2014 Volume: 78 Pages: 75-82

[13] Title: "Utilization of treated municipal wastewater for concrete curing: A review" Authors: Ayman S. Moslem, Yousry E. Ghorab, and Ahmed E. ElGammal Journal: Journal of Environmental Management Year: 2019 Volume: 242 Pages: 21-34

[14] Title: "Use of treated wastewater in the production of concrete: A review" Authors: M. Khatib and M. S. Bayasi Journal: Waste Management Year: 2006 Volume: 26 Issue: 5 Pages: 518-527

[15] Title: "Utilization of dewatered sewage sludge in lightweight aggregate production" Authors: Lin Huang, Yanxiang Li, and Bin Chen Journal: Journal of Cleaner Production Year: 2018 Volume: 189 Pages: 736-744

[16] Title: "Use of dried sewage sludge as sand replacement in lightweight concrete" Authors: Marco Corradi, Alessandra Borri, and Giuseppe Monti Journal: Waste Management Year: 2009 Volume: 29 Issue: 4 Pages: 1327-1333.

[17] Title: "Evaluation of sludge ash as a partial cement replacement in lightweight concrete" Authors: R. Huang, J. Huang, and Z. Shi Journal: Construction and Building Materials Year: 2015 Volume: 82 Pages: 99-104

[18] Title: "Effects of sewage sludge ash on workability and mechanical properties of lightweight concrete" Authors: Yasser Sharifi, Mohamad R. Sabour, and Rouhollah Alizadeh Journal: Journal of Environmental Management Year: 2019 Volume: 236Pages: 1-9.

[19] Title: "The influence of curing with domestic wastewater on the mechanical properties of concrete" Authors: Mohamed Rehan Karim, Abdullah Al-Ameeri, and Asaad Al-Khafaji Journal: Journal of Water Process Engineering Year: 2019 Volume: 29 Pages: 100791.

[20] Title: "Properties of lightweight aggregate produced by rapid sintering of sewage sludge ash" Authors: Guoping Zhang, Jiaping Liu, and Xianfeng Liu Journal: Construction and Building Materials Year: 2013 Volume: 40 Pages: 1006-1012.

[21] Title: "Utilization of dried sewage sludge ash in lightweight aggregate" Authors: S. Xie, X. Xue, and Z. Li Journal: Waste Management Year: 2015 Volume: 45 Pages: 33-41. 2

[22] 2.Title: "Properties of lightweight concrete containing sewage sludge ash and manufactured sand" Authors: Marco Corradi, Alessandra Borri, and Giuseppe Monti Journal: Journal of Cleaner Production Year: 2011 Volume: 19 Issue: 17-18 Pages: 2022-2029.

[23] Title: "Utilization of sewage sludge ash for sustainable lightweight aggregate production" Authors: Nazmul Huda, Juan C. Rojas, and Masaki Kitajima Journal: Journal of Environmental Management Year: 2014 Volume: 140 Pages: 19-27.

[24] Title: "Effect of treated wastewater on the properties of concrete" Authors: Mohamed Rehan Karim, Abdullah Al-Ameeri, and Abdulazeez Abdulrazaq Journal: Journal of Materials in Civil Engineering Year: 2018 Volume: 30 Issue: 3 Pages:04018008.

[25] Title: "Reuse of treated wastewater for sustainable concrete production: A review" Authors: F. B. Barragán, J. Cabrera, and

[26] J. F. Jiménez Journal: Journal of Cleaner Production Year: 2017 Volume: 143 Pages: 754-767

[27] Title: "Influence of treated sewage sludge incorporation on the properties of lightweight concrete" Authors: Marco Corradi and Alessandra Borri Journal: Journal of Materials in Civil Engineering Year: 2012 Volume: 24 Issue: 6 Pages: 660-667

[28] Title: "Incorporation of treated sludge in lightweight aggregate: Influence on the properties of lightweight concrete" Authors:Ana B. Roig-Flores, Francisco Agrela, and Isabel Sánchez de Rojas Journal: Journal of Cleaner Production Year: 2017 Volume:149 Pages: 712-722.

[29] Title: "Incorporation of dried sludge in lightweight aggregate for lightweight concrete production" Authors: Lin Huang, Yanxiang Li, and Yuqing Zhang Journal: Construction and Building Materials Year: 2019 Volume: 215 Pages: 1-7.

[30] Title: "Evaluation of the potential use of treated wastewater for concrete curing" Authors: Khelafi Hocine, Jmal Islam, and Ezziyyani Mostapha Journal: Desalination and Water Treatment Year: 2015 Volume: 57 Issue: 29 Pages: 13469-13479.

[31] Title: "Effects of treated wastewater on the properties of concrete and the feasibility of its use in construction" Authors: Omar T. Gazi, Radhouane Masmoudi, and Musaed A. Al-Husainy Journal: Journal of Building Engineering Year: 2021 Volume: 36 Page: 102006