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# TRANSFORMING COW DUNG INTO CLIMATE-FRIENDLY COATINGS TO ADVANCE SUSTAINABLE PAINT PRODUCTION

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## ABSTRACT

This study explores the development of an eco-friendly paint using cow dung as a sustainable and renewable raw material, aligning with the principles of green chemistry and supporting Sustainable Development Goals- SDG-12, Responsible Consumption and Production, and SDG-13, Climate Action. The paint formulation incorporated natural pigments, binding agents, and preservatives, leveraging cow dung's inherent properties. Physico-chemical analysis revealed a highly alkaline pH (12.2), moderate BOD (55 mg/L), and high COD (269 mg/L), indicating the presence of biodegradable and non-biodegradable substances. The paint exhibited a total phenolic content of 1.52, contributing to its antioxidant and antimicrobial activities. Heavy metal analysis confirmed the absence of hazardous metals such as lead and mercury, while trace amounts of cadmium (1 PPM), chromium (5.26 PPM), and nickel (3.8 PPM) were within acceptable limits. Manganese (11.6 PPM) was found to enhance durability and structural integrity. UV-Vis spectroscopy showed strong absorbance in the blue-violet region, indicating the presence of organic pigments, and microbial analysis demonstrated resistance to bacterial and fungal growth. Statistical evaluations identified key parameters influencing paint quality and environmental safety. The Water Pollution Index (0.20) confirmed minimal aquatic impact, while the Heavy Metal Pollution Index (900) reflected naturally sourced metallic content. The research highlights the potential of cow dung-based paint as a cost-effective, biodegradable alternative to conventional paints, promoting rural entrepreneurship, employment generation, and circular economy practices. The findings validate the feasibility of scaling production while integrating waste-to-resource innovations into mainstream manufacturing, thereby contributing to sustainable development, environmental protection, and public health.

**Keywords:** Cow Dung, Eco-Friendly Paint, Physico-Chemical Analysis, Antimicrobial Properties.
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## INTRODUCTION

India produces over 3 million tons of cow dung daily, much of which remains underutilized and contributes to unmanaged agricultural waste.[18] Despite the growing interest in sustainable materials, limited research has explored the direct utilization of cow dung in paint formulations. This study aims to fill this gap by investigating cow dung as a primary raw material for developing eco-friendly paint, evaluating its physico-chemical, antimicrobial, and environmental properties through a green chemistry approach. Cow dung, a byproduct of cattle rearing, has long been recognized for its multifunctional applications in agriculture, medicine, and environmental practices. Traditionally, it holds a prominent place in Ayurveda and sustainable living due to its antimicrobial, antifungal, and detoxifying properties. A classical Sanskrit verse highlights its cultural and medicinal importance: गोमूत्रं गोमयं चैव पवित्रं पापनाशनम्। अघं मर्षयते सर्वं रोगान् हन्ति शरीरजम्॥[2] that means, "Cow urine and cow dung are pure, capable of destroying impurities and diseases arising in the body." This reflects the traditional belief in cow dung's purifying and therapeutic potential, which has found support in modern scientific studies. Cow dung exhibits antibacterial activity, with extracts showing partial inhibition of *Klebsiella pneumoniae*, and Indian cow dung demonstrating higher efficacy compared to other varieties. Its antifungal properties are attributed to compounds like patulodin, synthesized by dung-associated microbes such as *Eupenicillium bovifimosum*.[14] In agriculture, cow dung serves as an organic fertilizer, enriching soil and supporting beneficial microbial populations. It has shown efficacy against plant pathogens like *Rhizoctonia bataticola* and has protected rice plants from bacterial infections,


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outperforming antibiotics such as penicillin and streptomycin.[11] The traditional formulation '*Panchagavya*'—a mixture of milk, curd, ghee, urine, and dung—is widely used in Indian farming for fertilization and pest control, with some studies attributing immunity-enhancing and medicinal properties to it. Environmental applications include bioremediation, where cow dung slurry has been effective in degrading urban, hospital, and oil-based wastes. Microorganisms such as *Acinetobacter, Bacillus, Pseudomonas, Serratia*, and *Alcaligenes spp*. Present in cow dung assists in the breakdown of pollutants. Notably, cow dung use during the 1984 Bhopal gas tragedy was associated with reduced exposure effects. It continues to be used in India and Russia to mitigate radiation in nuclear settings. Ritual burning of cow dung with ghee is also believed to contribute to good atmospheric ozone enhancement. Beyond agriculture and the environment, cow dung is being explored in industrial innovations such as paper manufacturing, insect repellents, and even toothpaste for dental health.[17] Aligned with the principles of green chemistry, recent studies have investigated cow dung's potential as a base for natural paint formulations. These eco-friendly paints present a non-toxic, biodegradable alternative to synthetic coatings. This study evaluates the physico-chemical and statistical properties of cow dung-based paints, aiming to validate their role as sustainable and culturally significant materials for contemporary use.

### Rationale for Transforming Cow Dung into Wall Paint

Conventional paints contribute to environmental pollution through the release of volatile organic compounds (VOCs), heavy metals, and biocides, posing risks to both ecosystems and human health.[15] In light of these concerns, this study explores the use of cow dung—a renewable, biodegradable, and abundant material—as a sustainable alternative for wall paint, aligning with green chemistry principles and promoting ecological preservation. This research supports SDG-12, Responsible Consumption and Production, and SDG-13, Climate Action, by promoting the sustainable utilization of agricultural waste (cow dung) to develop eco-friendly paint, thereby reducing impact of environmental emissions and encouraging circular economy practices.

## EXPERIMENTAL

### Materials and Methods

The following materials and equipment were used: beakers (100 mL, 500 mL), 500 mL measuring cylinder, analytical balance, hot plate with magnetic stirrer, heating mantle, round-bottom flask, pestle and mortar, 200 mm sieve, aluminium foil, spatula, and nitrile gloves.

### Paint Composition and Ingredients

The base of the paint was sterilized cow dung. Moringa gum (*Moringa oleifera*) was used as a natural binder, and neem extract *(Azadirachta indica*) functioned as a preservative and biopesticide. Cow urine or distilled water was used to adjust the viscosity. Natural pigments were derived from plant-based sources such as turmeric and rose leaves. Floral extracts (e.g., rose, jasmine, lavender, lily) were optionally added for fragrance.

### Preparation Procedure

Old cow dung was sun-dried, crushed, ground using a mortar and pestle, and sieved (200 mm) to remove coarse particles. A 5 g sample of the processed cow dung was mixed with 10 g sodium hydroxide and 50 mL of pre-boiled cow urine in a Soxhlet extractor. The mixture was heated at 70 °C for 25 minutes to obtain a homogeneous slurry. Cow urine was pre-boiled to eliminate volatile gases ($CO_2$, $CH_4$, $N_2O$).[6] Afterwards, 12 mL of neem leaf extract was added for its pesticidal properties. For pigmentation, turmeric powder and green leaf extract were incorporated. Separately, 20 g of Moringa gum was dissolved in 50 mL of cow urine, and 7 mL of this solution was added as a binder to the formulation. The experimental setup and process flow are illustrated in Fig.-1 and 2.

### Analytical Methods

All experiments were performed in triplicate. COD and BOD were measured according to IS 3025 Part 58 and Part 44, respectively. Total Phenolic Content (TPC) was determined using the Folin–Ciocalteu method. Heavy metals (Cd, Cr, Mn, Ni) were quantified using atomic absorption spectroscopy (iCE™ 3500 AAS).

### Instrumentation

COD digester (REMI), BOD incubator (Biogen Scientific, BOD3), UV-vis spectrophotometer (Thermo Scientific GENESYS 10S), pH meter (Contech CpH-102), conductivity meter (Contech CC-01), and TDS meter (Eutech ECPC70043S).

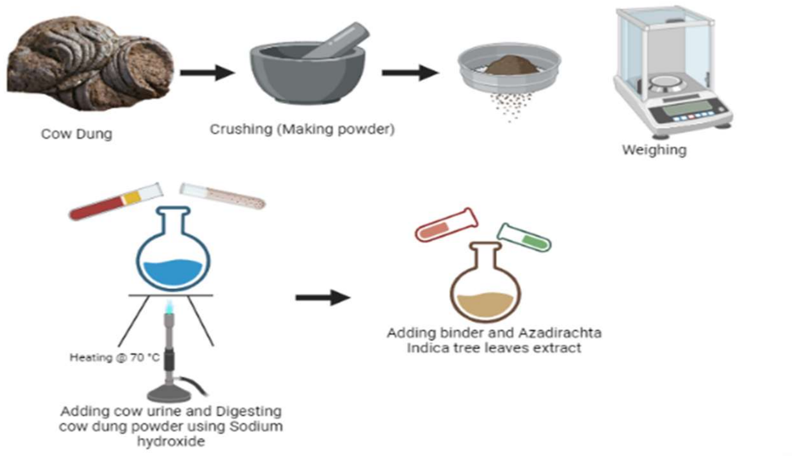


Fig.-1: Diagrammatic Presentation of Experimental Procedure

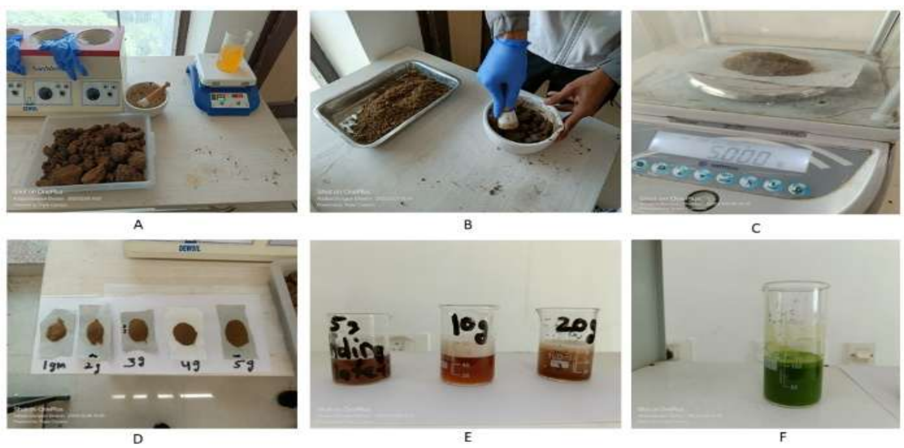


Fig.-2: Process of Cow Dung Paint Production: (A-C) Preparation (Weighing, Crushing and Mixing) of Raw Materials (Cow Dung, Cow Urine); (D) Cow Dung Powder in Different Amounts (E) Preparation of Binding Material Using Moringa Tree Leaves (F) A*zadirachta Indica* Tree Leaves Extract (Pest Repellent)

### Data Analysis

Descriptive statistics (mean and standard deviation) were calculated. Boxplots were generated to assess heavy metal distribution and detect outliers. Correlation analysis was evaluated to determine relationships between COD, BOD, TPC, and heavy metals. Ridge regression identified predictors influencing paint sustainability. Pollution indices, including the Water Pollution Index (WPI) and the Heavy Metal Pollution Index (HPI), were used to assess the environmental impact. Principal Component Analysis (PCA) determined the major contributing variables. UV-vis spectroscopy was used to study optical properties, and microbial analysis was conducted to assess microbial presence and morphology in the paint samples.

## RESULTS AND DISCUSSION

### Physico-Chemical Properties

The physico-chemical characteristics of the cow dung- and urine-based paint are summarized in Table-1 and Fig.-3. The average pH was 12.2, indicating a highly alkaline matrix. BOD and COD were measured at 55 mg/L and 269 mg/L, respectively. The Total Phenolic Content (TPC) was recorded at 1.522. TDS and conductivity readings exceeded the instrument detection limits. VOC levels reached 1,004,500 μg/m³, while heavy metals were present in the following concentrations: Cd (1.0 ppm), Cr (5.26 ppm), Ni (3.8 ppm), and

Mn (11.6 ppm). Pb, Hg, As, and Cu were below detectable levels. These results indicate that the formulation possesses a chemically stable and mineral-rich composition. The elevated pH and detectable levels of transition metals are notable for influencing both material stability and microbial resistance. VOC levels, while high, originate from natural sources, aligning with exemptions in some environmental guidelines. [7,10]

**Heavy Metal Analysis**

Lead, mercury, arsenic, and copper were below detection limits. Cadmium was detected at 1.0 ppm and chromium at 5.26 ppm. Nickel and manganese concentrations were 3.8 ppm and 11.6 ppm, respectively (Fig.-3). These values were compared against the CPCB permissible limits for the relevant materials. Table-1 details mean concentrations from triplicate measurements. The absence of highly toxic metals (Pb, Hg, As) supports the non-toxic profile of the paint. The presence of Cr, Ni, and Mn suggests possible functional contributions to coating strength and resistance. However, the Cr, Ni and Mn values slightly exceed the standard environmental thresholds.[3,4]

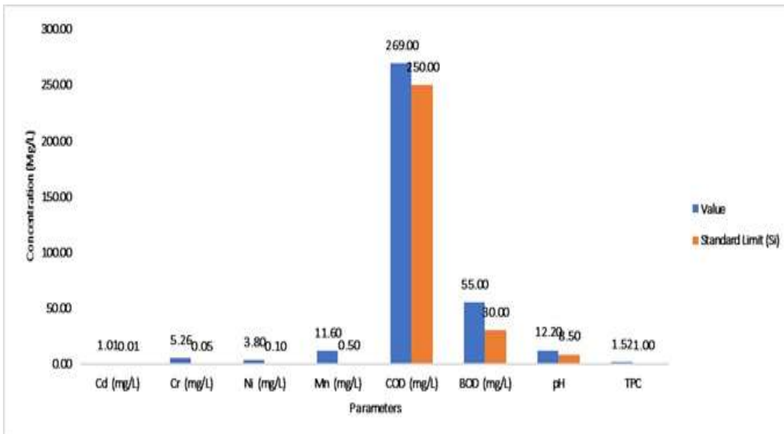


Fig.-3: Average Concentrations of Heavy Metals (Cd, Cr, Ni, Mn), COD, BOD, pH, and TPC

Table-1: Average Concentrations of Parameters for Cow Dung Samples in Triplicate

| Parameter | Value | Standard Limits[19,33] |
|---|---|---|
| Cd (mg/L) | 1.01 | 2.00 |
| Cr (mg/L) | 5.26 | 2.00 |
| Ni (mg/L) | 3.80 | 2.00 |
| Mn (mg/L) | 11.60 | 5.00 |
| COD (mg/L) | 269.00 | 250.00 |
| BOD (mg/L) | 55.00 | 30.00 |
| pH | 12.20 | 6.5-8.5 |
| TPC | 1.52 | 1.00 |
| VOCs | 1004500.00 | 50000.00 |
| WPI | 141.94 | |
| HPI | 900.00 | |

**Descriptive Statistical Analysis**

Log-transformation was applied to normalize the data. The transformed dataset had a mean of 1.29, a median of 0.72, and a standard deviation of 1.54, with values ranging from 0.18 to 6.00. Boxplot visualization (Fig.-4) showed Mn concentrations with the widest spread, while Cd exhibited the lowest and most stable values. These statistical summaries confirm distributional consistency across sample replicates and help identify variance-prone components for formulation refinement.[5,8]

**Correlation Analysis**

The correlation matrix (Fig.-5) identified strong positive relationships between COD and BOD (r = 0.95) and between Cd and Cr (r = 0.90). Ni and Mn showed a positive correlation (r = 0.85), while Cr and Mn

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were negatively correlated (r = –0.85). A negative correlation between COD and TPC (r = –0.70) and a positive correlation between VOC and pH (r = 0.88) were also observed. These associations highlight interdependencies among key parameters and can inform optimization strategies.[1]

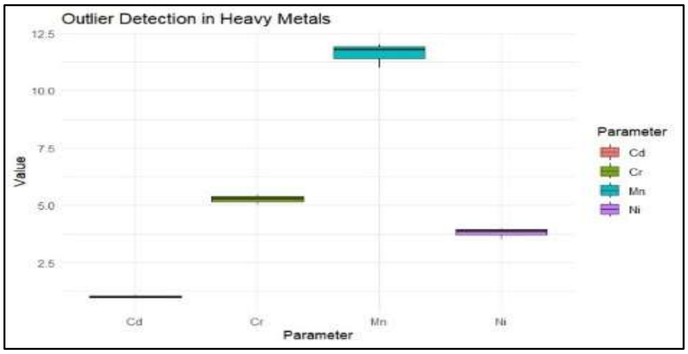


Fig.-4: Distribution of Heavy Metal Concentrations (Cd, Cr, Mn, and Ni) and Potential Outliers

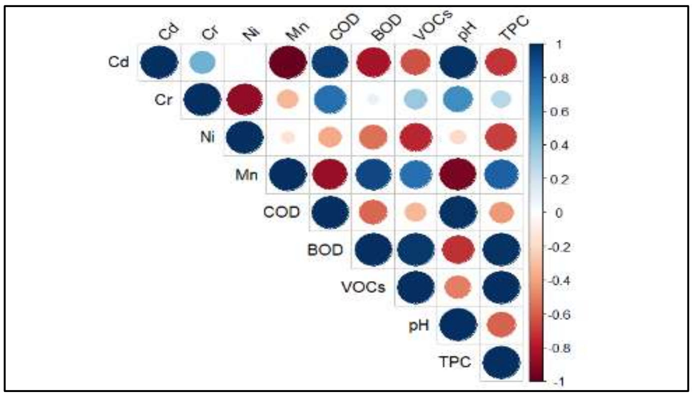


Fig.-5: Correlation Between Parameters (COD, BOD, Ph, TPC, and Heavy Metals)

## Ridge Regression

Ridge regression (Fig.-6) was used to determine the influence of individual variables on paint quality. Mn and Ni emerged as the strongest predictors, followed by TPC, COD, and BOD. Cd and Cr showed minimal influence on the model output. This analysis helps prioritize variables for enhancing performance and sustainability in future formulations.[9]

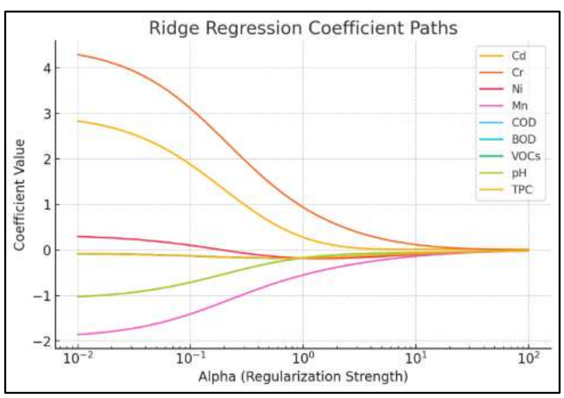


Fig.-6: Ridge Regression plot: X-Axis (Alpha - Regularization Strength): Higher Values Correspond to Stronger Regularization; Y-Axis (Coefficient Value): Shows the Estimated Coefficients for Each Feature.

## Pollution Indices

The Water Pollution Index (WPI) was calculated using the formula:

$$WPI = \frac{\sum(Ci/Si)}{N};$$

Where: Ci = Observed concentration of pollutants, Si = Standard limit for each pollutant, N = Number of pollutants

WPI value was recorded as 0.20 across the samples, indicating a low pollution potential. In contrast, the Heavy Metal Pollution Index (HPI) was calculated using the following formula:

$$HPI = \frac{\sum(Wi x Ci)}{\sum Wi};$$

Where: Wi = Weighting factor (based on toxicity), Ci = Concentration of heavy metal

HPI value was observed to be 900, reflecting a high cumulative metal load. While the WPI confirms water quality compliance, the elevated HPI suggests the need for careful control of metal concentrations, especially for environmentally sensitive applications.[20]

**Principal Component Analysis (PCA)**

PCA (Fig.-7) identified the co-alignment of VOCs, HPI, and heavy metals on PC1, while WPI and COD were distinct on PC2. BOD showed a moderate contribution. TPC aligned near VOCs, suggesting overlapping roles in paint behaviour. PCA effectively differentiates functional and environmental parameters, aiding component selection and formulation refinement.[19]

**UV-Vis Spectral Analysis**

The paint showed high absorbance in the 400–450 nm region, with λmax = >2.91 nm, and a gradual decline toward 650 nm (Fig.-8). This indicates the presence of strong chromophores, possibly plant-derived. The UV-Vis profile confirms the pigment presence and supports the assessment of optical properties critical to application performance.[12]

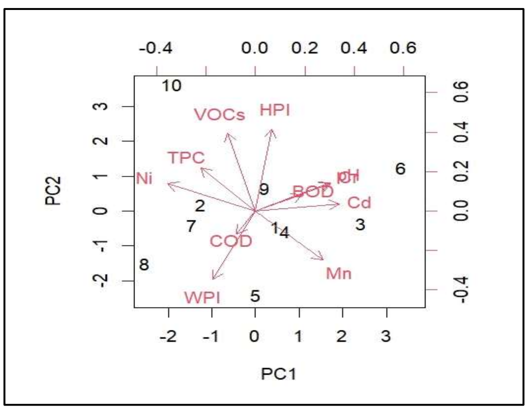


Fig.-7: PCA Biplot Showing the Relationships Among Physico-Chemical, Biological, and Environmental Parameters in Cow Dung-Based Paint Formulation

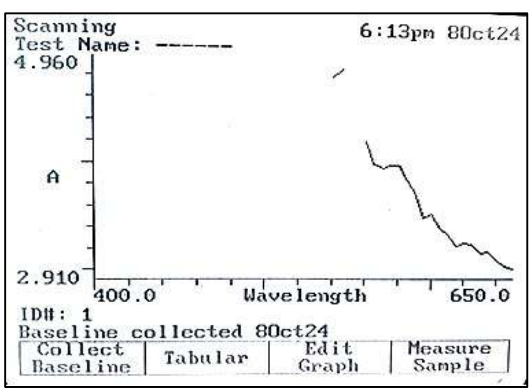


Fig.-8: UV-Vis Spectral Analysis of Cow Dung Paint Sample

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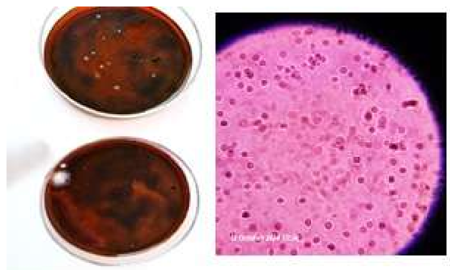
### Microbial Analysis

Petri dish cultures (Fig.-9a) revealed limited microbial colony growth. Microscopy (Fig.-9b) identified a few spore-like structures. Despite the organic content, microbial presence was low. Paint samples exhibited high pH (12.2), low BOD/COD ratio, and elevated VOCs and heavy metals, all contributing to microbial inhibition. These findings confirm the antimicrobial nature of the formulation, enhancing its durability and reducing contamination risk during use and storage.[13,16]



a b

Fig.-9: (a). Petri-Dish Culture, (b). Magnified Image Under the Microscope

## CONCLUSION

The development of cow dung-based paint presents a practical and sustainable alternative to conventional synthetic paints, utilizing agricultural waste to create an eco-friendly product. This innovation exemplifies the principles of green chemistry and supports the circular economy by minimizing environmental impact and promoting resource efficiency. The paint demonstrated favorable physico-chemical characteristics, antimicrobial activity, and minimal toxicity, making it suitable for safe indoor and outdoor use. The absence of hazardous heavy metals such as lead and mercury, along with the presence of beneficial trace elements and natural pigments, underscores its environmental and health advantages. Aligned with SDG-12, Responsible Consumption and Production, and SDG-13, Climate Action, this work contributes to minimizing environmental emissions, waste valorization, sustainable manufacturing, and responsible resource use. Additionally, it offers a pathway to empower rural communities through decentralized, low-cost production and entrepreneurship. Based on the findings, we recommend further research into optimizing the paint formulation for enhanced performance, durability, and shelf life, as well as feasibility studies for commercial-scale production. Promoting awareness and policy support for such bio-based innovations can facilitate broader adoption and integration into sustainable development strategies.

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## CONFLICT OF INTERESTS

The authors declare no conflict of interest.

## AUTHOR CONTRIBUTIONS

The present work is related to *SDG-13: Climate Action*. All the authors contributed significantly to this manuscript, participated in reviewing/editing, and approved the final draft for publication. The research profile of the authors can be verified from their ORCID ids, given below:

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