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Ratiometric fluorescence-based and chromogenic sensors for the detection of fluoride ions and their application in real samples

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This review focuses on the results of synthetic ratiometric fluorescent and colorimetric probes, which have been applied to qualitatively and quantitatively detect fluoride anions in cells, living organisms, and real samples. Primary attention is given to progress made in the working mechanism and applications of these probes to detect fluoride ions in living systems. In addition, design strategies and detection limit for these probes are discussed. This review aims to deliver a comprehensive compilation of the examples reported from 2005 to 2021 on the developments of ratiometric chromogenic and fluorogenic chemosensors for fluoride anions. A total of 20 different ratiometric/colorimetric sensors have been selected for the novelty in their design, sensitivity, detection limit, dynamic range, and speed of detection based on the three fundamental principles of F^- ion detection, namely Si–O bond cleavage; excimer emission; and intramolecular charge transfer emission through the B–F monomer, B–F–B bridged dimers, and deprotonation of the amide N–H. Special emphasis has been given to categorize the fluorophores that work in aqueous media, and possible strategies that might be adopted to design green sensors are discussed. Finally, a tabular summary of the comparative studies of all the sensors based on their sensitivity, detection limit, working solvent, and applications is provided. This extensive review may expedite improvements in the development of advanced fluorescent probes for vast and stimulating applications in the future.

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Introduction

Fluorescent and colorimetric probes have gained significant attention for applications in both fluorescence imaging and quantitative sensing owing to their high sensitivity, naked eye

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detection, real time application, and ease of operation.[1–6] Fluorescent and colorimetric probes are synthetically prepared small molecules that can be used for the precise detection and determination of biologically important analytes. Host–guest chemistry[7] was the basis of preparation of the fluorescent and colorimetric sensors for molecular recognition during the initial phases of this research. The chemistry behind this principle lies in the reversible host–guest binding property, which is the basic characteristic of supramolecular chemistry. With the gradual development of synthetic methodologies, single or multistep organic reactions have been carried out to develop reaction-based colorimetric and fluorescent probes.[8,9] It is very difficult to achieve fluorescent and colorimetric probes that possess single emission and naked eye color features for a selective desired analyte due to interferences from various competitive analytes, instrumental limitations, low detection limit in the presence of competitive analytes, poor water solubility, and other factors. Ratiometric methods have been adopted to circumvent the issues that originated from the superimposition of the single wavelength of analytes, which appeared as a barrier for the detection of the bio-molecules as mentioned above.[10,11] Ratiometric probes are favoured for their capability of generating new emission bands with recognizable changes in the intensity and naked eye color changes in the presence of desired analytes. A direct correlation has been observed between the peak-intensity ratio, thereby providing a ratiometric correlation between the concentration of analytes. The perceived color change would be useful not only for the ratiometric method of detection but also for rapid visual sensing. This approach of detection of desired analytes has been found to be very useful. Hence, this methodology has been widely adopted by various research groups.

The colorimetric probes have gained popularity for their ease of operation and "naked eye" detection of target species, which offer both qualitative and quantitative information.[12] The high degree of specificity (*via* choice of excitation and emission wavelengths) of the chemosensors based on their emission wavelength in the visible region is of particular interest as fluorimetric probes, which provides valuable information, such as spectral and intensity changes, fluorescence lifetime, *etc.* Especially, the probes with visible region excitation and emission have attained significance for their reduced scattering and low background emissions.

The design of selective and effective ratiometric fluorescent and colorimetric probes is typically based on sensing mechanisms, including 'internal charge transfer (ICT)',[13] 'fluorescence resonance energy transfer (FRET)',[13] 'monomer–excimer formation',[13] and 'excited-state intramolecular proton transfer (ESIPT)'.[14] Large Stokes shifts are observed for ICT fluorophores that are composed of conjugated electron-donating/electron withdrawing (donor/acceptor, D/A) moieties. Blue or red-shifts of the excitation/emission wavelengths have been observed with the addition of the analyte, owing to the interaction with one of the donor or acceptor moieties with concomitant naked eye color changes. FRET is based on the transfer of energy from an excited state of the donor fluorophore (DF) to the ground state of the acceptor fluorophore (AF). The FRET efficiency depends on the overlap of the emission spectrum of the DF with the absorption spectrum of the AF. A greater overlap results in a greater FRET efficiency. For monomer–excimer formation, aromatic hydrocarbons following Huckel's rule, such as naphthalene, anthracene and pyrene, have the ability to form effective excimers. The excimer formation is greater in pyrene compared to naphthalene and anthracene. An excited state complex, generally known as the 'Excimer', is produced when the excited state of a fluorophore interacts with the ground state of another molecule of this type; thereby broadening and red-shifting the emission bands originating from the excimer. ESIPT-based fluorophores are characterized by its intense emission, large Stokes shifts, and naked eye color changes. For example, ESIPT may transform a preferred enol-form of a fluorophore into an excited keto tautomer when it comes in resonance with a radiation of suitable wavelength. Relaxation of the excited keto-form results in the regeneration of the enol form by reverse proton transfer. Among the above, the ESIPT process is highly influenced by changes in pH, structural changes affecting the hydrogen bonding ability, as well as the solvent polarity. Inorganic fluorides have markedly different properties as compared to their halogen family members due to the extremely small size and the extraordinary electronegativity of fluorine. Fluoride plays important roles in human health, such as the prevention of dental caries and promoting healthy bone growth.[15] Despite the substantial benefits towards the human body, the harmful effects of excessive intake of F^- ion can cause severe toxic effects in humans. Intake of very high levels of fluoride can cause death, while long-term exposure may cause fluorosis, leading to disorders in metabolism, mottled teeth, bone related disease, immunological damage and urolithiasis.[16–18] Hence, very low levels of F^- are used in various sources of fluoride, such as toothpaste, drinking water, foods and beverages, pharmaceutical agents and other fluoride supplements.[19] Therefore, the control of F^- intake in the human body is of serious concern to governments throughout the world. For example, in the case of the United States, the U.S. Public Health Service regulates the total F^- exposure from all sources and the appropriate usage of F^- containing dental products. Currently, the optimal level for water fluoridate ion has been set at 0.7–1.2 mg L^{-1}. For this reason, the development of rapid, selective and sensitive methodologies for the detection of F^- has gained considerable interest.[20,21] Fluorescent and colorimetric sensing is a powerful tool that can be used to detect and image the location of F^- anions both qualitatively and quantitatively.[22]

Sensitive and selective methods that facilitate the detection and determination of F^- ions in biological cells are in high demand. In recent times, a number of ratiometric fluorescence-based colorimetric sensors for F^- ions in cells have been reported.

This review encompasses almost all publications during the period of 2005 to 2021 that dealt with the ratiometric fluorescent and colorimetric probes for determining fluoride ions. In all of these published works, it has been observed that three basic mechanisms have been adopted, namely: (i) cleavage of the Si–O bond of the probe; (ii) Lewis acid–base interaction

between boron and the fluoride ion in association with excimer formation of the pyrene moiety, and intramolecular charge transfer between the donor and acceptor in the presence of the fluoride ion; and (iii) deprotonation of the amide N–H group. All of the processes lead to the qualitative or quantitative detection of fluoride ion either *via* ratiometric fluorescence approach or colorimetric approach. The experiments were principally carried out at physiological pH (7.4) and at room temperature, especially for the Si–O cleavage approach. The beauty of the ratiometric sensing lies in its simplicity and independence of external stimuli, like pH, temperature, *etc.*[23]

The monomer-excimer emission wavelengths of naphthalene and anthracene are found to be too close. Hence, they are not suitable for the ratiometric approach. In order to overcome such hinderances, the pyrene moiety has been used in the design of the probes. The pyrene moiety's emission sensitivity occurs due to local environmental changes. This results in the monomer and excimer emissions occurring at different wavelengths which are far enough for unambiguous experimental detection.

The deprotonation of the N–H bond by the fluoride ion proceeds *via* strong H···F hydrogen bonding. Deprotonation of the amide N–H occurs to form HF. The deprotonated product thus formed is responsible for the colorimetric 'naked eye' detection, as well as fluorescence enhancement at different wavelengths, which is essential for ratiometric detection. Hence, for an efficient fluoride anion sensor, the design of the probe principally relies on the presence of either the Si–O bond, or presence of the boron moiety in conjugation with a pyrene/naphthalene group, or the presence of an amide N–H group.

The specificity of fluoride ions as a substrate lies in its inherent characteristics of being smaller in size and its very high electronegativity. This enables it to form a strong Si–F bond in the case of the Si–O cleavage process, as well as its capability to form a strong hydrogen bond with the amide N–H, leading to its deprotonation. Moreover, fluoride (being a hard base) can efficiently interact with boron (hard acid) to form dimers through a fluoride bridge, leading to emissions of the excimer and intramolecular charge transfer mechanism. The small size and high electronegativity are exploited for the detection of fluoride, which is absent in similar anions, such as chloride, bromide, iodide, and acetate. Thus, fluoride serves as the best substrate for ratiometric detection in the presence of its competitive anions.

Based on the ratio of fluorescence intensities at different wavelengths, regression analysis has been used as a mathematical tool for easy estimation of detection limits. Quantum yields are also calculated, and these two mathematical approaches are found to be quite effective in the quantification of the experimental results. In addition, theoretical molecular orbital energy calculation using 'Gaussian' or other suitable software has been performed by some groups to enhance the authenticity of the observed experimental results.

However, the detection of fluoride ions in aqueous media remains a challenge. The design of probes with regard to real samples in aqueous media has been discussed thoroughly in the 'Results and discussion' section.

Results and discussion

Tang and his research group have developed novel ratiometric fluorescent probes, namely **Mito-F** and **Lyso-F**, containing triphenyl phosphonium and dimethyl amino moieties to selectively monitor fluoride ions in mitochondria and lysosomes, respectively (Fig. 1).[24] The addition of fluoride (20 mM HEPES : DMSO = 1 : 1, pH 7.4), resulted in the removal of the *t*-butyldimethylsilyl (TBS) groups from **Mito-F** or **Lyso-F** to generate the corresponding *N*-substituted 4-amino-1,8-napthalmide *via* cleavage. The optimal speed of detection was achieved after 30 min between **Mito-F** and **Lyso-F** with F^-. **Mito-F** and **Lyso-F** give a blue emission at 475 nm in the absence of fluoride ion. Upon the addition of fluoride, the fluorescence band at 475 nm is decreased. A fluorescence band at 540 nm is increased with green emission (excitation at 405 nm) with an isosbestic point at 510 nm. Detection limits of **Mito-F** and **Lyso-F** for fluoride have been achieved as low as 0.067 ppm and 0.073 ppm, respectively.

Mito-F and **Lyso-F** exhibit high selectivity toward F^- in the presence of other anions, *i.e.*, Cl^-, Br^-, I^-, CO_3^{2-}, HCO_3^-, N_3^-, NO_2^-, AcO^-, $H_2PO_4^-$, and SO_4^{2-}. This selectivity helps to image fluoride ions in the mitochondria and lysosomes of HeLa cells. The probable sensing mechanism was based on the Si–O bond cleavage of **Mito-F** and **Lyso-F** by F^-. Consequently, the yellow-green fluorescent 4-amino-1,8-napthalmide is released, thereby inducing the ratiometric changes of fluorescence emission. **Mito-F** has been applied successfully to detect fluoride in mice.

Li and co-workers have introduced the ratiometric fluorescent probe **QF** for the detection of fluoride in (50 mM PBS, 25 μM CTAB, pH 7.4) (Fig. 2), which works on the principle of the transfer of two-photons.[25] **QF** possesses a blue emission at 404 nm. The addition of an increasing concentration of fluoride to **QF** (50 mM PBS, 25 μM CTAB, pH 7.4) shows a red shift towards 425 nm in the fluorescence band. Furthermore, a new

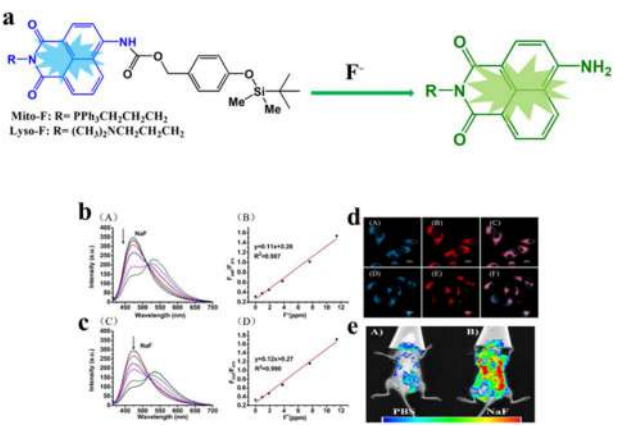


Fig. 1 (a) A proposed mechanism for sensing F^- by **Mito-F** and **Lyso-F**; (b) F^- concentration (0–11.40 ppm) dependent fluorescence changes in **Mito-F** (10 μM); (c) F^- concentration (0–11.40 ppm) dependent fluorescence changes in **Lyso-F** (10 μM); (d) its application for the detection of F^- in mitochondria and lysosome in HeLa cells; (e) its application for the detection of F^- of mice (reproduced from ref. 24 with permission from American Chemical Society, 2015).

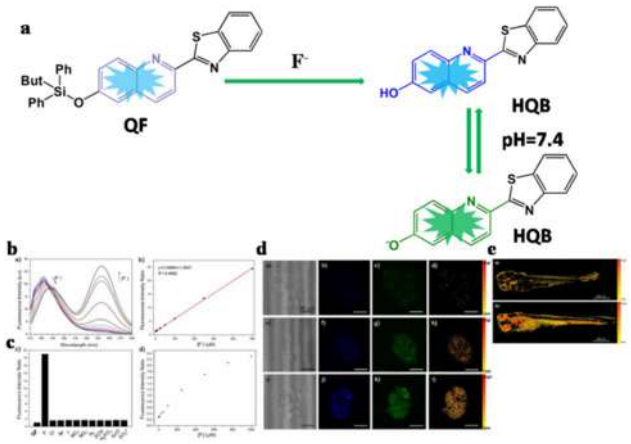


Fig. 2 (a) A proposed mechanism for sensing F^- by **QF**; (b) F^- concentration dependent (0, 2, 5, 10, 25, 50, 100, 250, 500, 750, 1000 μM) fluorescence changes in **QF** (10 μM); (c) F^- selective fluorescence changes in **QF** over other anions. (d) Its application for the detection of F^- in HeLa cells; (e) its application for the detection of F^- in zebrafish (reproduced from ref. 25 with permission from the Royal Society of Chemistry, 2016).

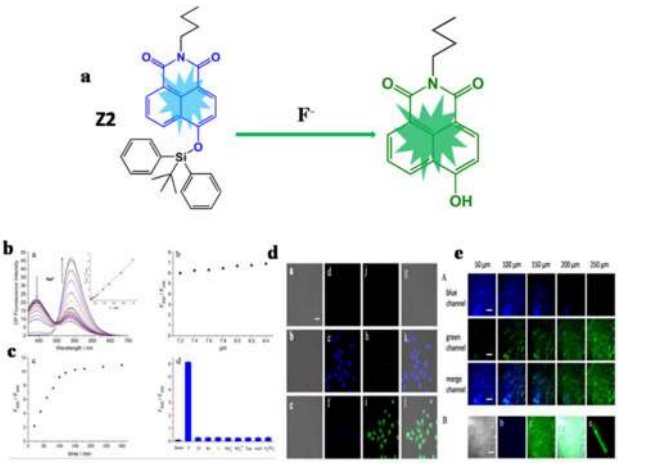


Fig. 3 (a) A proposed mechanism for sensing F^- by **Z2**; (b) F^- concentration dependent (0, 5, 10, 20, 40, 60, 80, 100, 125, 150, 200, 250, 375, 500, 750, 1000, 1500 μM) fluorescence changes in **Z2** (5 μM); (c) F^- selective fluorescence changes in **Z2** with reaction time and F^- selective fluorescence changes in **Z2** (5 μM) over other anions (1 mM); (d) its application for the detection of F^- in HeLa cells; (e) its application for the detection of F^- in fresh tumor tissue (reproduced from ref. 26 with permission from MDPI, 2015).

emission band emerged at 533 nm, which increased in intensity with 'two-photon excitation' at 730 nm or 'one photon excitation' at 366 nm. They have chosen *tert*-butyldiphenylsilyl (TBDPS) as a functional group, which is well-known for fluoride ion detection due to its high affinity and low 'auto turn-on emission' problem in aqueous solution. A thorough investigation regarding the sensing mechanism of fluoride ions led to the conclusion that a Si–O cleavage occurred in the **QF** probe, thereby forming a hydroxyl moiety in the **HQB** fluorophore. Cleavage of the t-butyldiphenylsilyl (TBDPS) group from **QF**, which was triggered by the fluoride ion, produces a free phenolic OH^- group that remains in equilibrium with the phenolate anion at neutral pH. The detection limit of **QF** for fluoride has been achieved as 0.5 μM. This probe can selectively detect fluoride in HeLa cells and zebrafish by two-photon fluorescence imaging.

The selectivity of **QF** towards F^- in the presence of other competitive anions, *i.e.*, Cl^-, Br^-, I^-, NO_2^-, NO_3^-, N_3^-, SCN^-, $H_2PO_4^-$, CH_3COO^-, SO_4^{2-} at the concentration of 0.5 mM has been thoroughly investigated. The ratiometric emission study (F_{green}/F_{blue}) has been successfully applied by **QF** towards F^- in HeLa cells and zebrafish by two-photon fluorescence imaging.

Zhang and co-authors have reported on the ratiometric fluorescent fluoride probe **Z2** for F^- anion, based on the ICT (intramolecular charge transfer) mechanism (Fig. 3).[26] **Z2** has an absorption maximum at 365 nm. Upon incremental addition of F^-, the absorption maxima at 365 nm decreased and a new peak at 456 nm appeared. When **Z2** was excited with the one-photon excitation wavelength of 365 nm, a weak blue emission at 440 nm appeared. On the other hand, when **Z2** was excited by two-photon excitation at 780 nm, a similar emission peak emerged at 440 nm. The optimal speed of detection was achieved after 150 min between **Z2** and F^-. When the *tert*-butyldiphenylsiyl (TBDPS) group in **Z2** is eliminated by the addition of an increasing concentration of fluoride (5, 10, 20, 40, 60, 80, 100, 125, 150, 200, 250, 375, 500, 750, 1000 and 1500 μM in 20 mM HEPES/DMSO = 7 : 3, pH 7.4), the fluorescence emission at 440 nm was found to be decreased and a green emission band at 540 nm was observed upon excitation at 365 nm (one-photon excitation). A similar observation was found for two-photon excitation at 780 nm. The selectivity study of **Z2** towards F^- has been investigated in the presence of various competitive anions, *i.e.*, Cl^-, Br^-, I^-, NO_3^-, SO_4^{2-}, $H_2PO_4^-$, AcO^- and cysteine (Cys) (1 mM each). **Z2** shows a blue weak emission at 440 nm due to ICT (intramolecular charge transfer) mechanism. Upon addition of F^-, cleavage of the TBDPS group in **Z2** occurred and *N*-butyl-4-hydroxy-1,8-naphthalimide was produced with a strong green emission. Selective imaging of fluoride ions in HeLa cells and tumor tissues was successfully performed by **Z2** *via* ratiometric imaging.

Chen and his colleagues have introduced a coumarin-based colorimetric and ratiometric fluorescent **Probe 1** that selectively detected fluoride in mitochondria *via* emission color changes from red to green in DMF–PBS solution (7 : 3 V/V, 50 mM, pH 7.4) (Fig. 4).[27] They incorporated the pyridinium cation in the conjugated system combined with coumarin in the **Probe 1** for targeting mitochondria. **Probe 1** showed an absorption maximum at 490 nm with 'red' as the naked eye color *via* ICT (intramolecular charge transfer) mechanism. After the addition of F^-, the absorbance maximum was blue-shifted towards 435 nm with a 'green' naked eye color *via* weakening of the ICT effect. From this result, it has been proved that **Probe 1** can successfully detect F^- through naked eye color changes from red to green. **Probe 1** exhibited a strong emission at 639 nm with a bright red emission. With increasing concentration of fluoride, the **Probe 1** (50 mM PBS/DMF = 7 : 3, pH 7.4), a new

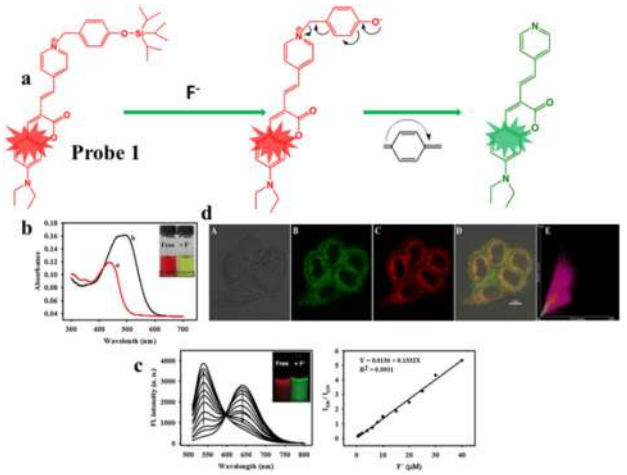


Fig. 4 (a) A proposed mechanism for sensing F^- by **Probe 1**; (b) F^- selective fluorescence changes in free **Probe 1** (10 μM) and in the presence of F^-; (b) F^- concentration dependent fluorescence changes in **Probe 1** (10 μM); (d) its application for the detection of F^- in in HepG2 cells (reproduced from ref. 27 with permission from Elsevier, 2018).

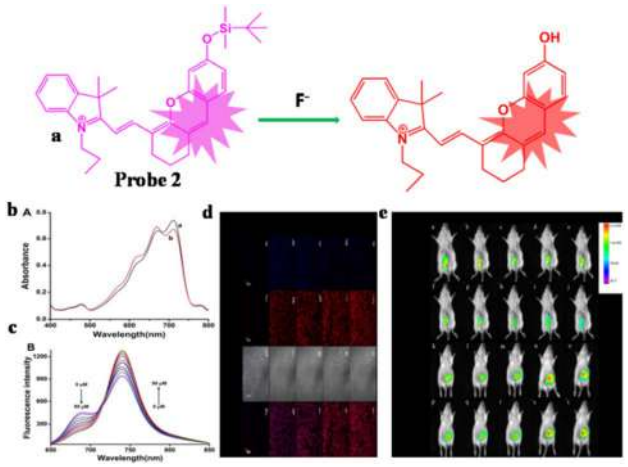


Fig. 5 (a) A proposed mechanism for sensing F^- by **Probe 2**; (b) F^- selective absorbance changes in free **Probe 2** (10 μM) and in the presence of F^- (60 μM); (c) F^- concentration (0, 10, 20, 30, 40, 50, 60, 70, 80 and 90 μM) dependent fluorescence changes in **Probe 2** (10 μM); (d) its application for the detection of F^- in HepG2 cells; (e) its application for the detection of F^- in BALB/c mice (reproduced from ref. 28 with permission from American Chemical Society, 2018).

fluorescence band emerged and was enhanced at 539 nm, while the emission band at 639 nm decreased with an isosbestic point at 600 nm. The optimal speed of detection has been achieved after 24 min between **Probe 1** with F^-. The mechanism was based on the F^--initiated cleavage of the triisopropylsilane (TIPS) group in **Probe 1** to remove the pyridinium cation. Consequently, a weak ICT process was found to occur from the coumarin moiety to pyridine. The selectivity study of **Probe 1** for F^- has been investigated in the presence of various competitive anions like Cl^-, Br^-, I^-, S_2^-, AcO^-, SO_3^{2-}, HSO_4^-, NO_2^-, CN^-, NO_3^-, SO_4^{2-}, SCN^-, and ClO^-. The detection limit of **Probe 1** for fluoride was determined as 1.2×10^{-8} M. As shown by the color change from red to green, the selectivity of **Probe 1** was proved through fluorescence imaging in a ratiometric manner of fluoride ions in the mitochondria of HepG2 cells.

Yang and co-researcher have developed a novel ratiometric NIR fluorescent probe **Probe 2** for the selective detection of fluoride *via* strong red emission (Fig. 5).[28] **Probe 2** exhibited an absorption maximum at 700 nm. Upon the addition of F^-, the maximum absorption peak of the reaction solution is blue-shifted to 670 nm and the absorption value was found to be relatively decreased. The free **Probe 2** displayed a relatively high fluorescence band at 690 nm. With the addition of an incremental amount of fluoride, the original emission band of the probe (10 mM PBS/DMSO = 2 : 8, pH 7.4) at 690 nm decreased, and a new emission band at 740 nm (excitation at 600 nm) was found to emerge. With the incremental addition of an increasing concentration of F^-, the emission band at 740 nm was found to increase. The emission bands of the free **Probe 2** and **Probe 2** bound to F^- ion were both observed in the near-infrared region, which was free from biological sample interferences. The optimal speed of detection has been achieved after 15 min between **Probe 2** with F^-. The ratiometric sensing mechanism was based on the F^--induced Si–O bond cleavage of **Probe 2** to form the hydroxo derivative. **Probe 2** has been found to possess a low detection limit of 0.2 μM for fluoride. **Probe 2** has been used to quantitatively detect fluoride in drinking water and white flour very effectively. The selectivity study of **Probe 2** towards F^- has been investigated in the presence of other competitive anions, cations, and biological reactive species, *i.e.*, Cl^-, Br^-, I^-, NO_2^-, NO_3^-, ClO_4^-, AcO^-, $H_2PO_4^-$, S^{2-}, SO_3^{2-} and SO_4^{2-}, K^+, Na^+, Ag^+, Cu^{2+}, Ca^{2+}, Hg^{2+}, Fe^{2+} and Fe^{3+}, Vitamin-B_6, Vitamin-C, arginine, serine, glucose, $^{\bullet}OH$ and H_2O_2. **Probe 2** has also been used for the ratiometric fluorescence imaging of fluoride in HepG2 cells and mice. Moreover, **Probe 2** has been successfully applied in real samples like living mice, and even imaging in mice *in vivo*.

Fang and co-researchers have developed and reported on the flavone-based excited-state intramolecular proton transfer (ESIPT)-based ratiometric fluorescent **Probe 3** for fluoride ion

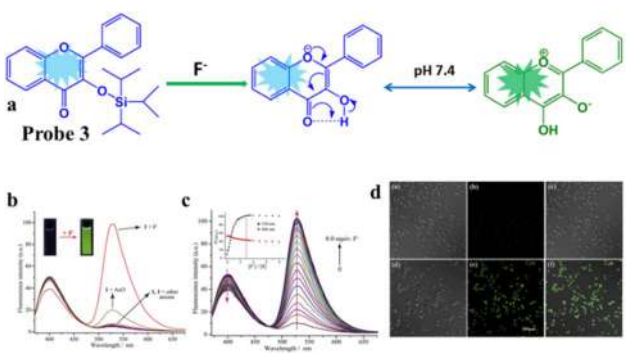


Fig. 6 (a) A proposed mechanism for sensing F^- by **Probe 3**; (b) F^- selective fluorescence changes in **Probe 3** (20 μM) in the presence of all of the anions (10 equivalent); (c) F^- concentration (0–8 equivalent) dependent fluorescence changes in **Probe 3** (20 μM); (d) its application for the detection of F^- in HGC27 cells (reproduced from ref. 29 with permission from Elsevier, 2019).

detection *via* green emission (Fig. 6).[29] The sensing behavior of **Probe 3** for anions, *i.e.*, F^-, Cl^-, Br^-, I^-, ClO_4^-, AcO^- and HSO_4^- (as their tetrabutylammonium salts) has been thoroughly examined in acetonitrile solution by absorption spectra. **Probe 3** displayed two broad absorption bands at 305 nm and 335 nm. Upon addition of 10 equiv. of the competing anions to **Probe 3**, a significant change has been observed for fluoride only. For the fluoride ion, absorption bands at 305 nm and 335 nm decreased. A new absorption band appeared at 455 nm with a 'fancy dark yellow' naked eye color from the original colorless condition. Free **Probe 3** only showed a weak emission band centered at 400 nm, due to the normal emission (enol form) of the flavone skeleton. In addition, the increasing concentration of fluoride to **Probe 3** ($CH_3CN/H_2O = 95:5$) led to a decrease in the fluorescence band at 400 nm, while the emission band at 530 nm gradually increased with an isosbestic point at 475 nm when excited at 350 nm. The optimal speed of detection has been achieved after 20 s between **Probe 3** and F^-. The sensing mechanism was investigated as a fluoride-triggered desilylation reaction through the cleavage of Si–O bonds in **Probe 3**, which generated the hydroxyl flavone wherein a strong ESIPT was found to occur, associated with a large Stokes shift. **Probe 3** was found to be very effective as its detection limit for fluoride is 0.68 μM. **Probe 3** was selectively used to ratiometrically monitor fluoride anion in paper strips under a UV lamp and in HGC-27 cells.

Yang and co-workers have reported on a novel ESIPT-based colorimetric and ratiometric fluorescent probe **BTTPB** for fluoride anion in THF (100 μL, 2.0 mm) into a micellar solution of cetyltri-methylammonium bromide CTAB in water (10 mL, 2.0 mM) (Fig. 7).[30] The sensor **BTTPB** has a high degree of selectivity

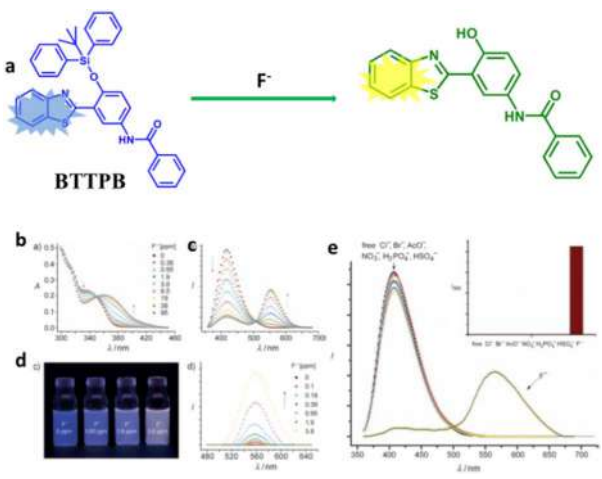


Fig. 7 (a) A proposed mechanism for sensing F^- by BTTPB; (b) F^- concentration (0, 0.38, 0.95, 1.9, 3.8, 9.5, 19, 38, 95 μM) dependent absorbance changes in BTTPB (2 mM); (c) F^- concentration (0, 0.38, 0.95, 1.9, 3.8, 9.5, 19, 38, 95 μM) dependent fluorescence changes in BTTPB (2 mM); (d) F^- concentration (0, 0.95, 1.9, 3.8 ppm) dependent emission color changes in BTTPB (2 mM) and fluorescence changes; (e) F^- selective fluorescence changes in BTTPB (2 mM) over other anions (500 equivalent) (reproduced from ref. 30 with permission from Wiley-VCH, 2010).

for fluoride ions, and operates through the special affinity between fluoride ions and silicon. For the design of the sensor, they have chosen *N*-(3-benzo[*d*]thiazol-2-yl)-4-(hydroxyphenyl) benzamide (3-BTHPB) as an excited-state intramolecular proton transfer (ESIPT) compound. **BTTPB** itself has a weak emission at 418 nm with blue light emission. Upon the addition of increasing concentration of fluoride ions to **BTTPB**, the blue-violet emission band at 418 nm decreased, along with the simultaneous formation of a new emission band at 560 nm, which gradually increased. The fluorescence color changes of **BTTPB** due to the addition of 1 equivalent of fluoride (*i.e.*, 0.38 ppm) ion is invisible to the naked eye, but can be detected fluorometrically. With increasing concentration of fluoride ion, the change could be observed by fluorescent spectroscopy, as well as by naked eye. The addition of 0.95, 1.9, and 3.8 ppm of fluoride ions causes the dispersion fluorescence color to change from blue-violet to violet, pink-purple, and to pink-white, respectively. For the interference study, the **BTTPB** dispersion was tested with the addition of 500 equivalents of competitive anions (in the form of sodium salts), like Cl^-, Br^-, AcO^-, NO_3^-, $H_2PO_4^-$, HSO_4^-, and F^-. Only NaF was found to be capable of causing an immediate red shift in the fluorescence maximum, which was observed to shift from 418 nm to 560 nm. All other anions did not cause any emission intensity changes. The sensing mechanism has been investigated as the rupture of the Si–O bond of **BTTPB**, by addition of fluoride ion. After the cleavage of the Si–O bond of **BTTPB**, it produced 3-BTHPB, which showed two emission bands. These two bands originated from the enol and keto forms at 418 and 560 nm, respectively. After the addition of fluoride ions, the Si–O bond of **BTTPB** ruptured, and 3-BTHPB was formed which imparted a bright yellow emission in water. It is expected that the fluorescence color change from blue-violet to yellow upon the gradual addition of fluoride ions reflected the extent of the fluoride-induced Si–O bond cleavage.

The lowest detection limit by **BTTPB** for fluoride ion determination was achieved as 100 ppb. In both colorimetric and fluorescent modes, the sensing process is rapid. It is completed within 200 seconds, and no interference from other common anions is detected. For the application of **BTTPB** for real sample analysis, the sensing study was performed in test paper.

James and co-workers developed a pyrene-based compound **Probe 4** for F^- ion detection in dichloromethane solution *via* excimer formation (Fig. 8).[31] **Probe 4** showed emission bands at 378 nm and 397 nm, which were characteristic emissions of the pyrene monomer. The addition of the fluoride anion to a solution of **Probe 4** led to an increase in the emission bands of the pyrene monomer and a larger increase in the emission band of pyrene excimer fluorescence at 488 nm, respectively. These results suggest that the fluoride anions enhance the π–π stacking of the pyrene units, resulting in the enhancement of the excimer band. With the addition of increasing concentration of fluoride ion, the excimer emission intensity of **Probe 4** was found to increase. They have also prepared two separate compounds to optimize the spacer effect between the pyrene and pyridyl boronic acid moiety. Between the methylene, ethylene and propylene spacers, the ethylene spacer of **Probe 4**

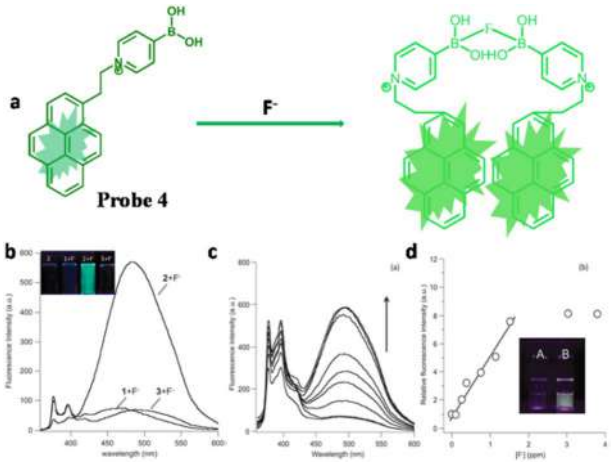


Fig. 8 (a) A proposed mechanism for sensing F^- by **Probe 4**; (b) F^- selective fluorescence changes in **Probe 4** (10 μM); (c) F^- concentration (0.10–3.80 ppm) dependent fluorescence changes in **Probe 4** (50 μM); (d) plot of the intensity ratio of **Probe 4** (50 μM) in the presence of F^-; inset depicts F^- (52.6 μM) selective emission color changes in **Probe 4** (50 μM) (reproduced from ref. 31 with permission from Royal Society of Chemistry, 2013).

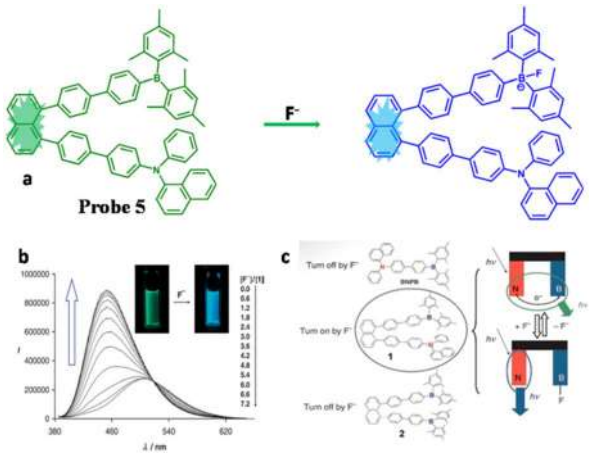


Fig. 9 (a) A proposed mechanism for sensing F^- by **Probe 5**; (b) F^- concentration (0, 0.6, 1.2, 1.8, 2.4, 3.0, 3.6, 4.2, 4.8, 5.4, 6.0, 6.6, 7.2 μM) dependent fluorescence changes in **Probe 5** (7.6 μM); (c) operating principle of **Probe 5** (reproduced from ref. 32 with permission from Wiley-VCH, 2006).

between the pyrene and pyridyl-boronic acid unit was found to be optimal for π–π stacking interactions to form the excimer. The sensing mechanism was based on those two boron atoms of **Probe 4**, which were chelated to a single fluoride anion. This anion chelation enhances the intermolecular π–π interaction with **Probe 4**, which caused the observed fluorescence changes. From the interference study, it has been clear that in the case of **Probe 4**, only the addition of fluoride ions enhances the pyrene excimer formation. In contrast, the other anions (Br^-, I^-, OH^-, BF_4^-, HSO_4^-, $H_2PO_4^-$ and PF_6^-) showed only the enhancement of the monomer fluorescence. Upon addition of F^- to **Probe 4**, a green emission under a UV lamp was observed due to the formation of the excimer of pyrene. The lowest detection limit for F^- by **Probe 4** has been achieved as 0.1 ppm.

Wang and co-workers have developed a "turn-on" organoboron-based sensor **Probe 5** for F^- in chloroform, based on intramolecular charge-transfer emission between the donor N(Ph)(1-naphthyl) and the acceptor B(mesityl)$_2$ (Fig. 9).[32] They synthesized the compound **Probe 5** by introducing N(Ph)(1-naphthyl) and B(mesityl)$_2$ as the donor and acceptor, respectively. The donor and the acceptor groups in **Probe 5** remained in a non-planar arrangement. **Probe 5** has a weak emission at around 505 nm with green emission. The emission spectrum of a solution of **Probe 5** was blue-shifted to a shorter wavelength (λ_{max} = 453 nm, in CH_2Cl_2) with the addition of increasing concentration of TBAF, and the emission intensity is drastically enhanced. The color of the emission of **Probe 5** changed vividly from green to blue after the addition of F^-. This observation conclusively proves that **Probe 5** can be described as a "turn-on" sensor for fluoride. A possible explanation for the color change was the presence of dual fluorescent pathways in **Probe 5**; that is, charge-transfer emission between the N donor and the B acceptor, as well as π*–π emission localized on the N donor. **Probe 5** demonstrates that dual signal pathways in non-planar three-coordinate boron compounds can also be modulated by intramolecular charge transfer, and exploited effectively for the detection of anions such as fluoride. Molecular orbital calculations (Gaussian 03) confirmed that the HOMO consists of contributions of the aminobiphenyl portion, and the LUMO of the (mesityl)$_2$B(biphenyl) portion. The lowest detection limit for F^- has been observed to lie between 0.015 and 0.020 mM.

The Kumar research group developed the *N*-aryl imidazolium-based compound **Probe 6** for the naked eye detection and ratiometric fluorescence detection of F^- ions in CH_3CN–DMSO (20 : 1), which is the first of its kind (Fig. 10).[33]

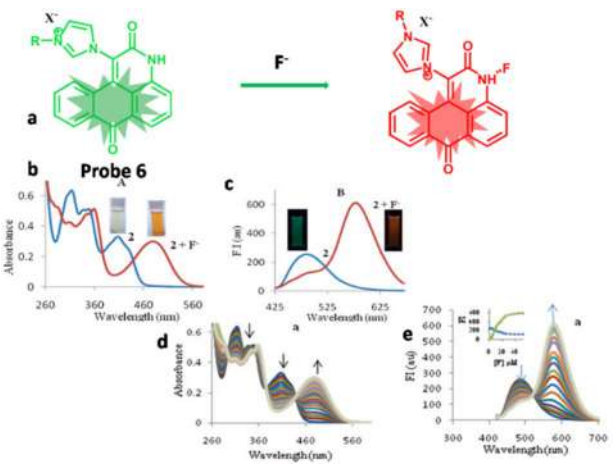


Fig. 10 (a) A proposed mechanism for sensing F^- by **Probe 6**; (b) F^- (100 μM) selective absorbance changes in **Probe 6** (50 μM); (c) F^- (20 μM) selective fluorescence changes in **Probe 6** (10 μM); (d) F^- concentration dependent absorbance changes in **Probe 6** (50 μM); (e) F^- concentration dependent fluorescence changes in **Probe 6** (10 μM) (reproduced from ref. 33 with permission from American Chemical Society, 2008).

The appearance of absorption and emission maxima due to the free probe (λ_{abs} = 405 nm; λ_{em} = 475 nm) and their complexes with the anion (λ_{abs} = 480 nm; λ_{em} = 580 nm) at different wavelengths has enabled **Probe 6** as a suitable colorimetric and fluorometric sensor for F^- *via* ratiometric approach. The chemosensor **Probe 6** (50 μM, CH_3CN–DMSO (20 : 1)) exhibited absorption maximum bands at 308 nm and 405 nm. On addition of tetrabutylammonium fluoride (TBAF) (100 μM) to a solution of **Probe 6**, the color of the solution changed from light yellow to orange, as observed by naked eye. From the interference study, it has been found that common anions, *e.g.*, Cl^-, Br^-, I^-, NO_3^-, HSO_4^-, CN^-, and ClO_4^-, caused no significant change in the absorption spectrum of **Probe 6**. With the gradual addition of increasing concentration of TBAF to a solution of **Probe 6** (50 μM, CH_3CN–DMSO (20 : 1)), the absorbance at 405 nm decreased in its intensity with a concomitant increase at 480 nm with an isosbestic point at 440 nm. Chemosensor **Probe 6** (CH_3CN) can be used for the estimation of fluoride ions between 5 and 100 μM. On excitation at 410 nm, the chemosensor **Probe 6** (10 μM, CH_3CN–DMSO (20 : 1)) exhibited an emission band at λ_{em} = 480 nm. The addition of Cl^-, Br^-, I^-, NO_3^-, CH_3COO^-, HSO_4^-, $H_2PO_4^-$, and ClO_4^- anions (0.01 M) to a solution of **Probe 6** caused no significant changes in its fluorescence spectrum. With the addition of fluoride ions (20 μM), the fluorescence intensity at 480 nm (green emission) was turned off. Simultaneously, a new red-shifted fluorescence emission band at 580 nm appeared (λ_{max} = 100 nm). The color of this solution under UV-vis radiation appears red due to the 580 nm emission band. With the addition of increasing concentration of F^- towards **Probe 6**, the emission band at 480 nm decreased and the emission band at 580 nm increased with a bright red emission light. The sensing mechanism was investigated as the fluoride ion-induced deprotonation of the amide NH-group in **Probe 6** was responsible for the spectral and visible color changes, both in colorimetric and fluorometric methods.

The Wang research group has reported on a ratiometric fluorescent **Probe 7** for fluoride based on excited state intramolecular proton transfer (ESIPT) in DMF–water solution buffered at pH 7.0 (Fig. 11).[34] **Probe 7** was prepared by the introduction of *tert*-butyldimethylsilyl chloride (TBS-Cl) because of the affinity of Si towards F^-. **Probe 7** showed an absorption maximum at 293 nm. With increasing concentration of fluoride ion, the absorption band at 293 nm decreased, while two new bands at 315 and 324 nm gradually increased. The mechanism for the changes in the absorbance maximum was due to the F^--induced deprotection reaction. In the absence of fluoride, **Probe 7** exhibited one typical fluorescence peak at 360 nm. However, upon addition of an increasing concentration of fluoride, the emission of **Probe 7** at 360 nm gradually decreased with the concomitant growth of a new emission band at 454 nm due to the restoration of the ESIPT process. The optimal speed of detection was achieved after 40 min between **Probe 7** with F^-. Once its hydroxyl group was protected by the TBS group, the ESIPT process of **Probe 7** was switched off and **Probe 7** only showed a fluorescence emission maximum at 360 nm. Because of the high affinity of fluoride for silicon, silyl ethers are easily

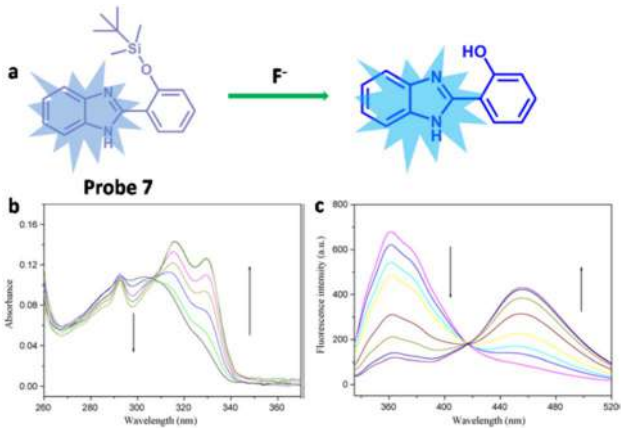


Fig. 11 (a) A proposed mechanism for sensing F^- by **Probe 7**; (b) F^- concentration (0, 2, 4, 6, 8, 10, 20 μM) dependent absorbance changes in **Probe 7** (5 μM); (c) F^- concentration (0, 0.3, 0.5, 1, 2, 4, 6 and 8 μM) dependent fluorescence changes in **Probe 7** (1.2 μM) (reproduced from ref. 34 with permission from Elsevier, 2009).

cleaved by fluoride. Upon introducing fluoride in DMF/water (80 : 20, v/v), the TBS group of **Probe 7** was removed readily through a fluoride-induced Si–O bond cleavage, and the ESIPT process of the probe was switched on. Accordingly, it was observed that the fluorescence emission at 360 nm switched over to the "turn-off" mode, while the fluorescence emission at 454 nm was converted to a "turn-on" mode. The proposed probe shows excellent selectivity toward fluoride over other common anions, and the proposed probe has been successfully applied to the fluoride determination in toothpaste and tap water samples.

Probe 7 features a ratiometric fluorescent response to fluoride with a marked emission wavelength shift, and displays high selectivity for fluoride over other anions, *i.e.*, Cl^-, Br^-, I^-, NO_3^-, NO_2^-, S^{2-}, HSO_3^-, SO_4^{2-}, SCN^-, OAc^-. The lowest detection limit was investigated as 0.19 μM L^{-1}.

Mahapatra and his research group have developed a new BODIPY-based colorimetric and ratiometric fluorescent sensor **Probe 8** for fluoride anions in 7 : 3 CH_3CN : H_2O solution (0.02 M HEPES buffer, pH 7.2) (Fig. 12).[35] **Probe 8** possesses an intense absorption band at 501 nm and a weak absorption peak at 350 nm. The absorption band at 501 nm is due to the BODIPY dyes. After addition of 0.5 M fluoride ions, no significant change was observed for 501 nm. However, upon the addition of a higher concentration of fluoride ions, new absorption bands appeared at 419 and 254 nm. The absorption band at 350 nm diminished and a new red-shifted band at 419 nm appeared due to the hydrogen bonding interaction between the indolic-NH of **Probe 8** and fluoride anions. The light yellow color of the **Probe 8** solution turned reddish-brown with the addition of the fluoride anion. Four well-defined isosbestic points at 266, 290, 369 and 460 nm were observed, indicating the formation of a new species upon treatment of **Probe 8** with F^-. In aqueous-organic solvent, **Probe 8** changed its color in the presence of F^-. This property of **Probe 8** makes it useful for naked eye detection of the fluoride anion. The optimal speed of detection has been

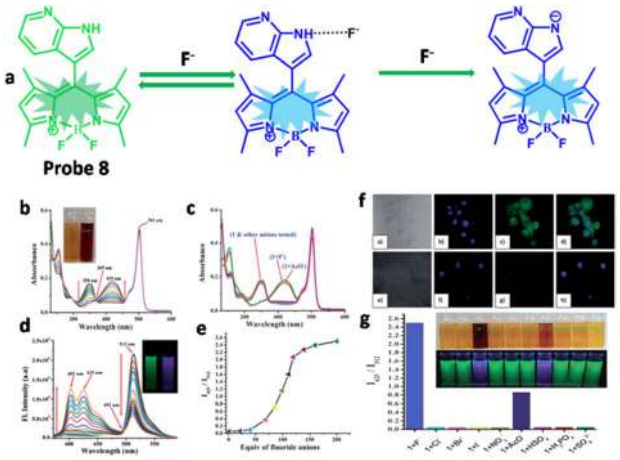


Fig. 12 (a) A proposed mechanism for sensing F^- by **Probe 8**; (b) F^- concentration (0–20 equivalent) dependent absorbance changes in **Probe 8** (4.5 μM); (c) F^- selective (0–300 equivalent) absorbance changes in **Probe 8** (4.5 μM); (d) F^- concentration (0–200 equivalent) dependent fluorescence changes in **Probe 8** (4.5 μM); (e) plot of the intensity ratio of **Probe 8** in the presence of F^-; (f) its application for the detection of F^- in RAW 264.7 cells; (g) F^- selective naked eye color changes and emission color changes in **Probe 8** in the presence of other anions under a UV lamp with other anions (reproduced from ref. 35 with permission from the Royal Society of Chemistry, 2014).

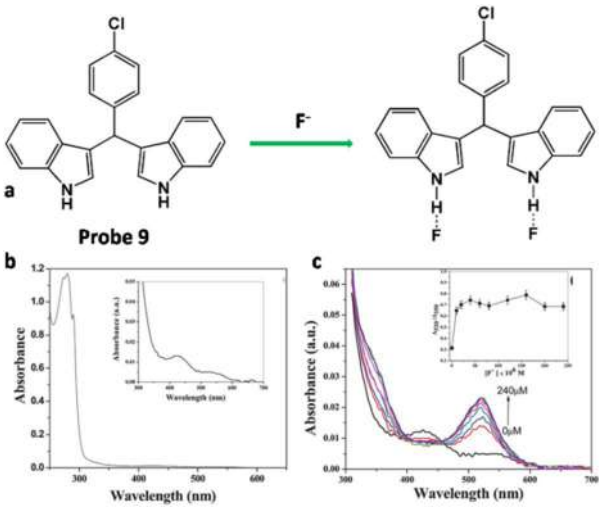


Fig. 13 (a) A proposed mechanism for sensing F^- by **Probe 9**; (b) F^- selective absorbance changes in **Probe 9**; (c) F^- concentration (0–240 μM) dependent absorbance changes in **Probe 9** (reproduced from ref. 36 with permission from the Royal Society of Chemistry, 2012).

achieved after a few seconds between **Probe 8** with F^-. Other competitive anions, such as Cl^-, Br^-, I^-, NO_3^-, SO_4^{2-}, HSO_4^- and $H_2PO_4^-$, did not induce any spectral changes. The binding constant for F^- was determined to be 3.43×10^4 M^{-1}. The detection limit of fluoride was investigated as about 1.21 μM. The sensor **Probe 8** also exhibited a ratiometric fluorescent response to F^- anions. Upon excitation at 350 nm, the free sensor displayed an intense emission band at 512 nm due to an efficient PET process from the lone pair of electrons on the azaindole moiety to the excited BODIPY fluorophore.

With the addition of increasing concentration of F^-, the new emission band at 425 nm was gradually enhanced with a clear iso-emission point observed at 492 nm. With the addition of 200 equiv. of F^-, the emission band at 512 nm was quenched efficiently. This could be attributed to the enhanced PET process upon binding of F^-. **Probe 8** can be successfully utilized to selectively detect fluoride anions in RAW 264.7 control cells.

Mallick and his research group have reported on a ratiometric absorbance fluoride ion sensor **Probe 9** in acetonitrile (Fig. 13).[36] **Probe 9** itself gives one strong high energy absorption band at 280 nm, with two vibronic shoulders at 273 and 290 nm and two low-energy, very weak bands at 425 nm and 530 nm in acetonitrile. Upon increasing the fluoride ion concentration, the band at 530 nm displayed a blue shift of 10 nm with a concomitant increase in optical density at the expense of the existing band at 425 nm. These responses can be successfully exploited, in a ratiometric fashion, to detect and estimate anion concentrations at sub-micromolar levels. They have subsequently chosen two wavelengths, 520 nm and 425 nm, where they measured the absorbance and acquired the wavelength ratiometric response. The plot of the ratio of absorbance at the two selected bands generates a calibration curve, which is very much independent of the sensor concentration. This allows one to detect and estimate the concentration of fluoride ions present even at the sub-micromolar level, which is accurate up to 2 μM. This ratiometric chemosensory response compares favorably to most of the known fluoride sensors. To verify the anion specificity, some assays have been performed with other tetrabutylammonium salts (TBA-X: X = Cl, Br, I, CN, CH_3COO, H_2PO_4 and HSO_4).

Under identical experimental conditions, the optical response of **Probe 9** is practically silent for these anions, in spite of their presence in large excess compared to fluoride. They have shown the discrimination plot as a bar diagram; the relative absorbance was measured at 520 to 425 nm and at 520 to 350 nm for all of the anions studied.

Tian and his research group have reported on a naphthalimide-based colorimetric and ratiometric fluorescent fluoride ion sensor **Probe 10** in acetonitrile solution (Fig. 14).[37] **Probe 10** (1×10^{-5} M) has a strong absorbance band at 360 nm, and it was colorless. Upon addition of increasing concentration of F^-, the band at 360 nm progressively decreased, while a new band with a peak at 490 nm formed and increased. The presence of two isosbestic points at 340 and 405 nm indicated that only two species coexisted at the equilibrium. These spectral changes are due to the deprotonation of the amino moiety of **Probe 10** by F^-. Upon fluoride addition, the colorless solution of **Probe 10** became yellow, which made **Probe 10** a useful tool for naked eye fluoride ion detector. The detection limit for the fluoride anion has been investigated as 2.0×10^{-5} M when **Probe 10** was used at 1.0×10^{-5} M by colorimetric method. The emission spectrum of free **Probe 10** displayed a broad band with a maximum at 468 nm with a bright blue colored emission. With the addition of increasing concentration of F^- to the solution of **Probe 10**, a significant decrease in the emission

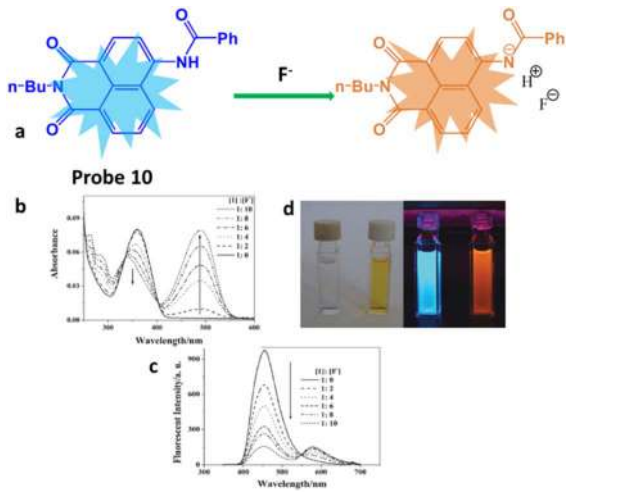


Fig. 14 (a) A proposed mechanism for sensing F^- by **Probe 10**; (b) F^- concentration (0, 2, 4, 6, 8, 10 equivalent) dependent absorbance changes in **Probe 10** (10 μM); (c) F^- concentration (0, 2, 4, 6, 8, 10 equivalent) dependent fluorescence changes in **Probe 10** (10 μM); (d) F^- (10 equivalent) selective naked eye color changes and emission color changes in **Probe 10** under a UV lamp (10 μM) (reproduced from ref. 37 with permission from Royal Society of Chemistry, 2005).

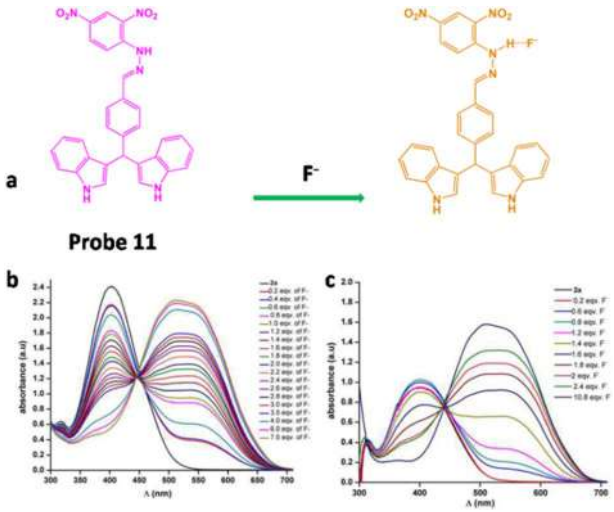


Fig. 15 (a) A proposed mechanism for sensing F^- by **Probe 11**; (b) F^- concentration (0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 2.8, 3.0, 3.2, 3.5, 4.0, 6.0, 7.5 equivalent) dependent absorbance changes in **Probe 11** (60 μM); (c) F^- concentration (0, 0.2, 0.6, 0.8, 1.2, 1.4, 1.6, 1.8, 2.0, 2.4, 10.8 equivalent) dependent absorbance changes in **Probe 11** (20 μM) (reproduced from ref. 38 with permission from the Royal Society of Chemistry, 2015).

band was observed at 468 nm, along with the emergence of a red-shifted emission band centered at 583 nm with a bright orange emission color.

A notable iso-emission point at 550 nm was also observed. The emission band at 583 nm was due to the formation of the naphthalimide anion. An interference study has been performed using other competitive anions, such as Cl^-, Br^-, and I^-. No significant change in the fluorescence spectra were observed. The probable mechanism has been investigated as enhanced ICT (intramolecular charge transfer) due to the change in the electron density of the amido moiety upon fluoride addition, and the charge transfer between the amido group (donor) and the electron-withdrawing imide moiety (acceptor).

Pratihar and his research group have reported on a dinitrophenylhydrazine-based colorimetric ratiometric sensor **Probe 11** for fluoride anion in DMSO (Fig. 15).[38] **Probe 11** showed absorption maximum peaks in DMSO at 262, 312 and 405 nm. An absorbance titration was performed with a variable concentration of **Probe 11** with increasing concentration of fluoride ion by UV-vis spectroscopy. **Probe 11** can successfully detect fluoride *via* ratiometric absorption even at 5 μM. The absorption spectra upon the addition of increasing concentration of F^- with **Probe 11** have been measured at two different concentrations of **Probe 11** (60 μM and 20 μM). Upon the gradual addition of fluoride to **Probe 11** in DMSO, a unique new broad absorption band at 560 nm appears. There is also a parallel decrease in the band at 401 nm, corresponding to the neutral species with a clear isosbestic point around 457 nm. This indicates the strong interaction between **Probe 11** and the fluoride ion. It has been noted that after the addition of nearly 2.2 equivalents of fluoride, the isosbestic point slightly shifted from 457 nm to 445 nm, with one additional blue-shift band centered at 520 nm, while the color of the solution turned from purple to orange. This unique property of **Probe 11** makes it a useful tool for selective detection of fluoride through naked eye color changes.

The shifting of the isosbestic point and the corresponding absorption band was the proof of the formation of tri-anion of **Probe 11** after the deprotonation of two indole N–H and one hydrazine N–H, and this was the possible mechanism for selective detection. **Probe 11** can detect fluoride at a concentration of about 2 μM. An interference study was performed by using competitive anions, such as TBAX: (X= Cl^-, Br^-, I^-, CH_3COO^-, BF_4^- and HSO_4^-), with **Probe 11**. None of the anions except fluoride could bring about any changes in the absorption spectra of **Probe 11**.

The Liu research group reported on a colorimetric ratiometric sensor **SH-GA** for fluoride based on gallic acid for the first time in both THF and DMF media (Fig. 16).[39] Firstly, they investigated the interactions between **SH-GA** in the presence of other anions (F^-, Cl^-, Br^-, I^-, ClO_4^-, SO_4^-, $H_2PO_4^-$, AcO^-) by naked eye and UV-Vis absorption spectra by the addition of tetrabutyl salt solution in both THF and DMF solutions, respectively. The color of **SH-GA** in THF changed from colorless to yellow under naked eye after the addition of F^-, which originated from a red shift of 80 nm in the absorption spectra. The optimal speed of detection has been achieved after a few seconds between **SH-GA** with F^-. No notable color change has been observed when other anions were added to **SH-GA**.

These results make **SH-GA** a naked-eye fluoride ion sensor with good selectivity. UV-vis absorption titrations were carried out by monitoring the absorption spectra of **SH-GA** in THF and DMF solution with the addition of increasing concentration of fluoride ion. The intensity of the maximum absorbance peaks of

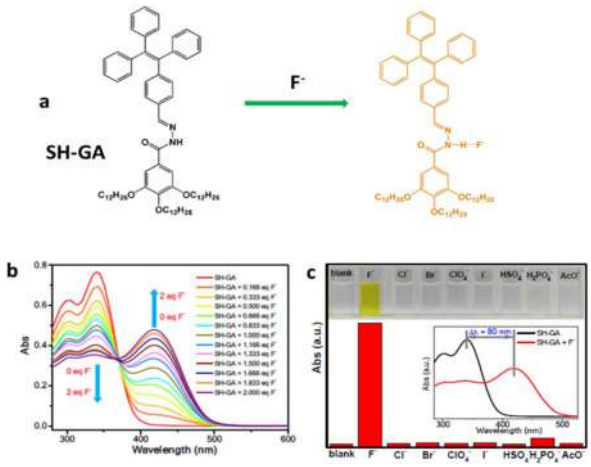


Fig. 16 (a) A proposed mechanism for sensing F^- by **SH-GA**; (b) F^- concentration (0, 0.166, 0.333, 0.5, 0.666, 0.833, 1.0, 1.166, 1.333, 1.5, 1.666, 1.833, 2.0 equivalent) dependent absorbance changes of **SH-GA** (25 μM); (c) F^- (2 equivalent) selective absorbance changes in **SH-GA** (25 μM) in the presence of other anions (20 equivalent) (reproduced from ref. 39 with permission from the Royal Society of Chemistry, 2021).

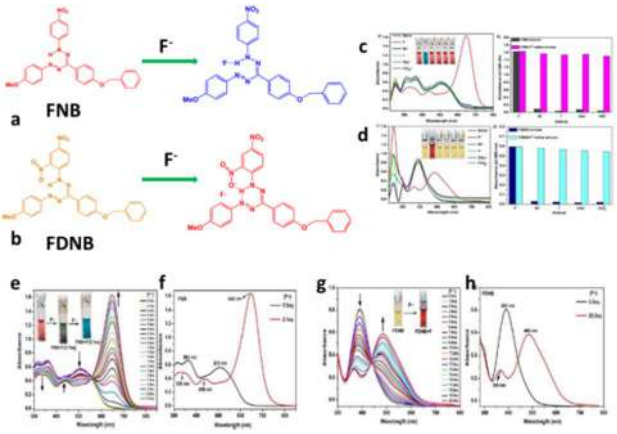


Fig. 17 (a) A proposed mechanism for sensing F^- by **FNB**; (b) a proposed mechanism for sensing F^- by **FDNB**; (c) F^- selective absorbance changes in **FNB** (17 μM) in the presence of other anions (10 equivalent); (d) F^- selective absorbance changes in **FDNB** (13 μM) in the presence of other anions (20 equivalent); (e) F^- concentration (0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 2.1 equivalent) dependent absorbance changes in **FNB** (17 μM); (f) F^- (2.1 equivalent) selective absorbance changes in **FNB** (17 μM); (g) F^- concentration (0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 equivalent) dependent absorbance changes in **FDNB** (13 μM); (h) F^- (20 equivalent) selective absorbance changes in **FDNB** (reproduced from ref. 40 with permission from the Royal Society of Chemistry, 2020).

SH-GA in the UV region around 340 nm decreased gradually with the increase of the concentration of fluoride, while a new absorption band in the visible region around 420 nm appeared and increased gradually. These results indicated that **SH-GA** exhibited similar sensing behavior for F^- whether in THF or DMF. A Job's plot has been investigated and a 1 : 1 stoichiometric ratio was formed between **SH-GA** and F^-. The limits of detection were determined to be 0.59 μM and 8.37 μM for **SH-GA** in THF and DMF, respectively. The sensing mechanism has been investigated as hydrogen bonding between **SH-GA** and F^- and deprotonation.

Turkoglu reported on the novel formazan-based colorimetric and ratiometric sensors **FNB** and **FDNB** for fluoride anion detection in THF (Fig. 17).[40] The anion sensing properties of **FNB** and **FDNB** with a variety of competitive anions, such as F^-, Br^-, I^- and ClO_4^-, in the form of their tetrabutylammonium salts and OAc^- as NaOAc have been investigated in THF by UV-Vis experiments. The selective interaction of sensors **FNB** and **FDNB** with anions in the THF solution displayed remarkable changes in the absorption spectra upon addition of the F^- (10 and 20 equivalents, respectively) at room temperature, while no absorption and color changes occurred in the presence of the same amounts of other anions, like Br^-, I^-, OAc^- and ClO_4^-. When F^- (10 equiv.) was added to **FNB**, absorbance at 510 nm decreased and a new band at a longer wavelength of 648 nm generated with an instant color change from red to blue could be observed by naked eye. In the case of **FDNB**, when F^- (20 equiv.) was added, the absorption band at 390 nm was reduced significantly. A new strong and higher wavelength absorption band appeared at 485 nm with a color change from yellow to deep red that was detected by naked eye.

A remarkable wavelength change has been found in the absorption peak for **FNB** by about 138 nm. For **FDNB**, the shift was observed to be 95 nm. The probable mechanism for selective sensing was based on the strong hydrogen bond between the donating –NH unit in **FNB** and F^-. This could be indicated by the intramolecular charge-transfer (ICT) interaction among the hydrogen-bonded fluoride-**FNB** complex with hydrogen bonding between the NH and N=N moiety in the formazan skeleton. Both sensors **FNB** and **FDNB** possessed a single nitrogen-based hydrogen bond donor, which was the main cause for visible color changes in the presence of fluoride. The lowest detection limit has been ascribed as 0.051 ppm for the fluoride anion by **FNB**.

Thomas and his research group have developed two colorimetric and ratiometric fluorescent sensors **Probe 12** and **Probe 13** for fluoride ion in acetonitrile and methanol/acetonitrile solvent systems (Fig. 18).[41] The absorption spectra of **Probe 12** and **Probe 13** were recorded in acetonitrile solution with the absorption maxima at 342 nm and 364 nm, respectively, which are attributed to the π–π* transition of the hydroxyaryl substituent and imidazole.

The hydroxynaphthyl derivative **Probe 13** showed red-shifted absorption and emission, compared to that observed for the hydroxyphenyl derivative of **Probe 12** because of its extended conjugation. UV-Vis absorption studies on **Probe 12** and **Probe 13** were conducted in the presence of common competitive anions, such as F^-, Cl^-, Br^-, I^-, HSO_4^- and AcO^- (20 equiv.). **Probe 12** showed an absorption maximum at 342 nm, which decreased along with the origin of a new absorption maximum at 404 nm upon the addition of F^- with an isosbestic point at 377 nm. **Probe 13** showed an absorption maximum at 364 nm,

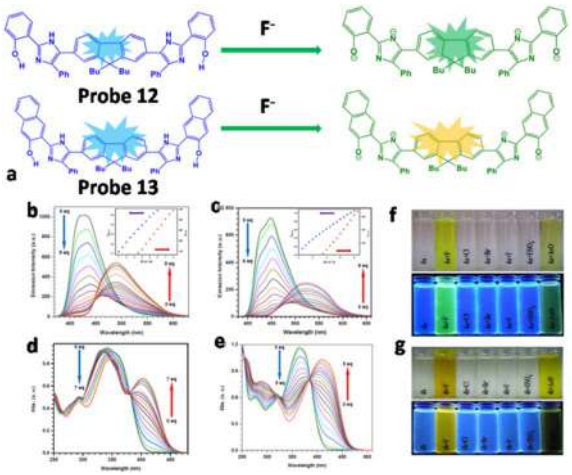


Fig. 18 (a) A proposed mechanism for sensing F^- by **Probe 12** and **Probe 13**; (b) F^- concentration (0–9 equivalent) dependent fluorescence changes in **Probe 12** (2 μM); (c) F^- concentration (0–6 equivalent) dependent fluorescence changes in **Probe 13** (2 μM); (d) F^- concentration (0–7 equivalent) dependent absorbance changes in **Probe 12** (20 μM); (e) F^- concentration (0–5 equivalent) dependent absorbance changes in **Probe 13** (20 μM); (f) F^- selective naked eye color changes and emission color changes in **Probe 12** in the presence of other anions in acetonitrile solution under a hand-held UV lamp; (g) F^- selective naked eye color changes and emission color changes in **Probe 13** in the presence of other anions in methanol/acetonitrile (4% v/v) solution under a hand-held UV lamp (reproduced from ref. 41 with permission from the Royal Society of Chemistry, 2014).

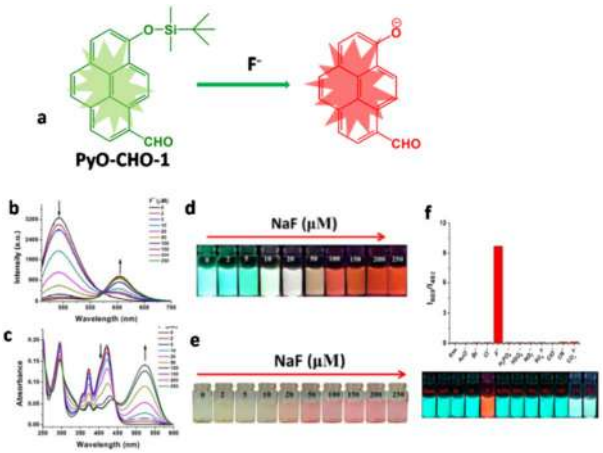


Fig. 19 (a) A proposed mechanism for sensing F^- by **PyO-CHO-1**; (b) F^- concentration (0, 2, 5, 10, 20, 50, 100, 150, 200, 250 equivalent) dependent fluorescence changes in **PyO-CHO-1** (10 μM); (c) F^- concentration (0, 2, 5, 10, 20, 50, 100, 150, 200, 250 equivalent) dependent absorbance changes in **PyO-CHO-1** (10 μM); (d) F^- (0–250 μM) concentration dependent emission color changes in **PyO-CHO-1** (10 μM) under a UV lamp; (e) F^- (0–250 μM) concentration dependent naked eye color changes in **PyO-CHO-1** (10 μM); (f) F^- selective fluorescence changes in **PyO-CHO-1** (10 μM) in the presence of other anions (200 μM) and their emission color changes under a UV lamp (reproduced from ref. 42 with permission from the Royal Society of Chemistry, 2016).

which decreased. A new absorption maximum was generated at 411 nm upon the addition of F^- with an isosbestic point at 384 nm. No other anions (Cl^-, Br^-, I^-, HSO_4^-) caused any noticeable change in the absorbance of **Probe 12** and **Probe 13**. An apparent change from a colorless solution to light-yellow color for **Probe 12** was observed by naked eye. Meanwhile, **Probe 13** showed a yellow to orange color change from a colorless solution. Similarly, the emission spectra of the compounds were also red-shifted with the gradual decrease of the free receptor peak on interaction with F^-. In the emission spectra, the peak at 431 nm was red-shifted to 489 nm for **Probe 12**, while **Probe 13** exhibited a peak intensity drop-off at 448 nm with the rise of a new peak at 521 nm in the presence of F^-. The probable mechanism for the selective optical response can be assigned to the deprotonation of the compounds by F^-, which induced an intramolecular charge transfer (ICT) in the host–guest complex. From the absorption experiments, the LODs of **Probe 12** and **Probe 13** for fluoride were investigated to be 0.049 μM and 0.042 μM, while the emission experiments provided 0.030 μM and 0.041 μM, respectively.

Li and co-workers have developed a very simple pyrene-based colorimetric and ratiometric fluorescent sensor **PyO-CHO-1** for fluoride ions in aqueous solution (Fig. 19).[42] A cationic surfactant, cetyltrimethylammonium bromide (CTAB), has been introduced by their research group to solubilize the hydrophobic pyrene derivatives in water. **PyO-CHO-1** displays an absorption spectrum with maxima at 295, 372 and 420 nm in the absence of fluoride ions. Upon the addition of an increasing concentration of fluoride ions (0–250 μM) to the solution, the absorption of **PyO-CHO-1** gradually weakens and a new absorption band at 523 nm appeared, which was assigned to the ICT absorption. This remarkable red-shifted new absorption band at 523 nm arises from the anionic type of the chromophore formed through the fluoride-mediated desilylation with two well-defined isosbestic points at 346 and 443 nm.

The color of the **PyO-CHO-1** solution changed from faint yellowish green to pale red, making **PyO-CHO-1** a suitable colorimetric detector of fluoride ions in water. From the naked eye color change of the solution, a concentration of fluoride ions as low as 10 μM (0.2 ppm) can be readily determined using **PyO-CHO-1** within 3 min. Free **PyO-CHO-1** exhibits only one emission band with a maximum at 492 nm, which is from the neutral form of the chromophore. Upon the addition of an increasing concentration of fluoride ions into the solution, the emission band at 492 nm decreased, and a new emission band at 603 nm was found. The emission color of **PyO-CHO-1** gradually shifted from cyan without fluoride ions to bluish green, to white, and finally to orange red or red in the presence of 5 μM (0.1 ppm), 10 μM, and more than 100 μM fluoride ions, respectively. From this result, fluoride ions below 10 μM (0.2 ppm) can be determined with good color resolution by observing the fluorescent color changes with naked eye. The optimal speed of detection has been achieved after 3 min between **PyO-CHO-1** with F^-. The detection limit of **PyO-CHO-1** towards fluoride ions was calculated to be as low as 0.14 μM (2.7 ppb). For the interference study of **PyO-CHO-1** towards fluoride ions in the presence of 200 μM, various competitive anions (like

AcO^-, Br^-, Cl^-, F^-, $H_2PO_4^-$, HSO_4^-, NO_3^-, SO_4^{2-}, ClO^-, CN^-, and CO_3^{2-}) have been investigated. Two commercially available toothpastes (A and B) were used as the representative samples. They successfully applied this **PyO-CHO-1** to quantitatively detect fluoride ions from two toothpaste samples with high accuracy.

Tian and his research group have developed a diketopyrrolopyrrole-based novel colorimetric and fluorescent ratiometric fluoride ion sensor **Probe 14**, in dichloromethane (Fig. 20).[43] When TBAF was added to **Probe 14** in DCM solution, a color change from orange to purple could be observed by naked eye. **Probe 14** exhibited an absorption maximum at 497 nm with an orange color by naked eye. Upon the addition of an increasing concentration of TBAF, the intensity at 497 nm gradually decreased, and a completely new band at 594 nm developed with a clear isosbestic points at 543 nm with bathochromic shift (~80 nm). Free **Probe 14** has an emission maximum at 563 nm with a bright yellow color. With the addition of an increasing concentration of fluoride ion, the emission at 563 nm decreased and the emergence of a red-shifted emission band at 635 nm was observed. A possible mechanism for the ratiometric absorption and fluorescence changes was the intermolecular proton transfer (IPT) process between the amide moiety and fluoride ion, and its change from electronically neutral (**Probe 14**-NH) to negatively charged (**Probe 14**-N) in the presence of fluoride ion. In the presence of fluoride, the ICT effect from the amide anion to the electron-withdrawing moiety was enhanced, which was facilitated by the deprotonation of the amide moiety. This enhancement in the ICT effect also affords the reduced intensity and bathochromic shift of fluorescence as a function of fluoride concentration. Furthermore, F^- could be detected at the levels of parts per million when **Probe 14** was employed at

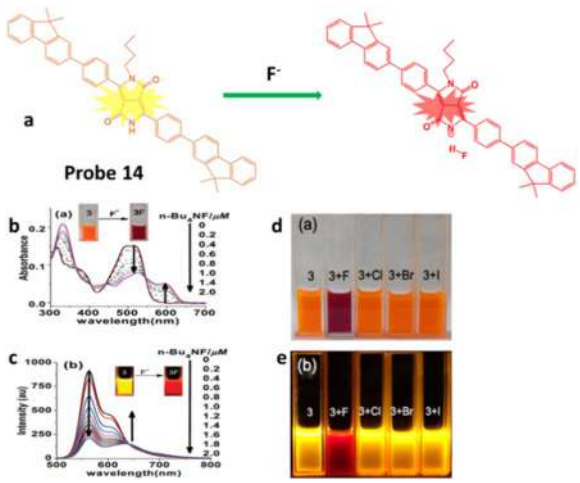


Fig. 20 (a) A proposed mechanism for sensing F^- by **Probe 14**; (b) F^-concentration (0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.4, 2.0 equivalent) dependent absorbance changes in **Probe 14** (5 μM); (c) F^- concentration (0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0 equivalent) dependent fluorescence changes in **Probe 14** (5 μM); (d) F^- selective naked eye color changes in **Probe 14**; (e) F^- selective emission color changes in **Probe 14** under a UV lamp (reproduced from ref. 43 with permission from American Chemical Society, 2010).

5.0×10^{-6} M. An interference study has been performed with **Probe 14** in the presence of other halide anions, such as Cl^-, Br^-, and I^-, which caused no changes in the emission spectra.

As discussed in the Introduction, the sole principle of ratiometric sensing of fluoride ion detection rests on three basic motifs; namely, the cleavage of the Si–O bond, excimer emission and intramolecular charge transfer emission through the formation of fluoride bridged dimers and monomer (B–F–B bridge and B–F bridge), and deprotonation of the amide N–H. None of these active moieties are water soluble. In addition, the bulky organic motifs attached to the active sites are even more hydrophobic, thereby posing a serious challenge to detect fluoride ions in aqueous media. Thus, the design of the fluorophore becomes even more important. Various modifications have been made, and introduction of the triphenylphosphonium cation or dimethyl amine groups has greatly contributed to the increased solubility of the sensors in aqueous media, as observed in the case of **Mito-F** and **Lyso-F** (Fig. 1), where the experiments have been carried out in HEPES/DMSO (1 : 1) medium. In the case of the sensor **Z2** (Fig. 3), the experiment was carried out in HEPES/DMSO (7 : 3) medium, indicating a significant improvement in the water solubility. The improvement in the water solubility of **Z2** can be attributed to a less bulky substituent ($R = CH_2CH_2CH_2CH_3$) as compared to the substituent in **Mito-F** and **Lyso-F** ($R = PPh_3CH_2CH_2CH_2$). It is also notable that **Z2** does not contain the organic spacer between the Si–O group and the naphthalimide moiety, which significantly increases the water solubility of **Z2**. In the case of **Probe 1** (Fig. 4), the experiment was carried out in PBS/DMF (7 : 3). The increase in water solubility may be ascribed to the presence of the pyridinium cation in the sensor, clearly indicating that the presence of the ionic moiety would enhance the water solubility of the sensor. Although **Probe 2** (Fig. 5) has been used to detect fluoride ions in potable water, the experiments were carried out in PBS/DMSO (2 : 8). This indicated that the xanthene moiety present in **Probe 2** is not suitable for enhancing the water solubility of the fluorophore. **Probe 7** (Fig. 11) also works in a DMF–water mixture (80 : 20, v/v). Similarly, the flavone-based **Probe 3** (Fig. 6) and thiobenzimidazole-based **BTTPB** (Fig. 7) are not favorable for designing hydrophilic fluorophores.

In the case of the excimer-based ratiometric study, the dimer formed through B–F–B bridging greatly enhances the hydrophobicity. This is due to the increased number of hydrophobic groups, as well as the π–π stacking of the pyrene moiety, as seen in **Probe 4** (Fig. 8). The B–F bridging also enhances the intramolecular charge-transfer between the N donor and the B acceptor, as well as the π*–π emission localized on the N donor *via* a naphthalene moiety in **Probe 5** (Fig. 9). Hence, none of the experiments on these probes were carried out in aqueous medium.

For the colorimetric and ratiometric detection of fluoride ions *via* deprotonation of the N–H group (mainly amide N–H) (**Probe 6** (Fig. 10), **Probe 8** (Fig. 12), **Probe 9** (Fig. 13), **Probe 10** (Fig. 14), **Probe 11** (Fig. 15), **SH-GA** (Fig. 16), **FNB** and **FDNB** (Fig. 17), **Probe 12** & **Probe 13** (Fig. 18), **Probe 14** (Fig. 20)), none

Table 1 Comparison of the important features of some of the reported F^- sensors

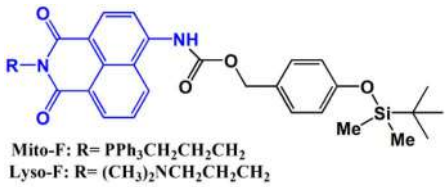
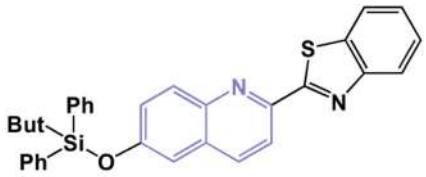
S. No.	Probe	Solvent	Detection limit	Mechanism	Applications with ref.
1	 **Mito-F** and **Lyso-F** Fluorometric changes from blue to green	20 mM HEPES/DMSO = 1 : 1, pH 7.4	0.067 ppm and 0.073 ppm	Si–O bond cleavage of **Mito-F** and **Lyso-F**	Selective image of fluoride in mitochondria and lysosomes of HeLa cells[24]
2	 **QF** Fluorometric changes from blue to green	50 mM PBS, 25 μM CTAB, pH 7.4	0.5 μM	Cleavage of the *t*-butyldiphenylsilyl (TBDPS) group	HeLa cells and zebrafish[25]

Table 1 (*Contd.*)

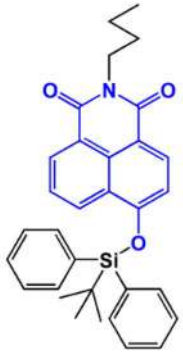
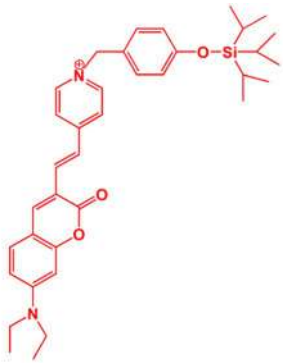
S. No.	Probe	Solvent	Detection limit	Mechanism	Applications with ref.
3	 **Z2** **Fluorometric changes from blue to green**	90% DMSO	NA	Intra molecular charge transfer and Si–O bond cleavage	HeLa cells and tumor tissues[26]
4	 **Probe 1** **Fluorometric changes from red to green and Colorimetric changes from red to green**	DMF–PBS solution (7 : 3 V/V, 50 mM, pH 7.4)	1.2×10^{-8} M	Intra molecular charge transfer and Si–O bond cleavage	Mitochondria of HepG2 cells[27]

Table 1 (*Contd.*)

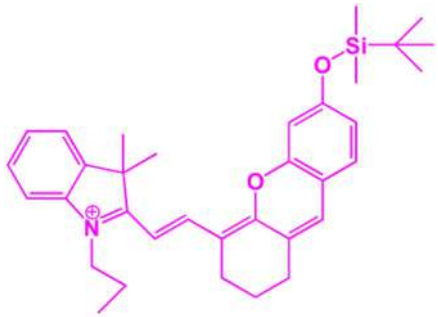
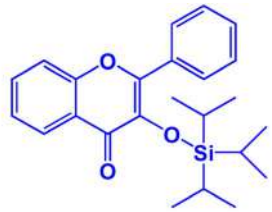
S. No.	Probe	Solvent	Detection limit	Mechanism	Applications with ref.
5	 **Probe 2 Fluorometric changes from pink to red**	10 mM PBS/DMSO = 2 : 8, pH 7.4	0.2 μM	Si–O bond cleavage	Drinking water and white flour, HepG2 cells and mice[28]
6	 **Probe 3 Fluorometric changes from blue to green and Colorimetric changes from colorless to fancy dark yellow**	CH_3CN/H_2O = 95 : 5	0.68 μM	Fluoride triggered desilylation reaction on the cleavage of Si–O bonds	Paper strips under UV lamp and in HGC-27 cells[29]

Table 1 (*Contd.*)

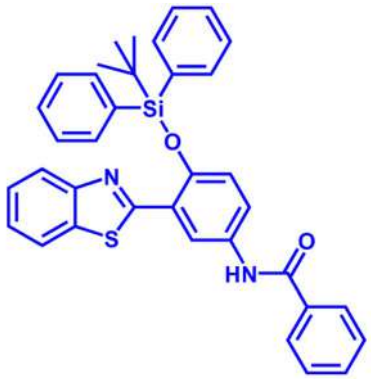
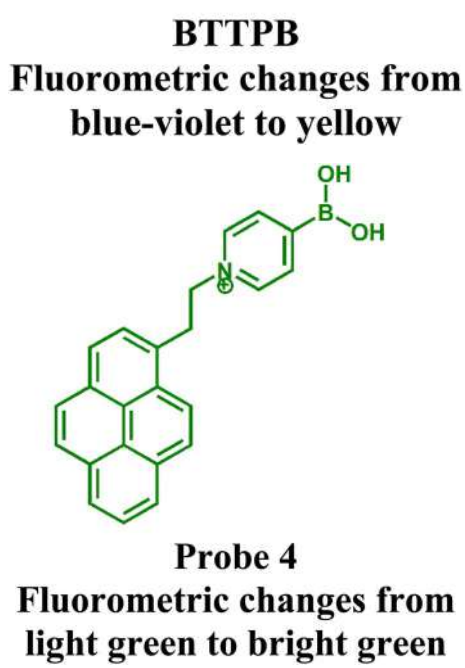
S. No.	Probe	Solvent	Detection limit	Mechanism	Applications with ref.
7		THF (100 μL, 2.0 mm) into a micellar solution of cetyltri-methylammonium bromide CTAB in water (10 mL, 2.0 mM)	100 ppb	Fluoride-induced Si–O bond cleavage	Sensing study in test paper[30]
8		Dichloromethane	0.1 ppm	Excimer formation	Fluoride ion detection in environmental samples[31]

Table 1 (*Contd.*)

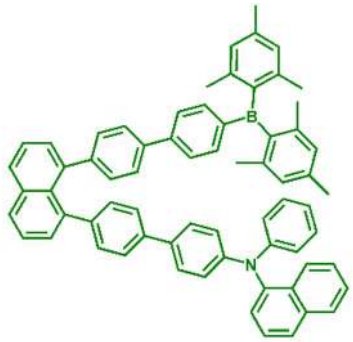
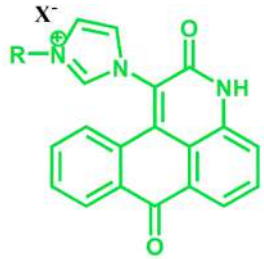
S. No.	Probe	Solvent	Detection limit	Mechanism	Applications with ref.
9	 **Probe 5** **Fluorometric changes from green to blue**	Chloroform	Between 0.015 mM and 0.020 mM	Intramolecular charge-transfer	NA[32]
10	 **Probe 6** **Fluorometric changes from green to red and Colorimetric changes from light yellow to orange**	CH_3CN–DMSO (20 : 1)	5 μM	Deprotonation of the amide NH group	NA[33]

Table 1 (*Contd.*)

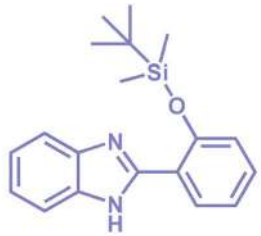
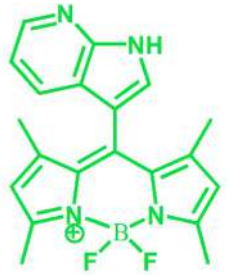
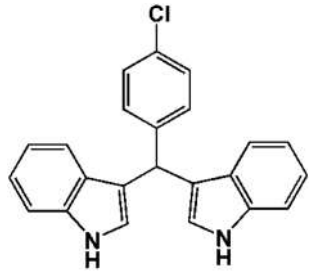
S. No.	Probe	Solvent	Detection limit	Mechanism	Applications with ref.
11	 **Probe 7** **Fluorometric changes from violet to blue**	DMF–water solution buffered at pH 7.0	0.19 μM L^{-1}	Fluoride-induced Si–O bond cleavage and excited state intramolecular proton transfer (ESIPT)	Fluoride determination in toothpaste and tap water samples[34]
12	 **Probe 8** **Fluorometric changes from green to blue and Colorimetric changes from yellow to reddish-brown**	7 : 3 CH_3CN : H_2O solution (0.02 M HEPES buffer, pH 7.2)	1.21 μM	Enhanced PET process due to hydrogen bonding interaction between the indolic NH of **Probe 8** and fluoride anions	RAW 264.7 control cells[35]
13	 **Probe 9**	Acetonitrile	2 μM	Hydrogen bonding interaction between the indolic NH of **Probe 9** and fluoride anions	NA[36]

Table 1 (*Contd.*)

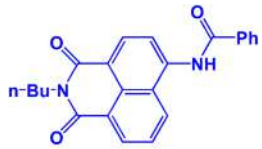
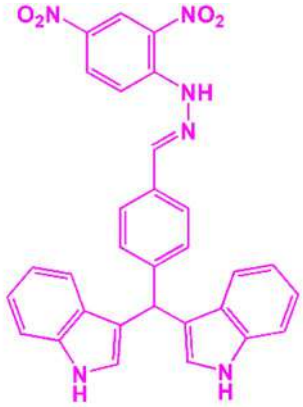
S. No.	Probe	Solvent	Detection limit	Mechanism	Applications with ref.
14	 **Probe 10** **Fluorometric changes from blue to bright orange and Colorimetric changes from colorless to yellow**	Acetonitrile	2.0×10^{-5} M	ICT (intramolecular charge transfer)	NA[37]
15	 **Probe 11** **Colorimetric changes from purple to orange**	DMSO	2 μM	Hydrogen bonding between NH of **Probe 11** and F^-	NA[38]

Table 1 (*Contd.*)

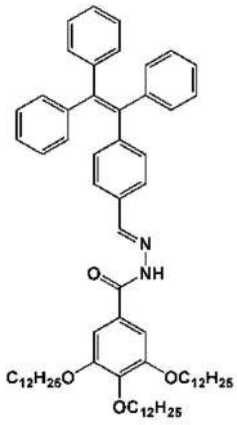
S. No.	Probe	Solvent	Detection limit	Mechanism	Applications with ref.
16	 **SH-GA** **Colorimetric changes from colorless to yellow**	THF and DMF medium	0.59 μM and 8.37 μM for **SH-GA** in THF and DMF, respectively	Hydrogen bonding between **SH-GA** and F^- and deprotonation	NA[39]

Table 1 (*Contd.*)

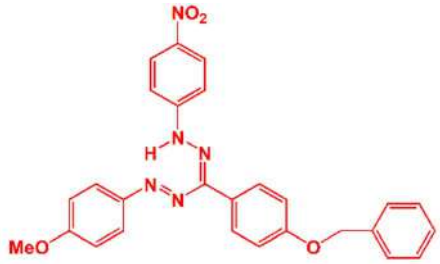
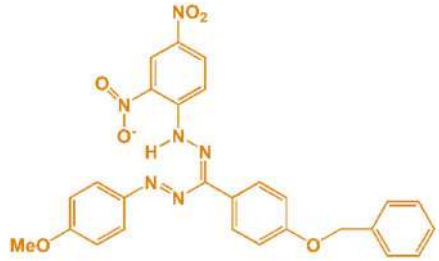
S. No.	Probe	Solvent	Detection limit	Mechanism	Applications with ref.
17	 **FNB** **Colorimetric changes from red to blue**  **FDNB** **Colorimetric changes from yellow to red**	THF	0.051 ppm for the fluoride anion by **FNB**	Intramolecular charge-transfer (ICT) interaction among the hydrogen-bonded fluoride-**FNB** complex with hydrogen bonding between the –NH and N=N moiety in the formazan skeleton	NA[40]

Table 1 (*Contd.*)

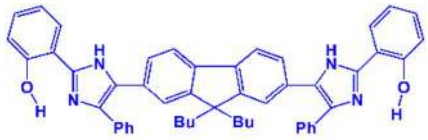
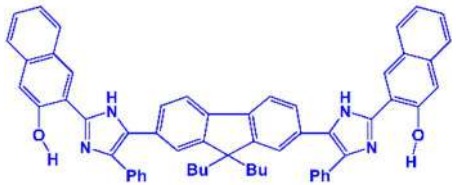
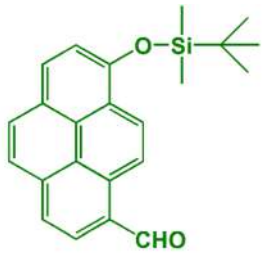
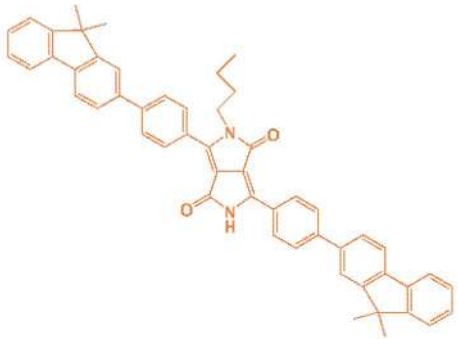
S. No.	Probe	Solvent	Detection limit	Mechanism	Applications with ref.
	 **Probe 12** **Fluorometric changes from blue to green and Colorimetric changes from colorless to light-yellow**				
18	 **Probe 13** **Fluorometric changes from blue to yellow and Colorimetric changes from colorless to orange**	Acetonitrile and methanol/ acetonitrile solvent systems	0.049 μM and 0.042 μM for **Probe 12** and **Probe 13**	Deprotonation of the compounds by F^-, which induced an intramolecular charge transfer (ICT) in the host–guest complex	NA[41]

Table 1 (*Contd.*)

S. No.	Probe	Solvent	Detection limit	Mechanism	Applications with ref.
19	 **PyO-CHO-1 Fluorometric changes from green to red and Colorimetric changes from yellowish green to pale red**	Aqueous solution in the presence of cetyltrimethylammonium bromide (CTAB)	0.14 μM (2.7 ppb)	Fluoride mediated desilylation of the O–Si bond	Fluoride ions from two toothpaste samples[42]
20	 **Probe 14 Fluorometric changes from bright yellow to red and Colorimetric changes from orange to purple**	Dichloromethane	5.0×10^{-6} M	Intermolecular proton transfer (IPT) process between the amide moiety and fluoride ion	NA[43]

of the fluorophores were found to be water-soluble. Hence, all experiments were carried out in organic solvents.

To summarize the observations, it will be relevant to mention here that among the three approaches (cleavage of Si–O bond, excimer emission and intramolecular charge transfer through the formation of fluoride bridged dimers and monomer (B–F–B bridge and B–F bridge), and deprotonation of amide N–H), only the Si–O bond cleavage mechanism is capable of being carried out in a water/organic solvent mixture. Thus, the introduction of ionic groups in the fluorophore in association with optimized hydrophilic organic derivatives and spacers may be considered as a favorable strategy to design the sensors for detecting fluoride ions in a greener way.

It is also relevant to highlight the sensor **QF** (Fig. 2) containing the quinoline group, where the experiments have been carried out in aqueous medium using phosphate buffer (PBS) and CTAB. Hence, **QF** stands as one of the best sensors designed for the detection of fluoride ions in aqueous media.

The future approach lies in the use of green solvents and greener sensors to reduce chemical toxicity. Hence, designing new probes to detect fluoride ions in aqueous media becomes even more pertinent. A notable innovative method has been applied for the sensor **PYO-CHO-1** (Fig. 19), where the pyrene-based Si–O bonded fluorophore was used for the ratiometric detection of fluoride ions in aqueous media using the CTAB surfactant.

As already discussed, the incorporation of ionic moieties, reduction in the number of hydrophobic organic derivatives and side chains, or introducing a hydrophilic moiety will be the key for designing new greener sensors, albeit maintaining the sensitivity, detection limit, and other important factors associated with a sensor for the detection of fluoride ions in real samples.

In view of the speed of detection, it has been observed that **Probe 8** (Fig. 12) and **SH-GA** (Fig. 16) required a few seconds to detect fluoride ions, while the maximum time required was 150 minutes for the sensor **Z2** (Fig. 3).

In summary, this review describes multiple ratiometric colorimetric and fluorometric sensors for fluoride in aqueous media and mixed solvents. Some important characteristics of these ratiometric sensors have been mentioned in Table 1. We include notable properties, such as the working solvent system, limit of detection, ratiometric wavelength changes with naked eye color and emission color changes, and their application in real samples and cell imaging.

Myto-F and **Lyso-F** can detect fluoride in 20 mM HEPES/DMSO = 1 : 1, pH 7.4 *via* ratiometric approach with LOD values of 0.067 ppm and 0.073 ppm, respectively (Fig. 1). In the presence of fluoride, the emission wavelength of **Mito-F** and **Lyso-F** changed from 475 nm (blue emission color) to 540 nm (green emission color) with an isosbestic point at 510 nm. Selective imaging of fluoride in the mitochondria and lysosomes of HeLa cells was done successfully by **Mito-F** and **Lyso-F**.

Fluoride was selectively detected by **QF** in 50 mM PBS, 25 μM CTAB, pH 7.4 with a detection limit of 0.5 μM (Fig. 2). The addition of fluoride towards **QF** changes its emission from 425 nm to 533 nm with an emission color change from blue to green. Selective imaging of fluoride in HeLa cells and zebrafish has been performed by **QF**.

Z2 detects fluoride in 90% DMSO solution with an emission wavelength change from 440 nm (blue emission color) to 540 nm (green emission color) (Fig. 3). This ratiometric approach has been well established by imaging fluoride in HeLa cells and tumor tissues.

Probe 1 worked in DMF–PBS solution (7 : 3 V/V, 50 mM, pH 7.4) to detect fluoride with a detection limit of 1.2×10^{-8} M (Fig. 4). **Probe 1** behaved as a ratiometric colorimetric and fluorometric sensor for fluoride *via* color changes from red (490 nm) to green (435 nm) (naked eye), and from red (639 nm) to green (539 nm) (emission color), respectively. The F^- ion concentration has been determined by **Probe 1** in the mitochondria of HepG2 cells.

The next sensor **Probe 2** has worked in 10 mM PBS/DMSO = 2 : 8, pH 7.4 for F^- ion determination with a limit of detection as 0.2 μM (Fig. 5). The emission color of **Probe 2** with F^- changed from pink to red with wavelength changes from 690 nm to 740 nm. **Probe 2** has been successfully applied for fluoride ion determination in drinking water, white flour, HepG2 cells and mice.

Probe 3 has worked in CH_3CN/H_2O = 95 : 5 solution for F^- ion determination with a detection limit of 0.68 μM (Fig. 6). Fluoride has been detected by **Probe 3** *via* ratiometric, colorimetric, and fluorometric approaches. The absorption color changed from colorless to a fancy dark yellow (455 nm), and the emission color changed from blue (400 nm) to green (530 nm). The F^- ion concentration has been monitored by **Probe 3** in paper strips under UV lamp. A live cell imaging experiment was also performed to detect F^- in HGC-27 cells.

Next, probe **BTTPB** can detect F^- in THF (100 μL, 2.0 mm) into a micellar solution of cetyltrimethylammonium bromide CTAB in water (10 mL, 2.0 mM) with a limit of detection of 100 ppb (Fig. 7). The fluorometric color changed from blue-violet (418 nm) to yellow (560 nm) after the addition of F^- to **BTTPB**. An application study has been performed in test paper for fluoride ion determination.

Probe 4 has successfully monitored F^- in dichloromethane with a detection limit of 0.1 ppm *via* ratiometric approach (Fig. 8). The emission color changed from light green to bright green with a wavelength change from 397 nm to 488 nm *via* the formation of an excimer from the monomer. **Probe 4** has been applied to detect F^- in environmental samples.

Probe 5 can detect F^- in chloroform with a detection limit between 0.015 mM and 0.020 mM (Fig. 9). The emission color changed from green to blue with wavelength changes from 505 nm to 453 nm.

The fluoride ion has been detected by **Probe 6** in CH_3CN–DMSO (20 : 1) with a LOD value of 5 μM (Fig. 10). **Probe 6** has worked as a ratiometric colorimetric and fluorometric sensor for F^-. The fluorometric color changed from green (480 nm) to red (580 nm), and the colorimetric color changed from light yellow (405 nm) to orange (480 nm), when F^- was added with **Probe 6**.

Probe 7 has worked well in DMF–water solution buffered at pH 7.0 for F^- ion determination with LOD of 0.19 μM L^{-1}

(Fig. 11). Upon addition of F^- towards **Probe 7**, the emission color changed from violet to blue with the emission wavelength change from 360 nm to 454 nm. **Probe 7** has successfully been applied for fluoride determination in toothpaste and tap water samples.

Probe 8 has monitored F^- in 7 : 3, $CH_3CN : H_2O$ solution (0.02 M HEPES buffer, pH 7.2) with a LOD value of 1.21 μM (Fig. 12). **Probe 8** served as a ratiometric colorimetric and fluorimetric sensor for F^- with naked eye color changes from yellow (350 nm) to reddish-brown (419 nm), and emission color changes from green (512 nm) to blue (425 nm). F^- ion determination has been well performed by **Probe 8** in RAW 264.7 control cells.

Probe 9 has worked in acetonitrile for F^- detection with LOD of 2 μM (Fig. 13). The absorption wavelength changed from 520 nm to 425 nm with the ratiometric approach.

Probe 10 has monitored F^- in acetonitrile with LOD of 2.0×10^{-5} M *via* ratiometric approach colorimetrically and fluorometrically (Fig. 14). The emission color changed from blue to bright orange, and the colorimetric color changed from colorless (360 nm) to yellow (490 nm).

Next, sensor **Probe 11** has monitored F^- in DMSO with LOD of 2 μM *via* colorimetric ratiometric approach (Fig. 15). The colorimetric color changed from purple (401 nm) to orange (560 nm) after the addition of fluoride to **Probe 11**.

SH-GA served as a colorimetric ratiometric probe for F^- in THF and DMF media with LOD of 0.59 μM and 8.37 μM for **SH-GA** in THF and DMF, respectively (Fig. 16). The colorimetric color changed from colorless (340 nm) to yellow (420 nm).

FNB and **FDNB** have successfully monitored F^- in THF in a colorimetric ratiometric manner with a LOD value of 0.051 ppm for fluoride anion by **FNB** (Fig. 17). The colorimetric color of **FNB** changed from red (510 nm) to blue (648 nm). For **FDNB**, the colorimetric color changed from yellow (390 nm) to red (485 nm).

Probe 12 and **Probe 13** can be applied for the determination of F^- in acetonitrile and methanol/acetonitrile solvent systems *via* ratiometric colorimetric and fluorometric approaches with LOD values of 0.049 μM and 0.042 μM, respectively (Fig. 18). For **Probe 12**, the emission color changed from blue (431 nm) to green (489 nm), and the colorimetric color changed from colorless (342 nm) to light-yellow (404 nm). For **Probe 13**, the fluorometric color has changed from blue (448 nm) to yellow (521 nm), and the colorimetric color changed from colorless (364 nm) to orange (411 nm).

PyO-CHO-1 has efficiently detected the F^- ion in aqueous solution in the presence of cetyltrimethylammonium bromide (CTAB) *via* ratiometric colorimetric and fluorometric approach with the LOD value of 0.14 μM (2.7 ppb) (Fig. 19). For **PyO-CHO-1**, the emission color changed from green (492 nm) to red (603 nm), and the colorimetric color changed from yellowish green (420 nm) to pale red (523 nm). For the application study, determination of fluoride ions from two toothpaste samples has been monitored using **PyO-CHO-1**.

Probe 14 has monitored F^- in dichloromethane *via* ratiometric colorimetric and fluorometric approach with a LOD value of 5.0×10^{-6} M (Fig. 20). The fluorometric color has changed from bright yellow (563 nm) to red (635 nm), and the colorimetric color changed from orange (497 nm) to purple (594 nm).

Conclusions

This review has outlined the multiple perspectives of ratiometric colorimetric and fluorescent probes for the fluoride anion over competing anions in aqueous medium or other solvent medium, and their applications. It includes their working solvent system, detection limit, interference studies, sensing mechanism, sensing properties, and applications to real samples and biological samples. The ratiometric wavelength changes with their naked eye color and emission color changes are also extensively discussed. The principal mechanisms of fluoride ion sensing; namely, the Si–O bond cleavage, excimer emission *via* formation of B–F–B bridged dimers and intramolecular charge transfer *via* B–F bond, and deprotonation of the amide N–H bond by means of strong H···F hydrogen bonding, are thoroughly discussed. The structural designs of the probes, along with their advantages and disadvantages with respect to detection of fluoride ions in water and biological samples, have been critically analyzed. The use of chromophores like quinoline, formazan, gallic acid, dinitrophenylhydrazine, naphthalimide, BODIPY, imidazole, flavone, coumarine, pyrene, and naphthalene derivatives having enormous significance as ratiometric colorimetric and fluorescent sensors, including the identification of fluoride anion and certain disease-related study in cells, has been highlighted throughout this review. Moreover, a critical analysis of the chromophores with regard to their use in aqueous medium and strategies to improve their solubility in water has been discussed. So far as the cost factor is concerned, it is obvious that the colorimetric detection method is cheaper and easier, especially for the real time detection of environmental water samples as compared to the fluorometric detection method. It is expected that the concepts and explanations discussed throughout this review article could further encourage the design of ratiometric colorimetric and fluorescent probes for fluoride anions with enhanced selectivity, and to realize their sensing mechanism, solvent dependency, wavelength changes, and their applications in therapeutic strategies. It will help readers gain insight into the design of ratiometric probes applicable for both colorimetric and fluorometric approaches.

Author contributions

The manuscript was prepared by both authors.

Conflicts of interest

Both authors hereby declare that they have no conflict of interest.

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MINI REVIEW

Synthetic Fluorometric and Colorimetric Sensors for Identification of Fluoride Anion: A Short Review

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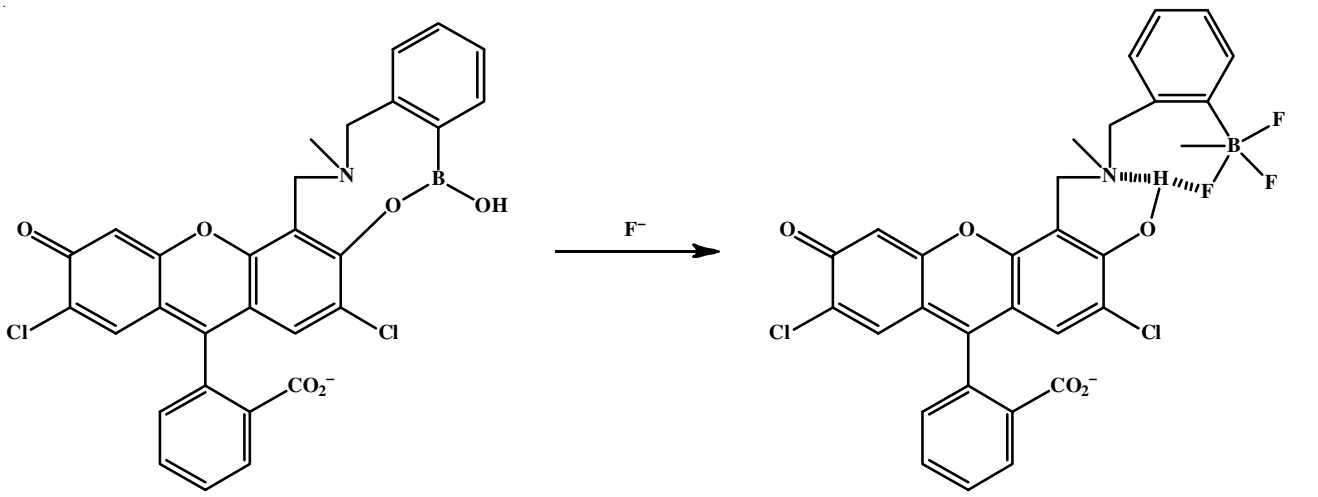
Over two decades of research in fluoride ion detection has been an intriguing field and many papers have been published enriching the possibilities of fluoride ion detection in even nano molar concentration levels. However, few reviews have been published, critically analyzing the design strategies, especially to detect fluoride ions in aqueous and real samples. About 21 colorimetric sensors and fluorescent probes, published during 1999 to 2014 have been covered to analyze their design strategies, speed of detection, limit of detection and their applicability in real samples and in aqueous medium. The fundamental principles can be broadly classified into 5 categories namely Si-O bond cleavage, B-F monomer formation, deprotonation of amide hydrogen, Si-F bond formation and Sb-F bond formations which enable fluoride ion detection. Variations in the organic substituents attached to the Si-O bond, B-F monomer and amide groups is the key to the efficacy of the sensor. Optimization of applicability of the sensors in aqueous solvents *vis-a-vis* maintaining the sensitivity, range of detection, speed of detection, both quantitatively and qualitatively are a challenge. This review aims to present a comprehensive and critically analyzed discussion of the published probes, which will encourage further research in this field.

Keywords: Fluoride detection, Colorimetric sensors, Fluorometric sensors, Si-O bond cleavage, N-H deprotonation.

INTRODUCTION

Sensing of fluoride in real samples as well as samples dissolved in water has been a challenge and designing of fluorogenic and chromogenic sensors have ever since gained intense attraction because of their fast response time, sensitivity, anion specific response and their ease of usage [1-6]. Apart from the fluorometric measurement, naked-eye change of colour has been advantageous for instant detection of fluoride ion. With the help of such probes, analytes can be visualized and monitored quantitatively in living cells microscopically. Initial research was typically based on molecular recognition and host-guest interaction [7]. Naturally, these probes operated in a reversible manner. With time, self-immolated fluorescent probes have been designed for better detection, both qualitatively and quantitatively [8,9]. Inspired from anion binding proteins found in nature, hydrogen-bonded bases like amide, urea, indole, pyrrole, guanidium, *etc*., fluorescent probes have been synthesized that essentially bind fluoride through hydrogen bonding [10-16]. Since the basic principles lies in the deprotonation of amide hydrogen of amide linkage, cleavage of silicon-oxygen bond or B-F-B bonds, fluoride stands as the most suitable anion due to its small size and extraordinary electronegativity. Moreover, due to the high electronegativity of fluorine, it can delocalize π-electron density thereby forming strong hydrogen bonds which ultimately lead to the snapping of Si-O bond or deprotonation of N-H group of amide or hydroxyl group. All these factors result in the fluorometric and colourimetric detection and quantification of fluoride ions [17-24]. The binding fluoride ion lead to the origin of new emission peaks at a non-interfering wavelength which results in unambiguous detection as well as quantitative detection of fluoride ion [25]. Internal charge transfer (ICT) [26], photo-induced electron transfer (PET) [27], excited state intramolecular proton transfer (ESIPT) [28], are some of the predominant mechanisms used for chromogenic and fluorogenic chemo-sensors. Apart from these, excimer/exciplex emission [29], enhancement/quenching of luminescence [30] upon fluoride attachment as well as amplification



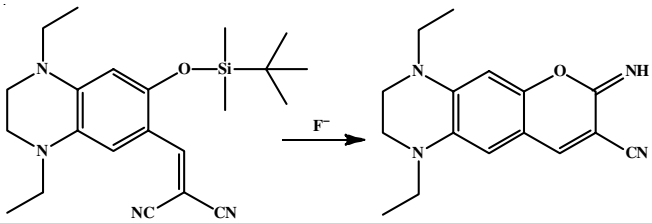
Probe 1

Fig. 1. A proposed mechanism for sensing F^- by **Probe 1**

of signal upon exciton-migration [31,32] are also popular mechanisms. Since fluoride is beneficial for healthy bone and teeth and at the same time detrimental if acquired in excess, detection of fluoride both qualitatively as well as quantitatively is of paramount importance [23]. In this review, we provide a compilation of various probes reported and critically analyze the advantages and disadvantages of these probes. Moreover, the principles of fluoride ion detection, designing strategies of sensors and their application in real and greener solvents have been discussed, which will be beneficial for further research in this field.

A fluorescein-based **Probe 1** principally consisting of a boronic acid group has been reported by Yoon *et al*. [34] which acts as a chemosensor for fluoride ion *via* fluorometric method showing an intense green emission in acetonitrile-methanol (9:1, v/v) (Fig. 1). When excited at 483 nm, **Probe 1** depicted a selective fluorescence "turn-on" behaviour for fluoride ion selectivity among other anions. The Cl^- ion showed minimum fluorescence enhancement with **Probe 1**, which was negligible compared to F^- ion. F^- ion selective concentration dependent fluorescence titration experiment has been performed by using 1, 10, 50, 100, 250, 500, 750 equivalent of F^- with **Probe1** (3 μM). The association constant has been investigated as 9.2×10^{10} M^{-3} from the fluorescence titration experiment. The mechanism may be best described by the blocking of PET mechanism through hydrogen bonding of the phenolic-H with F^- ion as well as with benzylic amine, thereby enhancing the fluorescence.

Song *et al*. [35] have introduced amino coumarin based **Probe 2** for selective F^- ion sensing with red light emission at pH 7.4, having 30% MeCN (v/v), buffered with HEPES (Fig. 2). **Probe 2** showed an absorption band with λ_{max} at 492 nm with brown colour in naked eye. When fluoride is added, the λ_{max} was found to be blue-shifted at 473 nm with concomitant colour change from brown to light brownish yellow. **Probe 2** does not show any emission in absence of fluoride ion, but shows an intense red coloured emission at 616 nm indicating the presence of fluoride ion. From the fluorescence titration spectra detection limit has been calculated and it has been found as



Probe 2

Fig. 2. A proposed mechanism for sensing F^- by **Probe 2**

5.4×10^{-6} M. From the time dependent fluorescence study, it was found that after 10 min, saturation has achieved for **Probe 2**-F^- system. They have found a 3-fold emission enhancement after the addition of 0.01 mM F^- towards **Probe 2** (10 μM), which makes **Probe 2** as a successive tool for F^- ion detection. Interferences study has been performed using Cl^-, Br^-, I^-, CN^-, NO_3^-, HSO_4^-, AcO^-, ClO_4^-, SCN^-, N_3^-, CO_3^{2-}, cys, SO_4^{2-}, BSA and GSH with **Probe 2** in presence of fluoride ion, proving that **Probe 2** is applicable of detecting F^- ion selectively among other competitive anions as well as other biological analytes. The cleavage of silicon-oxygen bond of **Probe 2** and consequent cyclization imparting more rigidity in presence of fluoride ion may be regarded as responsible for the emission generated by **Probe 2**. **Probe 2** shows a stokes shift of 143 nm (λ_{max}abs = 492 nm, λ_{max}em = 616 nm) at pH 7.4, having 30% MeCN (v/v), buffered with HEPES, which is very much desirable for fluorescence microscopy studies. Fluorescence microscopy experiments has been performed and proved the selectivity and specificity of **Probe 2** for the identification of F^- in living HaCaT cells.

Talukdar *et al*. [36] developed a fluoride selective colourimetric and fluorescent sensors **Probe 3** (Fig. 3) had no characteristic absorption in the range 300-700 nm in DMSO, but when 300 equivalents of tetrabutylammonium fluoride (TBAF) was added to a 10 μM solution of **Probe 3** depicted a strong yellow colour, which is easily observed through naked eye. **Probe 3** exhibited a strong emission at λ_{em} = 523 nm when excited at λ_{ex} = 460 nm upon addition of fluoride ion (TBAF = 0, 0.5,

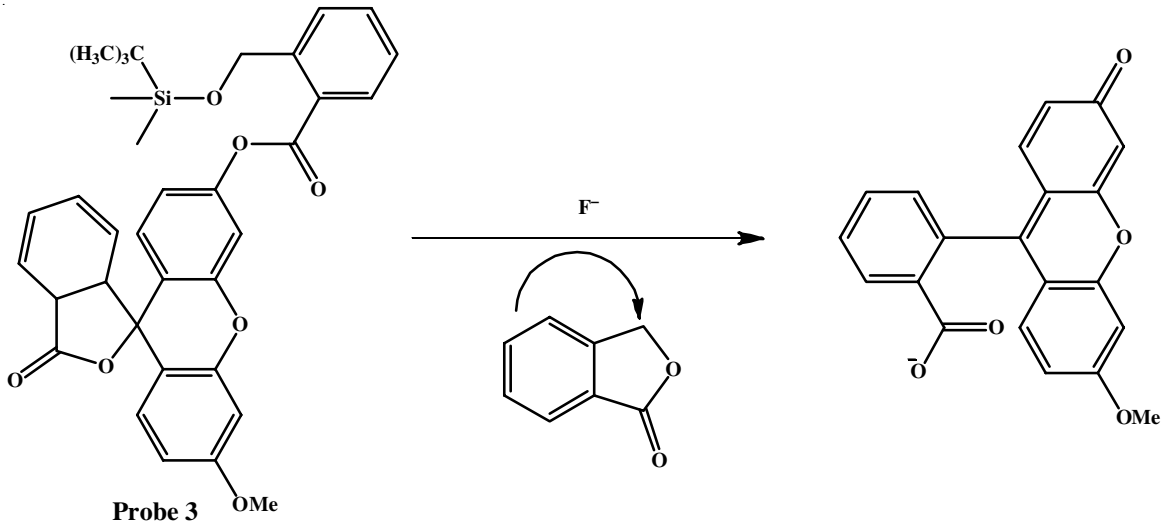


Fig. 3. A proposed mechanism for sensing F^- by **Probe 3**

1.0, 1.5, 2.0, 2.5, 3.0, 3.5 mM), thereby emitting a bright green colour. Reaction kinetics has proved the reaction to be of pseudo-first order having a rate constant k = 0.28 min^{-1} and a half-life ($t_{1/2}$) of 2.41 min. The entire sensing process took ~7 min to reach completion. **Probe 3** develops yellow colour through naked eye towards F^- ions and green emission colour in presence of fluoride ion under an UV-lamp. So, **Probe 3** is capable of being used successfully used for colourimetric and fluorometric detection of F^- in DMSO. The limit of detection for F^- by **Probe 3** as obtained from the experiment was 1.03 μM (19.6 ppb) much lower than 4 ppm, which is the permissible limit of F^- in drinking water as stated by the USEPA [36]. It may be mentioned here that interferences study of **Probe 3** showed selectivity towards fluoride ions among other anions (Cl^-, Br^-, I^-, ClO_4^-, NO_3^-, PF_6^-, HSO_4^-, OAc^- and SO_4^{2-}) as well as other analytes (H_2O_2, cys and GSH) with λ_{em} = 523 nm when excited at λ_{ex} = 460 nm. The mechanism of sensing was based on the cleavage of the silicon-oxygen bond of **Probe 3**, which is originally non-fluorescent. When treated with fluoride ion, it undergoes cleavage to form phthalide with consequent release of carboxy-fluorescein based fluorophore, which is the origin of yellow colour.

Zhang *et al*. [37] has reported a new chemodosimeter, **Probe 4** (Fig. 4) based on benzothiazoliumhemicyanine for selective fluorometric and colourimetric sensing of F^- in ethanol/water (30:70, v/v) solution buffered with PBS (phosphate buffer saline) (20 mM) at pH 7.4. Under this condition, **Probe 4** showed one absorption band at 407 nm, which is essentially colourless, but underwent a 110 nm red-shift with the addition of fluoride ion with an isosbestic point at 442 nm accompanied by a naked eye colour change from slight yellow to orange. Hence, **Probe 4** may be considered as useful for the identification of fluoride ion *via* "naked-eye" colour change. In the fluorescence emission spectrum λ_{em} (max) is observed at 500 nm when fluoride ion was absent, while in presence of fluoride ion, it gives a blue emission. After the addition of incremental concentrations of F^- (0, 0.5, 2, 4, 6, 10, 13, 16, 20, 24, 28, 36, 40, 50, 60 mM) with **Probe 4** (5 μM), λ_{em} is red-shifted to 558

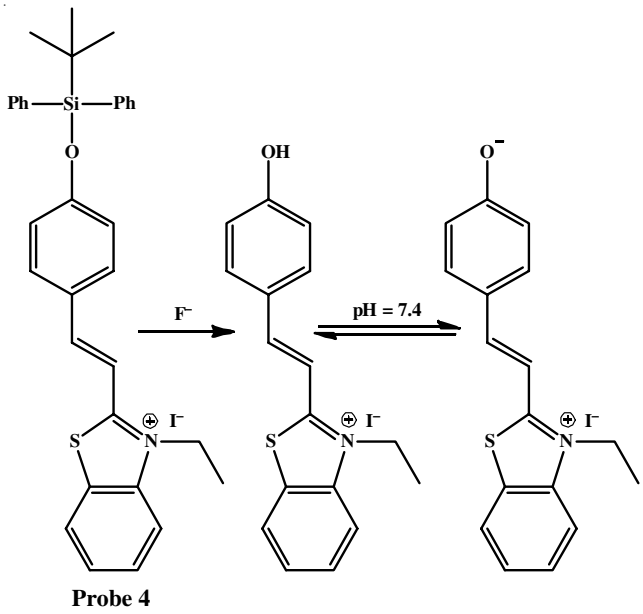


Fig. 4. A proposed mechanism for sensing F^- by **Probe 4**

nm through an iso-emission point (539 nm) resulting in the colour change from blue to green. Time dependent study has been performed and all the emission and absorption spectra were taken after 50 min. The limit of detection for F^- by **Probe 4** has been ascribed as 0.08 mM. It was found that fluoride ion detected by **Probe 4** was independent of interference by other competitive ions like Cl^-, CO_3^{2-}, Br^-, I^-, SO_4^{2-}, SCN^-, NO_3^-, N_3^- as well as other biomolecules like cysteine (cys), glutathione (GSH), bovine serum albumin (BSA) and human serum albumin (HSA). It has been found that no anions or biomolecules showed any interference for the selective detection of F^-. This selective study is based on ICT-mechanism involving fluoride ion and benzothiazolium hemicyanine dye (as fluorophore) and the mechanism is principally based on the desilylation of **Probe 4**.

Ahn *et al*. [28] reported coumarin based red light emitting fluorescent **Probe 5** (Fig. 5) for detecting the fluoride ion selectively in 20% MeCN containing 10 mM HEPES buffer

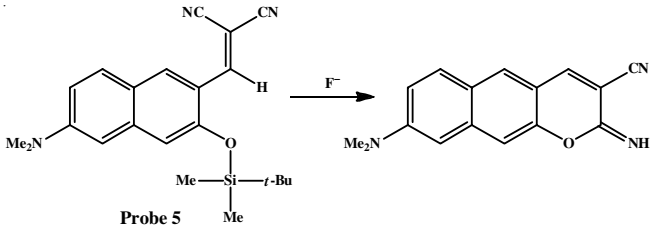


Fig. 5. A proposed mechanism for sensing F^- by **Probe 5**

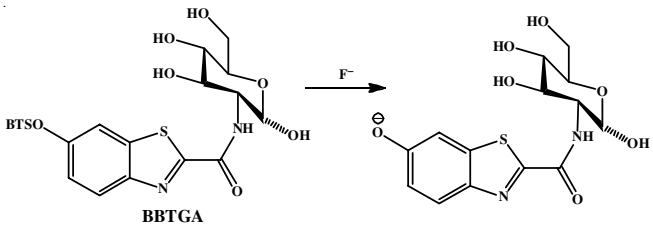


Fig. 6. A proposed mechanism for sensing F^- by **BBTGA**

at pH 7.4. **Probe 5** showed absorption maximum at 460 nm, which has been taken as excitation wavelength for fluorescence studies. Addition of F^-, produces no changes to absorbance of **Probe 5** and has very weak emission at 595 nm. Upon gradual addition of fluoride, more and more iminocoumarin was produced leading to the emission of more intense red light. With incremental concentration of fluoride ion (0-20 mM) towards **Probe 5** (20 μM), the λ_{em} at 595 nm increased. From the time dependent study, it has been found that after 60 min saturation was achieved for emission study. Studies involving interference of other anions have been investigated that other anions such as Cl^-, I^-, CN^-, Br^-, HSO_4^-, NO_3^-, PF_6^-, ClO_4^-, SCN^-, CH_3COO^-, N_3^- and cysteine with **Probe 5** (20 μM) the Si-O bond cleavage in presence of fluoride ion was not interfered by the above mentioned competing anions, even when the concentration of the anions were 10-fold higher than F^-. The highly selective fluoride ion detection was due to the fluoride-mediated desilylation process to produce red light emitting iminocoumarin, which can be showed under UV lamp. The limit of detection F^- by **Probe 5** has been estimated to be below 4 ppm, which is the permitted limit of fluoride ion in drinking water as set by USEPA. They have successfully monitored fluoride ions distribution in the three different parts of zebrafish (head, abdomen and tail parts) depending on the duration of incubation of the probe and fluoride with **Probe 5** (20 μM and 5 mM).

Wang *et al*. [39] have reported sugar-based probe **BBTGA** (Fig. 6) as fluoride selective fluorescent sensor in (DMSO 0.5%, pH = 7.4) based on desilylation process. The sugar part has been introduced to improve the water solubility of probe **BBTGA**. **BBTGA** has very weak fluorescence, but its emission intensity has been increased by 3-fold after an incubation period of 4 h in 10 mM PBS in DMSO (0.5%) at pH = 7.4 and 5-fold after 10 h. Upon adding 0.1 M NaF to **BBTGA** in 10 mM PBS containing 0.5% DMSO at biological pH led to increase the fluorescent intensity 30 folds in 10 min at 508 nm with a green emission light. Fluorescence titration experiment has been performed by adding increasing concentration of fluoride ion (0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1 mM) with **BBTGA** (10 μM). All the emission spectra were recorded after incubation time 5 min for BBTGA and F^-. **BBTGA** can selectively identify F^- among other competing anions by adding 0.1 M I^-, Br^-, Cl^-, F^-, $H_2PO_4^-$, NO_2^-, NO_3^-, N_3^-, AcO^- and SO_4^{2-} (total concentration 50 mM) to its solution in 10 mM PBS in 0.5%, DMSO at pH = 7.4. The selective green turn-on fluorescence of **BBTGA** in presence of F^- was achieved due to the desilylation reaction in aqueous medium. To monitor the sensitivity of **BBTGA** towards F^- ions, living cell imaging study has been done by using KB human carcinoma cell lines. This probe **BBTGA** has proved its utility as novel fluorescence sensor by some excellent properties such as excellent interference free detection of F^- ions and fast reaction rate, in presence of other competing anions and non-cytotoxic to mammalian cells, which is essential for cellular imaging.

Misra *et al*. [40] designed and synthesized triarylborane substituted naphthalimide based **Probe 6** (Fig. 7) for selective detection of F^- by the Sonogashira cross-coupling reaction in THF solvent. **Probe 6** can selectively detect F^- and CN^- ions in the presence of myriad competing anions like NO_2^-, Cl^-, I^-, Br^-, *etc*. by turn-off method. Upon addition of increasing concentration of fluoride ion, the absorption bands at 378 and 398 nm gradually decreases with concomitant emergence of a new band at 427 nm through two isosbestic points at 304 and 407 nm, respectively. **Probe 6** (10.66 μM) has significant emission intensity at 423 nm with blue emission light. With incremental concentration of fluoride ions to **Probe 6** in THF, the intensity of emission **Probe 6** at 423 nm decreased gradually and underwent a red-shift towards 501 nm with emission intensity quenching. The selective turn-off detection of fluoride ion by **Probe 6** has been based on the binding of F^- towards boron centre in **Probe 6**. The sensing mechanism of F^- and CN^- ions by **Probe 6** has been observed by performing DFT calculations. The theoretical calculations were in tune with the experimental

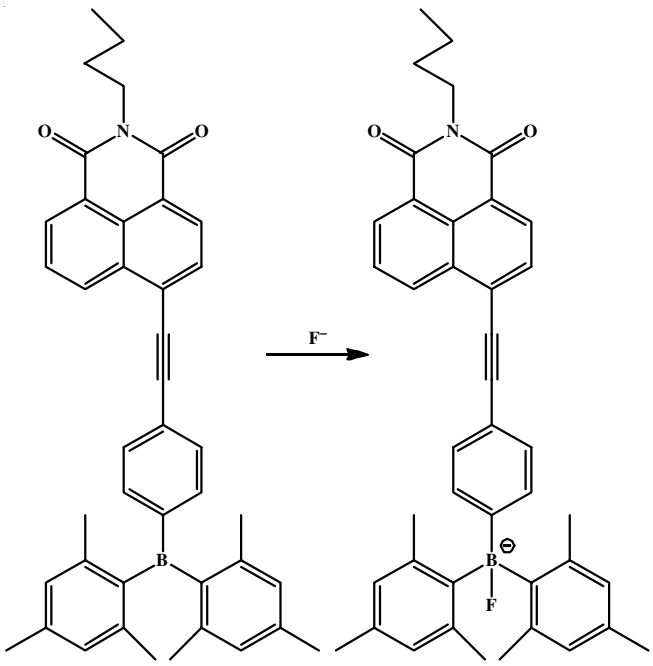
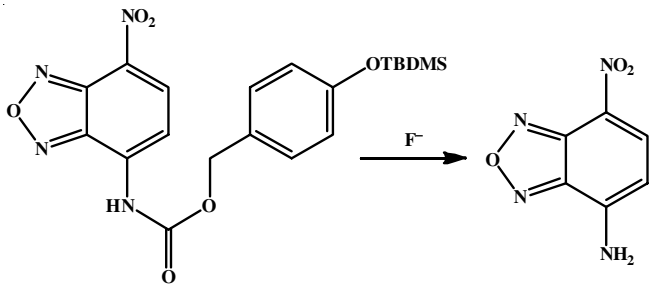


Fig. 7. A proposed mechanism for sensing F^- by **Probe 6**

findings. The computation of energy levels showed that the energy gap between the HOMO and LUMO decreased considerably upon binding with fluoride and cyanide, thereby red-shifting of absorption maxima of triarylborane substituted napthalimide **Probe 6**.

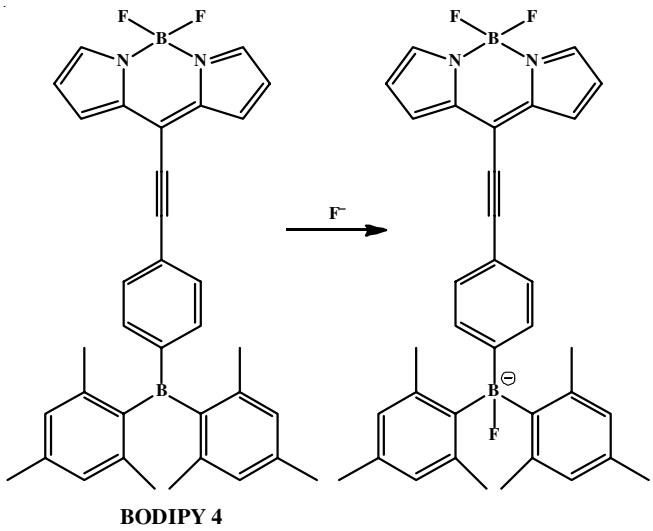
Talukdar *et al.* [41] have reported **Probe 7** (Fig. 8) for selective detection of F^- *via* green fluorescence in ethanol-HEPES buffer (10 mM, pH = 7.4) solution taken in 9:1 ratio, which displayed a strong absorption centred at λ_{max} = 399 nm having a molar extinction coefficient value, ε = 12 190 M^{-1} cm^{-1}. After addition of fluoride ion towards **Probe 7**, a selective yellow colour was produced, which may be due to the formation of amine derivative of **Probe 7** after the addition of F^-. **Probe 7** displayed negligible fluorescence intensity as well as a low quantum yield at 535 nm. After the addition of 0-3.5 mM of TBAF to **Probe 7** (10 μM) in 10 mM EtOH–HEPES buffer (pH = 7.4) taken in 9:1 (v/v) ratio, the fluorescence intensity at λ = 535 nm (λ_{ex} = 460 nm) increased till 60 min. Interferences study of **Probe 7** (10 μM) was carried out for F^- in the presence of many competing anions *e.g.* NO_3^-, Cl^-, Br^-, I^-, ClO_4^-, PF_6^-, OAc^-, HSO_4^- and SO_4^{2-} (2 mM) in presence with F^- (2 mM). It has been found that in presence of all competing anions, **Probe 7** can selectively and effectively detect F^-. Colourless to yellow change of colour was visible through naked eye only in the presence of the F^- ion and other anions failed to provide any colour changes. Fluorescence microscopic technique was successfully applied for live-cell imaging using the with the A549 (human lung carcinoma) cell line, which proved the cell permeability of **Probe 7** and its capability to detect intracellular F^- ions.



Probe 7

Fig. 8. A proposed mechanism for sensing F^- by **Probe 7**

Misra *et al.* [42] reported **BODIPY 4** (Fig. 9) based colourimetric and fluorescent sensors for fluoride anion detection in THF medium. The triarylborane based BODIPY can serve as highly sensitive 'naked eye' marker for fluoride ions with the colour changing from orange to pink. Selectivity of fluoride over other anions by **BODIPY 4** has been monitored by performing fluorescence titration using **BODIPY 4** against other competing anions *i.e.* I^-, Cl^-, Br^- and NO_3^-. It was found that **BODIPY 4** can selectively detect fluoride ion while it does not respond to other anions like Cl^-, I^-, Br^- and NO_3^-. The absor-ption spectra of **BODIPY 4** (10 μM) shows the significant changes with different concentrations of fluoride ions (0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0 equiv.); causes significant colour changes from orange to pink through naked eye, (a) the

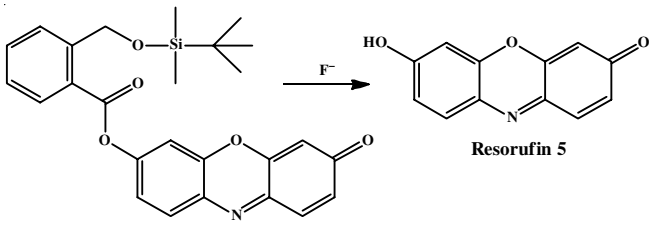


BODIPY 4

Fig. 9. A proposed mechanism for sensing F^- by **BODIPY 4**

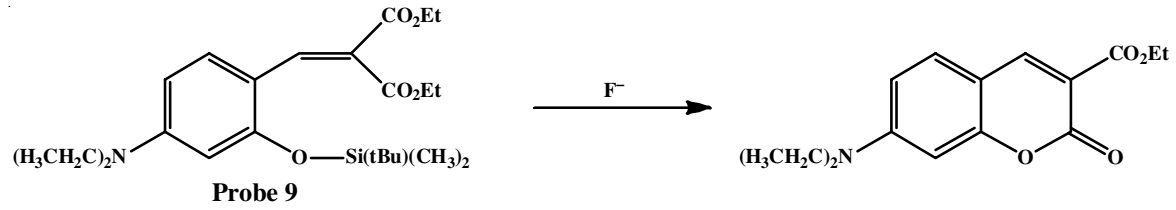
band at 300-430 nm decreases gradually and (b) the absorption band at 547 nm experiences a blue shift of 15 nm with its intensity increasing gradually. The probable reaction mechanism of this type of absorption changes is thought to be due to the binding of fluoride ion to the trivalent boron species of **BODIPY 4** to give rise to a tetrahedral species, which decreases the degree of π-extended structure of **BODIPY 4**. Job's plot was performed at 427 nm by absorption study and a 1:1 stoichiometry between **BODIPY 4** and fluoride ions have been found. The calculated binding constant has been investigated as 2.41 × 10^4 M^{-1} for complex formation between **BODIPY 4** and F^-. Incremental concentration of F^- ion (0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0 equiv.) to the solution of **BODIPY 4** (10 μM) in THF, leads to decrease in emission intensity at 566 nm accompanied by a colour change from yellow to green under UV light.

Talukdar *et al.* [43] designed and synthesized a resorufin based colourimetric and fluorescent sensor **Probe 8** (Fig. 10), which is found to be highly selective for fluoride ion in THF medium. **Probe 8** has strong absorption bands at λ = 347 and 437 nm and was totally non-fuorescent in THF. After addition of 0.5 mM TBAF to **Probe 8** (10 μM) in THF, the peaks obtained from absorption spectra at λ = 347 and 437 nm, which decreased gradually with newly emerging absorption peaks at λ = 550, 573 and 591 nm with a strong pink colour through naked eye. These new absorption peaks are attributed to the liberated 'free resorufin derivative' and release of the fluoro-phore was observed to be completed after 5 min. Absorption titration experiment has been performed where the signals correspond



Probe 8 **Resorufin 5**

Fig. 10. A proposed mechanism for sensing F^- by **Probe 8**



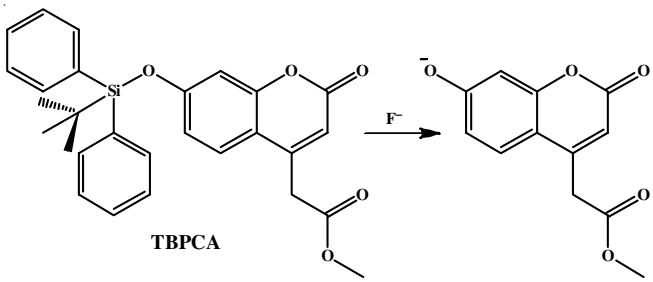
Probe 9

Fig. 11. A proposed mechanism for sensing F^- by **Probe 9**

to **Probe 8** (at λ = 347 and 437 nm) were disappeared and signals corresponding to resorufin (at λ = 550, 573 and 591 nm) appeared. Emission titration experiment was also conducted by using **Probe 8** (10 μM) with addition of 0-0.7 mM F^- ion in THF (λ_{ex} = 550 nm, λ_{em} = 595 nm) and all spectra were recorded in after10 min of mixing. After addition of F^- towards **Probe 8** in THF, red emission colour was developed. In terms of the selectivity of **Probe 8**, various interfering anions were tested in 0.5 mM of Cl^-, Br^-, I^-, PF_6^-, ClO_4^-, NO_3^-, SO_4^{2-}, HSO_4^-, OAc^-, Na_2S, H_2O_2, cys and GSH for a span of 10 min at room temperature. None of these interfering analytes showed any significant enhancement in the emission wavelength or intensity. The detection limit has been investigated as 60 nM (1.15 ppb). For fluoride, **Probe 8** gives strong pink fluorescence and for other analytes no fluorescence was observed. The mechanism of sensing was based on fluoride anion triggered of silicon-oxygen bond cleavage in **Probe 8** and production of resorufin.

Swager & Kim [31] introduced a new system **Probe 9** (Fig. 11) with an objective of fluoride ion detection based on fluoride triggered Si-O bond cleavage and cyclization reaction, which was found to amplify the signal within a semiconducting organic polymer and the mechanism is believed to have been caused by exciton migration. In comparison to previously reported semiconductive-polymer sensor strategies that depend on the variations in emission intensity, **Probe 9** tracks a new fluorescence signal observed at 450 nm. The cyclization reaction between **Probe 9** and fluoride ion is irreversible and governed by the reaction kinetics. The fluorescence monitored the cyclization kinetics of **Probe 9** in THF concluded that it was of first-order and was independent of the concentration of fluoride ion and also relatively slow reaction takes place as the rate constant value was 2×10^{-4} s^{-1}. The rate constants did not vary with the addition of fluoride ion in the range 0.5 to 3 molar ratio relative to **Probe 9** (3.2 μM). They have found that the silyl cleavage occurred rapidly while the cyclization was the slow step. In the fluorescence titration experiment, it has been found that there was an enhancement in the rate when a 10-fold excess of fluoride ion was added and a saturation of the emission intensity was observed after 2 h. Additional ionic associations helped acceleration of rate at the high fluoride concentrations.

Hong *et al.* [44] developed a coumarin based fluoride ion sensor **TBPCA** (Fig. 12) in HEPES buffer. With an objective to improve the water solubility and cell permeability of sensor, the hydrophilic moieties were introduced using a methyl ester group to 4-acetic acid on the fluorescent coumarin moiety. With addition of all competing anions *i.e.* Cl^-, Br^-, I^-, NO_3^-, AcO^-, N_3^-, $H_2PO_4^-$; only F^- was able to enhance the emission

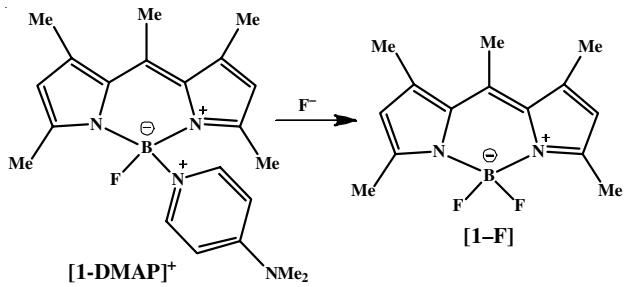


TBPCA

Fig. 12. A proposed mechanism for sensing F^- by **TBPCA**

of **TBPCA**. The emission saturation was observed after 4 h of addition of 1 mM of NaF in HEPES buffer to 2 μM solution of **TBPCA**. Fluorescence titration experiment has been done with addition of 0-1.3 mM of F^- to **TBPCA** (2 μM). From the fluorescence titration experiment, emission at 461 nm was taken and linearity was achieved against concentration of F^- to **TBPCA**. The advantage of the calibration graph at 461 nm is that quantitative estimation of NaF, obtained from any sample can be easily plotted and determined. The interference study of **TBPCA** for F^- has been performed in presence of various competing anions (1 mM) such as Cl^-, Br^-, I^-, N_3^-, AcO^-, NO_3^-, $H_2PO_4^-$, *etc*. The mechanism for specific ion based turn-on fluorescence of **TBPCA** in presence of NaF may be due to the ICT mechanism and Si-O bond cleavage upon the attack of fluoride ion on the silyl ether moiety.

Hudnall & Gabbai [45] described an unique approach for the fluorescent sensing by 'turn-on' mechanism for F^- ions in $CHCl_3$ based on bond cleavage of **[1–DMAP]**$^+$ and formation of brightly fluorescent **1–F**. In this, BODIPY boronium cation (**[1-DMAP]**$^+$) (Fig. 13) was treated with fluoride ion was converted to a neutral BODIPY dye (**1–F**). The neutral BODIPY dye (**1–F**) was highly fluorescent with emission colour of green. Interferences study has been done in presence of other anions like Cl^-, I^-, Br^- and it was found there were no any significant emission enhancement from other anions. After addition of 1 equiv. of TBAF, the fluorescence intensity has increased by a factor of 500% and the emission colour can be easily observed with

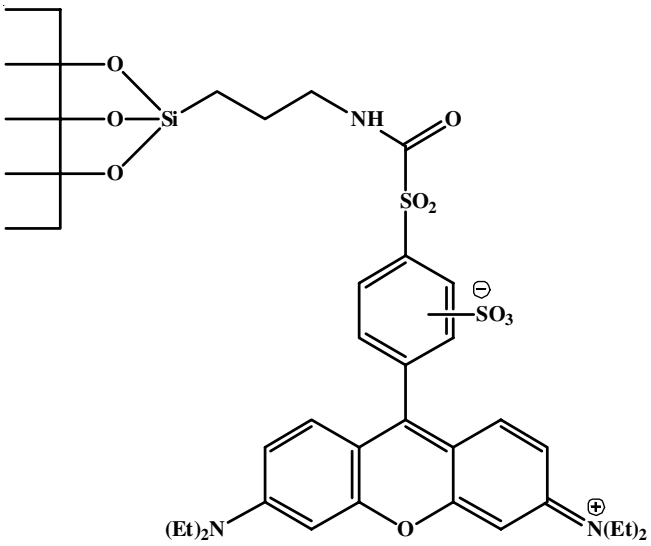


[1-DMAP]$^+$ **[1–F]**

Fig. 13. A proposed mechanism for sensing F^- by **[1-DMAP]**$^+$

naked eye. In presence of iodide ions, the cationic *p*-dimethylaminopyridine adduct of 1,3,5,7,8-pentamethylpyrromethene-boron fluoride **[1–DMAP]**$^+$ reacts with fluoride ions to produce the corresponding brightly fluorescent **1–F**.

Manez *et al.* [46] used a silica matrix to impregnate the **Probe 10** (Fig. 14) to detect the presence of fluoride ion in real samples. The solvent used was acetonitrile-water (7:3, v/v) buffered with 0.1 M potassium hydrogen phthalate and HCl, maintaining a pH of 2.5. **Probe 10** gives pink colour which can be seen by naked eye, which makes this probe as an excellent colourimetric tool for fluoride anion. Large surface area (*ca*. 1000 $m^2 g^{-1}$) of the probe allows a high degree of functionalization which, in turn, will be translated to a higher response of the final solid. At the same time, the MCM-41 silica porous system may provide proper protection for the signalling molecules. **Probe 10** can develop a significant pink colour in presence of 0.5×10^{-6} M fluoride. In order to support their approach, they have successfully applied their method for the quantitative determination of fluoride in the commercial toothpaste and a very good correlation with the claimed concentration has been found.

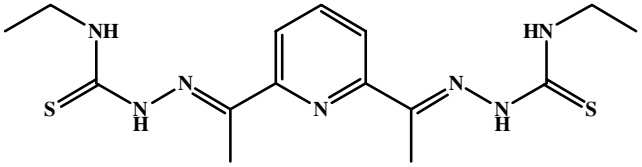


Probe 10

Fig. 14. Structure of **Probe 10**

Bermejo *et al.* [47] introduced **Probe 11**, which possesses two thiourea-containing unsaturated side chains connected to a central pyridine ring (Fig. 15) and enabled the naked-eye detection of fluoride ions without any particular chromophore in acetonitrile. The interference study of **Probe 11** (10 μM) with several anions *i.e.* Cl^-, Br^-, I^-, AcO^-, HSO_4^- have been studied by the spectrophotometric titrations in acetonitrile by addition of a tetraalkylammonium salt of the competing anions to a solution of **Probe 11**. It has been showed that addition of F^- salt resulted in decreasing the peak at 324 nm with the emergence of a new band at 412 nm. In the absorbance titration, it has been showed that with the addition of different concentrations of F^- to **Probe 11**, the absorbance band at 412 nm increased gradually. The presence of an isosbestic point at 345 nm proved the presence of two species at equilibrium: **Probe 11** and a **Probe 11**-F^- adduct. The interaction of the thiourea-hydrogen atoms with the fluoride ion enhanced the π-delocalization and shifted the π–π* transition from the UV to the visible region and produced yellow colour. Enhanced π-delocalization on the organic backbone was expected to reduce the energy of the π–π* transition. As a result, the absorption band was shifted from the UV to the visible region and a yellow colour appeared. The visual aspects of fluoride ion recognition and sensing by **Probe 11** have been monitored by using a 10^{-4} M solution of **Probe 11** in MeCN. Addition of one equivalent of F^- ions to **Probe 11** (10 μM) induced the appearance of a bright yellow colour while the addition of 10 equiv. of the other competing anions *i.e.* Cl^-, Br^-, AcO^-, I^-, HSO_4^- did not induce any notable colour development.

Sessler *et al.* [48] developed dipyrrole systems (**Probes 12** and **13**) (Fig. 16) for F^- ion detection using UV-visible absorption methods in dichloromethane and DMSO solvents. **Probe 13** has developed fluoride anion-induced dramatic colour change from yellow to purple. In both solvents, the colour changes were reversed upon addition of water. This was due to the water molecule which competes for F^- at the pyrrolic-NH donating sites through hydrogen bonding. The unique sensitivity of **Probe 13** compared to **Probe 12** was may be due to the greater electron deficiency of the mononitro derivative (**Probe 13**) lead to an increase in its hydrogen bond-donating character. The diketone-2 derivative of **Probe 13** have relatively large extinction coefficient but did not fluorescence. Diketone-2 was brightly coloured in dichloromethane solution and like **Probe 12**, undergoes a naked-eye colour changes from yellow-green to orange, in presence of F^-. The binding constant of **Probes 12** and **13** for F^- was investigated using fluorescence



Probe 11

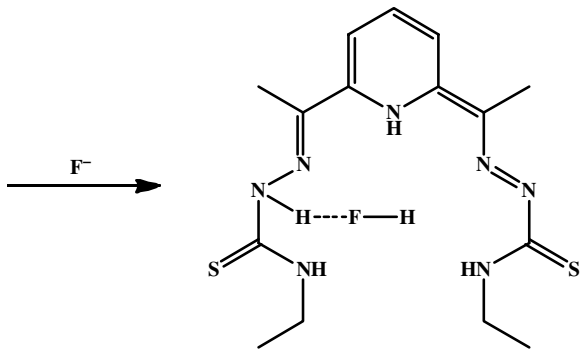


Fig. 15. A proposed mechanism for sensing F^- by **Probe 11**

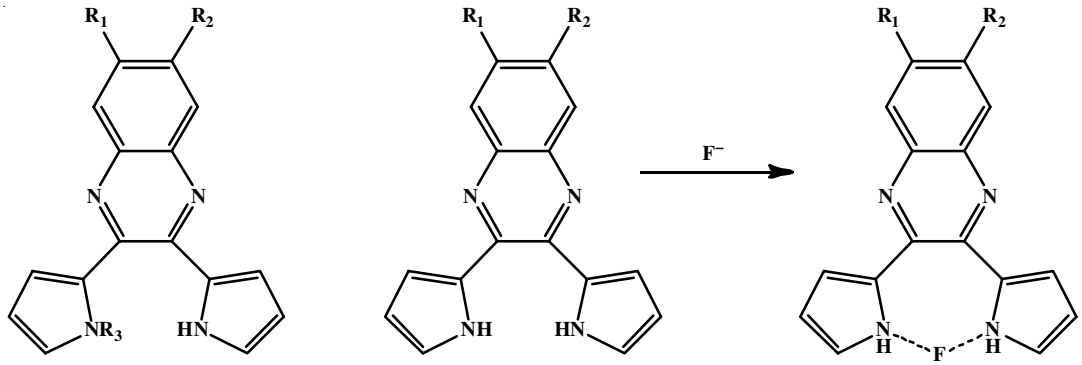


Fig. 16. A proposed mechanism for sensing F^- by **Probe 13**

quenching data at 490 and 600 nm, respectively. It has been found that the binding constant of **Probes 12** and **13** for F^- was 18200 M^{-1} and 118000 M^{-1}, respectively. The sensing mechanism was due to the presence of two pyrrole –NH groups in **Probes 12** and **13** that functioned as anion binding sites and a built-in quinoxaline ring that served as a colourimetric reporter.

Tamao *et al.* [49] also reported a new type of trianthryl-fluorosilane based sensor **Probe 14** (Fig. 17) with a remarkable changes in the UV-visible absorption and fluorescence spectra in the presence of TBAF in THF solution. **Probe 14** showed absorption maximum at 401 nm. In the UV-visible absorption titration spectra, with the addition of increasing concentration of TBAF (0, 6.9, 14, 21, 27, 34, 41, 51, 62 μM) to **Probe 14** (40 μM), new bands appears at about 9 nm shorter wavelengths relative to **Probe 14** at 392 nm, along with the disappearance of the absorption bands of **Probe 14**. Fluorescence titration experiment has also been investigated adding increasing concentration of TBAF (0, 1.7, 3.4, 5.1, 6.9, 8.6, 10, 12 μM) to **Probe 14** (0.2 μM). In the fluorescence titration spectra, the emission intensity was significantly increased with about 20 nm hypsochromic shifts of the emission maxima from 416 nm to 396 nm. The "off-on" behaviour of anthryl fluorophore was controlled on the basis of coordination number of the silicon atom. In the interferences study, when other competing anionic species such as Cl^-, Br^-, I^-, ClO_4^- and BF_4^- as their *n*-Bu_4N^+ salts were added to the silane **Probe 14**, no changes were observed both in the UV-visible absorption and fluorescence spectra. The sensing mechanism was the decrease in the degree of through-space interaction between the anthryl groups by the structural change from tetrahedral **Probe 14** to trigonal bipyramidal **Probe 14-F**, as observed in the crystal structures.

Gabbai *et al.* [50] also developed another new fluorescent sensor **Probe 15** based on 9-anthryltriphenylstibonium cation (Fig. 18) for fluoride anion in aqueous DMSO solution. **Probe 15** was found to be meagrely fluorescent, with an emission band at 427 nm which is essentially anthryl-based. Conversion of [**Probe 15**]OTf into **Probe 15**-F by addition of TBAF resulting in a blue shift of the absorption band that was principally anthryl-based, accompanied by a drastic increase in the fluorescence intensity of the anthryl fluorophore. Up to pH 5, [**Probe 15**]OTf exists as the free cation as justified by UV-vis spectroscopy. Above this pH, a distinct blue shift in the UV-Vis spectrum was observed, suggesting a binding of hydroxide anion to the antimony center. All these studies indicated that **Probe 15-**OTf served as an efficient fluoride anion sensor, predominantly at slightly acidic pH. Emission titration experiment has been carried out in 9:1 (v/v) H_2O/DMSO (CTAB, 10 mM) at pH 4.8 (pyridine buffer, 10 mM) indicated that [**Probe 15**]OTf binds fluoride anion with a binding constant of 12000 ± 1100 M^{-1}, which can be used for the detection of fluoride in ppm. Inter-

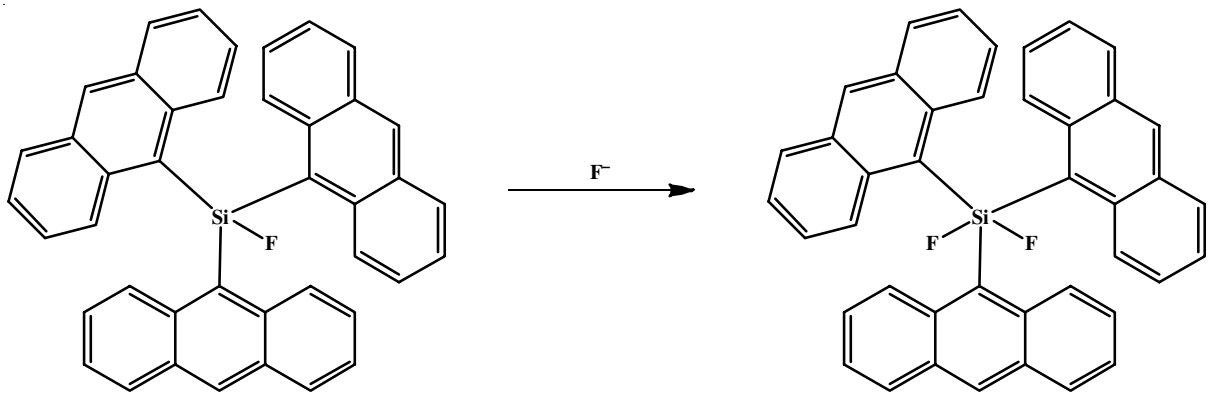
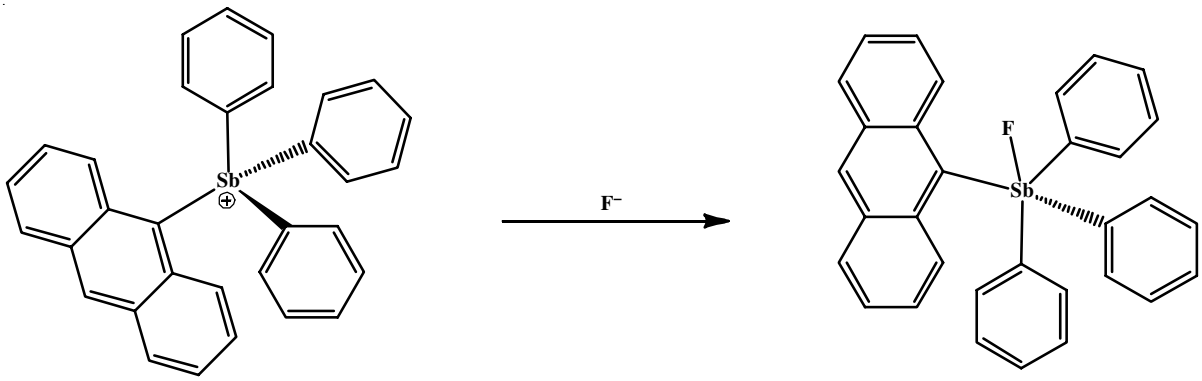


Fig. 17. A proposed mechanism for sensing F^- by **Probe 14**

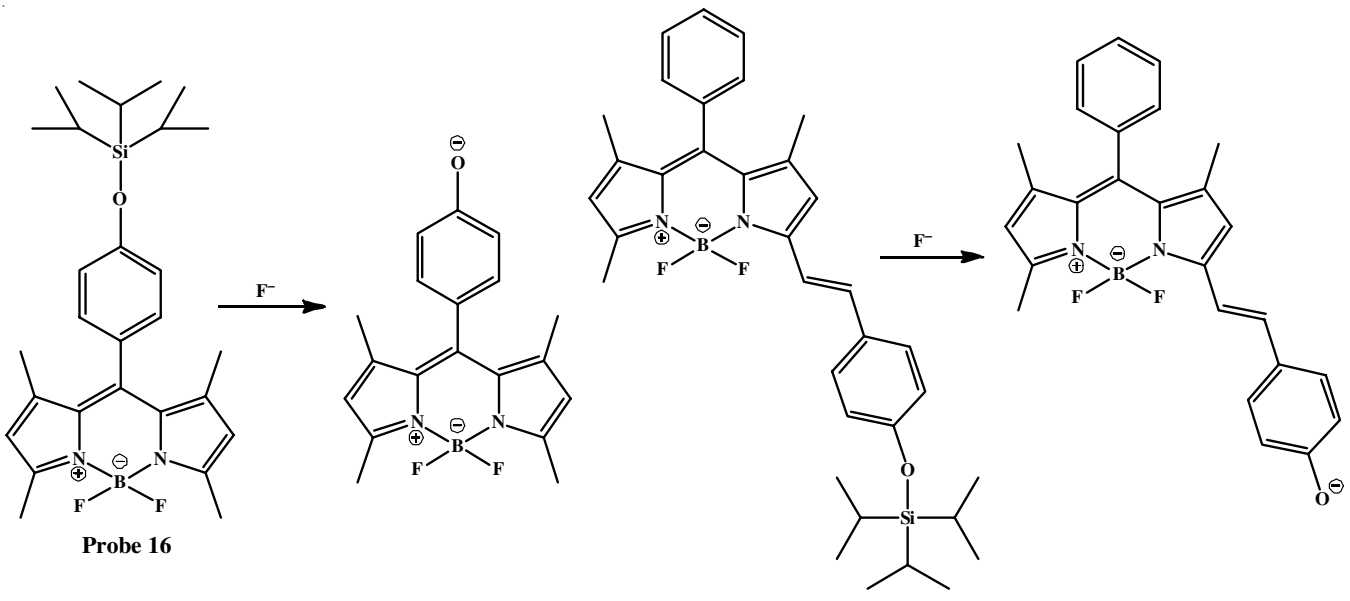


Probe 15

Fig. 18. A proposed mechanism for sensing F^- by **Probe 15**

ference study was performed in presence of other anions such as Cl^-, I^-, Br^-, NO_3^-, HCO_3^-, N_3^- and HSO_4^- and found no interferences. They have performed fluoride ion sensitivity test by tap water as sample and bottled water. The fluorescence turn-on response was observed with the naked eye within 1 min for concentrations of at least 1 ppm.

Akkaya *et al.* [51] developed colourimetric and fluorometric sensors based on BODIPY (**Probes 16** and **17**) for fluoride in acetonitrile solution (Fig. 19). **Probe 16** has the absorption maximum at 498 nm. In the absorption titration experiment, with the addition of increasing concentration of fluoride ions (0, 0.025, 0.05, 0.075, 0.1, 0.125, 0.15, 0.2, 0.25, 0.375, 0.5 mM) in the form of a tetrabutylammonium salt to solution of **Probe 16** (5 μM), resulted changes of 10 nm blue shift to the absorption spectrum. In the emission titration of **Probe 16** (5 μM), the emission at 506 nm was quenched by a factor of 20 in the presence of increasing concentration of fluoride ions (0, 0.025, 0.05, 0.075, 0.1, 0.125 0.15, 0.2, 0.25, 0.375, 0.5 mM). In the absorption titration experiment, **Probe 17** (5 μM) showed a large bathochromic shift on addition of increasing concentration of fluoride ions (0, 0.025, 0.05, 0.075, 0.1, 0.125 0.15, 0.2, 0.25 mM). The absorption peak at 560 nm gradually decreased and a new peak at 682 nm emerged with an isosbestic point at 581 nm. Red shift of 120 nm in absorption was a remarkable change in solution and corresponds to a colour change from purple to green. In the emission titration spectrum of **Probe 17** (5 μM), the emission was quenched in the presence of increasing concentration of fluoride ions (0, 0.025, 0.05, 0.075, 0.1, 0.125 0.15, 0.2, 0.25 mM). **Probes 16** and **17** can selectively detect F^- which has been visualized by the naked eye colour and emission colour under UV lamp. All the spectra were recorded for **Probes 16** and **17** with F^- after few seconds and 5 min of mixing respectively. Interference study has been performed for **Probe 16** (5 μM) and **Probe 17** (5 μM) in presence of F^- with other competitive anions *i.e.* Cl^-, I^-, Br^-, CN^-, AcO^-, NO_3^-, $H_2PO_4^-$, HSO_4^- (0.5 mM and 0.25 mM, respectively) and it was found that no any anions gave any interference during the detection of F^-. The plausible mechanism for the



Probe 16 **Probe 17**

Fig. 19. A proposed mechanism for sensing F^- by **Probe 16** and **Probe 17**

unique sensitivity was due to the silicon-oxygen bond cleavage facilitated by fluoride anions and generated strong intramolecular charge transfer (ICT) from donor phenoxide ion in complete conjugation with BODIPY dye and resulted in a significant red shift in the absorbance spectra.

Lee *et al.* [52] developed a *tris*(N-salicylideneamine)-derived 'turn-on' fluorescent sensor (**Probe 18**, Fig. 20) for fluoride anion through covalently triggered conformational switching mechanism in dichloromethane solvent. A cleavable silyl-ether groups was introduced to a dynamic fluorophore system for structural unfolding and fluorescence quenching. After the addition of increasing concentration of fluoride ion, desilylation process was occurred which triggered spontaneous structural folding and the recovery of an intense blue emission originating from a planar conjugated *tris*(*N*-salicylideneaniline) motif. In CH_2Cl_2, **Probe 19** displays intense visible absorptions at 420 and 440 nm. Upon excitation at 340 nm, **Probe 19** emits at 458 nm which reflects the rigid molecular structure. The mechanism of fluorescence turn-on in this system was based exclusively on the Si-O bond cleavage reactions of **Probe 18**. The interferences study of **Probe 18** (5 μM) for F^- against Cl^-, CN^-, Br^-, I^-, ClO_4^-, SCN^-, NO_3^-, HSO_4^-, PF_6^- and $H_2PO_4^-$ anions (50 μM) has been investigated. Only F^- among the competing anions generated measurable increase in the fluorescence signal, whereas Cl^-, CN^-, Br^-, I^-, SCN^-, HSO_4^-, NO_3^-, PF_6^-, ClO_4^- and $H_2PO_4^-$ had no effect under similar conditions.

Kim & Hong [53] reported dosimeter based on resorufin (**Probe 20**, Fig. 21) for selective fluoride anion detection *via* colourimetric and fluorometric method in 1:1 (v/v) acetonitrile-water as well as in acetonitrile. With the addition of F^- in different concentrations induced decrease in the absorption maximum of **Probe 20** at 20 μM at 445 nm and increase at 586 nm in acetonitrile with naked-eye colour change from pale yellow to pink. Other anions did not cause any change in absorption spectra as well as in naked eye colour. **Probe 20** depicted an eye-catching change in UV-vis absorption and fluorescence emission by fluoride addition as compared to other anions in acetonitrile as well as in acetonitrile-water mixture (1:1, v/v).

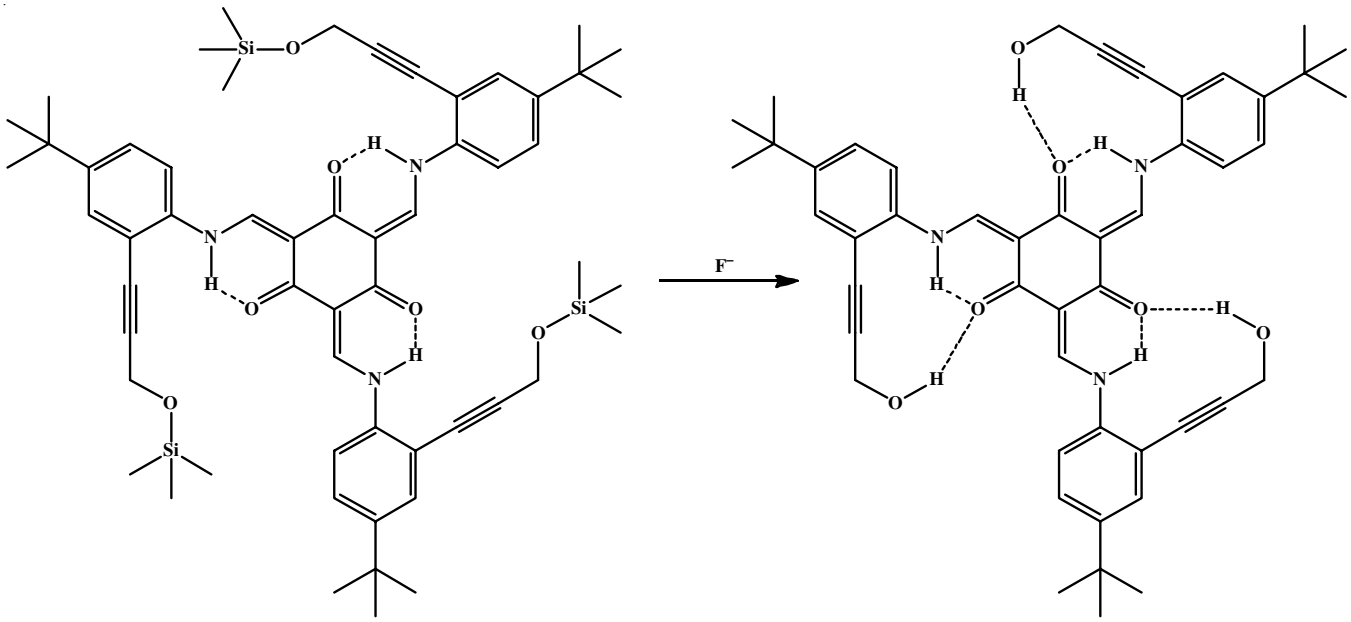


Fig. 20. A proposed mechanism for sensing F^- by **Probe 18**

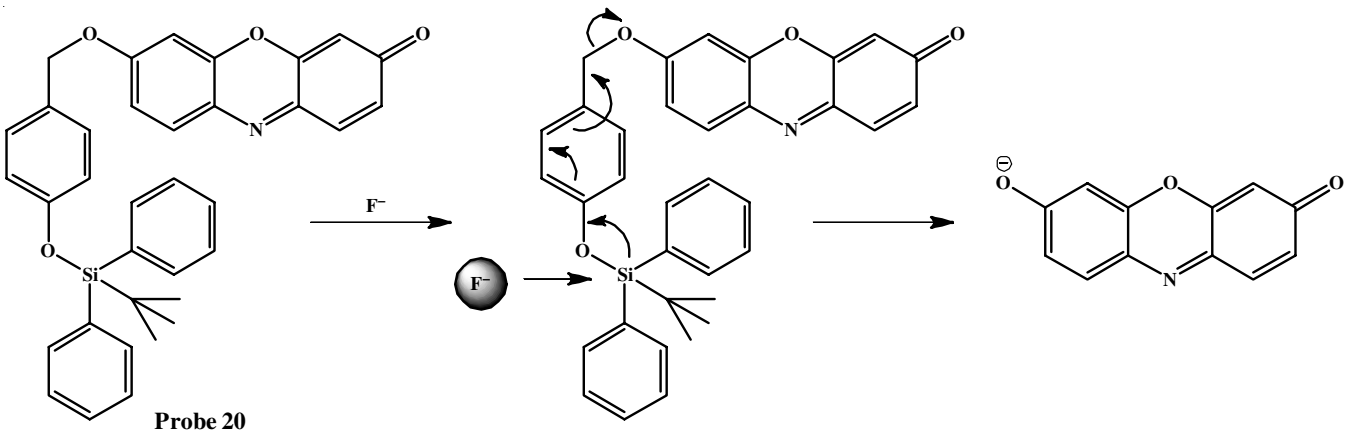


Fig. 21. A proposed mechanism for sensing F^- by **Probe 20**

Fluorescence emission titration experiment of **Probe 20** (5 μM) with increasing concentration of F^- at 591 nm (λ_{ex} = 550 nm) has been examined in acetonitrile. In presence of F^- in different concentrations, the emission intensity of **Probe 20** increased by 500-folds at 591 nm and saturated at 1400 equivalents of F^-. Over time, the colour changed from pale yellow to pink. Upon addition of TBAF (5 mM) to **Probe 20** (5 μM) also depicted a large enhancement of emission in 1:1 MeCN/H_2O solution. The possible mechanism for such remarkable colour change and enhancement in emission was attributed to fluoride induced silicon-oxygen bond cleavage that resulted in the formation of a highly fluorescent resorufin.

To summarize, this review describes various colourimetric and fluorometric sensors for fluoride ions in aqueous medium as well as mixed solvents. Some important characteristics of these sensors are mentioned in Table-1. The remarkable parameters like working solvent system, limit of detection, wave length changes with naked-eye colour and emission colour changes and their application in real samples and cell imaging are also summarized.

Since in the ratiometric approach, the wavelength is generated at a different wavelength hence this method is also useful in the unambiguous determination of fluoride ion. Hence, the ratiometric approach is extremely popular among

TABLE-1
COMPARISON OF IMPORTANT FEATURES OF REPORTED FLUORIDE ION SENSORS

Probe	End point	Solvent	Detection time	Detection limit	Mechanism	Applications	Ref.
Probe 1	Fluorometric changes from light green to bright green	Acetonitrile-MeOH (9:1, v/v)	n.d.	n.d.	Inhibition of PET process and hydrogen bonding	–	[34]
Probe 2	Fluorometric changes from light green to bright green and colorimetrically from brown to brownish yellow	HEPES buffer (pH = 7.4, containing 30% CH_3CN, v/v)	10 min	5.4×10^{-6} M	F-triggered Si–O bond cleavage **Probe 2** and a subsequent rigidizing, cyclization reaction	Living HaCaT cells	[35]
Probe 3	Fluorometric changes from light green to bright green and colorimetrically	DMSO	7 min	1.03 μM (19.6 ppb)	Cleavage of the Si–O bond of **Probe 3** and release of carboxy fluorescein-based fluorophor	Living cells (HeLa cells)	[36]
Probe 4	Fluorometric changes from slight yellow to orange and colorimetrically from blue to green	Ethanol and water (3:7, v/v) solution containing phosphate buffered saline (PBS) (20 mM, pH 7.4)	50 min	0.08 mM	ICT-mechanism between **Probe 4** and F-and the cleavage of Si-O bond in **Probe 4**	RAW 264.7 macrophage living cells	[37]
Probe 5	Fluorometric changes from colorless to bright red	HEPES buffer solution (10 mM, pH 7.4) containing acetonitrile (20% by volume)	60 min	Below 4 ppm	Fluoride-mediated desilylation process to produce iminocoumarin	Zebrafish (head, abdomen, and tail parts)	[38]
BBTGA	Fluorometric changes from colorless to green	PBS (phosphate buffered saline) (DMSO 0.5%, pH = 7.4)	5 min	n.d.	Fluoride-mediated desilylation process	KB human carcinoma cell lines	[39]
Probe 6	Fluorometric changes from blue to light blue	THF	n.d.	2.01×10^{-10} M	Binding of F- towards the Boron centre of **Probe 6**	–	[40]
Probe 7	Fluorometric changes from blue to green and colorimetrically from colorless to yellow	(9:1) ethanol-HEPES buffer (10 mM, pH = 7.4) solution	60 min	n.d.	Fluoride-mediated desilylation process and production of ammine derivative of **Probe 7**	A549 (human lung carcinoma) cell line	[41]
BODIPY 4	Fluorometric changes from yellow to green and colorimetrically from orange to pink	THF medium	n.d.	n.d.	Photoinduced electron transfer process from BODIPY to trivalent boron	–	[42]
Probe 8	Fluorometric changes from colorless to red and colorimetrically from yellow to pink	THF	5 min	60 nM (*i.e.* 1.15 ppb)	Fluoride-mediated desilylation process and production of resorufin	HeLa cell line	[43]
Probe 9	Fluorometric changes from colorless to blue	THF	2 h	n.d.	Fluoride triggered Si-O bond cleavage and formation of a highly fluorescent coumarin through cyclization reaction	–	[31]
TBPCA	Fluorometric changes from colorless to blue	HEPES buffer (water)	4 h	n.d.	ICT mechanism and Si-O bond cleavage upon the attack of fluoride ion on the silyl ether moiety	A549, human epithelial lung carcinoma cell	[44]
[1-DMAP]$^+$	Fluorometric changes from light green to bright green	$CHCl_3$	n.d.	n.d.	bond cleavage of [**1-DMAP**]$^+$ and formation of brightly fluorescent **1–F**	–	[45]

Probe 10	Colorimetric changes from colorless to pink	Acetonitrile:water (7:3) (v/v) solutions buffered to pH = 2.5 with 0.1 M potassium hydrogenphthalate and HCl acid	n.d.	n.d.	–	Commercial toothpaste	[46]
Probe 11	Colorimetric changes from colorless to yellow	Acetonitrile	n.d.	n.d.	The interaction of the thiourea-hydrogen atoms with the fluoride ion via hydrogen bonding	–	[47]
Probe 13	Colorimetric changes from yellow to purple for **Probe 13**	Dichloromethane and DMSO	n.d.	n.d.	Hydrogen bonding between pyrrole NH groups of **Probe 12** and **Probe 13** and F^-	–	[48]
Probe 14	Fluorometric changes from light blue to bright blue	THF	n.d.	n.d.	Decrease in the degree of the through-space interaction between the anthryl groups by the structural change from tetrahedral **Probe 14** to trigonal bipyramidal **Probe 14-F**	–	[49]
Probe 15	Fluorometric changes from light blue to bright blue	DMSO	n.d.	0.38 ppm	Structural change from tetrahedral **Probe 15** to trigonal bipyramidal **Probe 15-F**	Tap water sample (College Station, TX) and bottled water (Evian, France)	[50]
Probe 16	Colorimetrically from yellow to brown	Acetonitrile	5 min	n.d.	Si-O bond cleavage facilitated by fluoride anions will generate strong intramolecular charge transfer (ICT)	(PMMA) films impregnated with **Probe 16** and **Probe 17**	[51]
Probe 17	Colorimetrically from purple to green						
Probe 18	Fluorometric changes from light blue to bright blue	CH_2Cl_2	n.d.	n.d.	Si-O bond cleavage reactions of **Probe 18** and hydrogen bonding	–	[52]
Probe 20	Fluorometric changes from colorless to red and colorimetrically from pale yellow to pink	CH_3CN/H_2O (50:50, v/v), CH_3CN	3 min	n.d.	Fluoride-triggered Si-O bond cleavage that results in the formation of a highly fluorescent resorufin	–	[53]

n.d. = not detected

researchers, so far as fluoride ion detection and quantification is concerned. Sahana & Dutta [54] had thoroughly discussed the ratiometric approach in a recent critical review and hence, this review is dedicated to t he discussion of the merits and demerits of colourimetric and fluorometric sensors only.

Comparative study of the fluoride sensing Probes

Detection time: From the above table, it is evident that **Probe 20** is most efficient with a detection time of 3 min. A close peer of **Probe 20** is **Probe 8** with a detection time of 5 min. Both these probes contain the resorufin moiety which is principally responsible for a very quick detection of fluoride ion. Similarly, **BBTGA**, **Probe 16** and **Probe 17** also possess a quick detection time 5 min although **Probe 16** and **Probe 17** comprise of **BODIPY** moiety while **BBTGA** contain benzothiazole as the active fluorophore. Hence, all these 5 probes may be considered as equally effective so far as the detection time is concerned and the choice for applicability of these probes has to be determined by comparing the other parameters.

Detection limit: Among the studied sensors, **Probe 6** has a detection limit of 2.01×10^{-10} M of fluoride ion, while its closest competitor is **Probe 8** with a detection limit of 60 nM. Rest of the probes have much lower detection limit typically ranging in mirco-molar concentration of fluoride ion.

Water solubility: TBPCA is unique among all the probes because of its functioning in aqueous medium (HEPES buffer). The increased water solubility is due to the incorporation of 4-acetic acid group with methyl tagged coumarin. This side chain not only increases the cell permeability of the active fluorophore but also enhances its retaintivity of the fluorophore within the cell because of the negatively charged carboxylate group, thereby providing a better insight of the sensor mechanism of association of the fluorophore with fluoride ion within the cell.

Probe 5 stands next to **TBPCA** for its applicability in aqueous medium as its working solvent is found to be water: acetonitrile (80:20, v/v) in HEPES buffer, while **Probe 2** is close to **Probe 5** with its applicability in water:acetonitrile (70:30, v/v) in HEPES buffer. It may be mentioned here that with coumarin based fluorophores, the water solubility is found to be increased and hence coumarin may be considered as the fluorophore of choice for designing sensors that can work effectively for water soluble fluoride samples.

However, there is no unique probe which can be singled out as the best sensor for fluoride ion detection as each one of them has some merits on one parameter, while the other has better quality on a different parameter. For example, while **TBPCA** is applicable in aqueous medium, **Probe 20** has the minimum detection time of 3 min and **Probe 6** has the lowest detection limit of 2.01×10^{-10} M of fluoride ion. It will be intriguing for future researchers to design sensors for fluoride ion detection with optimized value of all the parameters like time of detection, detection limit *vis-a-vis* its applicability in applicability in aqueous medium.

Conclusion

This review article provides an overview of the many viewpoints on the colorimetric and fluorescent sensors for the detection and measurement of fluoride ions among other competing anions in water or other solvents as well as the research conducted on their potential uses. Discussion regarding the working solvent system, limit of detection, association constant, time required for sensing, studies involving interference of other anions, mechanism of sensing, sensing properties and their applications in the real samples as well as biological samples. Fluoride ions specific changes in the wavelength as observed by naked eye and emission/fluorescence colour changes are also thoroughly discussed. The principal mechanisms that have been utilized for fluoride ion sensing namely silicon-oxygen bond cleavage, formation of monomer boron-fluorine bond, deprotonation of amide bond by means of strong H···F hydrogen bonding, silicon-fluorine bond formation and antimony-fluorine bond formations are also extensively discussed. Strategic designing of the probes *vis-a-vis* their advantages and disadvantages so far as the various parameters are concerned, with respect to detection and identification of fluoride ion in water and biological samples have also been critically analyzed. The use of chromophores like benzothiazoliumhemicyanine, naphthalimide, benzothiazole, benzoxadiazole, thiourea, rhodamine, BODIPY, fluorescein, coumarine, resorufin, anthracene derivatives possessing huge importance as colourimetric and fluorescent sensors, as well as disease-related study in cells have been discussed in this review. A critical analysis of the probes in view of their use in aqueous medium and possible ways to improve their solubility in water or water-based medium have also been discussed. It is hopeful that the concepts regarding the principles of fluoride ion detection and explanations of the observations that have been discussed in this review article would further enhance the ability of future researchers to design colourimetric and fluorescent probes for the qualitative and quantitative determination of fluoride anion with increased selectivity and to realize their mechanism of sensing, solvent dependency, wavelength or colour changes as well as their applications in therapeutic usage.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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Article

Multifunctional Interpenetrated 3D Supramolecular Structure Based on 1D Coordination Polymers: Selective Adsorption, Magnetism, Optical Property, Theoretical Analysis, and Electrical Conductivity

Soumen Kumar Dubey, Biplab Biswas, Dibakar Halder, Suman Mallick,* Indrajit Saha, Kajal Gupta, Sanjib Giri, Abhay Shankar Patra, Corrado Rizzoli,* Ajit Kumar Meikap, Subham Bhattacharjee,* and Rajat Saha*

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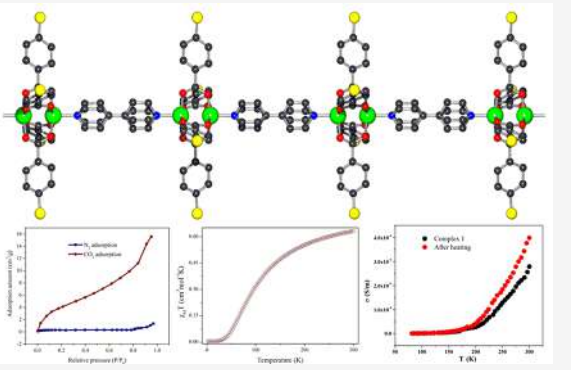
ABSTRACT: A paddle-wheel-based multifunctional 1D coordination polymer (CP) $\{[Cu_2(4\text{-Cl-Bz})_4(4,4'\text{-bipy})](DMF)_2\}_n$ (where 4-Cl-BzH = 4-chlorobenzoic acid, 4,4′-bipy = 4,4′-bipyridine, and DMF = dimethylformamide), (complex **1**) have been synthesized via the solvothermal method and characterized by single-crystal X-ray diffraction analysis along with other spectroscopic studies. Structural analysis shows that **1** crystallizes in the tetragonal $P4_{/ncc}$ space group and 1D coordination chains are formed by connecting $[Cu_2(4\text{-Cl-Bz})_4]$ paddle wheel units using 4,4′-bipy moieties along the crystallographic *c* axis. These 1D coordination chains are assembled to each other through weak $\pi\cdots\pi$ interactions to form interpenetrated 3D supramolecular structure, forming channels along the [1 1 0] and [−1 1 0] direction hosting DMF molecules. Hirshfeld surface analysis and corresponding 2D fingerprint plots indicate that $\pi\cdots\pi$ interaction is the major interaction among the coordination chains. Thermal analysis shows that guest DMF molecules are released within the temperature range of 70−150 °C and powder X-ray diffraction (PXRD) analysis reveals the quenching of the void space after removal of the solvent molecules. The desolvated framework selectively adsorbs CO_2 over N_2. The magneto-luminescent behavior of the framework has also been studied. This π-induced 3D supramolecular complex shows semiconducting behavior and conductivity increases upon desolvation.



1. INTRODUCTION

Metal−organic frameworks (MOFs) or coordination polymers (CPs) have gained much attention based on their structural diversity and porosity-dependent functionalities like gas and solvent adsorption, catalysis, sensing, guest-dependent magnetism, and so on.[1−10] Recently, design of multifunctional MOFs has become the prime focus in order to control one functionality through another property, for example, photomagnetism,[11] photoconductivity,[12] magnetoresistance,[13] etc. Previously, a number of research groups have reported a huge number of MOFs[14] having multiple functionalities like porosity with magnetism,[15] porosity with catalysis,[16] magnetism and catalysis,[17] porosity and sensing,[18] catalysis and sensing,[19] magneto-luminescence, etc.[20] For example, Sheikh and coworkers have widely explored the magneto-luminescent properties of Lanthanide CPs based on the partially filled 4f orbitals.[21−25] In this regard, 1D or 2D CPs have gained more attention than 3D ones due to their structural flexibility.[26] 1D or 2D frameworks can modify the interlamellar spaces available after the removal of the guest molecules[27] or even can transform a nonporous framework to a porous one.[28] These structural changes can be both reversible or irreversible.[29]

In coordination chemistry, $[M_2(RCOO)_4]$ paddle-wheel clusters have been extensively used as secondary building units in designing different types of complexes having geometries from 0D to 3D.[30] The so-called HKUST-1 is a 3D CP formed by connecting $[Cu_2(RCOO)_4]$ paddle-wheel units by tripodal benzene tricarboxylate ligands.[31] Numerous 1D CPs having $[M_2(RCOO)_4]$ paddle-wheel units are synthesized using different types of monocarboxylic acids in combination with different di-topic bridging organic ligands like pyrazine, 4,4′-bipyridine, etc.[32] These 1D coordination chains are further packed mostly through $\pi\cdots\pi$ interactions to form 3D supramolecular structures.[33] Different research groups have

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Insight on the presence of dimethylammonium cation within anionic metal-organic supramolecular host: structural, Hirshfeld surface, optical and theoretical analysis

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ABSTRACT

A new supramolecular metal-organic complex, $[(DMA)^{+}\{Fe(IDA)_2\}^{-}]$ (where H_2IDA = iminodiacetic acid and DMA = dimethylammonium cation) (**1**), has been synthesized solvothermally at 90 °C from reaction of ferric(III) chloride hexahydrate with nitrilotriacetic acid (H_3NTA) in stoichiometric ratio. The complex was characterized by single crystal X-ray diffraction (SCXRD) along with spectroscopic analyses. During the reaction process, H_3NTA is degraded into IDA^{2-} ligand. Structural analysis reveals that **1** is mononuclear and crystallizes in the monoclinic space group *C2/c*. Within the $[Fe(IDA)_2]^{-}$ unit, Fe^{3+} shows six-coordinate distorted octahedral geometry. The $[Fe(IDA)_2]^{-}$ units are connected by strong N1-H1···O4 hydrogen bonds to form anionic 2D supramolecular layers which are further connected by weak C-H···O hydrogen bonds to form a 3D metal-organic supramolecular host (MOSH) structure having 1D supramolecular channels along the crystallographic *c*-axis. DMA cations are present within the supramolecular channels through N2-H2···O2 hydrogen bonding interactions. Hirshfeld surface analysis and corresponding 2D fingerprint plots indicate that O···H interactions are the major supramolecular interactions present between MOSH and guest DMA cation. DFT calculations reveal that the HOMO and LUMO of the $[Fe(IDA)_2]^{-}$ unit are composed of mixed metal-ligand orbitals. Both the absorption and emission spectra of the complex were studied in aqueous phase and the result was correlated with the TDDFT study.

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Metal-organic supramolecular host; weak interactions; Hirshfeld surface analysis; optical property; TDDFT study

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Review

Strategies to Improve Electrical Conductivity in Metal–Organic Frameworks: A Comparative Study

Rajat Saha,* Kajal Gupta, and Carlos J. Gómez García*

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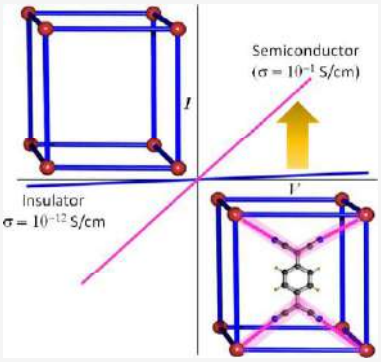
ABSTRACT: Metal–organic frameworks (MOFs), formed by the combination of both inorganic and organic components, have attracted special attention for their tunable porous structures, chemical and functional diversities, and enormous applications in gas storage, catalysis, sensing, etc. Recently, electronic applications of MOFs like electrocatalysis, supercapacitors, batteries, electrochemical sensing, etc., have become a major research topic in MOF chemistry. However, the low electrical conductivity of most MOFs represents a major handicap in the development of these emerging applications. To overcome these limitations, different strategies have been developed to enhance electrical conductivity of MOFs for their implementation in electronic devices. In this review, we outline all these strategies employed to increase the electronic conduction in both intrinsically (framework-modulated) and extrinsically (guests-modulated) conducting MOFs.



1. INTRODUCTION

In modern society, the implications of electronic devices are enormous. Currently the main efforts are focused on the miniaturization and more efficient device fabrication at the nanoscale.[1,2] Although classic metals, such as Cu, Ag, etc., are commonly used as conducting materials, there are also many applications that require semiconductors,[3] including inorganic[4] and organic ones.[5] Pure elements (Si, Ge), metal-oxides/chalcogenides (ZnO, CdS, etc.), and doped metals (groups II–VI or III–V) have been used extensively in the semiconductor industry.[4,6−8] The electron conduction in these inorganic materials follows the band model.[9] On the other hand, organic molecules, charge transfer donor–acceptor molecules and organic polymers have gained much attention in organic electronics.[10] Electron conduction in organic molecules and polymers depends on the conjugation of π-electrons, while the electron/hole transfer occurs between the donor–acceptor pairs.[11] Thanks to their physical and chemical properties and their charge transport behavior, hybrid organic–inorganic structures as metal–organic frameworks (MOFs) have found a rapid development in the past decade as conducting materials.[12−14]

Metal–organic frameworks (MOFs) are a class of hybrid organic–inorganic materials having potential voids and a periodic three-dimensional structure formed by connected discrete metal ions or clusters with different di- or polytopic organic ligands.[15−18] The most interesting feature of MOFs is that their structure, topology, and pore functionality can be tuned in a controlled manner through judicious selection of metal ions and bridging organic ligands.[19,20] These distinct structural features of large porosity, chemically functionalized cavities, flexible skeletons, etc., make them suitable for gas and solvent adsorption,[21,22] storage[23] and separation,[24] catalysis,[25] sensing,[26] drug delivery,[27] etc. Recently, electrically conductive MOFs[28,29] have gained much attention for their numerous applications in electrocatalysis,[30] capacitors,[31] charge storage,[32] chem-resistive sensing,[33] etc., along with their porosity-based functionalities. Generally, small organic ligands, as used in conventional MOF synthesis, are weak electrical conductors, and the poor overlap between p-orbitals of ligands and d-orbitals of metal ions results in insulating or poorly conducting MOFs, which constitutes the major obstacle for practical applications of conducting MOFs.[34] However, conducting MOFs have several advantages, like: (a) the structural rigidity and the doping of inorganic semiconductors can be modified through organic functionalization; (b) amorphous organic polymers can be converted into crystalline MOF structures trough bonding with metal ions; (c) the infinite choice of metal ions and organic bridging ligands provides enormous opportunity to modulate the structure and topology, i.e., the compositional versatility offers the possibility to modulate the functionality through infinite ways; (d) detailed structural analysis offers a platform to tailor the electrical properties for suitable and desired

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Pseudo-prime submodule elements of an le-module

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Here we introduce and study the concept of pseudo-prime submodule elements of an le-module. The pseudo-prime submodule elements of an le-module are useful to characterize several class, like topological, multiplication, content, pseudo-primeful le-modules. Besides we extend the Nakayama's lemma to le-modules.

Keywords: Pseudo-prime submodule element; topological le-module.

AMS Subject Classification: 13C05, 16P70

1. Introduction

We introduced [2] the concept of le-modules over a commutative ring as an abstraction of the lattice of all subsets of a module, with a view to developing an alternative "abstract submodule theory". In spite of an existing well-developed theory of lattice modules [6–9, 13, 15, 16], we introduced such a notion to study properties of a ring R more directly in the abstract framework of submodule theory. That is why we take action of a ring R on a lattice ordered monoid whereas in the existing theory of lattice modules, the action considered is of the multiplicative lattice of all ideals of a ring. For more details we refer to [2]. Also we refer to [10–12] for all results we already have on the characterizations of rings via le-modules.

In this paper, we study the pseudo-prime submodule elements of an le-module. This concept abstracts the pseudo-prime submodules of a module over a commutative ring [4, 5]. In Sec. 3, we introduce pseudo-prime radical of a submodule element n as the meet of all pseudo-prime submodule elements containing n.

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Pseudo-prime submodule elements of an le-module

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Abstract

Here we introduce and study the concept of pseudo-prime submodule elements of an le-module. The pseudo-prime submodule elements of an le-module are useful to characterize several class, like topological, multiplication, content, pseudo-primeful le-modules. Besides we extend the Nakayama's lemma to le-module

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Toxicity Prediction of Selected Phytochemicals of Hatisur Weed (*Heliotropium indicum* Linnaeus) and Synthetic Medicines: An *In Silico* Approach by Using ProTox-II Tool

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Abstract: ***Heliotropium indicum Linnaeus is a common medicinal weed known as Hatisur in Bengali and many parts of the Asian country. This plant contains several phytochemicals, which are used for many disorders and also anti-inflammatory agent. This study predicted different types of toxicity parameters viz. acute toxicity (rat oral LD_{50}), organ toxicity, toxicity and genotoxicity endpoints of selected phytochemicals of H. indicum and synthetic medicines (Indomethacin and Ibuprofen) by using ProTox-II online tool. The phytocompounds Heliotridine, Retronecine and β-Linalool were predicted class V, may be harmful if swallowed. All the phytochemicals were predicted inactive, while both the synthetic medicines were found active for hepatoxicity. All compounds were obtained non-neurotoxic except Trachelanthamidine and Indomethacin. There were 5 compounds viz. Heleurine, Heliotridine, Trachelanthamidine, β-Linalool and Ibuprofen non-nephrotoxic. Only 2 compounds viz. β-Linalool and Ibuprofen were found inactive for respiratory toxicity. All compounds were obtained clinical toxicity inactive while only 1 compound (Indomethacin) was obtained immunotoxic. Regarding toxicity endpoints, only 1 compound (β-Linalool) was obtained ecotoxic. Only 5 compounds viz. Indicine N-oxide, Trachelanthamidine, Supinine, β-Linalool and Ibuprofen were obtained inactive for clinical toxicity while. only 3 compounds viz. Trachelanthamidine, β-Linalool and Ibuprofen were found inactive for nutritional toxicity. All compounds were found non-cytotoxic and non-mutagenic while only 3 compounds viz. were β-Linalool, Indomethacin and Ibuprofen were obtained non-carcinogenic. In conclusion, β-Linalool can be used as non-toxic phytocompound and substituted as synthetic medicines viz. Indomethacin and Ibuprofen. Moreover, experimental assay is suggested to validate the present prediction with this phytocompound.***

Keywords: Anti-inflammatory agent, *Heliotropium indicum*, Predictive toxicity, *In silico*, Toxicity endpoints

1. Introduction

The medicinal weed in Bengali "Hatisur" and the scientific name *Heliotropium indicum* Linnaeus under the Family: Boraginaceae, this name as is derived from the Greek words "Helios" meaning "sun" and "Tropein" meaning "to turn," which is indicating that the flowers and leaves turn toward the sun. [1,2] This weed is commonly found throughout Bangladesh, Nepal, Sri Lanka, Thailand, India, and other areas of tropical Asia and in few sites of Africa.[3]

Interestingly, this medicinal weed has potential phytochemicals to prevent many disorders such as inflammation, pain, bone fracture, nociceptive activity, wound healing, etc. [2,4-6] But some studies reported that plant extract may contain allelochemicals cause allelopathy and toxicity to animals. [7,8]

With regards, prior to using crude extract, toxicity screening is extreme concern based on *in vitro* and *in vivo* assay, but these studies may take long-duration, huge laboratory cost and animal sacrifice. Whereas *in silico* prediction through computational tools helps faster screening, no animal harming and inexpensive method.[9,10] In recent research, many investigators reported *in silico* toxicity prediction of natural and synthetic compounds for new drug design. [9-12]

This study was focused to predict toxicity of selected phytochemicals of Hatisur weed (*Heliotropium indicum* Linnaeus) and synthetic medicines used for anti-inflammation by using ProTox II online tool.

2. Materials and Methods

All established phytochemicals of *Heliotropium indicum* Linnaeus and synthetic medicines viz. Indomethacin and Ibuprofen were considered from available literature. [2,4]

As per the protocol by Banerjee et al.[10] in the ProTox-II online tool (version, 3.0) in which different types of toxicity parameters viz. acute toxicity (rat oral LD_{50}),[9] organ toxicity, toxicity and genotoxicity endpoints of selected phytochemicals of *H. indicum* and synthetic medicines (Indomethacin and Ibuprofen) were evaluated.

The pictorial representation of medicinal weed specimen is exhibited in Fig 1.

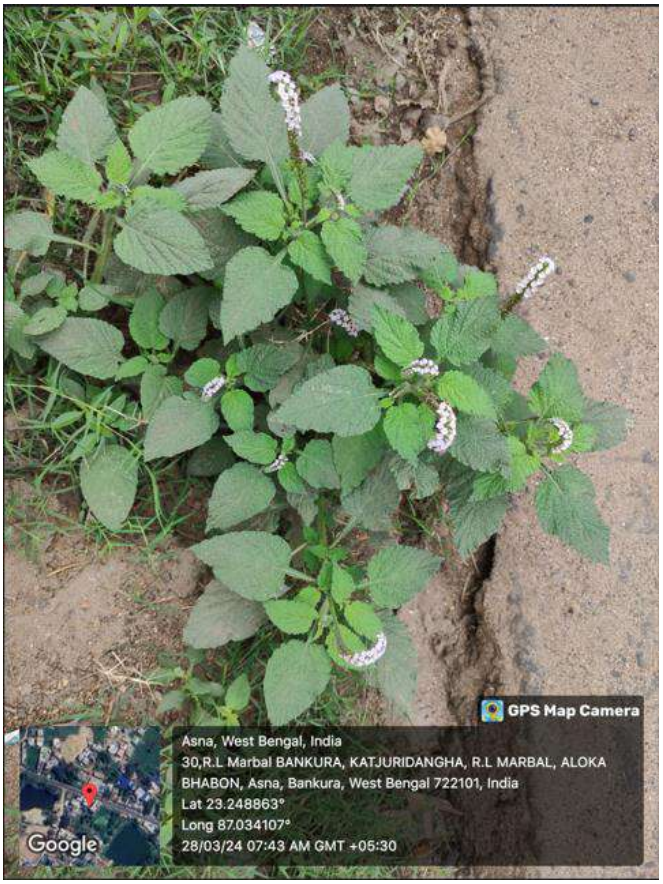


Fig 1: Medicinal weed specimen (*Heliotropium indicum* Linnaeus)

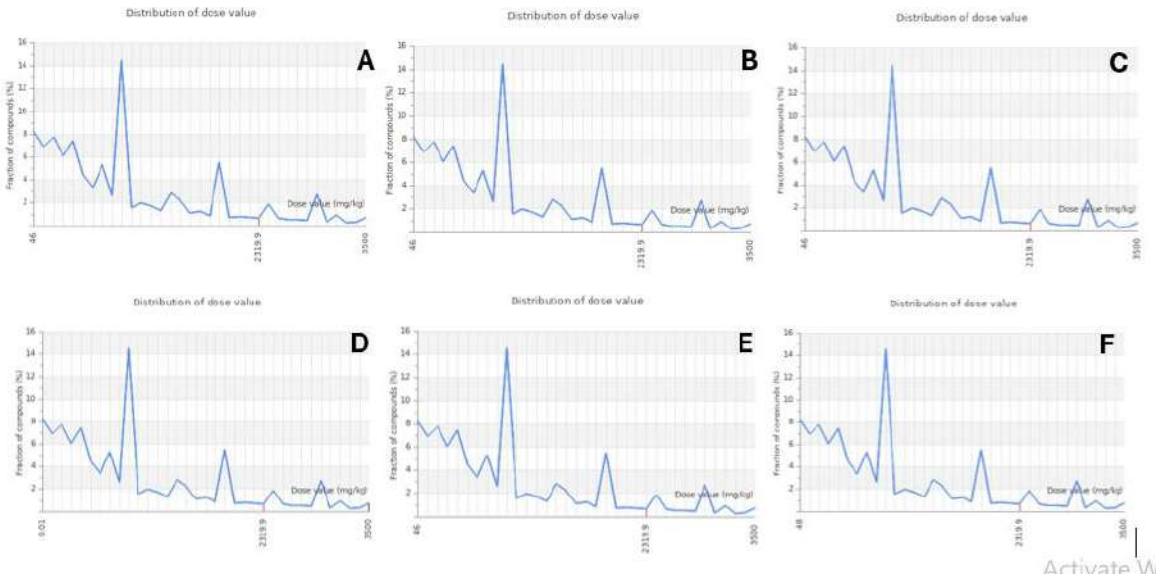
3. Results

Table 1 summarizes the values of predictive oral acute (LD_{50}) toxicity (mg/Kg), class and predictive accuracy of phytochemicals and synthetic medicines. The phytocompounds Heliotridine, Retronecine and β-Linalool were predicted class V, may be harmful if swallowed. Fig 2 depicts the dose response curves of studied compounds.

Table 1: Prediction of acute toxicity of phytochemicals of areal parts of *H. indicum* and synthetic medicines

Sl. No.	Compounds name	Rat oral LD_{50} value (mg/Kg)	Predicted toxicity class	Probability
Phytochemicals				
1.	Heleurine	46.0	II	69.26
2.	Echinatine	46.0	II	70.97
3.	Heliotrine	46.0	II	70.97
4.	Heliotridine	3500.0	V	67.38
5.	Indicine	46.0	II	70.97
6.	Indicine N-oxide	48.0	II	69.26
7.	Lasiocarpine	110.0	III	100.00
8.	Trachelanthamidine	227.0	III	70.97
9.	Retronecine	3500.0	V	67.38
10.	Supinine	46.0	II	69.26
11.	β-Linalool	2200	V	100.00
Synthetic medicines				
1.	Indomethacin	12.0	II	100.00
2.	Ibuprofen	299.0	III	100.00

Class II: fatal if swallowed ($5 < LD_{50} \leq 50$); Class III: toxic if swallowed ($50 < LD_{50} \leq 300$); Class V: may be harmful if swallowed ($2000 < LD_{50} \leq 5000$)



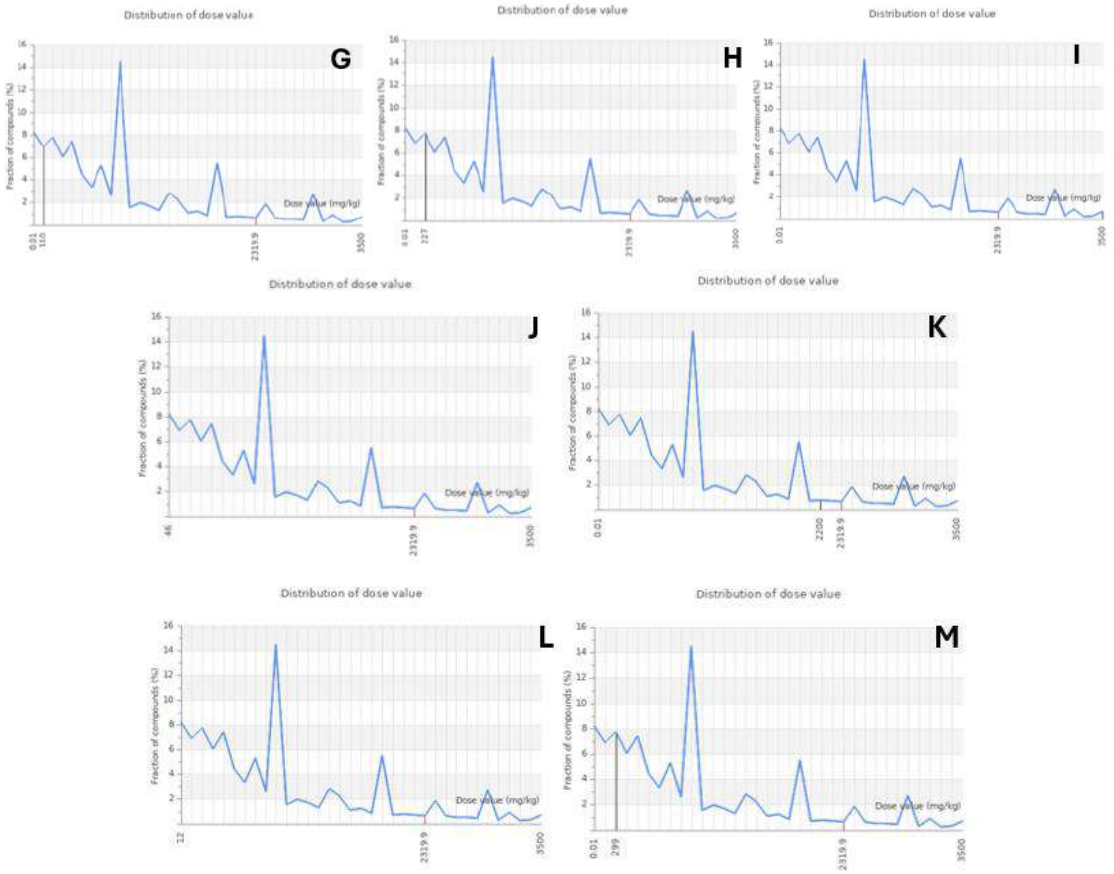


Figure 2: Dose response curve for phytochemicals of areal parts of *H. indicum* and synthetic medicines (A = Heleurine; B = Echinatine; C = Heliotrine; D = Heliotridine; E = Indicine; F = Indicine N-oxide; G = Lasiocarpine; H = Trachelanthamidine; I = Retronecine; J = Supinine; K = Indomethacin; L = Ibuprofen

Table 2 predicts organ toxicity of phytochemicals of areal parts of *H. indicum* and synthetic medicines. For hepatotoxicity, all phytochemicals were obtained inactive while both the synthetic medicines were found active for hepatoxicity. For neurotoxicity, all compounds were obtained non-neurotoxic except Trachelanthamidine and Indomethacin. For nephrotoxicity, 5 compounds viz. Heleurine, Heliotridine, Trachelanthamidine, β-Linalool and Ibuprofen were non-nephrotoxic. For respiratory toxicity, 2 compounds viz. β-Linalool and Ibuprofen were found inactive. All compounds were obtained clinical toxicity inactive while only 1 compound (Indomethacin) was obtained immunotoxic.

Table 2: Prediction of organ toxicity of phytochemicals of areal parts of *H. indicum* and synthetic medicines

Sl. No.	Compounds name	HT	P	NT	P	NPT	P
Phytochemicals							
1.	Heleurine	I	0.92	I	0.65	I	0.51
2.	Echinatine	I	0.90	I	0.66	A	0.53
3.	Heliotrine	I	0.91	I	0.66	A	0.53
4.	Heliotridine	I	0.91	I	0.52	I	0.58
5.	Indicine	I	0.90	I	0.66	A	0.79
6.	Indicine N-oxide	I	0.77	I	0.75	A	0.52
7.	Lasiocarpine	I	0.89	I	0.67	A	0.54
8.	Trachelanthamidine	I	0.92	A	0.54	I	0.60
9.	Retronecine	I	0.91	I	0.52	I	0.58
10.	Supinine	I	0.90	I	0.66	A	0.50
11.	β-Linalool	I	0.76	I	0.62	I	0.87
Synthetic medicines							
1.	Indomethacin	A	0.86	A	0.59	A	0.59
2.	Ibuprofen	A	0.66	I	0.89	I	0.52
		RT	**P**	**CT**	**P**	**IT**	**P**
Phytochemicals							
1.	Heleurine	A	0.79	I	0.78	I	0.97
2.	Echinatine	A	0.79	I	0.74	I	0.99
3.	Heliotrine	A	0.81	I	0.76	I	0.97
4.	Heliotridine	A	0.74	I	0.74	I	0.89
5.	Indicine	A	0.79	I	0.74	I	0.99
6.	Indicine N-oxide	A	0.76	I	0.75	I	0.98
7.	Lasiocarpine	A	0.80	I	0.78	I	0.87
8.	Trachelanthamidine	A	0.69	I	0.72	I	0.99
9.	Retronecine	A	0.74	I	0.74	I	0.99
10.	Supinine	A	0.80	I	0.77	I	0.99
11.	β-Linalool	I	0.99	I	0.75	I	0.99
Synthetic medicines							
1.	Indomethacin	A	0.87	I	0.91	A	0.62
2.	Ibuprofen	I	0.77	I	0.71	I	0.99

HT = Hepatotoxicity; NT = Neurotoxicity; NPT = Nephrotoxicity; RT = Respiratory toxicity; CT = Cardiotoxicity; IT = Immunotoxicity, I= Inactive; A = Active; P = Probability

Table 3 predicts toxicity endpoints such as ecotoxicity, clinical toxicity and nutritional toxicity of phytochemicals of areal parts of *H. indicum* and synthetic medicines. For ecotoxicity, only 1 compound (β-Linalool) was obtained ecotoxic. For clinical toxicity, 5 compounds viz. Indicine N-oxide, Trachelanthamidine, Supinine, β-Linalool and Ibuprofen were obtained inactive. For nutritional toxicity, 3 compounds viz. Trachelanthamidine, β-Linalool and Ibuprofen were found inactive.

Table 3: Prediction of toxicity endpoints of phytochemicals of areal parts of *H. indicum* and synthetic medicines

S. No.	Compounds name	ET	P	CLT	P	NUT	P
Phytochemicals							
1.	Heleurine	I	0.52	A	0.50	A	0.53
2.	Echinatine	I	0.64	A	0.59	A	0.71
3.	Heliotrine	I	0.64	A	0.61	A	0.69
4.	Heliotridine	I	0.63	A	0.58	A	0.57
5.	Indicine	I	0.64	A	0.59	A	0.71
6.	Indicine N-oxide	I	0.59	I	0.67	A	0.71
7.	Lasiocarpine	I	0.68	A	0.60	A	0.69
8.	Trachelanthamidine	I	0.51	I	0.57	I	0.63
9.	Retronecine	I	0.63	A	0.58	A	0.57
10.	Supinine	I	0.58	I	0.50	A	0.60
11.	β-Linalool	A	0.56	I	0.63	I	0.70
Synthetic medicines							
1.	Indomethacin	I	0.69	A	0.70	A	0.77
2.	Ibuprofen	I	0.59	I	0.71	I	0.96

ET = Ecotoxicity; CLT = Clinical toxicity; NUT = Nutritional toxicity; I= Inactive; A = Active; P = Probability

Table 4 predicts genotoxicity endpoints such as cytotoxicity, mutagenicity and carcinogenicity of phytochemicals of areal parts of *H. indicum* and synthetic medicines. All compounds were found non-cytotoxic and non-mutagenic while only 3 compounds viz. were β-Linalool, Indomethacin and Ibuprofen were obtained non-carcinogenic.

Table 4: Prediction of genotoxicity endpoints of phytochemicals of areal parts of *H. indicum* and synthetic medicines

S. No.	Compounds name	CYT	P	MUT	P	CARC	P
Phytochemicals							
1.	Heleurine	I	0.67	I	0.80	A	0.76
2.	Echinatine	I	0.66	I	0.91	A	0.83
3.	Heliotrine	I	0.66	I	0.86	A	0.79
4.	Heliotridine	I	0.74	I	0.89	A	0.59
5.	Indicine	I	0.66	I	0.91	A	0.83
6.	Indicine N-oxide	I	0.66	I	0.80	A	0.71
7.	Lasiocarpine	I	0.65	I	0.83	A	0.92
8.	Trachelanthamidine	I	0.73	I	0.75	A	0.54
9.	Retronecine	I	0.74	I	0.99	A	0.59
10.	Supinine	I	0.66	I	0.87	A	0.79
11.	β-Linalool	I	0.82	I	0.95	I	0.64
Synthetic medicines							
1.	Indomethacin	I	0.79	I	0.86	I	0.63
2.	Ibuprofen	I	0.85	I	0.99	I	0.74

CYT = Cytotoxicity; MUT = Mutagenicity; CARC = Carcinogenicity; I = Inactive; A = Active; P = Probability

4. Discussion

The phytocompounds Heliotridine, Retronecine and β-Linalool were predicted class V, may be harmful if swallowed but rest compounds were obtained class II (fatal if swallowed) and III (toxic if swallowed). Earlier toxicity studies reported that 14-day oral administration of 1–2 gm/kg of *H. indicum* aqueous extracts induced pathological impacts on the liver, kidney, heart, and lungs, [2,13] which is supported the present study that most of the phytocompounds obtained nephrotoxic and respiratory toxic but did not show hepatoxicity and cardiotoxicity.

Moreover, pain relief was observed by ethanolic and aqueous extracts of the aerial parts of *H. indicum* (30-300 mg/kg) in a mouse model after formalin-induced pain. [2,13] In another study, the chloroform extract of leaf of *H. indicum* extract (150 mg/kg of body weight) observed a significant anti-inflammatory effect (80.0%) on carrageenan-induced paw edema in albino Wistar rats.[14]

All compounds were found non-cytotoxic and non-mutagenic while only 3 compounds viz. were β-Linalool, Indomethacin and Ibuprofen were obtained non-carcinogenic. Azeez et al. [15] observed chromosomal aberrations for the cytotoxic and genotoxic activities of *H. indicum*.

In the present study, β-Linalool observed inactive for the studied parameters except ecotoxicity. An agreement with earlier study that Linalool has anti-inflammatory effects.[16] On the other hand, for genotoxicity end points, β-Linalool did not observe cytotoxicity, mutagenicity and carcinogenicity, which is an agreement with other experimental study that Linalool was found non-genotoxic. [17]

5. Conclusion

In conclusion, among these phytocompounds and synthetic medicines, β-Linalool was found to be better efficacious for all toxicity parameters like Indomethacin and Ibuprofen like drugs. Moreover, experimental assay is suggested to validate the present prediction with this phytocompound.

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Conflict of interest
It is declared none.

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899. Boosting ESD (Education for Sustainable Development) through Teacher Education: A Modular Approach

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ABSTRACT

A functioning social structure is essential for human survival because we are social beings. All the natural systems are perpetuated by a balance between humans and nature. If mankind interrupts this rhythm, it affects all of nature, including humans. Thus, development must be sustainable to ensure that the coming generation can survive properly. Sustainable means something lengthy or persistent. The prime goal of every civilization is 'sustainable development'. The important element in attaining this target is education. Both deal with quality living, justice and social equality, socio-economic development, and other concerns. Even though it is widely known that teachers carry the spark for mankind, if a 'teacher educator' cultivates the crops of 'sustainable development' among his or her students, then its grounds would be firmly embedded in the culture and community. The teacher may provide helps in the production of law-abiding citizens and educate citizens to support the norms of society. The significance of "teacher education" in achieving the goal of 'sustainable development' is covered in the current study. In this study, researchers discuss the theoretical concept of 'Teacher Education' and 'Sustainable Development', how teacher education programmes boost ESD, and the Global and Indian perspectives of 'sustainable development' in the field of 'Teacher Education'.

Keywords: Teacher Education, Education for sustainable development (ESD), Modular Approach, Sustainable development.

Introduction

Education is the cornerstone of any successful civilization. Education is a fundamental aspect of a nation's overall development and position in the global community. Education is necessary for all these facets of human life. Within the context of education, the role of the teacher is especially important. If the role of the teacher is so important, then we must educate the teachers in such a way that they can perform their duties perfectly. Here comes the role of teacher education. "Teacher education" teach educators how to interact with students and facilitate effective learning. The purpose is to prepare the applicants to acquire and gain knowledge of numerous topics through procedures, regulations, and policies. The would-be teachers receive training to have the best teaching abilities, information, attitudes, and behaviours needed for a learning environment, such as a classroom or school.

Today, sustainable development is not a new notion. The idea behind sustainable development is that our use of resources should be managed in a way that strikes a balance between meeting our immediate requirements and ensuring that those resources are available in the future. Brundtland (1987), the former director of the WHO, defined sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." Something is said to be sustainable if it is valuable and can be maintained over an extended period in ways that do not cause harm to people but do provide them with equivalent benefits. The interaction between the environment, the economy, and society as it moves forward and adapts is what people mean when they

talk about development. A higher quality of life for all people, both in the here and now and for future generations, is one of the primary goals of sustainable development**.**

ESD relies on a well-trained teaching professional, so these programmes must continue to evolve to meet the needs of the area. That is why it's essential to enhance and customize teacher preparation programmes to advance education for sustainable development. To accomplish this, numerous efforts were made, and various models were developed. Thus, consequently, researchers not only talk about the theoretical parts but also strive to concentrate on how teacher education enhances ESD. In addition, scholars designed a structural framework stressing the importance of teacher education programmes in boosting the effectiveness of the implementation process of education for sustainable development.

Key Intends of the Work

The major purposes of the research are written below-

- To know the theoretical concepts of Teacher education.
- To discuss the theoretical concepts of Sustainable development
- To analyze Teacher Education in the Context of ESD.
- To develop a model of ESD in the light of Teacher Education.

Theoretical concepts of Teacher Education

Teacher education is a programme of training or skilling young minds to teach the coming generation that starts from the pre-primary level and extends to higher education. In this context, NCTE defines it as "A programme of education, research and training of persons to teach from pre-primary to higher education level."

Teacher training is a crucial component of any educational system. Teacher education refers to the policies and practices created to provide teachers with the information, perspectives, and abilities they need to carry out their duties successfully in the classroom and at school. Teacher education assists teacher educators in how to interact with students and facilitate effective learning. From 1906 to 1956, the teacher preparation programme was known as 'teacher training.' Teachers were trained to think like mechanics and experts. It focuses on skill training only. As a result, the perspective and scope of teacher education were much bounded. According to W.H. Kilpatrick, "Training is given to animals and circus performers, while education is to human beings." Teacher education is an umbrella term that includes content mastery, professional expertise, and experience.

Teacher Education = Content Mastery + Professional Expertise + Experience

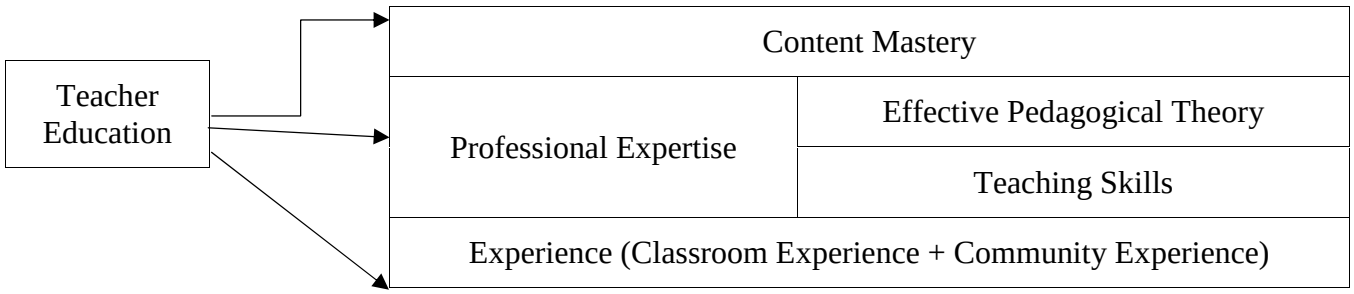

Fig-1: Components of Teacher Education

Teacher Education comprises Content Mastery, Professional Expertise and Experience (Fig-1). Content mastery means mastery over the subject. This has been acquired over a long period of academic exercise, at least for five years.

Professional expertise means professional skills, including methods, strategies and techniques. It helps the teachers to develop professionally. It is the combination of Effective Pedagogical Theory and Teaching Skills. Effective Pedagogical theory means Ideological, Psychological and socio-cultural ideas that give teachers a solid foundation for putting their teaching skills into practice in the classroom. This theory helps teachers to know learners' needs and understand their age-specific demands. Teaching skills indicate practice and training in education. It indicates the various techniques, strategies, and methods that would assist teachers in planning and delivering instruction, ensuring adequate reinforcement and conducting the practical evaluation. Skills in classroom management, planning, and presenting information to students are also part of this category.

Experience is one of the important components of teacher education. It's gathered in two ways: one is in Classroom, called Classroom Experience, and another is community experience acquired through numerous interactions with community members and one's own life experience.

Theoretical Concepts of Sustainable Development

The word "sustainability" originates from the Latin word "sustinere," which means "to keep alive" and connotes either ongoing assistance or performance. Sustainable development is a strategy to a nation's economic growth without affecting the quality of the environment for present and future generations. According to "Brundtland Report (1987)", "sustainable development" was defined as "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs". Sustainable development has mainly three important components: economy, society and environment. Sustainable economic growth requires the use and preservation of natural resources; protection and preservation of the environment bring sustainability, and inclusive growth of society with reduced poverty and enhanced cultural and spiritual understanding promotes the highest social well-being. The picture below will help to understand the elements of sustainable education better.

Fig-2: Elements of sustainable development, (Purvis, 2019)

Teacher Education in the Context of ESD

Concept of ESD

ESD is a worldwide attempt to bring awareness about the environment among the upcoming generation through an organized effort. In this context, UNESCO says, "Education for sustainable development empowers learners to take informed decisions and responsible actions for environmental integrity, economic viability, and a just society, for present and future generations while respecting cultural diversity." It further adds, "Education for sustainable development allows every human being to acquire the knowledge, skills, attitudes and values necessary to shape a sustainable future" (UNESCO, 2014).

Goals of ESD

i. To combat climate change, biodiversity loss, resource depletion, and inequity, ESD equips students of all ages with the information they need to take action. As a result, students of all ages can bring positive economic, social and environmental change through their efforts and those of their communities.
ii. To assure environmental protection and conservation, social fairness, and economic sustainability by fostering the development of the informational knowledge, abilities, skills, understanding, mindset, and actions necessary to build a sustainable world.
iii. Promoting economic growth by providing quality education is a goal of ESD. Educating oneself increases one's income and the economy as a whole, according to studies both small and large. The only way to overcome extreme poverty is through quality education. Equality in economic development is related to the availability and affordability of quality of education. Thinking creatively and strategically is a key skill learned through teacher training programmes.
iv. Social well-being is another ingredient of ESD where the would-be teachers can be trained with the knowledge and skills, they need to make ethical judgments and contribute to improving their communities and the world. True teaching-learning has been seen as a crucial element of sustainable development by cultures all over the globe. ESD must be incorporated into high-quality education as a comprehensive, lifelong learning process. It encompasses all aspects of education, from the course contents and teaching strategies to the student's internal and external reactions to what they have studied.

ESD in Classroom Context

Education for sustainability must be given the central focus in teacher preparation programmes. Teachers can encourage students in the classroom to use and develop various learning strategies by employing various pedagogical approaches. Learners have the opportunity to develop and strengthen their knowledge, abilities, and insights when presented with new challenges. A good education is one in which the requirements of the students are thought of and cared for.

UNESCO, in 2005, compiled a list of ten important factors for effective ESD related to the student or to the educational system. The learner is accountable for five of these considerations. These are:

a) By identifying the learner's needs and interests.
b) By valuing the learner's prior knowledge and experience.
c) By customizing the material to the learner's needs and interests.
d) By employing a wide range of instructional strategies.
e) By improving the classroom setting.

As a fundamental principle of ESD, social equity can be understood as the effort to provide equal educational opportunities for all students. However, teachers have only begun connecting classroom practices with social justice. In the past, only students who were exceptionally skilled at reading,

remembering, and speaking could reach their full academic potential. Students who did not have these characteristics struggled academically and often dropped out of school, severely limiting their future employment and income prospects. It is crucial to our society and economy to address the problem of youth dropout. However, equality in the classroom can be addressed using a wide range of teaching strategies.

The primary determinants of equitable economic growth are the inclusivity, access, and quality of teacher education programmes, with good curricular and co-curricular programs. Future teachers tend to be more ambitious, and the knowledge and abilities they've gained in the classroom are crucial when formulating strategies for profit-making. The more businesses there are, the more jobs are created for the population, especially those in extreme poverty.

In the classroom context, ESD helps people to take responsible actions for the environment, and to do this, it employs both formal and non-formal methods of education. When pursuing its objectives, ESD draws from a wide range of fields, methods, and tools. ESD can serve as a unifying method for a wide range of pedagogical approaches, given that future educators draw on a wide range of non-traditional, multiple intelligences in their education. Teachers can improve their ability to take action by taking part in environment-based problem-solving programmes that are built into teacher training courses. UNESCO manages different projects in this regard and holds workshops with educators. Culen (2001) writes: “Curricula that provide the necessary knowledge related to the issues, tools to adequately analyze and evaluate issues, and skills to help resolve issues are essential. These ingredients are proven links to success in promoting environmental behavior.” (pg. 38).

In addition to teaching students about the importance of social, economic, and environmental sustainability, this approach shows them what these concepts look like in action. Like other educational practices (such as a whole-school approach to sustainability), pedagogies employed in schools have the potential to advance ESD principles. Simulations, class discussions, topic analysis, and storytelling are described, along with examples of how they might be used in the classroom. Distinct cognitive functions are sparked by each method of instruction.

ESD can be promoted methodologically in Classroom settings. The given picture explains it better.

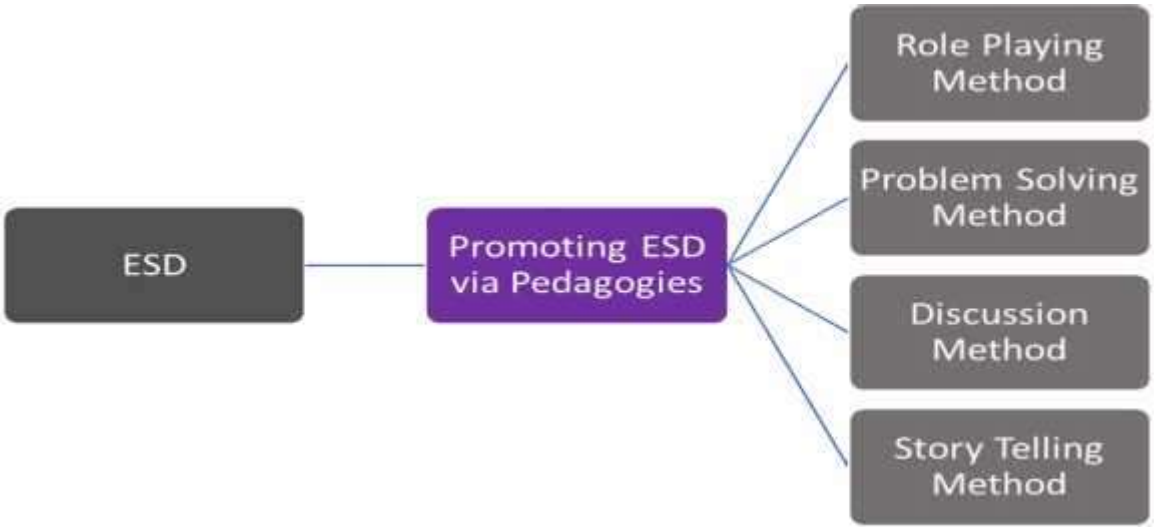

Fig-3: Pedagogical approaches to promote ESD (By-UNESCO Source Book-2012).

How does ESD Pedagogy work?

Roll Playing Method: Roll-playing or simulated teaching is a vital part of teacher education. It is a type of interactive learning activity in which the teacher trainers create the environment in which trainee teachers' play. Trainee teachers actively engage with the scenarios and derive meaning from exploring them. It might also be appropriate for ordinary students at various academic opportunities. Meanwhile, simulations create a sense of reality, inspiring and engrossing students of all ages because of the authentic experience they provide. Besides, Sustainability is a tough matter. Simulations simplify and highlight important details and make abstract concepts concrete. Children and teens in the concrete stages of cognitive development need concrete examples for abstract concepts. For example, children may be asked to perform a 'save trees' awareness campaign through role-playing. One might play the tree or the tree cutter. One can also play with the surroundings.

After deploying a simulation in class, it's crucial to assess if the students learned what was expected. The teacher can correct any misconceptions during the conversation. Process the scenario using these three questions, and that is - 1. Learn anything? 2. How realistic is this simulation? 3. What's different about the simulation from reality?

Problem-Solving Method: A problem-solving method is used for identifying and investigating the interconnected environmental, social, and economic factors that contribute to social concerns. Students can benefit from conducting problem-solving by learning to identify the main parties involved in a community problem and the various aims, beliefs, and views that are held by those parties. This method is general and can address issues in many other domains, including environmental, social, and economic ones. Individuals, small groups, or the entire class could work together to solve a problem.

For example, the Water crisis is a burning issue in our present world. Students can be taught problem-solving through a popular story such as thirsty crow, where a crow, by using its intelligence, could drink the water unreachable to it.

Discussions Method: Discussions in class facilitate not only the typical one-way flow of information from teacher to student but also student to student and student to teacher. Backgrounds and experiences can enhance curriculum delivery. Students can contribute to sustainability discussions by sharing their home and community experiences with what is and isn't sustainable. Teachers can use students' real-world experiences to help them apply abstract principles in practical settings. It also applies to teacher education. ESD helps students and teachers improve verbal and nonverbal communication.

Teachers can examine student understanding and application of the environment, society, and economy through sustainability.

For example, teachers may create groups to involve their students and make the debate on various topics like -water conservation, environmental sustainability and renewable energy etc. This process may help students to think critically and robust their knowledge.

Story Telling Method: The principles expressed in traditional stories are frequently the wisdom of the elders or derived from creation stories, which serve to transmit respect for cultural heritage and the environment, making storytelling an effective ESD pedagogy. Explaining abstract topics and theories using narratives makes classroom learning more engaging. Using storytelling can put a human face on data that would otherwise be uninteresting. Students that learn best via listening can benefit greatly from storytelling.

It is essential to connect the story's events and themes to those of the lesson and the concept of sustainability. A teacher could discuss with students how the plot reflects the goals and concepts of sustainability. It's vital that the story be clearly connected to what's being covered in class.

A Model for ESD

In this study, researchers bring up a model that can provide a conceptual framework (Figure: 4) which shows how teacher education help in smoothly boosting ESD.

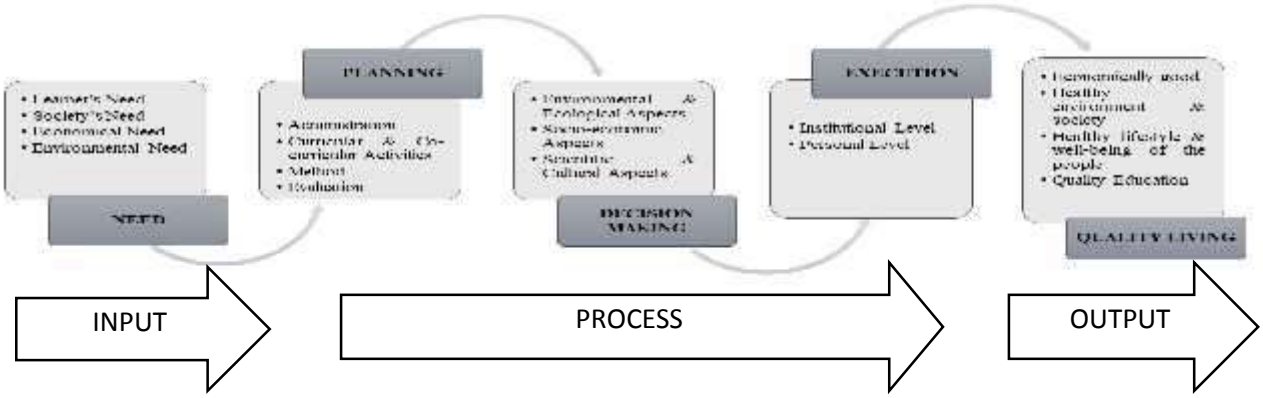

Fig-4: Model of Teacher Education in the Context of ESD

Based on the model presented above, researchers attempt to draw attention to how teacher education programmes must be developed to enhance "education for sustainable development (ESD)."

Researchers have picked a small set of words crucial to grasping this modular approach and procedure. The following table contains all the relevant terminology for this system (Table-1).

Contents	Concerns	Explanations
(INPUT)		
Needs	• Learner's Need • Society's Need • Economical Need • Environmental Need	The demands of learners (future teachers), societies, economies, and environments should be considered while designing teacher education programmes. Teachers should continue to address these issues. All these requirements serve as inputs to the procedure. • Trainee Teachers require natural, social, and humanities knowledge to grasp sustainable development principles, implementation, etc. For example, in Geography, nature is perceived in three ways– theocratic, geocratic and weocratic. But the theocratic view is more sustainable and, therefore, should be included in the regular syllabus. This will provide good knowledge of sustainability to the learners. • Societal needs emphasize building a sustainable society and community. For that, learners need to know the social fabric, its aspirations, and its goals. Then they can decide the aptness of the needs. • Economic needs indicate resource conservation and management. But the question is, how to handle economic sustainability? Effective resource management is one of the important keys to meeting economic needs. For example, recently, a new vehicle called "Toto(E rickshaw)" is replacing the three-tire vehicle "Auto", which is economically viable and environmentally sustainable • To meet environmental needs, the best way is awareness through syllabi, projects, and workshops conducted on sustainable development. using renewable energy in larger amounts at different aspects of social life will be an essential factor for this. It is environmentally good and economically sustainable. For example, in different household of rural India Kerosine is replaced by more environmentally sustainable solar power.

(PROCESS)		
Planning	• Administration • Curricular & Co curricular Activities • Method • Evaluation	Well-planned teacher education can enhance ESD. The following are required for better planning. • An effective educational administration will embrace and communicate sustainability concepts across all levels of education, including the teacher preparation and professional development fields. For example, to promote environmental sustainability, the use of E-mail for professional communication instead of paper letters would lessen deforestation to a great extent. Because papers are the product of plants. These plants are being chopped up and used for economic purposes. The use of e-mail in official communication would decrease the use of paper. • Curriculum and cocurricular activities must promote sustainability. For example, projects related to environmental sustainability must be included in Syllabus. Various cultural programs which promote environmental sustainability, like "One tree, one life," may be practised in school programs. • Sustainability-focused strategies should be taught and communicated to teachers at all levels of education. Like teaching aid should be made to use home waste or institutional waste. • Continuous and comprehensive evaluation model is more sustainable than the traditional evaluation system. This lessens the burden of learners and makes the learning more permanent.
Decision Making	• Environmental & Ecological aspects • Socio-economic aspects • The scientific & cultural aspects	Decisions are to be made with the support of thoughtful preparation, taking three factors into consideration– socio-economic, scientific and cultural, environmental and ecological. • The decision-makers evaluated the future teacher's environmental and ecological awareness when designing an acceptable teacher education curriculum. While constructing a new building, the school should see its environmental effect on students and on the larger population.

		• Socioeconomic variables should be considered. When a decision makes by teachers, administrators must think about social needs and economic sustainability. For example, when curriculum design planners must follow social demands and economic growth of society. • Decision makers also addressed the scientific and cultural spheres of human life to make new teachers more coherent and to embrace their own culture and other global cultures.
Execution	• Institutional level • Personal level	Execution will be best if it is done at two levels– Institutional level and personal level. At the institutional-level curriculum must follow the values and knowledge about the environment. Every act of academics is to be performed with respect to the three aspects of sustainable development – Environmental viability, economic feasibility, and social equity. The "Whole-School Approach to Sustainability" is a model recommended by UNESCO Source Book-2012 that tells the following to be taken into consideration. • Sustainability-related information, competencies, attitudes, and values are formally taught and embedded throughout the curriculum. • School environment is the key factor of the Execution process. The way people are treated and how the school operates are some of the examples of the school's sustainability culture. • Real-world problems are integrated into the classroom to increase student engagement and retention. • Sustainability is reflected in school management practices, such as trash management, water, and energy consumption etc. • Relationships between the school and the surrounding community are to be connection friendly, and interaction process need to occur on regular basis. • Environmental, social, and economic sustainability are reflected in school policy. • Sustainability lessons in the classroom are reinforced and expanded through special events

		and extracurricular activities. • Students need to have a voice in policy decisions at their school. At personal level of the Execution, learners and educators must follow the values and knowledge about the environment. For example, the use of personal cars should be reduced as far as practicable. This will help in environmental sustainability.
		(OUTPUT)
Quality Living	• Economically good • Healthy environment & society • Healthy lifestyle & well-being of the people • Quality Education	After the teacher education programmes were successfully completed, it was hoped that future teachers would be able to maintain a healthy environment and society while still living the good life. They could also improve their lives by making them balanced and healthy. People also could get a quality education. Therefore, when they can pass down ESD to future generations, these teachers begin to make a difference. • The financial security of the students and the next generation of educators would be ensured. • They would shape a healthy society by fostering a healthy environment. For example, classrooms and washrooms of the institution should be cleaned regularly to promote a Healthy environment & society. • Teachers would advocate for students' and communities' health, happiness, and high quality of life. For example, teachers and learners should be used jute bags instead of plastic bags. • All communities would have access to high-quality education. For example, Education should develop social well-being, mental health, Environmental awareness among the learners.

Table: 1 Teacher Education Model for boosting the ESD

Conclusion

In today's teacher education, sustainable development is an important issue. Our current educational system heavily relies on teacher preparation. ESD covers important themes related to sustainable development in education. It calls for interactive teaching and learning strategies that inspire and equips students to alter their behavior and advance skills like critical thinking, envisioning future possibilities, and collaborating with others to make decisions. Developing perspectives on equitable and sustainable development is one of the teacher education objectives in the "National Curriculum Framework for Teacher Education-2009". The responsibility of teachers is to prepare students with the

abilities they need to think critically, explain the logical analysis, and behave wisely in a diverse range of situations. Together, these factors produce a community that can make healthy, well-informed judgments for themselves and their families.SD relies on a well-trained teaching professional, so these programmes must continue to evolve to meet the needs of the area. That is why it is essential to enhance and customize teacher preparation programmes to advance education for sustainable development.

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INSIDE

Editorial

Upcoming State Elections: Semi-final 2024

Impending Legislative Assembly elections in five states of Rajasthan, Madhya Pradesh, Chhattisgarh, Telangana and Mizoram between late 2023 to early 2024 are going to be the strong determinant for the 18th Lok Sabha elections to be held in April-May 2024. Both the rivals, BJP and Congress would be eying in collaboration with alliances of other smaller regional and local political elements on 83 Lok Sabha seats in these states. Brainstorming for strategy has begun.

Bhartiya Janata Party (BJP) understands its Achilles Heel and has started working on it. Morale and motivations of Congress is sky high with *Bharat Jodo Yatra* that delivered Karnataka to its keg. Congress now seems to have learnt a lot from the BJP's ways of electoral calculations, election management and campaign strategy. Since 2014 BJP is being branded as 'New Congress' and now the way Congress is marching forward it may be branded as 'Disciplined and filtered BJP' as it has learnt the relevant arts from its rival in the arena of political power. BJP thus, faces strong challenges from Congress in particular and Indian National Developmental Inclusive Alliance (INDIA—recently framed alliance of opposition parties) in general.

Presently BJP has considerable edge in Rajasthan with 24 out of 25 seats of Lok Sabha in its bag. BJP also received 59.1% of the total votes polled in 2019 in the state. However, Congress is in the seat of authority in the state. Rajasthan Congress is now a disciplined dispensation with reconciliation between Gahlot and Sachin Pilot and is comfortably placed. BJP has failed to project any face for Chief Minister in the state. Vasundhara Raje is at loggerheads with the high command and would turn out to be a divisive force as that happens to be the ugly face of power struggle in India.

Chhattisgarh too is in the hands of Congress but BJP bagged 9 out of 11 seats of Lok Sabha in 2019 that too with voting percent of 50.7%. Here again BJP has thus far failed to project any strong face against Chief Minister Bhupesh Baghel of Congress, who is quite comfortably placed within the state as well as the Party. Congress is buoyed with recent spate of successes, whereas BJP is facing anti-incumbency wave across the country.

Madhya Pradesh too presents a gloomy picture for BJP even though it bagged 28 of the 29 Lok Sabha seats in 2019 elections. BJP in spite of being there in power is facing strong anti-incumbency factor against Shivraj Singh Chauhan, Chief Minister for last couple of decades. Internal conflict and power struggle on account of disgruntled elements within is obvious challenge before BJP. With 96 MLAs Congress is a force to be reckoned with. Jyotiraditya's realignment with BJP, bringing down the Congress Government ceases to be any bottleneck.

BJP has 4 out of 17 seats of Lok Sabha in Telangana at present. Ruling Bharat Rashtra Samithi (BRS), continues to be stronger. Congress has gained considerable ground to push BJP at the third place in the ensuing elections, unless BJP pulls itself up with control over internal power struggle or enters into alliance with BRS.

Mizoram though has only one Lok Sabha seat and that too is into the hands of Mizo National Front (MNF) since 2019. Though, MNF an ally of NDA, since 2014, has considerable stakes in view of the recent uprisings in Manipur. This may force MNF leaders to recalculate their stakes and rearrange their position on the eve of 2024 general elections. Moreover, MNF has opposed the Citizenship Amendment Act (CAA) of 2019. Hence, probabilities of MNF recalibrating its alliance are ripe.

All is not hunky dory for BJP. Major issues include: anti-incumbency factor; internal conflict on different issues of national and regional importance; power struggle within; leaders ever-escalating ambitions; floating-leaders calculating winning probabilities to change sides; unresolved social, economic and cultural issues are to name a few. Congress has been working hard on its mistakes and focusing on the changing circumstances and shaping its narratives accordingly. Print, electronic and social media is getting replete with narratives and counter-narratives; claims and counter-claims; arguments and counter-arguments, memes and reels. It is high time the voters need to learn and educate themselves as 2024 is all set to decide their fate and future of young India.

— BK

Electoral Delimitation of Assembly Constituencies in J&K: A Study in Electoral Geography

Mohd Shafi Dar* & Bijendra Singh**

[In this study, the electoral delimitation of assembly constituencies in J&K is examined. The assembly constituencies of both general and reserved categories and redrawing of constituencies are the subjects of the study, which was conducted on the union territory of Jammu and Kashmir. To determine electoral change or boundary limits, the study analysis the changes made by delimitation commission and assembly constituencies of both general and SC/STs. The study gives to assess the increase of assembly constituencies for reserved categories such as SC/STs that will help them in political participation and boost their developmental processes by political means. On secondary sources of information, the current paper is based. To analyze the data, statistical methods were employed.]

Delimitation is defined as the act or process of establishing the limits or boundaries of territorial constituencies in a country, province, or state with a legislative body. Regardless of the potential political consequences of the process, and the fact that countries conduct periodic electoral district delimitations, they are important because they direct public expectations, serve as a target for reformers to strive for, and serve as a benchmark for stakeholders in an electoral process to gauge the fairness of a given country's delimitation practices. Election irregularities including improperly allocated constituencies and gerrymandering electoral districts can have a significant impact on the results of an election and the make-up of a parliament. The legitimacy of the delimitation process would be impacted if voters and other stakeholders believe that the electoral borders have been unduly influenced to obtain a specific political outcome.

The Indian President appoints the Delimitation Commission, which collaborates with the Indian Election Commission of India. The Delimitation Commission is essential for the equitable distribution of geographic areas, equal representation of all population segments, and adherence to the "One Vote, One Value" principle to avoid electoral advantages for one political party over another. In 1952, the Delimitation Commission Act was passed. Under the Acts of 1952, 1962, 1972, and 2002, Delimitation Commissions were established four times in the past: in 1952, 1963, 1973, and 2002. To determine the boundaries of the Assembly and Parliamentary Constituencies in the Union Territory of Jammu & Kashmir, the Delimitation Commission was established by the Government of India under the authority granted by Section 3 of the Delimitation Act, 2002 (33 of 2002). Delimitation is a geo-political and administrative exercise and must necessarily produce reverberations that some like and others do not.

Study Area

The Union Territory of Jammu and Kashmir is situated in India's northwest corner of the Himalayan mountain range, between 32° 44'N latitude and 74° 54' longitude. Its altitude ranges from 220 to 8611 m and covers an area of 42,241 km2. The union territory has an international border and Line of Control (LOC) with Pakistan and China in the west and east, respectively. It also shares a border with the neighbouring Indian states of Punjab and Himachal Pradesh to the south. As per the 2011 census, the Union Territory of J&K has a population of 1,22,67,013. It was created on October 31, 2019, after the division of the former state of J&K into the UTs of Jammu & Kashmir and UT Ladakh.

The union territory of Jammu and Kashmir is divided into 20 districts viz. Srinagar, Anantnag, Pulwama, Kupwara, Shopian, Ganderbal, Bandipora, Baramulla, Budgam, Kulgam and Jammu, Kathua, Samba, Poonch, Rajouri, Udhampur, Reasi, Ramban, Doda, Kishtwar and has two divisions: Jammu Division and Kashmir Division. The Districts are further Sub-Divided into 207 Tehsils. Tehsils are Sub-divided into 523 Niabats, which in turn, are further subdivided into 427 GQ. Circles are further subdivided into 1632 Patwar Halqas having 6850 Villages in the State.

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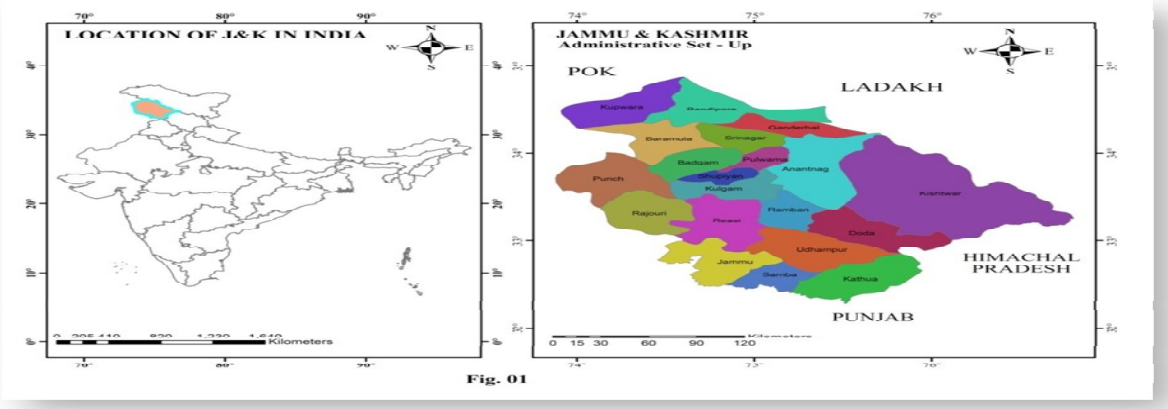

Fig. 01

Aims and Objectives

The present research paper is based on the following principle objectives

1. To examine the necessity of drawing new electoral boundaries in Jammu and Kashmir.
2. To analyze the impact of the delimitation commission on the SC/ST population to get political representation in J&K.

Database and Methodology

The secondary sources of data used in this study were gathered from a variety of official and non-governmental sources. From the Indian Election Commission, secondary electoral data have been gathered. The information was gathered from the various publications of the census of India. ArcGIS version 10.3 was used to create the map and the geospatial database forms the basis of the study. The numerous published research articles, magazines, books, and journals play important role in the study of electoral delimitation. The main goal of this study is to analyze the electoral delimitation of assembly constituencies in the Union Territory of J&K. The variables such as assembly constituencies and SC/ ST reserved constituencies have been used. The socio-economic development of the SC/ST population is based on their political representation. The delimitation of the general as well as reserved assembly constituencies of all districts of J&K was made under the Delimitation Act of 2002 and Section 60(2) (b) of the Jammu & Kashmir Reorganization Act of 2019. Tables are used to display the data effectively.

Result and Discussion

There were 111 seats in the former J&K state, comprising 24 seats set aside for Pakistan-occupied Kashmir (POK), Kashmir had 46 seats, Jammu had 37 and Ladakh had 04. The Jammu and Kashmir Representation of the People Act, 1957, was used by the state administration at the time to determine assembly seat boundaries. The delineation of parliamentary constituencies in the former state was governed by the Indian Constitution. The Commission has raised seven Assembly seats: six in Jammu and one in Kashmir. Following the provisions of Sections 9(1) (a) of the Delimitation Act of 2002 and Section 60(2) (b) of the Jammu & Kashmir Reorganization Act of 2019, 43 Assembly Constituencies will be included in the Jammu region, and 47 will be included in the Kashmir region, according to the final Delimitation Order. The major exercise of redrawing the electoral map of the Union Territory of J&K was changing the Lok Sabha and assembly constituencies. The Jammu Division shows a positive change i.e., the increase in the number of assembly constituencies from 37 to 43 almost 82.14 % of weightage is given to this district. Delimitation should be executed without regard for political party advantage. The delimitation commission is criticized by the politicians at both UT as well as central levels because of creating more seats in the Jammu division despite having less population than the Kashmir division. The new assembly constituencies added in the Jammu Division are Padder in Kishtwar District, Doda West in Doda District, added one in Udhampur District by dividing Udhampur AC into Udhampur East and Udhampur West ACs, Ramgarh in Samba District and Thanamandi in Rajouri District. But in Kashmir Division only one assembly constituency is added which is the Trehgam assembly constituency in the Kupwara district. These assembly constituencies were drawn by moving of tehsils or apart from one AC to another. The commission was permitted to do the redrawing of boundaries of assembly constituencies in J&K based on the census 2011

According to the 2011 census, J&K's assembly constituencies have an average population of 136300. Kishtwar, Reasi, Kathua, Samba, Rajouri, and Bandipora

are the districts with population sizes per assembly constituency that are below average, while the others are above average. In the Jammu region, there are 1.25 lakh people per assembly constituency, while in the Kashmir area, there are 1.46 lakh people.

Table – 1

No. of Assembly Constituencies, Districts, and Population in J&K

District	Population	No. of Assembly constituency	Kashmir Division	District	Population	No.of Assembly constituency
Kishtwar	230,696	3	1	Kupwara	870,354	6
Doda	409,936	3	2	Baramulla	1,008,039	7
Ramban	283,713	2	3	Bandipora	392,232	3
Reasi	314,667	3	4	Srinagar	1,236,829	8
Udhampur	554,985	4	5	Ganderbal	297,446	2
Kathua	616,435	6	6	Budgam	753,745	5
Samba	318,898	3	7	Pulwama	560,440	4
Jammu	1,529,958	11	8	Shopian	266,215	2
Rajouri	642,415	5	9	Kulgam	424,483	3
Poonch	476,835	3	10	Anantnag	1,078,692	7
Total	5378538	43		10	6888475	47

Source:

1. Data Compiled from the Census 2011, - Jammu & Kashmir - Series 02 - Part XII B, and Primary Census Abstract
2. The J&K Official Gazette Vol. 134, Jammu, Mon., the 14th March 2022,2022/23rd Phal., 1943.

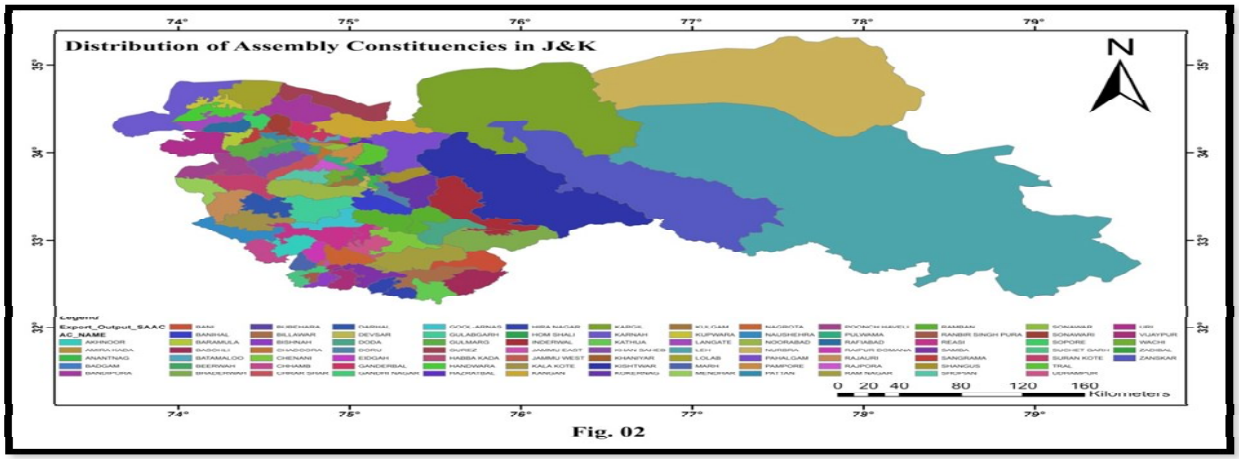

Fig. 02

The Commission also decided what changes needed to be made to the draught proposals after considering all the suggestions. The Commission approved the proposed constituencies' name changes in light of the public emotion surrounding them. These renaming included Tangmarg-AC becoming Gulmarg-AC, Zoonimar-AC becoming Zaidibal-AC, Sonwar-AC becoming Lal Chowk-AC, Padder-AC becoming Padder-Nagseni-AC, Kathua North-AC becoming Jasrota-AC, Kathua South-AC becoming Kathua-AC, Khour-AC becoming Chhamb-AC, Mahore-AC becoming Gulabhgarh-AC, Darhal-AC as Budhal-AC, etc.

Table – 2

Name Change of Earlier Assembly Constituencies in J&K

S. NO.	Earlier Name	New Name
1	Tangmarg-AC	Gulmarg-AC
2	Zoonimar-AC	Zaidibal-AC

3	Sonwar-AC	Lal Chowk-AC
4	Padder-AC	Padder-Nagseni-AC
5	Kathua North-AC	Jasrota-AC
6	Kathua South-AC	Kathua-AC
7	Khour-AC	Chhamb-AC
8	Mahore-AC	Gulabhgarh-AC
9	Darhal-AC	Budhal-AC

Source: Delimitation Commission Report, No. ECI/PN/ 41/2022, 05th May, 2022.

India is a multicultural nation that is home to all of the world's main religions. The desire of upholding the elite castes' monopoly on social prestige, wealth, education, and legislative seats led to the development of the hierarchical social order over many centuries. The caste system had the consequence of depriving the weaker groups of society access to land, schooling, and autonomy, equality of opportunity, economic opportunity, and political power. The caste system or higher-graded people not only deny some sections of society what they need on a social or economic level but also deny them political power by preventing them from being represented in parliament or legislative assemblies. This causes several disabilities in others that are passed down from generation to generation. The so-called higher castes have historically done social, political, and economic abuses against the lower castes, which have been routinely denied equal rights, opportunities, and resources. In the Legislative Assemblies, seats for Scheduled Castes and Scheduled Tribes are reserved according to Article 332 of the Indian Constitution.

The delimitation commission was permitted to reallocate the number of reserved constituencies in J&K based on the 2011 census. SC/STs reserved seats in the study area have increased in number after delimitation. The constituencies have undergone boundary changes to varying extents ranging from being retained intact through minor changes to major geographical boundary revisions of earlier assembly constituencies. Even after the boundary changes, and creation of new SC/ST constituencies in J&K. The Delimitation Commission has reserved Nine (9) Assembly Constituencies for Schedule Tribes for the first time in the history of electoral politics in the Union Territory of Jammu and Kashmir out of which six (6) Assembly Constituencies are in Jammu region and three (3) Assembly Constituencies in Kashmir Valley. The Erstwhile Constitution of Jammu and Kashmir State did not provide reservation of seats for the Schedule Tribes in the Legislative Assemblies. Rajouri district of J&K tops the list of having 3 Schedule Tribes assembly constituencies, Poonch district consists 2 Schedule Tribe Assembly Constituencies such as Surankote and Mendhar and Reasi district has one of its assembly constituencies as an ST. In the Kashmir region Gurez AC of Bandipora District, Kangan AC of Ganderbal district, and Kokernag AC of Anantnag district are Schedule Tribe Constituencies. These Schedule Tribe Assembly Constituencies have been carved by redrawing the tehsils or part of tehsils. The increase in the number of reserved seats at the cost of general seats is a new source of conflict in general and sc/st relations. The decrease in the number of general seats will affect candidates of all parties.

Table – 3

Seats Reserved for ST/SCs under Various Districts in J&K

District	Seats Reserved for STs	Seats Reserved for SCs
Bandipora	Gurez AC	
Ganderbal	Kangan AC	
Anantnag	Kokernag AC	
Poonch	Surankote ACMendhar AC	
Udhampur		Ramnagar AC
Kathua		Kathua South AC
Samba		Ramgarh AC
Jammu		Bishnah AC
		Suchetgarh AC

		Marh AC
		Akhnoor AC
Rajouri	Rajouri AC	
	Darhal AC	
	Thanamandi AC	
Reasi	Mahore AC	

Source: The J&K Official Gazette Vol. 134, Jammu, Mon., the 14th March 2022,2022/23rd Phal., 1943.

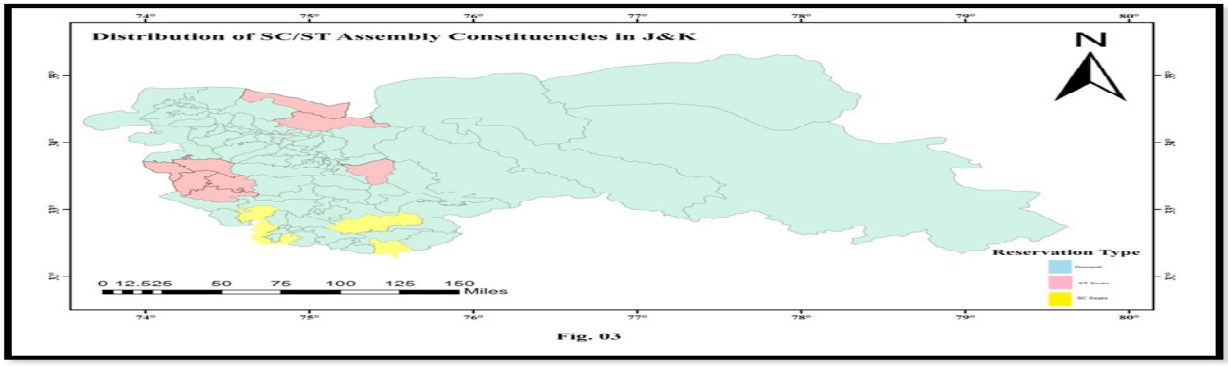

Fig. 03

Conclusion

To sum up, the delimitation procedure is essential for determining the election system's fairness. The country's delimitation history can be used to study the delimitation exercise, which is a complicated, multifaceted social and political event. Empowering its citizens for political involvement and national growth is the implementation of fair electoral boundaries based on the idea of population equality. The groups that have historically held the lowest position in Indian society due to the illogical and unconstitutional caste system are collectively referred to as Scheduled Caste and Scheduled Tribes in legal and constitutional contexts. Due to their history of unfair treatment, certain groups are acknowledged by the Indian Constitution to be particularly disadvantaged and are so entitled to certain rights and preferential treatment. The restructuring of J&K's electoral boundaries enhances political equality and the legitimacy of the state's government. Regions with a significant proportion of SC/ST residents are cut through by the assembly constituency limits. The creation of reserved voting boundaries aids SC/STs in being represented in elections.

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Emotional Intelligence and Academic Resilience among College Teens: A Comparative Study

Emon Ojha* & Pranay Adhikari**

[*The present investigation is well-known for looking into the link between teenagers' emotional intelligence and academic resilience across gender and residential lines. College teenagers remain a target for researchers. One hundred college students from Purulia District were surveyed for the study. Comprising 4 higher educational institutions, 2 located in urban areas and 2 in rural areas, all affiliated to the Sidho-Kanho-Birsha University, Purulia. In addition, the researcher employed the 'Academic Resilience Scale (ARS-30)' and the 'Emotional Intelligence Scale (EIS)' developed by Hyde, Pethe, and Dhar in 2002 to compare and contrast the levels of these two important traits among college-bound teenagers. Ultimately, the research indicates that emotional intelligence is crucial for academic resilience. Students with high emotional intelligence are better equipped to deal with stress and setbacks and to persist in the face of academic difficulties*.]

People are different from every other species on Earth because they are smart. Psychologists have found it to be one of their most fruitful areas of inquiry. Emotional intelligence (EQ) refers to a set of skills that includes the art of managing one's own feelings to make the necessary adjustments to succeed in social and academic situations. EQ has been shown to significantly impact a person's ability to succeed in school and life (Choudhury & Sharma, 2019). In a broad sense, the term "emotional intelligence" refers to a person's capability to manage and control his or her own emotions and the capacity to manage and control the emotions of others.

Emotions have the power to affect the feelings of others. The capability to perceive and identify feelings, to think using feelings, to recognize feelings and their changes, and to regulate and manage feelings (both your own and others) is often cited as the four main components of emotional intelligence (Landry, 2022). According to Goleman, EI is "the whole package" of what it takes to be an effective leader. Emotional intelligence is the capacity to understand and handle one's own feelings and those of others. It is universally believed that emotional intelligence encompasses a few abilities, including emotional awareness (understanding and expressing one's own feelings), the capability to manage oneself feelings (emotional regulation), and other people's emotions (emotional management is the skill to support others in achieving tasks) (Goleman, 1998).

A person's ability to find their way to resources supporting well-being is called resilience. Resilience is the capacity to navigate through significant life hardships and discover strategies for recovering and thriving (Choudhury & Sharma, 2019). Resilience is a psychological quality that some people exhibit, explaining why they may succeed in adversity. Regarding human characteristics, resilience is the capacity to recover and triumph over adversity. Academic resilience places the resilience concept in context and indicates a higher possibility of academic success in the face of hardship (Cassidy, 2016). Academic resilience is the ability to succeed academically in the face of challenges. Promoting it in schools requires thoughtful planning, careful execution, and the involvement of the entire school community to help disadvantaged students do better than their circumstances may have predicted.

Currently, learners experience a variety of pressures that affect their ability to think and feel, such as an unfavourable learning environment, a lack of resources for support, inadequate teacher support, inadequate parental support, exam pressure, etc (Ononye & et al., 2022). This present study is undertaken to comparatively discuss emotional intelligence and Academic Resilience among College Teens at some colleges in the Purulia district.

Review of the Related Literature

A study found a strong link between academic achievement and emotional intelligence. It supports the notion that students' emotions play a crucial role in learning in educational programs at schools where input and output are exclusively human. Emotionally well-adjusted students could perform better academically. This shows that high levels of EI and parental encouragement are linked with improved academic success (Choksi, 2012). Another research revealed a strong correlation between academic performance and emotional intelligence. The strength of the r value suggests a positive association between academic achievement and emotional intelligence.

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This indicates that increased emotional intelligence scores lead to increased academic achievement and vice versa. The researcher also found a positive correlation among various variables irrespective of gender, like male and female, and locality, like rural and urban students (Raino, 2017). Socially backward Secondary students showed that academic achievement and EI are positively correlated (r=0.633) among disadvantaged socially secondary pupils. The researcher also found a positive and moderate correlation (r=0.398) between creative thinking and emotional intelligence among socially backward students. Emotional intelligence significantly varies between boys and girls. This indicates that boys and girls both possess higher levels of emotional intelligence. The researcher also found academic achievement in secondary schools. Students from the socially disadvantaged group have a combined effect on creative thinking, emotional intelligence, and adaptability. This suggests that academic achievement will increase when creative thinking, emotional intelligence, and adjustment levels do, and vice versa (Bera, 2017).

Another study found that EI and resilience have a predictive impact on stress. Researchers also suggested resilience as a skill. Additionally, it has been demonstrated that training can be used to improve EI (Sarrionandia & et.al., 2018). Emotional intelligence is significantly correlated with academic resilience among university students (Saif, Khan, and Niazi, 2019). Similarly, emotional intelligence positively predicted academic resilience among Iranian high school students (Jenaabadi and Zarei, 2020). Another research found that strong relationship between EI and AR among adolescents. Investigators also revealed that the academic resilience of girls is higher than boys, and the emotional intelligence of boys is higher than girls. Results further showed that teenagers in the 16–18-year age group have higher levels of emotional intelligence (EI) and academic resilience than those in the 10–14-year age group (Pooja & Sharmila, 2021). Emotional intelligence intervention programmes significantly improved academic resilience among college students (Ramos and colleagues, 2021). A recent study on undergraduate students revealed that the positive effects of AR and EI lead to good academic performance. A positive association between the two factors confirms that AR influences EI. The same nature of the direct and indirect consequences led researchers to conclude that EI was a favourable fixer of the positive correlation between academic resilience and performance (Ononye & et al., 2022).

Statement of The Problem

Emotional Intelligence and Academic Resilience among College Teens: A Comparative Study

Purpose of the Present Study

Among college-aged students in Purulia District, this study aimed to distinguish between EI and AR and identify the factors contributing to each concept.

Listed below are some of the objectives of this research:

1. To reveal the gender difference between EI and AR.
2. To know the residence difference between EI and AR.
3. To reveal the gender relationship between EI and AR.
4. To understand the residence relationship between EI and AR.

Hypotheses

1. There is no significant difference between male and female teens toward EI.
2. There is no significant difference between rural and urban teens toward EI.
3. There is no significant difference between male and female teens toward AR.
4. There is no significant difference between rural and urban teens toward AR.
5. There is no significant relationship between EI and AR in Male Teens.
6. There is no significant relationship between EI and AR in Female Teens.
7. There is no significant relationship between EI and AR of Rural Teens.
8. There is no significant relationship between EI and AR of Urban Teens.

Operational Definitions

Operationally defined, the following major key terms which are used in this study are given in below –

Academic Resilience: In this study, Academic Resilience is relevant to the resilience concept and indicates higher chances of academic success despite adversity.

Emotional Intelligence: In this study, Emotional intelligence is defined as the capability to perceive and effectively manage one's feelings and those of others.

College Teens: In this study, College students mean undergraduate teens who have completed their high school education and have been enrolled in colleges.

Delimitations

1. This study is limited to Purulia District and some specific colleges.
2. It was also delimited to the general degree colleges of the Purulia District only.

3. All the general degree colleges were under Sidho-Kanho-Birsha University, Purulia.
4. The study was delimited to college teenagers only.
5. This work is bounded to the variables of Gender, Residence of college teenagers only.

Methodology

Study area

According to this work, the population of this study consisted of all the college-going teenagers in the Purulia District of West Bengal.

Sampling

In this study, 100 college-going teenagers from the Purulia district served as the representative sample of the entire population. For the purpose of obtaining the samples, the method of Stratified Random Sampling was employed.

Tools

The researchers utilized the 'Emotional Intelligence Scale (EIS)', developed by Hyde, Pethe, and Dhar in 2002, and it has 34 items with 10 subscales that adopt a 5-point scale. The researchers also used the 'Academic Resilience Scale (ARS-30)'. It is a 5-point Likert scale from likely (1) to unlikely (5).

Statistical Measures

The researchers have used Mean and Standard Deviation as descriptive Statistics and t-test and correlation as Inferential Statistics. The graphical presentation was also used in this study.

Data Analysis and Interpretation

Hypothesis 1: No significant difference exists between male teens and female teens toward EI.

Gender	N	Mean	SD	MD	Cal t Value	Table t Value (0.01 Level)	Remarks
Male	50	108.8	22.23	1	0.21	2.58 at 0.01 Level	Not Significant
Female	50	107.8	20.34				

Table 1: Difference between male teens and female teens toward EI

The above table-1 clearly shows that the mean scores of male and female teens were 108.8 and 107.8, and their SD scores were 22.23 and 20.34, respectively. The 't' value (0.21) was not significant at a 0.01 level of significance. It shows that there was no significant gender difference between male teens and female teens toward EI in Purulia District. Hence, the null hypothesis, "No significant difference exists between male and female teens toward EI." was conditionally accepted.

Hypothesis 2: No significant difference exists between rural teens and urban teens toward EI.

Residence	N	Mean	SD	MD	Cal t Value	Table t Value (0.01 Level)	Remarks
Rural	55	112.32	20.03	8.86	2.11	2.58 at 0.01 Level	Not Significant
Urban	45	103.46	21.80				

Table 2: Difference between rural teens and urban teens toward EI

The above table-2 clearly reveals that the mean scores of rural and urban teens were 112.32 and 103.46, and their SD scores were 20.03 and 21.80, respectively. The 't' value (2.11) was not significant at 0.01 level of significance. It shows that no significant residential difference exists between rural and urban teens toward EI in Purulia District. Hence, the null hypothesis, "No significant difference exists between rural teens and urban teens toward EI." was conditionally accepted.

Hypothesis 3: No significant difference exists between male teens and female teens toward AR.

Gender	N	Mean	SD	MD	Cal t Value	Table t Value (0.01 Level)	Remarks
Male	50	114.94	24.70	1.7	0.35	2.58 at 0.01 Level	Not Significant
Female	50	113.24	23.61				

Table 3: Difference between male teens and female teens toward AR

The above table-3 clearly shows that the mean scores of male and female teens were 114.94 and 113.24, and their SD scores were 24.70 and 23.61, respectively. The 't' value (0.35) was not significant at 0.01 level of significance. It reveals that no significant gender difference exists between male teens and female teens toward AR in Purulia District. Hence, the null hypothesis, "No significant difference exists between male teens and female teens towards AR." was conditionally accepted.

Hypothesis 4: No significant difference exists between rural teens and urban teens toward AR.

Residence	N	Mean	SD	MD	Cal t Value	Table t Value (0.01 Level)	Remarks
Rural	55	120.65	20.79	14.59	3.15	2.58 at 0.01 Level	Significant
Urban	45	106.06	25.53				

Table 4: Difference between rural teens and urban teens toward AR

The above table-4 clearly explores that the mean scores of rural and urban teens were 120.65 and 106.06, and their SD scores were 20.79 and 25.53, respectively. The 't' value (3.15) was significant at 0.01 level of significance. It shows a significant residential difference between rural and urban teens regarding their AR in Purulia District. Therefore, the null hypothesis, "No significant difference exists between rural teens and urban teens towards AR." was conditionally rejected.

Hypothesis 5: No significant relationship exists between EI and AR in Male Teens.

Correlation Matrix

Correlation Matrix

		EI Male Teens	AR Male Teens
EI Male Teens	Pearson's r	—	
	p-value	—	
AR Male Teens	Pearson's r	0.671 ***	—
	p-value	< .001	—

Note. * p < .05, ** p < .01, *** p < .001

Table 5: No significant relationship between EI and AR of Male Teens.

The above Table-5 shows that the 'p-value' is 0.671 of the EI and AR of Male Teens. Here, N is 100. It reveals that the relationship between EI and AR of Male Teens is greater than the table value. Thus, the null hypothesis is rejected.

Hypothesis 6: No significant relationship exists between EI and AR of Female Teens.

Correlation Matrix

Correlation Matrix

		EI Female Teens	AR Female Teens
EI Female Teens	Pearson's r	—	
	p-value	—	
AR Female Teens	Pearson's r	0.375 **	—
	p-value	0.007	—

Note. * p < .05, ** p < .01, *** p < .001

Table 6: No significant relationship exists between EI and AR of Female Teens.

The above Table-6 above shows that the 'p-value' is 0.375 for the EI and AR of Female Teens. Here, N is 100. It reveals that the relationship between EI and AR of Female Teens is greater than the table value. Thus, the null hypothesis is rejected.

Hypothesis 7: No significant relationship exists between EI and AR of Rural Teens.

Correlation Matrix

		EI of Rural Teens	AR of Rural Teens
EI of Rural Teens	Pearson's r	—	
	p-value	—	
AR of Rural Teens	Pearson's r	0.192	—
	p-value	0.160	—

Note. * p < .05, ** p < .01, *** p < .001

Table 7: No significant relationship exists between EI and AR of Rural Teens.

The above Table-7 shows that the 'p-value' is 0.192 of the EI and AR of Rural Teens. Here, N is 110. It reveals that the relationship between EI and AR of Rural Teens is lower than the table value. Thus, the null hypothesis is accepted.

Hypothesis 8: No significant relationship exists between EI and AR of Urban Teens.

Correlation Matrix

		EI of Urban Teens	AR of Urban Teens
EI of Urban Teens	Pearson's r	—	
	p-value	—	
AR of Urban Teens	Pearson's r	0.356 *	—
	p-value	0.016	—

Note. * p < .05, ** p < .01, *** p < .001

Table 8: No significant relationship exists between EI and AR of Urban Teens.

The above table-8 above evidence that the 'p-value' is 0.356 of EI and AR of Urban Teens. Here, N is 90. It reveals that the relationship between EI and AR of Urban Teens is greater than the table value. Thus, the null hypothesis is rejected.

Major Findings of the Study

After the above interpretation, researchers now may conclude –

1. The male teens (mean 108.8) are greater than the female teens (mean 107.8). So, the male teens have better EI in Purulia District.
2. The teens from the rural residence (mean 112.32) are greater than those from the urban residence (mean 103.46). So, the rural teens have better EI in Purulia District.
3. The male teens (mean 114.94) possessed a little higher than the female teens (mean 113.24). So, male teens possess better AR in Purulia District.
4. There is a significant residential difference between rural and urban teens concerning their AR in Purulia District. The teens from the rural residence (mean 120.65) are lower than those from the urban residence (mean 106.06). So, the rural teens have better AR in Purulia District.
5. Significant relationship is found between the EI and AR of Male Teens in the Purulia District.
6. Significant relationship is found between the EI and AR of Female Teens in the Purulia District.
7. Significant relationship is not found between the EI and AR of Rural Teens in the Purulia District.
8. Significant relationship is found between the EI and AR of Urban Teens in the Purulia District.

Limitations of Study

i. The study was conducted by some selected samples only.

ii. Sample size was small.

iii. More time is required for this investigation to be carried out thoroughly and methodically.

Conclusion

It is concluded their comparative work with a few final words summarizing their findings. In Purulia, teenage males dominate teenage females regarding emotional intelligence. Teenagers generally score better on emotional intelligence tests than their urban counterparts. In contrast, teenagers are typically more able to bounce back from academic setbacks than their female counterparts. Furthermore, there are large gaps in the Purulia District's academic resilience of rural and urban teens. Teenagers living in rural areas also tend to be more academically resilient. Further, teen males have a robust relationship between emotional intelligence and academic resilience. Female teens' academic resilience is so strongly correlated with emotional intelligence. However, no correlation exists between their emotional intelligence and academic resilience. Emotional Intelligence is significantly correlated with high levels of academic resilience among teenagers living in urban places. The emotional intelligence is crucial to academic perseverance. Emotionally intelligent students can better deal with stress and failure and keep going despite obstacles.

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Dynamic Inter-linkage of Macroeconomic determinants with Indian Stock indices

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[The market condition is dynamic with time and macroeconomic variables play crucial role in determining the market conditions. As any change occurs in the economy that can be measured by stock market as it is a barometer for every economy. The study has tried to examine the effect of change in macroeconomic variables on Indian stock market by applying Johansen Co-integration test, VECM, Granger Causality Block exogeneity/ Wald test and Impulse response function on high range of monthly data from Jan 2000 to March 2023. The study found the existence of long run co-integration among the variables and VECM confirmed the correcting variables are interest rate, gold, US stock Price and CPIs that correct the error in short run and maintain long run relation.]

The concept of "stock market discounts everything" suggests that the stock market reflects all events occurring within an economy. These events encompass a wide range of factors, including changes in inflation rates, interest rates, government policies, budget announcements, balance of payment structure, currency fluctuations, recessions or depressions, natural disasters like floods, cyclones, droughts, terrorist attacks, as well as events related to individual companies, such as dividend announcements, executive appointments, mergers, acquisitions, and internal or external restructurings.

The stock market acts as a barometer or mirror of the economy, providing insight into the impact of these economic and financial events. Many researchers have focused on the relationship between macroeconomic variables and stock prices. Bilson, Brailsford, and Hooper (1999) explored how well macroeconomic variables can explain changes in stock equity returns. Adam and Tweneboah (2008) examined the influence of macroeconomic variables on stock prices specifically in Ghana, establishing a long-term relationship between them using Johansen's multivariate co-integration test. They also found that exchange rates and inflation exerted short-term effects on stock prices. Sariannidis et al. (2009) employed a Generalized Auto Regressive Conditional Heteroscedasticity (GARCH) model to study the impact of various macroeconomic variables on Dow Jones Wilshire 5000 and Dow Jones sustainability indexes. Their findings indicated that crude oil prices negatively affected the US stock market returns, while bond returns (with a 10-year maturity) had a positive impact. Furthermore, the association between stock prices and exchange rates was found to be negative. Rasiah (2010) also utilized time-series analysis to investigate the long-run and short-run relationships between macroeconomic factors and the stock market, employing co-integration tests and a vector error correction model (VECM) to support their conclusions. Their study identified the influence of money supply, consumer price index, and exchange rates in predicting stock returns. Bilson, Brailsford, and Hooper (1999) explored whether macroeconomic variables could serve as alternative risk sources. While their study provided moderate evidence supporting this assumption, their investigation into commonalities in exposures across stock returns yielded little evidence.

Review of Literature

Mahmood and Mohd Dinniah (2007) conducted an analysis of the dynamic relationship between economic variables and stock prices in various countries, including Australia, Korea, Japan, Malaysia, Hong Kong, and Thailand. Their study utilized monthly data on foreign exchange rates, stock price indices, industrial production index, and consumer price indices. They found a long-term association between stock returns and economic variables in Korea, Australia, Japan, and Hong Kong, while a short-term association was observed in all countries except Thailand and Hong Kong. Engle, Ghysels, and Sohn (2008) revisited the association between stock market volatility and macroeconomic factors using a new model called the Generalized Auto Regressive Conditional Heteroscedasticity - Mixed Data Sampling (GARCH-MIDAS) model. The study focused on macroeconomic variables such as industrial production growth and inflation. The researchers observed that industrial growth and inflation accounted for 10-35% of volatility forecasting.

Hussain, Lal, and Mubin (2009) aimed to examine the long-term relationship between stock prices and macroeconomic factors in the Karachi Stock Exchange.

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The variables analyzed included foreign exchange reserve (FER), wholesale price index, foreign exchange rate, industrial production index, money supply, and gross fixed capital formation (GFCF). The researchers employed econometric tests such as the Johansen co-integration test and VECM. The results indicated that FERs and foreign exchange rates significantly influenced the stock market. The study also highlighted inflation as the macroeconomic variable with the highest forecast error for the index. Ilahi, Ali, and Jamil (2015) conducted a similar study on the impact of macroeconomic variables on stock returns in the Karachi Stock Exchange. Their analysis focused on the association between exchange rate, inflation rate, interest rate, and stock returns using data from 2007 to 2012. Multiple regression analysis was employed to determine the results, which indicated a weak association between stock returns and macroeconomic variables.

Kim and Qi (2010) explored the effect of business cycles and macroeconomic factors on accruals quality and its impact on pricing. The study suggested that accruals quality, as a contributor to the cost of equity capital and its effect on pricing, varied with different business cycles and macroeconomic factors. The findings highlighted the significance of accruals quality in determining the fundamental risk. Sharma, Singh, and Singh (2011) focused on analyzing the impact of macroeconomic variables on economic performance in India and Sri Lanka. The study examined various factors such as wholesale price index, consumer price index, gross national product, gross domestic product (GDP), and interest rates in both countries. To investigate the influence of macroeconomic factors on GDP, the researchers utilized tests including Granger causality test, unit root test, vector autoregression, variance decomposition, co-integration test, and variance decomposition analysis.

Tangjitprom (2011) conducted a study on the significance of macroeconomic factors in determining stock market performance. The results revealed that, after accounting for data lags, macroeconomic factors could explain stock returns. The study also utilized econometric tests like the Granger causality test and vector autoregression model. The findings indicated that stock returns could be used to predict macroeconomic variables, although macroeconomic variables were deemed less important in forecasting future stock returns. In their research, Naik and Padhi (2012) investigated the relationship between macroeconomic variables (wholesale price index, industrial production index, treasury bill rates, money supply, and exchange rates) and the Bombay Stock Exchange (BSE) Sensex. The results indicated a long-term association between these variables during the selected period (1994-2011). The study found a positive association between stock prices and money supply as well as stock prices and industrial production, but a significant negative association between stock prices and inflation. Tripathi and Kumar (2015) explored the relationship between interest rate, GDP, inflation, money supply, oil prices, exchange rates, and stock returns in the BRICS markets from 1995 to 2014. The researchers employed an autoregressive distributed lag model to evaluate this relationship. The study concluded that inflation and GDP did not significantly affect stock returns in most BRICS countries. However, negative relationships were observed between stock returns and exchange rates, oil prices, and interest rates, while a significant positive relationship was noted between stock returns and money supply. Sarika Keswani, Bharti Wadhwa (2019) Evaluating the Impact of Macroeconomic Variable on Indian Stock Market and found that A Change in macroeconomic factors except for disposable income Inflation and exchange rates have been statistically impacted by changes in share prices, whereas changes in stock prices also appear to be an insignificant factor explaining portion of stock market movements.

Objective of the Study

- To analyse the dynamic inter-linkage among the variables in long run and equilibrium relationship.
- To examine the causality between the selected macroeconomic variables in short run and quantify the level of Causality.
- To analyse the effect of unexpected shock in macroeconomic variables on stock indices.
- To examine the composition of other variables in one variable by applying variance decomposition analysis.

Research Methodology

The current study employed a range of statistical and econometric tools and techniques to examine the study's objectives. This section provides a comprehensive overview of the methodology utilized, including the study period, sample design, data variables, data sources, and the application of various statistical and econometric techniques using specialized software. A brief explanation of these techniques is provided to demonstrate their relevance to the present study, and equations are incorporated to support the analysis.

The study aims to examine the dynamic inter-linkage of selected macroeconomic variables with stock market returns. To accomplish this, a period spanning over 22 years, from January 2000 to March 2023, was considered by applying ADF test for Unit root test, Johansen Co-integration test for examine long run co-integration,

Granger Causality and Block exogeneity/ Wald test for short run causality test, Impulse response function for examine the response of variables to unexpected shock.

Analysis and Findings

- Unit root test show the Stationarity of the series by applying ADF and KPSS test. From the test result, we can say that all variables are belongs to non-stationary and coming stationary at first difference expect FIIs. So we have applied co-integration test for examine the long run relation among the variables and granger causality block exogeneity test for short run relationship. Before applying co-integration, we should decide the optimum lag length by employing lag length criteria.

The criteria of lag length selection is confirmed that the optimum lag length should be 1 as per FPE, AIC and HQ because these criteria confirming lag one is optimum for model specification.

- Johansen Co-integration Test- We believe that all of the data series have stochastic trends and this analysis proceeds to examine the long run and short run relationships between Indian Stock Market Index and the selected macroeconomic variables in the system assuming a linear trend in the VAR and the co-integrating relationship only has an intercept. The trace tests suggest three co-integrating vectors at the 5% significance level while the max-Eigen value tests support two co-integrating vector at the 5% significance level. As well as , the analysis allows for three co-integrating vector at the 5% significance level based on the maximum Eigen value statistic test following the recommendation of both Enders (2004) and Banerjee et al. (1993) who prefer the max-Eigen value test. The major implications derived from these two tests are: (1) the macroeconomic variables in the system are co-integrated. This means that they contribute to a long run equilibrium relationship. Hence each variable in the system tends to adjust proportionally to remove short run deviations from the long run equilibrium; (2) there is at least one direction of causality among the variables in the system as expected by the Granger representation theorem.
- Vector Error Correction Mechanism (VECM) – The result of VECM represents co-integration equation of the variables which depicts significance of the equation and speed of adjustment to correction error in long run. In the above table yellow dark value shows the significance level of the equation that should be more than 1.96 and here t-stats of Interest rate , Gold , S&P 500 and CPI is -2.72772, 2.45507, 3.21498 and 3.82770 respectively which is higher than critical value. The value of CointEq1shows the percentage of error correction in long runs of the significant variable that is known as speed of adjustment.
- Granger Causality Block Exogeneity/Wald test - To examine the causality between the selected variables in short run and quantify the level of Causality we have used this test. The test find that interest rate is significantly affected by the change in Crude and Forex Reserve in short run, IIPs and CPIs is significantly causes by Gold , Sensex, US exchange and Interest rate, Forex Res. is caused by CPIs, IIPs, and Gold in short run, S&P 500 is caused by crude, sensex, reserve, gold and IIPs, Gold is caused by interest rate, sensex, reserve, CPIs and IIPs, Crude is caused by S&P 500 only in short run, Sensex is caused by gold and IIPs.

In this way we have studied that in long run most of the variables were co-integrated but in short run some of the variables are causes to each other. So the investors who prefer momentum trading should follow the short run and the investors who prefer value trading they should go long run relation.

Conclusion

It has been observed that the various factors like investment inflows by FII, macro-economic policy of Reserve Bank of India, economic condition in world market, inflation, interest rates in domestic market affect the sentiments of the market. The crisis in world economies also has a negative impact on emerging economy stock market. Indian stock market was severely affected in 2008 due to US sub-prime crisis and in 2020 due to Covid Pandemic. Here, we have studied that in long run most of the variables were co-integrated but in short run some of the variables are causes to each other. So the investors who prefer momentum trading should follow the short run effect and the investors who prefer value trading they should consider long run relation among the variables.

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Transformation of Tribal Women in Politics of Arunachal Pradesh

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[Many political scientists looked upon political participation as an index of political development. The political participation of women is a central element of democracy, and the nature and degree of women's participation is a key indicator of the quality of democratic culture, yet they are under-represented in politics. The patriarchal structure of the family and society among the various tribal communities of Arunachal Pradesh has discouraged the participation of women in politics. Generally, traditional democratic theory regards participation by the individual in political activity as a virtue in its own right, but women were never included in any decision-making process in the traditional village councils of most of the tribal communities in Arunachal Pradesh. As far as the role of women in politics is concerned, it took various faces in different periods of time. In terms of a state like Arunachal Pradesh, the introduction of Panchayati Raj Institutions marked the advent of a modern democratic system.]

Arunachal Pradesh, one of the northeastern states of India is known for its substantial tribal population. The Political Participation of women has become one of the most important concerns as they constitute half the population of the world. Therefore, a comprehensive understanding of tribal women's participation in political engagement is crucial for promoting democratic governance in the existing vacuum of women in the political sphere. In the present century, the most received attentive question is, why do women play only marginal roles in politics? Explanation by many writers and researchers would believe to be; for women, it is very difficult to participate in the public and political domain due to a lack of support, resource, and gender discrimination. The division of work also holds situational constraints, why a woman may be bound by family commitments and other liabilities. Furthermore, the already established gender role of socialization in the context also boosts the gap of gender differentiation.

According to Carol Pateman, it has not been, and is not, a certainty for women to participate in political life. The cause is the long history of being subordinate to men at home and/or in public life, a subordination manifested and caused by women's limited opportunities for

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education, their lack of economic self-sufficiency, and the male-dominated values of the culture they live in. (2003: 1, 37, 215).

Women are still largely absent from their participation in decision and policy-making. Therein, social transformation to enhance their political representation in political activities is very crucial. The lack of political space and the insignificant role of political parties to encourage women has affected the ability of women to raise their concerns and issues. They are still vulnerable and chained to the patriarchal system, which for centuries has denied women equal rights and opportunities.

Background

For ages, politics has been considered a male-centric field, where women have been extensively cornered and left out. But with the dawn of new independence, the establishment of the Panchayat Raj Institution has paved women to openly and actively participated in areas such as voting, campaigning, rallies, and protests, but in areas requiring participation in policy formulation, idea accumulation, and political power execution, women have been marginalized. Since independence, the number of women in parliament has never crossed 20% of the total seats. And if we take a look at the number of women in ministerial positions, it is even lower than 20%.

The situation of tribal women in Arunachal Pradesh is no different. Most of the tribal communities residing in the state practice patriarchy. In general, gender roles are given paramount significance in all societal relationships. Women's roles are defined by customary laws and their voices are often suppressed in the name of traditions and customs as women are not permitted to become members of village councils. On the other hand, the status of women is very unique, societies adopt modern ways of living to a certain extent, yet deep down have not lost traditional roots. These traditional laws and customs still guide the daily lives of tribal people. Women often refrain from participating and voicing their opinions and are deprived of their property rights. The traditional village councils in almost all the tribes in Arunachal Pradesh acted as an organ of legislation, execution, and judiciary for eons. The structure and organization of village councils in different tribes vary to various degrees, but there are commonalities that are found in every village council. One of the overriding commonalities that exist in these village councils is the absence of women in these decision-making institutions.

Political Participation of the Tribal Women

In the state of Arunachal Pradesh, the epicentre of all the political decisions and activities in the olden days among most of the tribes was their traditional village councils, which barred women from having any kind of active participation. While solving cases, both civil and criminal, most of the tribes rely on customary laws. Customary laws among most tribes are not in written form; they are passed down orally from the older generation to the younger, and as such, men become the custodian of customary laws and women having been denied any participation in the traditional village council, never got the opportunity to know or learn about them. Women, therefore, never had the opportunity to acquaint themselves with politics or the decision-making apparatus of society. The idea of democracy or democratic principles was unknown to Arunachali women. It was only later on, when the process of democratization and grass-roots democratic institutions were introduced by the government of India, that they got the opportunity to participate in the democratic process.

Participation of Women in Panchayat Raj Institutions

The introduction of the Panchayat Raj Institution in Arunachal Pradesh brought a significant move in regard to the adoption of a policy to enlarge the base of political participation among the people of Arunachal Pradesh in general and women in particular. Traditional village councils existing in the state have no uniformity in their constitution, functions, and power. But in order to introduce grass-root democracy and decentralization of powers, a certain level of uniformity was desired. Therefore, the need to introduce Panchayat Raj Institutions in the erstwhile NEFA was felt and propagated. The Daying Ering committee made recommendations to introduce a four-tier Panchayat raj body in 1967. As B.B. Pandey mentioned in his book *Arunachal Pradesh: village state to Statehood* (1996), the period from 1947 to 1967 has been a period of administrative adjustment and a process of initiation for the democratic set-up at NEFA.

In tribal society, the system of franchise rights was exercised more in an informal way than in a formal setting. Age was never the criterion, men with family were considered as adults whereas a woman was never an adult in the context of the village administration (Pandey, 1996. p-174). In 1969, the first Panchayat election was held for 938-gram panchayat, 38 Anchal Simitis, and 5 Zilla Parishad. The election being the first one, a lot of bureaucratic interference and control were seen. In 1975, a drastic change took place, the Agency Council, which was the apex body of the panchayat raj institution, was separated. It was replaced by the Pradesh Council as a provisional Legislative Assembly for the Union Territory of Arunachal Pradesh. Subsequent

Panchayat elections were held in 1973, 1976, 1980, 1983, 1987, and 1992.

In terms of the participation of women in the Panchayat bodies, it was negligible during the first phase from 1969 to 1992. No women were elected or selected for the office of Zilla Parishad till 1992. In 1987, at the Anchal Samiti level, one woman was elected, and in 1992, three women representatives were elected. The ratio of nominated female members was also limited. Many districts did not have elected or nominated female Anchal Samiti representatives (Dubey, 2005, p- 8.9).

However, a drastic change was witnessed after the introduction of the 73rd Constitutional Amendment Act 1993 mandating at least, a 1/3rd reservation of total seats for women in all three bodies, as well as a 1/3rd reservation of the chairperson's office in all three levels of Panchayat on a rotation basis.

Table -1

Result of Panchayat elections

Sl. No	Year	Gram Panchayat Members		Anchal Samiti Members		Zilla Parishad Members		Total
		Male	Female	Male	Female	Male	Female	
1	2003	3927	2561	1062	577	91	45	8260
2	2008	4167	3018	1130	649	101	59	9287
3	2013	3933	3357	1120	646	109	66	9231
4	2020	2450	3701	———-	————-	128	88	6367

Compiled by a Researcher based on data provided by the Department of Panchayat Raj, Govt. of Arunachal Pradesh in the years 2003,2008,2013 and 2020.

Note: 2020 panchayat elections were held for two-tier panchayat body where Anchal Samiti was deleted by the Arunachal Pradesh Panchayat Raj (Amendment) Act 2018.

The introduction of the Arunachal Pradesh Panchayat Raj Act, of 1997 brought a welcome change in the form of reservation for women. Now seats were reserved for women in all three levels of Panchayat bodies and also for the office of Chairperson on a rotation basis. This marked the entry of women into grassroots politics in the villages of Arunachal Pradesh. Women are now not only voting but also fighting for political office. The role of women in the Panchayat can no longer be neglected, and slowly they are consolidating their position in the political sphere. Women in Arunachal Pradesh are showing interest in and participating in the panchayat institutions, and they are asserting their role as leaders.

Women in the Legislative Assembly

The Legislative Assembly of Arunachal Pradesh had an evolutionary antecedent, and it derives its existence from the erstwhile Agency Council that was inaugurated on December 3rd, 1969. It was created as an apex body of a four-tier Panchayat Raj Institution at the territorial level as an administrative arrangement without making any constitutional change (Dubey,2005, p-6.1). It was created on the recommendation of the Daying Ering Committee of 1967, which is responsible for ushering in democratic decentralization, and the roots of democracy were firmly planted in the erstwhile NEFA.

The first legislative assembly elections were held in 1978 on the basis of a universal adult franchise, thus formally cementing democracy in the state. With the passing of the Arunachal Pradesh Statehood Act, of 1986, Arunachal Pradesh was upgraded to full statehood status with a full-fledged sixty-member Legislative Assembly.

While all this development was taking place and the people of Arunachal Pradesh were getting used to the idea of democracy and a democratically representative polity, however, women were nowhere to be seen. The elected bodies of the Agency Council and the Pradesh Council conspicuously lack even a single woman representative. Unfortunately, no one addressed this issue. And the only role remotely political in nature that women played during this time was the role of an elector, which was restrictive in itself in many ways. There were no significant changes in the status of women in state politics even after the upgradation of full-fledged Statehood. To have a better insight into the problem, we have to discuss the role and status of women in state politics from two divergent yet connected perspectives, i.e., the status of women as electors in legislative Assembly elections and the status of women as elected representatives in the Legislative Assembly of Arunachal Pradesh.

Women as Voters

The tribal women of Arunachal Pradesh, hailing from different tribal communities, never participated as members of tribal village councils. So, the question of having an opinion or a say in matters of administration,

socio-economic activities, or political policies was never an option. Hence, universal adult franchise rights were something unknown to most tribal women. Unlike women in other parts of the world who had to struggle and fight for their voting rights, Arunachali women were granted these rights without incident. These rights were guaranteed to them by the Indian Constitution, which guarantees the right to equality and equal protection to all citizens, regardless of gender. Therefore, when the Panchayati Raj Institutions, which promoted grass-root democracy, were introduced in the region, voting rights were automatically extended to both male and female citizens of Arunachal Pradesh.

Table - 2 Voting percentage of Women in Legislative Assembly Elections

Sl. No	Year of Election	Voting Percentage		
		Male	Female	Total
1	1978	76.75	69.51	73.20
2	1980	74.76	64.49	69.79
3	1984	77.43	75.16	76.34
4	1990	72.47	73.26	72.84
5	1995	80.43	82.09	81.21
6	1999	72.38	73.58	72.95
7	2004	61.92	66.24	64.02
8	2009	75.52	77.10	74.80
9	2014	63.23	66.76	64.99
10	2019	46.29	50.30	76.48

Source: Election Commission of India, Statistics report on general election to the legislative assembly of Arunachal Pradesh:1978,1980, 1984,1990,1995,1999,2004,2009,2014 and 2019).

Analyzing the above numbers, we can clearly see that the number of women voters has seen a subsequent rise in Assembly elections. For the past 7 general assembly elections, the voting percentage of women was higher than men. Indications of a positive growth in political consciousness and political socialization among women can be seen. Women are making full use of their franchise rights and actively engaging in choosing their leaders.

Women as elected representatives in the Legislative Assembly

The level of participation of women in the Legislative Assembly of Arunachal Pradesh is dismal and discouraging. The performance of women in the panchayat is significantly higher than in the Legislative Assembly. Right from the days of the Agency Council, the apex body of four-tier Panchayati institutions at the territorial level, women were marginalized and were not given any representation. Even when the Agency Council was replaced by the Pradesh Council and fresh elections were held, women were conspicuously absent. As in most tribal societies, women are not viewed as leaders; they are kept out of the political business of the family and community. In Arunachal Pradesh, women started late to partake in politics at the state level. Women could not secure any seats in the Agency Council or Pradesh Council, so no women in the highest body of the regions engaged in providing crucial recommendations to the Chief Commissioner in relation to the socio-economic, administrative, and political matters related to the area. It was only after the creation of the provincial legislative assembly that women started to make themselves visible in the light of state politics steadily.

Table - 3 Number of Elected Women Members of Legislative Assembly

Sl. No	Year of Election	No. of Women Candidates Contesting	No. of Successful Women Candidate	Total Number of MLA in the State Assembly	% of Women MLA
1	1978	Nil	1-Sibo Kai (Nominated)	33	3 %
2	1980	2	1-Nyari Welly)	33	3%
3	1984	5	1-Nyari Welly 2-Komoli Mossang	33	6%
4	1990	2	1-Omem Moyong Deori 2-Komoli Mossang	60	3.3%
5	1995	4	1-Yadap Apang	60	1.6%
6	1999	4	1-Mekup Dolo2-Nyani Natung (By Election, 2001) 3-Yari Dulom (By Election,2002)	60	5%
7	2004	9	Nil	60	Nil
8	2009	9	1-Karya Bagang2-Nang Sati Mein 3-Gum Tayeng (bye Election, 2013)	60	5%
9	2014	6	1-Karya Bagang 2-Gum Tayeng 3-Dasanglu Pul (Bye Election, 2016)	60	5%
10	2019	10	1-Gum Tayeng2-Dasanglu Pul 3-Jummum EteDeori4-Chakat Aboh (Bye Election,2019)	60	6.6%

Source: Compiled by the researcher from Election Commission of India Report (Arunachal Pradesh Elections), Election Results 1978, 1980,1984,1990,1995,1999,2004,2009,2014 and 2019.

It is clear from the above table that women's representation in the state Legislative Assembly has never gone beyond 6 percent, indicating the marginalized role of women in shaping the policies and politics of the state. The absence of women in the highest policy-making body in the state is definitely a big concern. Arunachali tribal women are poorly represented in the ranks of power, policy, and decision-making (Dubey, 2000, pp: 6-13). In fact, it will not be wrong to point out that women in the state are not just behind in the political and managerial spheres they are still far away from their actual sharing of power with their male counterparts (ibid).

Conclusion

Participation in the political process is crucial for tribal women to endure greater social and political exposure and also to achieve all-round development. In order to bring meaningful and realistic political representation, efforts, and solidification must be made through their mindsets and attitude to bring a social transformation. Participation of women in politics and decision-making can change the structure of the institutions and also the negative impact of patriarchy. Women have the right to participate in the political process and it is observed that an increase in women's political participation and leadership tends to move toward a more responsible, inclusive, and democratic society. Therefore, there is a need to ensure more participation from women as electors and leaders. As long as women are marginalized and not empowered the gender gap in the field of politics will always exist. Henceforth, the need to ensure maximum participation of women is desired in the field of the political realm.

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India's SCO Presidency and Conclave at Goa

Alok Kumar Gupta*

Shanghai Cooperation Organization (SCO) Foreign Ministers' conclave was organised in Goa (India) during May 4-5, 2023. The conclave of the eight-nation grouping received fair amount of attention in the media and is also significant in view of the upcoming SCO Leaders' Summit in July 2023 in New Delhi. This is important as India is also holding the SCO presidentship which it assumed at Samarkand (Uzbekistan) in September 2022. The SCO presidentship has been overshadowed by the greatly highlighted G20 presidency of India that came to India on December 01, 2022 and would continue till November 30, 2023. SCO meeting was attended by Chinese Foreign Minister Qin Gang, Russia's Sergey Lavrov, Pakistan's Bilawal Bhutto-Zardari, and Uzbekistan's Bakhtiyor Saidov alongside others. The theme of the SCO Chair as articulated by Prime Minister Narendra Modi is 'Towards a SECURE SCO'. SECURE, the acronym was given by Modi at the 2018 Qingdao Summit of SCO which stands for Security, Economic Development, Connectivity, Unity, Respect for sovereignty and territorial integrity and Environmental Protection. The theme as articulated conclusively and convincingly includes the entire responsibilities that underlie the regional organization forum. Accordingly, India under its presidency scheduled to host more than 100 meetings and events. This responsibility has come to India at a time when there is an impending crisis with China on border in eastern Ladakh; and the relationship is also not well with Pakistan.

Significance of SCO

Founded in 2001 in Shanghai by the Presidents of Russia, China, the Kyrgyz Republic, Kazakhstan, Tajikistan and Uzbekistan, SCO today is an influential economic and security bloc that has emerged as a major transregional international organization. It is an intergovernmental organization. India and Pakistan became its permanent members in 2017. India was into an observer status in 2005 and been participating in the ministerial-level meetings of the grouping. India has been aiming to join the grouping since its commencement.

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SCO as a regional organization is significant due to its membership of eastward countries of Russia, China and four Central Asian Countries, India and Pakistan. Apart from the regular members several Asian countries like Israel and Vietnam have applied for dialogue partner status alongside other as mentioned later in the paper. United States has applied for an observer status which as of now stands rejected. The SCO is on the verge of transition, with the addition of Iran as a full member and Sri Lanka, Turkey, Azerbaijan, Egypt, and Saudi Arabia as dialogue partners. "SCO pursues its policy based on the principles of sovereignty and territorial integrity of nations, non-interference in internal affairs, equality of all member States and mutual understanding and respect for opinions of each of them." Ever since its inception SCO has expanded and emerged as one of the largest regional organizations and its member countries account for about 30 percent of global GDP and 40 percent of the world's population. Pending such statistical data the significant fact of SCO is that it consists of emerging economies like China, India and erstwhile military super power of cold war years Russia alongside underdeveloped countries of the central Asian region. On the other hand, SCO led by China and Russia is taken as counterweight to NATO and G20 which is dominated by USA and other western nations.

Thus, SCO is significant strategically, economically and culturally for rest of the world as most the members of the grouping are largely civilizational states. These countries are endeavouring to achieve economic stability and progress and countries with peace and tranquillity inside.

Focus of May 2023 Conclave

The agenda of the SCO under India's presidency was reported to be modernisation of the grouping with focus on advanced technology and digital infrastructure. The agenda also included discussions with regional counterparts on various regional, security, and political issues. However, the major focus of the May 2023 SCO conclave was as follows:

- Economic growth
- Regional cooperation
- Threat of terrorism

- Ukraine crisis
- Afghanistan situation
- Trade in National Currencies

The Conclave was also being expected to finalise agreements for the inclusion of Kuwait, the United Arab Emirates (UAE), Myanmar and the Maldives as dialogue partners in the SCO. The proposal to admit Iran and Belarus as full members of the grouping which was reaching its final stage.

The Goa Conclave was also supposed to finalise proposals for the consideration of the grouping's Head of Government Council Summit in July 2023 and the participants agreed on the agenda for the Heads of State Council meeting and the list of documents to be submitted for consideration, including the drafts of the New Delhi Declaration. The proposal was aimed at: expanding cooperation among the SCO member countries in the areas of trade, technology, commerce, security and socio-cultural ties.

SCO has thus far agreed on common approaches to combating terrorism, separatism, and extremism, yet has been impeded in its functioning. Conflicting national interests have hampered the competence of the regional organization to achieve any significant regional cooperation.

Conflicts within the SCO

The national interests are the most dominant defining feature of nation-states on the globe. It is the conflicting national interests of the members of this organization which has belittled their achievement. The bilateral relations of the member states are ridden with conflicts or carry potentials to give rise to conflicts could be enumerated as follows:

- India has border dispute with China;
- India has major concerns about cross-border terrorism emanating from Pakistan;
- India is hardly on even talking terms with Pakistan since 2011;
- Sino-Pakistan nexus is another cause of concern with India;
- Russia-China nexus also carry potentials to jeopardise or affect Indo-Russia traditional friendship;
- China has sinister and divisive designs on Taiwan (though not a member of SCO), and in South China Sea which are irritant to many of the members of the grouping.

Developments during Conclave

India demanded tough action against cross-border terrorism and appealed that the channel of finances for terror activities must be blocked without any distinction. On the other hand, Pakistan's foreign minister Bilawal Bhutto Zardari called for not to get caught up in "weaponizing terrorism for diplomatic point-scoring" and also raised the issue of "violation of international law" referring to Kashmir. Both India and Pakistan did not name any countries but made the statement indirectly on each other. However, the member states of SCO agreed on following matters during the conclave:

- To deepen cooperation on security matters.
- To step up combined efforts to fight terrorism, extremism, separatism, drug trafficking, cybercrime etc.
- To explore ways to assist Afghanistan and help stabilise the situation and rebuild the country.
- Exchanged views to expand practical cooperation in transport, energy, finance, investment, free trade, digital economy, as well as stepping up cultural exchanges.
- To work together to protect the environment and countering climate change.

The ministers also paid special attention to the following issues during the conclave:

- To expand SCO membership by completing the accession procedures for the Islamic Republic of Iran.
- To accelerate the formal procedures to enable the Republic of Belarus to join SCO as a member state.

The SCO member ministers also signed memorandums granting the SCO dialogue partners status to the state of Kuwait, Republic of Maldives, Republic of the Union of Myanmar, and the United Arab Emirates.

Thus, the conclave made considerable success towards taking many of the issues forward and some of the impending tasks to its logical conclusion.

Imperatives for SCO

Given the nature of SCO members and the existing conflict among them the forum could be geared-up to ease many of the bilateral tensions that exists within the region. SAARC (South Asian Association for Regional Cooperation) must be taken as an example which became a victim of Indo-Pak bilateral hostility and hardly could ever take off. Thus, the member states must endeavour to address their bilateral issues to make this regional organization increasingly successful.

The regional organization must be developed constructively to play an effective role towards facilitating dialogue that would lead to enhancement of regional security. Selfishness of the west as evident in Russia-Ukraine conflict could be another motivating factor to strengthen the organization to mitigate any such endeavour by major powers to dare escalate any of the existing conflict in the region, especially attempts at pitting Taiwan against China.

India's Role and Stakes

India has been playing a constructive role not only to protect and promote its stakes but also to bring peace to the region as peace is the key to prosperity.

Firstly, ever since India attained the full membership of SCO in 2017, India has been pushing the bloc to add 'English' as an official language of communication. SCO's official language thus far has been only Russian and Mandarin. Hopefully, India's demands shall be adhered to at earliest.

Secondly, China and Russia are considered to be the major drivers of the SCO as a regional organization, which is largely seen as the alternative to NATO (North Atlantic Treaty Organization). The way India has not allowed QUAD (Quadrilateral Security Dialogue) to become NATO in the Indo-Pacific, similarly India must not allow SCO to be an alternative to NATO. A narrative which must be put at rest, to promote cooperation with the west rather than conflict.

Thirdly, India has been emerging as a major player among the SCO countries. India has revealed keen interest towards deepening its security-related cooperation and its Regional Anti-Terrorism Structure (RATS), which specifically deals with issues pertaining to security and defence. External Affairs Minister of India made it obvious without mincing words to member-states about India's policy of zero tolerance on cross-border terrorism.

An official statement of the SCO meeting said, "The ongoing engagement with SCO has helped India promote its relations with the countries in the region with which India has shared civilizational linkages, and is considered India's extended neighbourhood." This statement of India convincingly sums-up India's role in SCO.

Conclusion

SCO's mission is to maintain regional security and stability and foster cooperation and engagement among the member countries. The region is faced with major evil forces which are threat to security in the region which are namely cross-border terrorism, drug trafficking, transnational organised crime, and cybercrime. The escalating scale of these crimes necessitates closer interaction and working together of states in the region and members of SCO to contain and mitigate the crimes perpetuated by non-state actors. However, the regional organization would fail to gain even modicum of success if the conflicts of bilateral nature are not controlled and non-state actors allowed to operate under the umbrella and protection of states.

On the economic front member states are required to work to facilitate the creation of institutional mechanisms towards enhancing trade, commerce, transportation and customs. SCO has tremendous potentials and opportunities in the field of science and technology, innovations, intellectual property protection, migration, tourism, education etc. Hence, the imperative is to evolve institutional and operational mechanism to enhance engagement and improve constantly on free flow of goods and services. India has yet another golden opportunity to expand its international and regional personality on account of its presidency of SCO.

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Impact of Social Media on Learning and Communication in Higher Education: A Survey of Graduate Students in Kalaburagi

Dr. Pratibha*

[*Social media is major media of communication especially among students getting higher education. In this respect, it is observed that, the degree students are using different types of Information and Communication Tools (ICT) tools and gadgets to use social media. No doubt, social media is powerful tool of communication and all the students are getting benefits of it. Apart from this, the students are getting educational knowledge. In this context, a sample survey has been made to analyse the importance and use of social media by graduate students in selected degree colleges. Hence, it is suggested to the teachers and parents to educate these students to get knowledge on learning and educational activities from social media.*]

Social media is a powerful new form of communication and the number of users on popular social media sites is growing at exponential rates. Millions of people are using social media tools as part of their everyday lives for work, studies and play because of its ubiquity (Sonawane and Patil, 2015). Social media are media for social interaction, using highly accessible and scalable publishing techniques. Social media uses web-based technologies to turn communication into interactive dialogues. Social media is the medium to socialize. They use web-based technology to quickly disseminate knowledge and information to a huge number of users. They allow creation and exchange of user-generated content. A social network is a collection of individuals linked together by a set of relations. Online social networking sites 'virtually' link individuals, who may or may not 'know' each other. They enable rapid exchange of knowledge, high levels of dialogue and collaborative communication through text, audio and video (Manjunatha, 2013).

Role of Social Media in Education

Social media networks are considered crucial for educational and professional skill development now-a-days as it eliminates geographical and time barriers providing scope for wide connectivity to vast community sharing information and interests. It also provides speedy dissemination of information and ideas. Within the social media Facebook, Twitter and others are now gaining more and more patronage. These websites and social forums are way of communicating directly with other people socially. Hence, Social media has the potentials of influencing decision-making in a very short time regardless of the distance. Social media offers lots of opportunities for learning and interaction.

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Students have easy, free access to resources online to help them learn, improve their grades and reduces absenteeism. Report shows 59% of student uses social networking to discuss educational topics and 50% uses the sites to talk about school assignment. The learning of academic material and self-responsible behaviour is assured because teachers utilize method based upon cooperative learning a social development research through social media. The youth learner, teachers and administrators in a tribal school or districts also work together in supportive groups. They too enjoy participatory democratic process and creative collegiality under digital environment (Sharma, 2016).

Educators and advocates of new digital literacy are confident that social networking encourages the development of transferable, technical, and social skills of value in formal and informal learning. In a formal learning environment, goals or objectives are determined by an outside department or agency. Tweeting, instant messaging, or blogging enhances student involvement. Students who would not normally participate in class are more apt to partake through social network services. Networking allows participants the opportunity for just-in-time learning and higher levels of engagement. The use of SNSs allows educators to enhance the prescribed curriculum. When learning experiences are infused into a website, students utilize every day for fun; students realize that learning can and should be a part of everyday life (Srivastava, 2012).

From the above discussion, it is clear that, social media is playing significant role in learning and getting knowledge by students and teachers. In this context, a sample survey has been made to analyse the importance of the social media in education of young students in Kalaburagi city of Karnataka.

Objectives of the Study

Social media and social networking sites are used by all the graduate level students in Kalaburagi city. It is essential to know whether these students are aware of the advantages and benefits of social media for their academic and educational studies. Further, it is aimed to explore the use of social media by students for different types of communications and different purposes. Apart from this, the study is aimed to get usage of different types of gadgets and tools used by graduate level students studying in Kalaburagi city.

Scope and Methodology

A sample survey of 1000 graduate level students studying in Arts, Commerce and Science has been made using questionnaire and of these students, 50 students were not furnished authentic information. Hence, primary data collected from 50 graduate students has been excluded from the study and finally, the primary data collected from total 950 students studying in graduation or degree courses has been considered for the present study. The primary data collected from these students is analysed, interpreted and discussed as under.

Analysis, Interpretation and Discussion

Age-wise Distribution of Students

The social media vary with the age of the students. For instance, users between 18 to 20 years prefer to share jokes, stories, etc and users of age between 21 to 25 years share the information on their educational issues and studies, etc. The youth after the age of 25 to 30 years are interested in entertainment, cinema, politics, general knowledge, etc. As the present survey covers the graduate students studying in degree colleges of Kalaburagi city, their age groups is generally between 18 to 24 years. In this way, social media interests are different according to age groups. The age of the students surveyed is as under.

Table No. 1. Age-wise Distribution of Students

Particulars	No's of Students	Percentage
18-19 Years	397	41.79
20-21 Years	442	46.53
More than 21 Years	111	11.68
Total	950	100

The age of all the students surveyed revealed that, 442 (46.53%) are between 20 to 21 years followed by, 397 (41.79%) are between 18 to 19 years and the remaining 111 (11.68%) are of more than 21 years respectively.

Technological Aids, Gadgets and Tools Owned

The present study has focussed on social media and its usage by graduate students to gain knowledge and information for their education. To use social media, it is essential for the students to possess technological aids, gadgets and tools. It is observed that, a few of the students are using the technological aids and tools owned by their parents. Still, majority of the students have owned cell phones, laptops and computers on their own. The technological aids, gadgets and tools owned by the students surveyed are as under.

Table No. 2. Technological Aids & Tools Owned by Self

Particulars	No's of Students	%
Computer System/ Laptop/ Tab	314	33.05
Mobile & Cell Phone	853	89.79
Smart Watch	—	—
Owned by Parents	97	10.21
Total	950	100

Note: It is observed that, many of the students have owned more than one or two of the technological aids and tools and hence, the total number of students is not considered.

Many of the students have owned more than one or two of the technological gadgets, tools and aids to use social media. Particularly, among all the students, 314 (33.05%) have owned computer systems, laptops and tabs, 853 (89.79%) have owned mobile or cell phones and 97 (10.21%) of the students have not owned the same, but using social media on cell phones, mobiles, computers and laptops owned by their parents.

Knowledge Gained about Social Networking Sites

Thousands of social networking sites are available online so as to communicate and spread information and knowledge with other persons. Except a few popular sites, many of such social networking sites are not used by many people. Of the most used sites, WhatsApp, Face book, Share Chat, Hike, Linked Inn and such others are most used social media sites. It was asked to the students that how they have gained knowledge about different social networking sites and collected primary data is tabulated as under.

Table No. 3. Knowledge Gained about Social Networking Sites

Particulars	No's of Students	Percentage
Friends	411	43.26
Relatives	63	6.63
Neighbours	58	6.10
Mass Media	134	14.11
Self	284	29.90
Total	950	100

As expressed by all the students surveyed, 411 (43.26%) have got knowledge about social networking sites from

their friends followed by, 284 (29.90%) have gained knowledge on social networking sites on their own, 134 (14.11%) have got knowledge on social networking sites from mass media, 63 (6.63%) have gained knowledge from their relatives and the remaining 58 (6.10%) have got knowledge from their neighbours. It is highlighted that; the friends are playing important role in getting knowledge about their social networking sites and the students are intelligent to search and find out new social networking sites.

Importance of Social Media in Life

Social media is playing important role in everyday life as it spread awareness and helps to share information and knowledge on education, healthcare, news, events, science, technological developments, culture, devotion, etc. Based on the areas of interest, each of the person can get memberships to various groups and forums in various topics. In the groups or forums, the members share their opinions, facts, figures, profession, statistics, news, etc, so that each of the member get knowledge about the same. In this way, social media has become essential for work life as well as family life including social life. Still, social media has not made considerable impact on the life of few and made higher impact on the life of many. Hence, the importance of social media in the lives of students is gained and shown as under.

Table No. 4. Importance of Social Media in Life

Particulars	No's of Students	%
Very Much	255	26.84
Highly Important	365	38.42
Somewhat Important	138	14.53
Unimportant	192	20.21
Total	950	100

As stated by the students, 255 (26.84%) have opined that, social media is very much important in their lives, 365 (38.42%) have felt that social media is highly important in their lives, 138 (14.53%) have agreed that social media is somewhat important in their lives and 192 (20.21%) have remarked that, social media is not at all important in their life. It shows that, majority of the students have felt that social media is very much and highly important in their lives.

Use of Social Media for Getting Knowledge

The age group of students is age of learning. As such, the students have to provide much importance to increase their knowledge and understanding on different issues in society which may be culture, education, entertainment, politics, current awareness, general knowledge, competitive examinations, research and development, science and technology, etc. The information was collected from the students on how they are getting useful knowledge from social media and collected information is tabulated as under.

Table No. 5. Use of Social Media for Getting Knowledge

Particulars	No's of Students	%
Provide Latest Knowledge	64	6.74
Update News & Events	132	13.89
Helps to Gain Knowledge on Everything	47	4.95
Sharing Ideas Help to Develop Knowledge	682	71.79
Any Other	25	2.63
Total	950	100

On the use of social media for getting knowledge, among all the students covered under the study, 64 (6.74%) have expressed that social media provide latest knowledge, 132 (13.89%) have stated that social media helps to update news and events, 47 (4.95%) have agreed that social media helps to gain knowledge on everything, 6\82 (71.79%) have felt that sharing ideas through social media helps to develop knowledge on everything and 25 (2.63%) have also given other means of getting knowledge from social media.

Impact of Social Media on Education

The students who have realized that, social media is of greater use for them so as to communicate knowledge for their education, competitive examinations and employment. In this regard, the impact of social media on education was collected from the students and tabulated as under.

Table No. 6. Impact of Social Media on Education

Particulars	No's of Students	%
Help to Get Guidance from Experts & Teachers	421	44.31
Getting Awareness & Knowledge from Friends	391	41.16
Disturbing due to Habit of Social Media	83	8.74
Worse due to Cyber Bullying	18	1.89
Any Other	37	3.90
Total	950	100

On the impact of social media on education and among all the students, 421 (44.31%) have stated that social media helped them to get guidance from experts and teachers, 391 (41.16%) have mentioned that they are getting awareness and knowledge from their friends

through social media, 83 (8.74%) have remarked that social media is disturbing their studies due to its addiction, 18 (1.89%) have opined that social media has worse effect on students due to cyber bullying and 37 (3.90%) have given other types of impacts of social media on education.

Impact of Social Media on Academic Studies of Students

As revealed by few of the studies made on the impact of social media on students, there is increase in knowledge of students as there is frequent guidance from teachers and subject experts and also sharing of knowledge from their friends. In this regard, the information was collected from the students on impact of social media on academic studies of the students and presented in the following table.

Table No. 7. Impact of Social Media on Academic Studies of Students

Particulars	No's of Students	%
Reading & Studying is Declined	267	28.11
Increased Reading & Studying	129	13.58
Timely Good Guidance from Teachers & Experts	314	33.05
Belief on Unreliable Knowledge	240	25.26
Any Other	—	—
Total	950	100

Impact of social media on academic studies of the students disclosed that, 267 (28.11%) of the students have opined that there is decrease in reading and studying, 129 (13.58%) have felt that there is increase in reading and studying among students, 314 (33.05%) have agreed that there is timely good guidance from teachers and experts and 240 (25.26%) of the students have commented that there is belief of the students on unreliable or unauthentic knowledge shared through social networking.

Concluding Remarks

It is revealed that, the students are habituated towards social media usage. When their knowledge is analysed, it is found that, they are well aware of educational applications of social media. No doubt, the social media has greater impact on learning and communication. Still, there are few of the disadvantages such as cyber bullying, waste of students' time in other activities such as entertainment, dating, etc. Hence, it is essential on the part of the teachers and parents of students to gain advantages of social media for their education rather than wasting time in entertainment and such other activities.

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Financial Literacy among Rural Women: A Case Study from the Perspective of Self-Help Groups Assam

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[Financial literacy and inclusion are crucial for economic empowerment in the process of economic development of a country. In this ever increasing risky and globalised world of the 21st century, people must be well-informed to make their financial decisions securely (Lusardi & Mitchell, 2011). In this regard, financial literacy plays an important role as it assists people in sound financial inclusiveness and decision-making along with ensuring proper financial management and stability. A person is financially literate when he is able to manage his finances with more confidence and can have less negative effects on his financial wellbeing. The women, particularly in the rural areas, are believed to have less access to economic, financial and social well-being. In this regard, SHGs can play a significant role in enhancing the financial literacy among the rural women.]

Financial literacy and inclusion are crucial for economic empowerment in the process of economic development of a country. In this ever increasing risky and globalised world of the 21st century, people must be well-informed to make their financial decisions securely (Lusardi & Mitchell, 2011). In this regard, financial literacy plays an important role as it assists people in sound financial inclusiveness and decision-making along with ensuring proper financial management and stability.

Jump Start defined financial literacy as "the ability to use knowledge and skill to manage one's financial resources effectively for life time financial security."

The OECD INFE has defined financial literacy as "A combination of awareness, knowledge, skill, attitude and behavior necessary to make sound financial decisions and ultimately achieve individual financial wellbeing."

A person is financially literate when he is able to manage his finances with more confidence and can have less negative effects on his financial wellbeing. It should be noted that the level of financial literacy differs from individual to individual (Sekar & Gowri, 2015). Factors like age, gender, educational level, income, profession, marital status etc. determine whether a person is financially literate or not. In India, the men are considered more financially literate than the women (Mishra et al., 2021). The women, particularly in the rural areas, are believed to have less access to economic, financial and social well-being. Lack of economic, financial and social well-being pose a serious hindrance in the financial literacy of women. In this regard, Self-Help Groups (SHGs) have emerged as an important strategy for economic, financial and social empowerment of women. SHGs can play a significant role in enhancing the financial literacy among the rural women. SHGs are small voluntary associations of 10 -20 people preferably from the homogeneous socio-economic background. The members of the SHG come together voluntary to participate in the economic and developmental activities such as saving, credit and income generation etc. thereby ensuring self-reliance and economic independence. The SHGs through their bank linkage programme introduce the members to bank account (many of whom had never had a bank account before SHGs), savings, credit, insurance etc. which encourage them to promote banking literacy. Moreover, the members of the SHGs by attending various financial literacy training programmes get the necessary knowledge that help them in handling their finances securely. It is seen that the members whose membership in the SHGs is longer and who attends more training camps are found to be more confident in their decision making. They are also financially secure, and have better control of their lives (Selvaraj et al., 2016). As such, SHGs can ensure towards promoting financial literacy and empowerment among the members through its different activities.

Review of Literature

Murugesan et. al., (2021) in their paper studied the financial literacy of Ramanagar district women self-groups in Karnataka before and after joining the SHG. The Research was carried out on 160 SHG members and found out that the members of the SHG become more financially literate only after joining the SHGs. The financial antecedents that strengthen the financial literacy of the members include savings, investments, financial planning and awareness and risk taking.

Mishra and et al., (2021) in their research paper concluded that SHGs plays a vital role in making the

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women of the Sisilo district in Bhubeneshwar financially literate. The women of this district learned about the banking services such as operating a saving bank account, credit, insurance etc, once they joined the SHGs.

Thilagraj (2020) pointed out that with the development of the SHGs economic empowerment of rural backward women is increasing. It has helped them in becoming financially independent and secure.

Selvaraj et al. ,(2016) carried out their research work on 400 women SHGs in Virudhunagar district in Tamil Nadu and found out that financial literacy such as the financial knowledge, borrowing and investment and saving skills has a great impact in economically empowering the women SHGs in that district.

Objective

The aim of the paper is:

i. To study about the Pre-SHG and Post-SHG status of rural women in the field of financial literacy and inclusion on the basis of different perspectives.

ii. To study about the role of SHGs in enhancing financial literacy among the rural women.

Methodology

The present study is conducted by following the procedures as mentioned below:

This paper is based on primary data collected from the respondents of women SHGs. In this connection, Simple random sampling technique and Stratified random sampling technique are applied to select the samples. The primary data are collected from field survey through well planned filled in questionnaire

In the initial stage 05 (five) Development Blocks in the district of Dhemaji, Assam, India are considered for the study.

After careful examination, in the second stage, 02 numbers of women SHGs from each development block are selected as samples and hence a total of 10 women SHGs are selected.

In the third stage, 6 members from each SHG are selected and thus a total number of 60 (sixty) respondents are considered for the study.

Result and Discussion

Table-1: Age characteristics: The age group of the respondents of the SHGs under the study is mentioned below :

Age (Year)	No of respondents	%
Below 30	12	(20%)
30 to 45	38	(63.33 %))
Above 45	10	(16.67%)
Total	60	(100%)

Table-2: Educational characteristics: The educational background of the women members of the SHGs selected as respondents is mentioned below :

Educational level	No. of respondents	%
Illiterate	3	5%
Primary	15	25%
Secondary	28	46.67%
Graduate	14	23.33%
Total	60	100%

Table - 3: Components of Financial Literacy: Information/Data from the women respondents selected from the SHGs are collected on the following basic components

SL. No	Parameters	Pre-SHG status	Post-SHG status
1	Possessing any individual bank account	08 (13.33%)	60 (100%)
2	Possessing individual knowledge about banking transactions and activities	05 (8.33%)	51 (85%)
3	Able to Plan for saving	06 (10%)	60 (100%)
4	Able to Prepare monthly budget of the family	03 (5%)	53(88.33%)
5	Able to Take loans from institutional sources	05 (8.33%)	46 (76.67%)
6	Attending any financial literacy programme	0	38(63.33%)
7	Knowledge about investing in insurance policies	0	12 (20%)
8	Knowledge and ability of using banking products (ATM, Debit card, Credit card etc.)	3 (5%)	49 (81.67%)
9	Knowledge and ability of doing digital/ online financial transactions	0	17 (28.33%)

Table-3 shows that only 13% respondents have individual bank account in the pre-SHG status against 100% in this regard in the post-SHG status. After joining SHG, 85 % members have individual knowledge about banking transaction and activities against 8.33% in the pre-SHG period. It is also found that only 10% and 05% members have idea about saving plan and monthly family budget in the pre-SHG status against 100 % and 88.33% respondents in the post-SHG status respectively. It is found that 76.67% respondents are able to get micro

credit from formal institutions and sources in the post-SHG period against only 8.33% during pre-SHG period and thus indicating a decreasing trend in case of taking loans from informal sources. It is found that 63.33% respondents have attended financial literacy programmes organized by concerned departments in the post SHG status against none in the pre-SHG period. It is also seen that no one has knowledge about insurance during pre-SHG period, but after joining SHGs 20% respondents have acquired minimum knowledge about investing in insurance policies. It is observed that 81.67% respondents have knowledge to use ATM, Debit card etc. in the post SHG status against 05% only in the pre SHG status. It is found that 28.33% have knowledge and ability of doing digital/online financial transaction in the post-SHG status against none in the pre-SHG status.

On the basis of the findings, it has been realized that the rural women are yet to be fully equipped with required financial inclusion and literacy and in this regard effective institutional planning and strategies towards empowering women SHGs in rural areas is the need of the hour. In this regard the following recommendations may be forwarded:

Recommendations

The issue of financial inclusion and literacy is related with different socio-economic and other related variables and hence it is multi-directional in nature. It becomes more critical and complex when we discuss the issue of financial literacy and inclusion among rural women in underdeveloped regions. Hence strategic and multi-directional initiatives are required to ensure the goals of financial literacy and inclusion particularly among the women in rural areas. In this regard the following recommendations may be forwarded:

i. Organization of financial literacy training programmes on regular basis may be helpful in this regard. Therefore initiatives should be taken to organize such programmes by the concerned departments and institutions on regular basis. In this regard strategic SHG-Financial institution linkage may provide positive outcomes to enhance financial literacy and inclusion among the rural women.

ii. It has been observed that the women empowerment initiatives have been hampered due to the lack of financial literacy among the women in rural areas. Therefore, the women empowerment initiatives and strategies should impose proper emphasis on financial literacy programmes particularly in rural areas.

iii. Apart from the initiatives by the concerned departments and institutions of the government, it is also urgent necessary to undertake programmes on financial literacy and inclusion among women in rural areas on regular basis by the NGOs related with the fields. In this regard strategic and well planned NGO-SHGs linkage model especially in the fields of financial literacy and inclusion may deliver positive results.

iv. The performance and evaluation of the SHGs should also be linked with the level of financial literacy and activities of the members of the SHGs. As such, this aspect should be incorporated in the domain of SHGs performance to enhance the effectiveness of financial literacy initiatives.

v. Moreover, apart from organizing financial literacy programmes, it is also equally important to make awareness among the members of SHGs at the grass root level. Therefore, awareness campaign on financial literacy among women in rural areas should be organized on regular basis.

vi. It has been observed that in most of the cases majority of the banks and financial institutions provide only standard banking and financial services, with no efforts made to cater to women and grass root level people or creating innovative banking and financial services and programmes for them. Due to the high and difficult prerequisites to use these services, rural women are discouraged from financial literacy and learning the necessary vocabulary. Therefore, it is important to introduce required initiatives to ensure the services of banks and financial institutions more customer friendly for all sections of people, particularly for women in rural areas.

Conclusion

Financial education and financial literacy are important for economic development of any country as it stimulates financial access and savings which increases economic growth, reduces poverty, augments livelihoods and leads to overall economic development. In rural areas in India, women are lagging behind in this regard. Most of them have minimal financial education and lack of financial literacy makes them unable to engage in different financial activities. In rural areas, women SHGs have emerged as a tool to empower women economically and socially. Financial literacy programmes should equip rural women with knowledge of cash management, savings, banking, insurance, investment tools and other financial services. Financial literacy programme along with digital literacy programme will improve the ability of the rural women to manage their finances and enable them to do their basic banking and other financial activities and help them in empowering themselves.

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Awareness on Ujjwala Yojana among rural people: - A Study in Birkona Village in Chhattisgarh

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[*About 10 billion households in India still lack access to LPG, forcing them to cook mostly with charcoal, coal, dung cakes, etc. The most direct victims are women, who are typically in charge of meal preparation. The BJP government introduced the Ujjwala Yojna in 2016 to address this issue with the primary goal of empowering rural people. The main objective of this paper is to investigate how well-known and satisfied rural communities are with the Ujjwala Yojana rural development programmes. According to the study's findings, rural residents' understanding of and contentment with the Ujjwala Yojana are rather hazy*.]

The most widespread programme in the world to give cleaner cooking fuel to low-income households is the Pradhan Mantri Ujjwala Yojana (PMUY), which was introduced by the Indian government in 2016 (National Portal of India, n.d.). This programme offers a loan of INR 1600 to a woman over the age of 18 who is identified as living below the poverty line in order to help her acquire an LPG connection and stove. This sum is subsequently subtracted from the refill cylinder subsidy during installation (National Portal of India, n.d.).

More than 24 billion people live in India, yet only roughly 10 billion of those people have access to liquefied petroleum gas (LPG) for cooking, instead relying on firewood, coal, dung-cakes, etc. as main source fuel for cooking. According to a WHO research, the smoke that women breathe in from dirty fuel is the equivalent of smoking 400 cigarettes in an hour. A considerable number of acute respiratory infections in young children are also caused by indoor air pollution. PMUY is a programme of the Ministry of Petroleum & Natural Gas that offers LPG connections to women (BPL households) in order to empower them and safeguard their health because it is true that women's empowerment is essential for the growth of any community or nation.

In addition, because the poor have limited availability of cooking gas, women and children must endure the work of gathering firewood. LPG cylinder use has been mostly concentrated in middle-class and wealthy homes, primarily in metropolitan and semi-urban areas. Since rising LPG use and, more crucially, decreased chulha use may drastically lower levels of household air pollution (HAP), PMUY is anticipated to have a considerable positive impact on health (Sidhu et al., 2017). There are still difficulties in supplying LPG connections to the most under-resourced areas, such as tribal tribes, despite the fact that PMUY has mostly been successful in providing connections to homes that have never used one (Mani et al., 2020).Even though the programme has been effective in giving LPG connections to over 54 million households (Gould et al., 2020),

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JEL classification code- C83, I31, L95, O19

nothing is known about the PMUY beneficiaries' sustained usage of LPG (Kar et al., 2019; Mani et al., 2020).

But on August 10, 2021, in Mahoba, Uttar Pradesh, Prime Minister Narendra Modi introduced PMUY 2.0 (PMUY: New Ujjwala 2.0 Connection, n.d.). This was done by handling an LPG connection. Provision for an additional one crore LPG connections under the PMUY scheme was announced in the Union budget for FY 21-22. This additional one crore PMUY connection intends to offer deposit-free LPG connections to low-income families that were unable to be covered under the initial PMUY phase. No ration cards or residence verification will be required of migrants under Ujjwala 2.0. It is acceptable to use a self-declaration as both a family declaration and a proof of address. Ujjwala 2.0 will assist in achieving the Prime Minister's goal of providing LPG to everyone.

The primary focus of this paper is to understand the awareness, satisfaction level regarding Pradhan Mantri Ujjwala Yojana (PMUY), among rural population in Birkona village in Chhattisgarh state.

Review of Literature

Yadav, Sharma, & Raj, (2020) In order to evaluate the success of the Yojana on women's empowerment in the rural sector, the authors of this article aimed to analyse how the PMUY programme has affected the socioeconomic standing of women in India's rural sector. The results of the study demonstrate how much each PMUY dimension affects the numerous facets of women's empowerment. According to the women's comments, the report also examined the obstacles to LPG refills, finding that 56 percent of them are related to affordability and accessibility of biomass. According to the research's survey-based findings, there is a positive correlation between women's managerial ability, financial independence and the sustainability of the Yojana.

(Jaiswal & Meshram, 2019) Their investigation, which was conducted in the rural Nagpur district of the Indian state of Maharashtra, served as the foundation for their paper. According to the study, domestic air pollution poses a threat to the health of women in developing nations. The article also focuses on past initiatives, such as national projects on enhanced chulhas that began in 1983 and ended in 2004, and nonconventional energy sources that were established in 1982 to improve cook stoves. The lack of social understanding of government policy, the accessibility of biomass, and the high cost of these conventional fuels are mentioned as the main obstacles to the Pradhan Mantri Ujjwala Yojana success in these areas.

(Mall & Rani, 2020) 110 women beneficiaries from the two blocks of Kanti and Musahari who were in the age range of 35 to 65 were chosen for the present study, which was conducted in the Muzaffar district of Bihar. According to their study's findings, SC-ST respondents made up the majority of the sample, followed by OBC and general caste. In addition to being Hindu, more than half of the recipients were illiterate. Of the beneficiaries, 35.45% were Muslims, 0.91 percent were Sikhs, and 2.73 percent were Christians. According to additional information, the majority of beneficiaries were happy with the connection to subsidy offered by the Indian government. The recipients of this programme expressed low levels of satisfaction with the LPG cost and refill subsidies.

Objective of this study

- To study the awareness level of Pradhan Mantri Ujjwala Yojana (PMUY) among rural population.
- To know the satisfaction level with Pradhan Mantri Ujjwala Yojana (PMUY) among rural population.
- The aim of the study was to know how many rural people are availing Ujjwala Yojana and how many are not.

Research Methodology

In this study, a survey of rural people was undertaken to ascertain their level of awareness with and satisfaction with the Ujjwala Yojana in that area. Due to a lack of time, a reduced sample size of 80 respondents (rural people) from Birkona, a village in Belha Tehsil, Bilaspur District, Chhattisgarh State, was used for the survey. Well-designed questionnaires were created for this purpose.

Data Analysis and Result

From the sample of 80 respondents we found that, five years after the Ujjwala Yojna's implementation, 80% of the rural population were aware of it, while only 20% were not. This indicates that the plan is effective because no policy can be effective if the people who need it are unaware of it, hence efforts for more effective implementation should be made.

Only 24 of the 80 households were found to not be using the Ujjwala Yojana, according to the research. This shows that the Ujjwala Yojana was being used by 70% of the households. They all received LPG. Free LPG cylinders and connections, in keeping with the Yojana's original requirements, which called for only free cylinders and connections. While 30% did not use the Ujjwala Yojana.

When we questioned the PMUY users, it became clear that this scheme has greatly facilitated women's cooking and greatly improved their quality of life. Their burden has significantly decreased. Kerosene and cow dung cake

are still being used by those who cannot afford it. This demonstrates the rural population's continued lack of awareness (25 percent), corruption, and urgent demand for LPG cylinders. It was found that 86% of those who benefit from this programme had a BPL card, with the remaining 14% not having one. Additionally, it turned out that 91 percent of the 80 respondents have a bank account, while 9 percent do not.

According to the data collected from respected sample, the majority of them i.e. 86 percent do not receive financial assistance from the government for buying gas, which shows that their understanding of the scheme does not entitle them to benefits. Therefore, execution needs to be done with greater rigour. Consequently, this caused the program's beneficiaries to become dissatisfied.

According to the study, even though they benefited from their initial LPG connection, they did not receive financial support from the government to renew their gas connection. Due to the fact that the majority of people lack enough ventilation in their homes, they are forced to rely on their outdated cooking techniques, which are dangerous over the long term. This demonstrates that despite knowing, most people rarely reap the rewards. Which made those who benefited from this programme unhappy

Even though the user does not consistently receive the program's promised benefits, they still think the government-run programme is beneficial. This suggests that if the scheme is carried out effectively, success will come soon.

Suggestions

- The expense of LPG cylinders and the lack of subsidies are the main issues faced by the recipients, as evidenced by our poll and other studies. Therefore, it is also recommended that subsidies be provided and costs be reduced.
- In the research the paper mentioned above, we saw that consumers were having issues getting the refill cylinders. It is necessary to expand the number of vendors in order to fill the "white spaces". A top priority for the government should be offering options for home delivery. This could aid in the supply of LPG and, thus, reduce unemployment.
- It is also necessary to create alternative LPG booking procedures. Many people can simply stop utilising the plan because they find the process to be too difficult. People should be given a variety of options to choose from.
- It is advised that the government use data from the consumers' side rather than the demand side to offer a more accurate image of the actual situation so that the issues faced and the resources available to rural households are immediately made available without any inconsistencies.
- The government is also advised to work more arduously on all employment policies for providing better employment opportunities, particularly targeting rural people, so that they can afford cleaner fuel. The majority of people are unable to afford the fuel because they either do not have employment or have a lower pay.

Conclusion

The study has been able to draw the conclusion that the awareness and satisfaction level of the Ujjwala Yojana on rural people has been somewhat murky by the analysis of many studies and conducting a survey in the hamlet of Birkona. There have been both good and bad things. We have found instances where theory and practise have been completely in sync. There are certain places where the policy has been very effective. For example, it has encouraged rural India to switch to LPG cylinders and made people aware of the negative consequences that traditional fuels are having on the environment. The article includes a list of PMUY's accomplishments in great detail. However, there have been numerous instances where the theory and the practise were incompatible, and the PMUY satisfaction was not what it should have been. For instance, there may be a decrease in gas in LPG cylinders, problems with pricing, or a return to earlier fuels.

The conclusion of the paper expresses hope that the Ujjwala Yojana's flaws would be addressed and fixed as soon as practicable. In the hopes that there won't be a gap between theory and practise in ensuring the welfare of rural people, fragile efforts will have a far wider influence on rural people.

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Economic Ideas of Dr. B.R. Ambedkar: Vision and Mission

Dr. Sharanappa Saidapur*

Ambedkar was the first Doctoral Degree holder in economics among the Indians. He was a great economist in the world. He was also a beacon of economic ideas. Dr. B.R. Ambedkar was basically economics scholar who had studied and written many aspects of economics. Babasaheb Ambedkar was not only an economist by training, but he devoted considerable attention to analyzing the economic dimensions of social problems. His interest in and insights into contemporary economic problems stand out in many memoranda he submitted to the government from time to time. Against this background, the general ignorance about Ambedkar's contributions as an economist is surprising as it is unfortunate. Dr Ambedkar points out rightly as to how common man was leftout of economic and planning.

We know Dr.Ambedkar as a great scholar, the architect of India's Constitution and as an emancipator of the poor and the deprived. He had multifaceted personality. He dwelt with many aspects of India's polity and economy. Only a few know him as an economist and social philosopher whose brilliant and luminous analysis of the prevailing economic scenario of the first half of the centaury challenged conventional wisdom. Ambedkar made phenomenal contribution to the evolution of Indian economic thoughts and in addressing India's economic problems. The Indian society has done a great injustice to itself by neglecting the economic thoughts of Ambedkar. In the intellectual section of society of India, Dadabhai Naoroji and R.C Dutt each had written only one theory of economics. Even then the Indian Society had recognized them as the noted economists of the Country. But Dr.B.R.Ambedkar had touched upon many aspects of economics. However, Indian society did not recognize Dr.Ambedkar as an economist. That shows the caste ridden society or caste biased mentality of Indian people. In this way the Indian society has done great injustice to Dr.Ambedkar. Hence, this article focuses on different dimensions of economics of Ambedkar.The further discussion is vision and mission of B.R Amedkar. Nowadays, the economy of the country is under crises. But a solution lies in Ambedkar's economic thoughts.

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Objectives of the Paper

The main objectives of study are as follows:

1. To understand the economic thoughts of B.R Ambedkar.
2. To analyze the economic contributions made by B.R. Ambedkar.
3. To apply the economic thoughts to present Indian Society.

Methodology

This paper is an attempt to investigate the economic ideas of Dr.B.R. Ambedkar which were neglected and ignored by contemporary scholars. The present paper is based on secondary data collected from the books, journals and newspapers and reports. The descriptive and analytical method has been adopted for the analyses.

Discussion and Analysis

Dr.B.R. Ambedkar's contributions to diverse discipline such as law, sociology, political science, anthropology and comparative religion are well recognized. His contributions as a parliamentarian, educationist, journalist and above all as a social reformist and emancipator of downtrodden masses in India are also widely appreciated. However, his contribution as an economist has remained unacknowledged. In this background it has become necessary to study Dr. Ambedkar's economic thoughts and philosophy in a comprehensive manner. There is no doubt that Ambedkar's contribution to the Indian economic thought has been varied and diverse.

Indeed, it has been multi-dimensional on the face of it. Ambedkar's contributions may even appear to be disparate and disjointed. To illustrate, his scholarly contributions, such as administration and finance of the East India Company and the Evolution of Provincial finance in British. India falls in the arena of public finance whereas The Problem of the Rupee, its origin and solution could be classified under the discipline of monetary economics and international finance. Ambedkar's role in abolition of Khoti system and Maharvatan qualified him as an eminent applied agricultural economist, while his struggle for the industrial labour gave him a distinction as a labour leader. Ambedkar's incisive analyses of the economic dimensions of social maladies in India, such as the caste system and untouchability placed him in a unique position blending economics and sociology while his perceptive analysis of the strategy of India's economic development made him an authority of India planning.

The variety and enormity of Ambedkar's contributions to the Indian economic thought and in addressing India's economic problems may tend to obscure the intricate inter-linkages among theme. That is precisely, why it is important to note that there is a unified them running through all his apparently diverse contributions. Indeed all of Ambedkar's contributions as an economist emanate from clear and consistent economic philosophy.

Dr.Ambedkar ideas on Monetary Economics

In his first book, Administration and Finance of the East India Company which provides a historical review of the changes in administration and finance of the East India Company during the period 1972 through 1858, the focus really is on demonstrating how injustice was inflicted upon the Indian people by the British Company Government.

Ambedkar argues that finance of the country should be judged from the view point of development expenditure such as the public works (i.e. railways, road, canals etc.) Observing that during 1834 to 1848, the single city of Manchester in England had spent on water alone a larger amount of money that what the East India Company had spent on all public works all over India, he demonstrates the iniquitous treatment given to the Indian people by the British. He also points out that on abolition of the East India Company in 1858; the heavy load of the so called Indian debt was placed on the shoulders of the poverty-stricken natives who had no voice in the doing of the (East India) company. Ambedkar concludes his analysis stating that "The immenseness of India's contribution to England is a much astounding as the nothingness of England's contribution to India."

Ideas on Public Finance

Ambedkar's concern for the oppressed which found expression in the above mentioned paper was even more pronounced in its sequel titled. The evolution of provincial finance in British India while it dilates on the evolution of the centre state financial relations in British India, during the period 1833 to 1921, the accent once again is really on demonstrating faulty fiscal system marked by injurious taxes (eg. Land tax, salt tax as well as customs taxes) and unproductive and extravagant expenditures (eg: military employment of the Europeans without much spending on education or public works). Even when Ambedkar reviews the evolution of provincial finance through various schemes of assignment assigned revenue and shared revenues his emphasis is on the economic uplift of the poor through decentralization of the Government finance.

Subsequently, when Ambedkar wrote his magnum opus, problems of rupees, which offer an insightful historical analysis of the evolution of the Indian Rupee through the period 1800 to 1921 the common man, remained as the focal point of his analysis. This becomes evident from his perceptive analysis of the choice of currency standard of India.

Ideas on Gold Exchange Standard

The, then mainstream view as advocated by well-known economists like John Maynard Keynes and others favoured the 'gold exchange standard' as the ideal currency standard for India on the ground that it offered flexibility. According to them the liquidity creation in the economy under the gold exchange standard is not considered by the availability of gold in the economy and the resultant flexibility of operations was deemed to be desirable for the country's future development. Ambedkar conceded the flexibility offered by the gold exchange standard but argued that it was a mixed blessing. He emphasized the need for some regulator by which the discretion left to the issues of currency is regulated. According to him, the gold exchange standard does not offer any such anchor and is, therefore, likely to lead to generation of excessive liquidity, fuelling inflation, which jeopardize socio-economic stability and hurts the poor the most.

Ideas on Agriculture Economics

In the early 19th century, the major problem of Indian agriculture was low productivity. Ambedkar owe this to possession of small landholding by majority of farmers. He was of the opinion that instead of owing small land holdings, the land must be consolidated and farming must be done on bigger scale. The consolidated land must be owned by the State. In 1917 a committee was formed which suggested that, State should acquire the land holding from private players, owners, tenants and mortgagers and pay them the required compensation and then distribute the acquired land to original cultivators in right size. But Ambedkar criticized about what can be the right size. As land is only a single factor, there are other factors of production as well such as labour and capital that contributes towards the low productivity of land. Because of insufficient amount of capital, surplus labour leading to diminishing returns and deficient irrigations there is low productivity in agriculture. Ambedkar in his paper small holdings in India and Remedies (1918) he suggested some remedial measures. They are as follows; (1) Industrialization that will absorb the surplus labour (disguised unemployment), (2) State owned co-operative farming that will ensure the productivity of land will also reduce the cost of production and 3) Nationalization of land's theory of State Socialism had three points: 1) Ownership of agricultural land, 2) the maintenance of resources for production by the State and 3) a just distribution of these resources to the population.

Ideas on Employment and Development

Employment is pipeline of the development. It is instigating all-round development of the personality. Ambedkar in his work "State and Minorities", in fact, laid down a strategy for India's economic development. The strategy placed an obligation on the state to plan the economic life of the people on lines which would lead to highest point of productivity without closing every avenue to private enterprise and also provide for the equitable distribution of wealth. "He advocated an economic policy frame work specifically aimed at providing protection to the vulnerable section of society against economic explanation."

Ambedkar emphasized that what was implicitly in the caste system, was not merely division of labour but also a division of labours. He characterized the caste system as "a hierarchy in which the division of labourers is graded one above the other" and argued that, "Civilized society undoubtedly needs division of labours. But in no civilized society is division of labour accompanied by this unnatural division of labourers into water tight compartments." Dr.Ambedkar brought 8 hours working day system to India in place of 14 hours working day system. Dr.Babasaheb Ambedkar was instrumental in establishment employment exchange office in India. It was because of him dearness allowance, paid holidays, leave benefits and revision of pay scale benefits were provided for employees.

Concluding Remarks

The economic philosophy underlying Ambedkar's contribution to the evolution of Indian economic thought and in addressing India's economic problems is now clearly evident. This philosophy could be captured in his own phrase Bahujan Hitaya Bahujan Sukhaya.

Ambedkar's economic philosophy is couched in social, religious and moral considerations. The focal point of this philosophy is the oppressed and the depressed. The economic philosophy underscores liberty, equality and fraternity in connotations. The philosophy aims at giving life to those who are disowned, at elevating those who are suppressed, at ennobling those who are downtrodden and at granting liberty, equality and justice to all irrespective of their castes and creeds. The establishment of casteless democratic society based on Pragna (intellect), Sheel (character) and Karuna (compassion) is the essence of this philosophy.

The Indian society has inflicted a grave injustice upon itself by not taking cognisance of Ambedkar as an economist. After all his economic thoughts were not parochial. What he always had in mind was the best in the interest of the nation as a whole. To brand him only as a leader of the downtrodden in India is an insult to this great patriot. Depriving the Indian society of the benefit of Ambedkar's economic thought has proved to be self-defeating for India as a nation. Irreparable damage has already been done by ignoring Ambedkar's diverse contributions to the Indian economic thought.

Bharat Ratna Dr. B.R. Ambedkar is known widely as a leader of oppressed classes who fought against caste system and untouchability but his contributions as an economist is often ignored which is shocking for our economic fraternity. In this way Balagangadhar Tilak emphasized Swa-raj while Ambedkar fought for making it a Su-raj. That was attitudinal difference between them. In a nutshell, Ambedkar stressed upon the economic democracy not a political democracy. The economic ideas of Ambedkar were only solution for all economic evils of society in India.

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Protection of Forest and Wildlife: An Analysis in the Light of Present Legal Regime

Manoj Kumar Aggarwal* & Meenu Gupta**

[The relationship between a forest and its animal inhabitants is founded on the same ideas that govern any species' relationship to the ecosystem in which it lives. Environmentalists are profoundly worried about the destruction of habitats, such as deforestation, because one effect is the harm done to the species in that habitat. This is because there is an intrinsic relationship between organisms and their ecosystems. The animals that make the forest their home is those that can access the food sources to which they have adapted, as well as places for resting, nesting, and other necessities of existence.]

We have got our planet the earth and environment to be used by forest, wild animals, and humans. Without the environment, not only would human life end, but that of all other living creatures as well. It enhances the beauty of the environment, preserves the balance of life, supports the food chain, and is advantageous to people and their many activities. Historical factors determine the presence or absence of an animal or plant in a region. Animals and plants serve as live markers of the qualities of their surroundings, and their geographic ranges identify areas with comparable or identical environmental circumstances. Knowing in-depth the conditions needed for a species to survive and prosper is crucial in order to interpret a species' range correctly[1].

Constitutional Provisions

Global consciousness for the protection of environment in the Stockholm Conference and increasing awareness of the environmental crisis prompted the Indian Government to enact 42nd Amendment to the Constitution in 1976. The Environment (Protection) Act, 1986 defines environment. Articles 14, 15, 21 under part III of the Constitution of India[2] that are fundamental Rights are concerned with right to clean and wholesome environment. Articles 48A, 49A under Directive Principles of State Policy and 51A under Part IVA cast duty on citizens to safeguard and improve the natural environment to protect and improve the natural environment including forests, lakes, rivers, and wildlife, and to have compassion for living creatures. In order to promote ecological awareness at the local level, panchayat have been given the authority to conduct actions such as water management, afforestation, biodiversity preservation, and soil conservation and pollution control. However, because of the degradation of natural resources and the damage of the environment brought on by rising population and urbanization, India currently makes great efforts to achieve extraordinary sustainable development and the preservation of ecological balance[3].

Major Statutory Provisions to Protect Wildlife and Forest

The Indian Forest Act of 1927

The Indian Forest Act of 1927 establishes a legal structure for forest management in India. This act tried to ensure, consolidation and maintenance of forest-covered areas, wildlife management in forest areas, control the movement of forest resources, impose a tax on timber and other natural resources, as well as other forest products, categorization of areas into Reserved Forests, Protected Forests, and Village Forests.

The Wildlife (Protection) Act, 1972

WPA for short, is India's primary legal framework for protecting creatures that are in risk of extinction. The modern Biological Diversity Act and Biological Diversity Rules regulate the use and preservation of biodiversity, but both rely on the WPA's schedules as a general framework for species protection. The WPA is an admirable piece of legislation for present day, and it has proven useful over the years, particularly in terms of protecting large mammals and other species. We do not have integrated national wildlife policy[4].

The Indian Forest Policy of 1952

It was a straightforward continuation of colonial forest policy. Forest land of Zamidars was taken by the government. Agriculture was given priority, forests were cut to use land as agricultural land. Though under this policy forest land to be secured as 33 percent of the

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total area of the country (65% tree cover in hilly and 25% in plains)[5].

The Forest Conservation Act of 1980

It prohibits the use of forest land for non-forestry purposes. All demands and proposals to use forest land for development and infrastructure building, such as providing drinking water, irrigation projects, transmission lines, railways, electricity, defense, and mining, are enforced by the State government. The Forest Conservation Act of 1980 stipulated that in order to practice sustainable agro-forestry in forest areas, central permission is required. Violations or the absence of a permit is considered criminal offences.

The National Forestry Policy 1988

The principle of joint forest management, emphasises that the villages and the appropriate forest department always collaborate to manage small forest blocks (SMBs).The ultimate goal of the National Forest Policy, established in 1988, was to preserve environmental stability and ecological balance by conserving forests as a natural heritage[6].

Wildlife Protection Act 1972

When Wildlife Protection Act 1972 was passed then the wildlife protection was also added in state list. The Parliament by using power provided under article 252 passed this Act. This Act focuses on protecting wild animals, trees, and tree species, (flora and fauna) and makes hunting and collecting them as criminal offence. The National Tiger Conservation Authority (NTCA) was constituted in 2005 for strengthening tiger conservation in India and other Endangered Species. Wildlife Crime Control Bureau (WCCB) was constitution to combat organized wildlife crime in the country.

The Wild Life (Protection) Amendment Act 2022

It got assent of the President on 19th December 2022. The Act of 2022 enhanced punishment for illegal wildlife trade. It provides for better management of protected areas by permitting certain activities like grazing or movement of cattle and *bona fide* use of drinking and house hold water by local communities. Protection of foreign lands is as critical as it equally inculcates in itself the protection of the rights of the people who are resident there since ages. A new schedule has been added in appendices under CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) which is an arrangement of governments between nations on a global scale. CITES has goal is to make sure that the survival of the species is not threatened by international trade in specimens of wild animals and plants. It was drafted and adopted in 1963 by IUCN (The World Convention Union). The CITES Secretariat is administered by UNEP (United Nations Environment Programme) and is located at Geneva, Switzerland. India is also a signatory to the CITES[7].

Section 6 of the Wild Life Protection Act 1972 has been amended to constitute a Standing Committee, which exercise such powers and duties which may be delegated to it by the State Board for Wildlife. Section 43 of the act amended which permitted the use of elephants for 'religious or any other purposes'. To enable the Central government to appoint a Management Authority Section 49E has been inserted. To allow the Central Government to appoint a Scientific Authority to provide guidance on matters relating to the impact on the survival of the specimens on being traded. The Act also empowers Central government to regulate and stop the import, trade or possession of invasive plant or animal alien species. The Act also enhances the penalties prescribed for violation of provisions of the Act. For 'General violations', maximum fine is increased from 25,000 to 1 lakh. In case of Specially protected animals, the minimum fine of Rs. 10,000 has been enhanced to Rs. 25,000.

The Legal Dilemma over the Elephant's Status

The Indian elephant is an endangered wildlife species. Elephants are very valuable domestic animal. Elephants' Preservation Act 1897 was passed to prohibit the killing or capture of wild elephants with certain exceptions like self-defence or to protect crop and property, or under a licence issued by the district collector. Under the Indian Forest Act 1927 elephant was listed as 'cattle'. It prescribes the highest fine of Rs 10 for every impounded jumbo while a cow attracted a fine of Re 1 and a camel of Rs 2. The Wildlife (Protection) Act (WLPA), 1972, identified the elephant bullock, camel, donkey, horses, and mule as a 'vehicle'. While given the highest legal protection in 1977, the elephant is the only animal in Wildlife (Protection) Act's Schedule-I where that can still be owned legally by as means of gift or inheritance.

Section 3 of the Wildlife Protection Act, in 2003, has prohibited trade in all captive wildlife (these are animals that are held by humans and prevented from escaping).Any(non-commercial) type of transfer across

state boundaries without permission from the concerned chief wildlife warden was also prohibited.

The WLPA (Amendment) Act 2021 has made an exception to Section 43 stated that 'This section shall not apply to the transfer or transport of any live elephant by a person having a certificate of ownership, where such person has obtained prior permission from the State Government on fulfilment of such conditions as may be prescribed by the Central Government'. The Parliamentary Standing Committee which was headed by Jairam Ramesh along with conservation and animal welfare groups objected that the blanket exemption and recommended that it should be limited to temple elephants kept for religious purposes only[8].

The Vermin Conflict (Nuisance Animals)

When wild animals has done the damage to crop depredation, then it has never been computed. There is the biggest challenge to livelihood of millions of farmers around the many protected forests and not to mention the occasional threat to life. Since 1972, the WLPA has identified a few species as fruit bats, common crows and rats as vermin or nuisance animals that spread diseases or destroy crops and are not protected under the Act. According to Section 11 of Wildlife Protection Act, 1972 stated that the killing animals outside this list were allowed under two circumstances is as follows:-

The chief wildlife warden can allow the killing of willed animals in following circumstances.

- When the animal has become dangerous to human life of diseased in such a manner that recovery is not possible.
- Killing or wounding animal in self-defense.

This act further says that wild animal wounded or killed in self-defence will be property of the government[9].

Under Section 62 of WLPA, given sufficient reasons, any species other than those accorded the highest legal protection (such as elephant and tiger but not wild boar or nilgai) can be declared vermin at a certain place for a certain time. The state governments took the decisions under Section 62 until 1991 when an amendment handed these powers to the Centre. The purpose was apparently to restrict the possibility of eliminating a large number of animals at a species level as vermin.

Under Section 11, states could issue culling permits only locally and for a few animals. The central government should declare wild animals as vermin by credible scientific assessment. But in recent years, the Centre has started using its powers under Section 62 to issue sweeping orders declaring species as vermin at even state levels. Such as when, nilgais were declared as vermin across 20 districts in Bihar for a year in 2015 then the Large-scale destruction of agriculture was seen as the ground for declaring monkeys (Rhesus macaque) vermin in Shimla municipality in 2019. The issue has become the matter of Centre-state politics[10].

Response of Judiciary

Under 'Public Trust Doctrine' (PTD) state is entrusted with responsibility to protect and improve forest and wildlife. According to the PTD, the government holds some natural resources in trust for the benefit of the people, including water, fish, and wildlife. The Institutes of Justinian (AD 529) are where the PTD originated, and since the Magna Carta, English common law has firmly established the sovereign as the trustee of the people's interest in nature[11]. This important case was the first to mention the public trust doctrine in India. The SPAN Motel case is another name for this one. A PIL in this matter criticized Mr. Kamalnath, the minister of the environment, for allowing SPAN Motel to build a hotel close to the mouth of the Beas River in Himachal Pradesh and for allowing the company to alter the path of the river by blasting the riverbed[12]. Social activist lawyer M. C. Mehta by lodging many Public Interest Litigation has fought for the cause of trees and wild life and Indian Judiciary has given very positive response in this field.

Response of Common People

It is common knowledge that habitat loss is to blame for declining animal and plant populations. Commercial trafficking of wildlife and plant resources can also be detrimental to sensitive species. Various societal taboos serve to discourage and restrict hunting, or to safeguard particular ecologies by outlawing or regulating unsustainable resource exploitation[13]. Various movements had been started to protect the trees and environment few are as Bishnoi Movement started in the year 1700in Khejarli, Marwar Region of Rajasthan to save the trees from cutting. In *Chipko* Movement under the leadership of Sundarlal Bahugunaa group of women in the Reni forests of the Garhwal Himalaya successfully chased away timber felling contractors on March 26, 1999. *Chipko* has taken on a variety of forms, principally as an endeavour by the impoverished to conserve natural resources, a fight for local control of

those resources, and an initiative by women to safeguard their environment. Has *Chipko's* global influence achieved its local goals? Author visited the Garhwal and Kumaon districts and spoke with individuals who created the *Chipko* as well as others whose lives it has impacted. He examines *Chipko's* accomplishments, its strife, and its current standing as he traces its beginnings and spread. Five *Chipko* observers, some of whom have connections to the movement, provide their perspectives in the Crosscurrents section, while Gayatri Devi, a *Chipko* heroine, recalls the difficult times[14]. It was a non-political movement emerged for the protection of trees. Silent Valley is a tropical location in Kerala that is densely forested and rich in biodiversity. The thick evergreen cover, however, was to be deforested in 1978 for the Kerala State Electricity Board's building of a hydroelectric dam across the Kunthipuzha river (KSEB). The principal goal of Narmada Bachao Andolan was to oppose the construction of three huge dams across the Narmada river. Despite their failure, they shifted their focus to the preservation of the valley's environment and ecosystems. The NBA called into question the global model of unfettered development.

Conclusion

Indian Constitution has sufficient provision for the protection of forest and wildlife. Various statutes have been framed for the conservation and protection of forest and wildlife. Rapid urbanisation causes overcrowding and slums, which have serious issues with unemployment, bad sanitation, poverty, and high crime rates. Similar to this, as a result of highly polluting businesses' poisonous gas emissions, industrialization has resulted in environmental degradation. These contaminants are the main reason why numerous species of living things are going extinct and biodiversity is declining. Another significant factor contributing to environmental contamination is public ignorance of pollution control Acts and Regulations. Public education campaigns on various environmental protection techniques can help to keep the ecosystem's equilibrium at a particular level. In the absence of balancing the requirements of both humans and wild animals, the legislation has not been able to properly solve the issues.

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National Education Policy 2020 and Folk Knowledge

Dr. Saurabh Kumar Singh*

[National Education Policy 2020 has created a new sensibility towards appreciation and understanding of the rich heritage of Indian Knowledge System inherent in traditional folk knowledge. The treasures lying in folk knowledge has hitherto been ignored and neglected. But NEP 2020 has made the academicians realise the futility of carrying out the legacy of west and the time has come to explore, understand, and disseminate the troves of knowledge regarding ecology, economy, values, ethics, and so many others aspects of life which are the part and parcel of everyday folk knowledge.]

National Education Policy 2020 (2020) has opened a new vista while recommending the role of traditional folk knowledge system. It clearly says that:

"Knowledge of India" will include knowledge from ancient India and its contributions to modern India and its successes and challenges, and a clear sense of India's future aspirations with regard to education, health, environment, etc. These elements will be incorporated in an accurate and scientific manner throughout the school curriculum wherever relevant, in particular, Indian Knowledge Systems, including tribal knowledge and indigenous and traditional ways of learning, will be covered and included in mathematics, astronomy, philosophy, yoga, architecture, medicine, agriculture, engineering, linguistics, literature, sports, games as well as in governance, polity, conservation. (p. 16)

This vision reflects the need to develop a holistic and integrated education system which is more rooted in Indian ethos so that India can reclaim its pride and glory while modeling an education system in terms of folk knowledge traditions. But sadly, education hitherto, has been on the wrong tracks as an almost blinded belief has been invested in western imported education systems. Very systematically we have been made to see our folk knowledge as 'inferior' and 'low' whereas western counterparts as 'superior' and 'high'. This imposition of imported baggage of western education (Macaulay system), rapid growth of international market, environmental degradation, rapid process of modernisation, and cultural homogenisation has led to almost extinction of the traditional knowledge system. These cumulatively have made us blind to the rich repertoire of cultural heritage and folk wisdom which, before the colonial period, was the source for self-reliance, self-awareness, and self-pride culminating into self-knowledge and wisdom. But with the advent of colonisation and Macaulayan education plan which successfully created a new Indian educated class in color and blood but British in taste and mentality:

We must at present do our best to form a class who may be interpreters us and the millions whom we govern – a class of persons Indian in blood and colour, but English in tastes, in opinions, in morals, and in intellect. To that class we may leave it to refine the vernacular dialects of the country, to enrich those dialects with terms of science borrowed from the Western nomenclature, and to render them by degrees fit vehicles for conveying knowledge to the great mass of the population (1835, para. 31).

This was strongly opposed by Mahatma Gandhi (1910) as he declared that, "To give millions a knowledge of English is to enslave them. The foundation that Macaulay laid of education has enslaved us" ((p. 103-104). He further added, "It is we, the English knowing men that have enslaved India. The curse of the nation will rest not upon the English but upon us" (p. 103-104). This education system not only forced us to adopt dress, food, manners but also in the adoption of western perspectives and ways of thinking. This led to the inculcation of disbelief, disrespect and a sense of inferiority towards folk/indigenous culture, tradition, arts, languages, science, literature and so many other cultural practices.

Any understanding of folk knowledge traditions of India, while keeping in mind the vast geographical and cultural contours, has to begin with a specific geographical region. In this connection this paper aims to invoke the researchers to document and restore the wide-ranging folk knowledge traditions of India. These traditions of folk knowledge pertaining to all aspects of life are cumulative, representing generations of experiences, and careful observations including the management of the natural environment. The folk knowledge of India has the immense possibilities in imparting quality education that might help Indians to reclaim their long-lost glory and paving the way for the status of India as "Vishwa Guru."

Folklores have always been an integral part of community life. India, being the hub of multiple cultural identities,

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is full of various folkloric traditions. But these traditions were presented as 'low' and 'superficial' especially by colonial masters before political independence. After the independence, some intellectuals thought it to be of utmost importance to revive the various regional/ traditional folklores as a part of cultural renaissance. But somewhere those attempts have been exclusive in their approach as they primarily focused on some aspects of folklores such as performing arts (music, dance and drama), material arts (woodwork, metalwork, pottery, clothes and others) etc. But folklores are not limited to these only. They have wider subject matters and most of them are still unexplored. In this connection it becomes necessary for the academicians to explore the multiple dimensions of folklores as the reservoir of our cultural diversity as well as cultural richness.

There can be three major aspects of folk knowledge and their studies. *Verbal Folk Knowledge* includes traditional knowledge skill, wisdom and literature such as myths, legends, folktales, jokes, proverbs, riddles, chants, charms, blessings, curses, oaths, insults, retorts, taunts, teases, tongue twisters, leave taking formulas etc. *Material Folk Knowledge* covers folk art and craft or the artifacts comprising metal works, bamboo works, cane works, wood works, stone works, weaving and textile works etc. *Cultural or Traditional Folk Knowledge* consists of folk customs, beliefs, magic and folk religious practices, ceremonies, festivals, inheritance rules, marriage, family, household, kinship etc. It also contains folk performing arts such as folk dance, folk songs, folk music, folk theatre and drama, etc. The discipline devoted to the identification, documentation, characterisation, and analysis of traditional expressive forms, processes, and behaviors is *folkloristics* (alternatively identified as folklore studies or folklife research).

Different functions of folk knowledge have been identified by folklorists. Noted American folklorist William R. Bascom (1965) has talked about four distinct functions of folklore studies. *First* important function is to amuse and entertain thee folk. *Second* significant function is the validation of rituals to those who perform and observe them. It helps in the expression and enhancement of beliefs. It also strengthens the tradition and endows it with greater value. *Third* significant function of folklore is its role in education particularly but not exclusively, in non-literate societies. It also focuses on the incorporation of morals and values for pedagogic purposes. *Fourth* seminal function of folklore is an important but often overlooked function of maintaining conformity to accepted patterns of behaviour. In this way folklore works as a tool to exercise social pressure resulting in social control (p. 290-94). B. Malinowsky (2011) talks about folk knowledge as "a warrant; a chart or even a practical guide" (p. 37).

Westernised education has made us look down upon India's traditional folk knowledge systems. It has made us believe that the Indian knowledge system is outdated, unscientific, and no more relevant as per the needs of emerging challenges which have erupted in the wake of modernity. It has been believed that education with a stronger emphasis on western models is the right way to prepare people for life and its complexities. Western model is the only panacea to get rid of all the ills and evils of society. It is essential to live a life of prosperity and happiness.

But this view is too short to understand the worth and power of traditional folk knowledge systems. The value of traditional knowledge with its emphasis on biodiversity and cultural diversity cannot be missed. As it is rightly said that if given enough time, everything that is old will become new once again. In this connection traditional folk knowledge must be understood as an alternative collective wisdom relevant to a variety of matters at a time when existing norms, values, and laws are increasingly called into question.

Folk knowledge traditions have the potency to make us think of some really burning issues which we are facing in contemporary times such as (to name some):

- The question of ecological deterioration
- The question of exploitation of natural resources like soil, water, and forest
- The question of nutritional loss due to avoidance of traditional food system
- The question of erosion of traditional medicine
- The loss of morality and character-building components due to non-adherence to folklores

Traditional knowledge is a record of human achievement of comprehending the complexities of life and survival in unfriendly environments. It reflects the complex amalgamation of intellectual, experiential, spiritual, and social elements of human culture. This is a holistic manifestation of social norms and values that facilitate and govern interactions between groups of people and also with the natural world. Societies have been developing over the centuries by picking up this practical knowledge and have been passing it on to next generations. Traditional folk knowledge, with its intrinsic emphasis on practical, philosophical, technological, social, and economic knowledge of particular society with shared mental abilities, habits and ways of living while incorporating wide ranging topics such as mathematics, law, agriculture, food, and so many others, constitutes the framework for sustainable development.

According to the United Nations (1987) sustainable development is a "development that meets the need of the present without compromising the ability of future

generation to meet their own needs" (Chapter 2, para. 1). There are four pillars of sustainability:

1. Human Sustainability
2. Social Sustainability
3. Economic Sustainability
4. Environmental Sustainability

Recently the United Nations have called for the need of The Sustainable Development Goals (SDG) which are based on the primary needs to survive in a better world. National Education Policy 2020 has mentioned these SDGs and has given a call to align education in India to these goals. Education has always been the most important agency to bring about a desired change in the society. In this connection NEP 2020 rightly states that all curriculum and pedagogy right from the school level to higher studies will be rooted in the traditional knowledge system. The vast treasures of folklores and sustainable dimensions of knowledge is a must which would pave the step to bring harmony in all walks of life. We must aim to understand the relevance of traditional folk knowledge and its proper integration with NEP policies in framing the curriculum for the benefit of all. In this connection NEP 2020 says, "This policy proposes the revision and revamping of all aspects of the education structure, including its regulation and governance, to create a new system that is aligned with the aspirational goals of 21st century education, including SDG4, while building upon India's traditions and value systems" (Introduction, p. 3).

This is the right time to involve in a meaningful dialogue with all the stakeholders: teachers, students, administrations and above all the reservoir of these traditional knowledge. Some of the lessons which one can draw, are:

1. To promote and adopt an education system which is an amalgamation of formal, informal, and non-formal learning. This would aim to be more responsive and flexible.
2. Ensuring the effective participation of indigenous people in the observation and recording of traditional knowledge, data analysis, and the documentation of experiences.
3. To take necessary actions to prevent the loss of traditional knowledge and its being extinct.
4. Giving equal credit to folk knowledge and wisdom in policy making for future development.
5. Teaching methodologies should be made more integrative and holistic while bringing in the practice of blending different languages and cultures.
6. In the high time of Information technology, it becomes necessary to integrate this knowledge with the World Wide Web.

As we are celebrating Azadi Ka Amrit Mahotsav it becomes our primary requirement to be familiar with the country's rich past in order to understand the present scenario. It becomes the moral obligation of academia to act as torch bearers as the current society seems to be in too much grip of western influences. It has led to the emergence of a very grim situation where people are becoming more insular, short - sighted and disrespectful to indigenous art forms. There is an urgent need to enlighten the society, especially the younger generation, the future of the country, regarding the values and ethics inscribed in these lines. They must be exposed to India's rich cultural heritage to have the sense of greater and deeper interconnectedness which is the need of the time. Apart from this, folklore functions greatly to understand different societies in the light of cultural diversity and urgency to preserve and protect indigenous folk cultures. In the light of the path shown by NEP 2020 scholars, academicians, researchers and social scientists must come together in meaningful deliberations regarding the present state of folk knowledge and their studies as evidence to highlight the rich cultural fabric of Indian heritage. People need to be aware of vast treasures of folklore materials lying around unnoticed, marginalised and ignored. Fortunately, after independence various governmental and no-governmental agencies have seriously been involved in the revival and resurrection of various folkloric traditions across India. The time has come when we should give a new perspective to whole education system while incorporating the tremendous power lying in the folk knowledge so that we may enhance our understanding of folklores as powerful tools to enkindle the spirit of cultural plurality, integrity and solidarity to bring about a newer and energised sense of cultural consciousness.

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Revisiting Art for Wellbeing

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[*Art plays a huge role in the expression and perception of human emotions. The purpose of this paper is to study the various ways in which art has proven to be a successful intervention in a clinical setting to attain wellbeing. This research focuses on the success of art therapy as a resource for initiating wellbeing in the four different domains, namely depression, anxiety, personality disorders, and self-esteem*.]

A visual work of art is something that is intentionally created via the application of skill or imagination. A wide range of diverse media is included in art, such as painting, sculpture, printmaking, drawing, photography, etc. (Britannica). All art that is perceived by our physical eyes is interpreted by the brain, making it a cognition subject. (Solso R., 2003)

Art can be used as an outlet for self-expression, for inculcating wellbeing, as it often involves the creation of aesthetically stimulating representations of reality, which makes art a topic of interest in psychology-based research, specifically in the context of art therapy.

Depending on the ways in which art and psychotherapy are combined, there are several types of art therapy. (Birtchnell J., 1984)

Artist Adrian Hill was the first to use the term 'art therapy' to describe the therapeutic application of image-making (Junge, M. B., 2015). Art therapy is a mental health and human services integrative profession that enhances the lives of individuals, families, and communities via active art-making, creative process, applied psychological theory, and human experience within a psychotherapy relationship. A qualified art therapist can effectively support both individual and relational treatment objectives as well as social issues through art therapy. Art therapy is used to advance societal and ecological change, boost self-esteem and self-awareness, build emotional resilience, encourage insight, improve social skills, and improve cognitive and sensory-motor functioning. (American Art Therapy Association, 2017)

Positive art therapy emphasizes not just the alleviation of suffering but also the promotion of positive emotions and making use of the therapeutic properties of the flow of emotion. It can foster mastery, elevate mood, and incite, inspire, and illuminate meaning and purpose. (Wilkinson R., Chilton G., 2013)

Psychologists frequently recommend art therapy as the treatment of choice for identifying secure coping mechanisms and enhancing social abilities. (Slayton S. C., D'Archer J., Kaplan F., 2010)

Barbara Ball performed a quantitative study on the impact of art therapy interventions such as drawing, painting, and sewing on emotionally disturbed young children with attachment disorder in a residential setting. Carried out over 50 sessions, the study yielded the results that both the client and art therapist were able to identify positive change and growth by the end of a year. (Ball B., 2002)

Similar findings were obtained from a second quantitative study that involved 10-year-olds with family problems, sorrow, and other stressors in school-based group art therapy sessions. After a year, all of the kids said that art therapy in particular had improved their ability to handle emotions. (Gersch I., Goncalves S., 2006)

In a clinical trial of undergraduate students assessed for trauma history and symptoms, the experimental group drew three mandalas with symbols representing stressful occurrences, whereas the control group made three still-life drawings. The study discovered that while the experimental group had more severe symptoms than the control group before the trial, the experimental group showed less severe symptoms one month after the study. (Henderson P., Mascaro N., Rosen D., 2007)

Researchers showed statistically significant improvements for all clients using individual art therapy on individuals with learning and developmental impairments over the course of a year, including affective, attention, and degree of acuity. (Pounsett H., Parker K., Hawtin A., Collins S., 2006)

In a different clinical trial conducted with older persons with dementia receiving day and residential care, the experimental group received group art therapy while the control group engaged in non-art activities. After 40 weeks, there was undisputable proof that the art therapy group had seen favorable and long-lasting improvements in mental acuity, sociability, and physical and social involvement. (Rusted J., Sheppard L., Waller D., 2006)

With numerous studies providing evidence for the effectiveness of art therapy, this paper will discuss the use of art therapy for the treatment of (a) depression, (b) anxiety, (c) personality disorders, and (d) self-esteem.

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Methodology

The purpose of this paper is to analyze research done on art therapy and psychology and art. This research paper is a synthesis of studies already done on the subject matter. External secondary data was used to compile this paper. It is a meta-analysis of studies picked up from various journals and online libraries such as Taylor & Francis, The Wiley Library, and Research Gate.

Results

Art Therapy for Depression

Prior research has shown that art therapy can lead to an improvement in attitude, better compliance with authority figures, improvement in mood, socialization, and problem-solving abilities in patients with depression.

In a pilot study conducted in a medium to maximum security male adult prison in rural Florida, 48 inmates with depression received art therapy sessions for four weeks. The inmates were rated on a pre and post-test observation survey after every session. These results were analyzed to find differences in the pre-and post-test surveys, the findings indicated that the participants improved their attitude, compliance with staff and rules, and socialization skills. These behavioral changes were observed in the art therapy sessions.

In the follow-up study, there were two groups of participants: the experimental group receiving the art therapy and the control group. A standardized psychological assessment, a 6-point Likert-type scale, was also administered pre-and-post sessions. The results of these tests supported the hypothesis that if an inmate receives art therapy services, they will exhibit marked improvement in their mood, socialization, and problem-solving abilities. Art therapy was concluded to be beneficial to the inmate population of this prison as supported by the pilot and the follow-up studies. (Gussak D., 2007)

Another study was performed with cancer patients, who are particularly vulnerable to depression and anxiety. The purpose was to determine whether there was an improvement in depression, anxiety, or fatigue during chemotherapy following anthroposophy art therapy intervention which is based on the idea that illness frequently has its roots in the soul, and that artistic activity is an expression of the soul. The sixty participants were classified into the intervention group (participated in >/= 4 sessions) and the participant group (participated in </= 2 sessions). The Hospital Anxiety and Depression Scale (HADS) and the Brief Fatigue Inventory (BFI) were administered. The study found that the median score on these tests was reduced by two points in the intervention group post the fourth session, indicating a positive change in the participants' depression and anxiety levels. (Bar-Sela G., Atid L., Danos S., Gabay N., Epelbaum R., 2007)

Blomdahl et al. (2013) conducted a three-round study aiming to elicit expert opinion on the use of art therapy in the treatment of depression patients. In the first round, 18 mental health professionals were given a questionnaire including 74 claims about the essential features of clinical practice. In the second round, the experts were asked to either adopt a new viewpoint or stick with their existing one based on whether they agreed or disagreed with the assertions in round one. In the third round, they were given one more opportunity to change their minds. After data collection and analysis, it was discovered that the experts agreed on the therapeutic usefulness of including traumatic life events and encouraging verbal and visual communication. The experts also concurred that it is crucial for patients with depression to comprehend and identify the causes of their emotional responses to people and situations in life. The experts concurred that creating art helps people have a better sense of who they are, gives them a way to explain their emotional experiences, and improves activity performance. (Blomdahl et al., 2013)

Art Therapy for Anxiety

There is research that suggests that art therapy also decreases stress and anxiety levels, promotes confidence building, and satisfaction, and has an overall calming effect.

Participants in a quantitative quasi-experimental design study to assess the effect of art therapy on stress and anxiety in female healthcare professionals were separated into a study group and a control group, with the study group receiving art therapy interventions. Stress questionnaires, cortisol detectors, anxiety scales, and interviews were among the methods used to assess the dynamics of the art therapy and changes in the emotional state during the session day. The study group's cortisol levels significantly decreased. Significant adjustments in the study group's anxiety levels were also noted. According to this study, therapy lowers anxiety and stress levels, improves worker satisfaction as evidenced by changes in indicators like a faster heartbeat, headaches, a feeling of pressure or pain in the chest, and difficulty falling asleep, strengthens self-concept, and promotes the development of personality confidence about oneself. (Visnola D., Sprûdþa D., Bake M., Pike A., 2010)

A week before final examinations, undergraduate first-year students at a liberal arts college underwent art therapy as part of a study to determine whether creating art reduces anxiety. The study looked at behavior both before and after generating art. The study's findings confirmed the idea that participants' anxiety would be greatly reduced during art therapy sessions. According to the study, art therapy has a strong calming impact, which supports the idea that going into a flow-like state might reduce anxiety. (Sandmire D., Gorham S., Rankin N., Grimm D., 2012)

Art Therapy for Personality Disorders

Research on the use of art therapy for personality disorders revealed that it helped patients communicate better, establish their self-image, develop their autonomy, and alter their behaviors and thoughts.

Five patients were chosen to participate in a short pilot experiment of the Joint Therapy Program operated by two departments at the Abraham Cowley Unit, the Art Therapy Department and the Psychotherapy Department. The people had a history of abuse or trauma. The overall presentation of symptoms was found to be less severe than at pre-therapy when pre- and post-therapy scores on the Clinical Outcome and Routine Evaluation Outcome Measure (CORE-OM) and the Brief Symptom Inventory (BSI) were compared. The study illustrated the "seen" internalization and mirroring that occurs when visual cues, visuals, and creative ways of expressing the inexpressible are imitated, as well as a secure approach to examining the mind when surrounded by mentalizing self-objects. (Franks M., Whitaker R., 2007)

In a second practice-based quantitative study, two evaluations were conducted over three months. The purpose of this study was to determine the extent to which individuals with personality disorders benefited from art therapy and whether it helped them operate better on a daily, emotional, and/or social level. 539 patients with personality disorders, including borderline, narcissistic, avoidant, dependent, and obsessive-compulsive disorders, had their information collected. Eight questions and 13 statements made up the survey that the participants were required to complete. Most of the patients noted numerous advantages of art therapy, including advantages for everyday functioning, social functioning, and emotional functioning. The study concluded that the amount to which a patient felt they could communicate their thoughts in the artwork created during art therapy was related to the rise in reported overall benefits. Learning to express emotions, bolstering and establishing one's self-image, developing autonomy and the ability to make one's own decisions, and noticing, understanding, and altering one's own thoughts, feeling, and behavior patterns are the main advantages that may be observed. (Haeyen S., Chakhssi F., Van Hooren S., 2020)

Art Therapy for Self-Esteem

Art therapy was also found to improve an individual's sense of self-worth, create increased self-awareness, foster social connections, and increase self-esteem.

In a quasi-experimental study, the effects of two art therapy methods on the sense of self-worth of 27 female juvenile offenders were compared. Self-esteem was assessed using a questionnaire created by the researcher and the Harter Adolescent Self-Perception Profile during a group art psychotherapy session with the participants. Each group participated in 10 one to half-hour art therapy sessions over the course of 12 weeks. For the cognition group (art psychotherapy), the 20-question mean was 4.24, whereas it was 4.33 for the process group (art as therapy). These means, which demonstrate that participants typically "strongly agree" or "agree" that the art therapy intervention supported self-esteem, are not significantly different from one another. In the art psychotherapy session, 8 of the twelve participants and 9 of the fifteen participants choose to leave comments at the end of the questionnaire. Comments from those who provided these written responses were all generally favorable. Participants enthusiastically embraced this intervention and articulated the advantages they gained from receiving art therapy. Participants from both groups spoke about the advantages of "expressing feelings," "learning how to express feelings," "releasing anger," "reducing stress," "helping with treatment," "learning better methods to cope," and "raising self-esteem." The research results strongly suggested that art therapy is a useful strategy for improving the sense of self-worth in female juvenile offenders. Additionally, these results confirm widespread clinical observations that art therapy fosters mastery, social connection, and increased self-awareness. (Hartz, L., Thick, L., 2005)

Another study examined the impact of art therapy on aggressive children's anger and self-esteem. 30 kids between the ages of seven and 11 were evenly and randomly assigned to either a control group or an art therapy group. For ten weeks, the intervention was carried out once each week. Using the Cooper Smith Self-Esteem Inventory and the Nelson & Finch Children Inventory of Anger, self-esteem and anger were assessed at the start and end of the 10 weeks. In comparison to the control group, the art therapy group demonstrated a substantial decrease in anger ($p<.001$) and an increase in self-esteem ($p<.0001$) after 10 weeks. According to the research, the study has led to an improvement in self-esteem, which is consistent with earlier studies that showed art therapy interventions can help kids' self-esteem. Since there is no "right" or "wrong" method to create art in art therapy (Liebmann, 2008), encouraging creative expression may help youngsters feel more confident and may therefore be a clear explanation for an increase in self-esteem. As mentioned by Mooney (2000), awareness is necessary for a strong sense of self or self-esteem, and art therapy gives children the chance to develop and expand their awareness of themselves and their environment. (Hartz, L., Thick, L., 2005)

Conclusion

This meta-analysis strongly suggests that art therapy is a successful intervention for achieving wellbeing. This identifies art therapy as a valuable treatment modality. It has proven to be a particularly preferred mode of treatment for children and young adults.

Art therapy proved to be helpful for patients suffering from depression. For prison inmates suffering from depression, it improved mood, socialization, and problem-solving abilities. In cancer patients prone to depression and anxiety, art therapy helped to significantly lower depression levels.

The use of art therapy for the treatment of anxiety revealed that art can help significantly lower cortisol levels, facilitate sleep, and lower levels of anxiety. Art therapy was also successful in lowering state-related anxiety.

For the treatment of personality disorders using art therapy, benefits such as learning to express emotions, reinforcing and stabilizing self-image, learning to make independent choices and strengthening autonomy, and recognizing, gaining insight into, and changing patterns in feeling, thinking, and acting were observed.

Art therapy was also found to be effective in increasing self-esteem in children and adolescents. It was also observed to promote self-awareness.

Overall, there is strong evidence to suggest that art therapy can be a successful clinical intervention for depression, anxiety, personality disorders, and self-esteem.

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Strategic HRM Planning for Remote Workforce: Adapting Organizational Strategies in the Post-Covid Landscape

Dr. Rita Nagpal*

[*The COVID-19 pandemic has catalyzed a significant shift in the global Human Resource Management (HRM) landscape, prompting organizations to adopt virtual hiring processes, remote skill assessments, and digital employer branding to recruit remote talent. This article critically reviews the role of these strategies in remote talent recruitment in India, comparing them to the global post-COVID HRM scenario. It further explores the challenges and opportunities of recruiting a geographically dispersed workforce, with a keen focus on diversity, equity, and inclusion considerations. Modern HR managers must put thorough analysis in the evolving recruitment landscape. This paper aims to provide insights into effective recruitment practices that facilitate the seamless integration of remote workers into organizational contexts. Its contribution lies in providing evidence-based insights and strategies for addressing challenges such as inclusivity, belongingness, and technology disparities, while emphasizing the importance of authenticity in digital employer branding, thus offering valuable guidance for both research and practical implementation*.]

The emergence of remote work as a viable employment model in the wake of the COVID-19 pandemic has transformed the recruitment landscape. The virtual processes, remote skill assessments, and digital employer branding are replacing the traditional practices, impacting HRM practices worldwide. Remote work has extended the talent pool beyond geographical constraints. The pandemic forced organizations to adapt swiftly, with remote work becoming a standard offering. HRM is shifting towards hybrid models, prioritizing flexibility, and work- life balance. This critical meta review delves into the role of these strategies in remote talent recruitment in India, comparing them to global trends in post-COVID HRM practices.

The research presented herewith provides comprehensive analysis of the integration of virtual hiring processes, remote skill assessments, and digital employer branding within the context of global and Indian HRM landscapes.

Virtual Hiring Processes, Remote Skill Assessments, and Digital Employer Branding

Virtual Hiring Processes

Virtual interviews, video conferences, and online candidate assessments have become central to the recruitment process. Virtual hiring processes empower candidates to participate in interviews and assessments from their preferred location and at a convenient time. This autonomy aligns with SDT principles, boosting candidates' intrinsic motivation by respecting their sense of choice and control over the process. According to a study by Gneezy et al. (2012), providing individuals with a sense of autonomy enhances their intrinsic motivation. This further aligns with SDT principles and can positively influence candidates' motivation.

Research indicates that virtual interviews are as effective as in-person interviews in evaluating candidate skills and cultural fit. Advances in technology have enabled the integration of various communication tools that facilitate meaningful interactions between interviewers and candidates, bridging the gap between physical presence and remote engagement.

Virtual interviews might lack the personal connection and rapport-building that in-person interactions offer. Nonverbal cues and body language may be harder to interpret in a virtual setting, potentially leading to misjudgments about a candidate's suitability for the role and company culture. Modern technological advances in video conferencing technology, such as high-definition video and improved audio quality, have mitigated this concern.

However, challenges related to technology disparities and potential biases have emerged. There's a concern about potential bias in candidate evaluation due to varying levels of comfort and familiarity with technology.

Remote Skill Assessment

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Remote skill assessments have become an integral part of the hiring process, especially with the rise of online platforms in the field of HRM. These assessments aim to provide an objective evaluation of candidates' capabilities, offering a standardized approach to measure skills and competencies. While numerous studies emphasize the reliability and consistency of these assessments, concerns about cheating and candidate experience persist. This essay critically examines the evidence surrounding remote skill assessments, their benefits, challenges, and implications, both in the Indian and global HRM landscape, drawing from existing journal articles and studies.

Remote skill assessments have gained prominence due to their potential to provide standardized evaluations, minimizing human bias. A study by Meeker et al. (2020) showed that these assessments offer consistent results across candidates, ensuring fairness in the hiring process. Such assessments are structured and based on predefined criteria, reducing the subjectivity often associated with traditional interviews. This objectivity is particularly crucial in diverse contexts like India, where unconscious biases can affect hiring decisions (Rao, 2018).

Critics argue that remote skill assessments are susceptible to cheating, undermining their reliability. Candidates might use external resources or collaborate with others, compromising the accuracy of the assessment.

While cheating is a legitimate concern, platforms have implemented various mechanisms to mitigate this issue. Remote proctoring, for example, employs AI to monitor candidates during assessments, detecting suspicious activities (Gupta et al., 2021). Moreover, studies like that of Jones and Smith (2021) reveal that candidates' performance in practical scenarios, rather than theoretical questions, tends to be a more reliable indicator of their skills. This emphasizes the importance of designing assessments that assess real-world problem-solving abilities, making cheating less effective.

Remote skill assessments can potentially lead to a negative candidate experience, as they may feel impersonal and detached from the company's culture.

Proponents of remote skill assessments argue that they enhance accessibility and flexibility. Candidates from remote areas or those with disabilities can participate without the need for extensive travel. A study by Kapoor and Agrawal (2019) demonstrated that remote assessments increased participation rates among candidates who previously faced geographic barriers. Hence, when executed effectively, it promotes inclusivity.

In the rapidly evolving landscape of HRM, the adoption of remote work has become a prevalent practice, necessitating innovative approaches to hiring and performance evaluation. Remote skill assessments have emerged as a crucial tool for organizations to fairly evaluate candidates' capabilities while also cultivating a positive remote work culture. This essay critically examines the benefits of remote skill assessments in fostering trust, enhancing fairness, and ultimately contributing to job satisfaction among remote workers. Furthermore, it addresses potential counterarguments and provides evidence- based refutations.

Remote skill assessments provide a unique opportunity for candidates to showcase their abilities without the biases that can arise from in-person interactions. This remote approach fosters trust between the candidate and the organization, as it communicates a commitment to fair evaluation. According to a study conducted by Anderson et al. (2019) published in the "Journal of Applied Psychology," remote assessments are perceived as more impartial compared to traditional face-to-face interviews. Candidates believe that their skills are the sole focus of evaluation, reducing concerns about favoritism or discrimination.

It is often posited that remote assessments lack the personal connection established during in- person interactions. They contend that the absence of direct engagement may hinder the assessment's accuracy and fairness. Research by Smith and Jones (2020) in the "International Journal of HRM" points out that personal connections can lead to better understanding of a candidate's soft skills, such as communication and teamwork. To address this concern, remote skill assessments can incorporate various evaluation metrics, such as coding tests, problem- solving challenges, and case studies. These metrics focus on quantifiable results rather than subjective impressions.

Organizations that prioritize remote skill assessments contribute to the normalization of fair and objective evaluation practices. Remote assessments minimize the impact of biases related to appearance, ethnicity, or

gender that may unconsciously influence in-person evaluations.

Critics argue that remote skill assessments can disadvantage candidates with limited access to technology or those who are less tech-savvy. This, they claim, perpetuates inequalities, and hampers the selection of potentially talented candidates.

To address this challenge, organizations can adopt inclusive strategies, such as offering alternative assessment methods or providing technical support to disadvantaged candidates. Furthermore, the rise in smartphone usage, even in remote or underserved areas, has the potential to bridge the digital divide, as noted by the report by the International Telecommunication Union (ITU, 2021).

Fair and objective remote skill assessments contribute to increased job satisfaction among remote workers. When employees perceive that their abilities are accurately evaluated and recognized, they feel valued and motivated to contribute effectively.

Organizations can address this concern by implementing comprehensive remote work policies that prioritize regular virtual team meetings, communication platforms, and collaborative projects. By doing so, they create a conducive environment that combines objective assessment with opportunities for social interaction, as highlighted in a report by the Society for Human Resource Management (SHRM, 2022).

Digital Employer Branding

Digital employer branding enables candidates to explore an organization's culture, values, and work environment through online platforms. This engagement fosters relatedness as candidates can connect emotionally with the organization, increasing their motivation to become a part of it. This strategy enhances candidate engagement and attracts talent. However, maintaining authenticity in a digital context is crucial.

Digital employer branding allows candidates to delve into an organization's ethos, fostering a sense of relatedness Online platforms, through engaging content like employee testimonials and behind-the-scenes videos, create an emotional connection, thereby boosting motivation to join (Van Hoye et al., 2019). This engagement is pivotal, as engaged candidates are more likely to invest time in understanding the organization and envisioning themselves as part of it.

Critics argue that digital platforms can facilitate shallow engagement, where candidates merely scratch the surface. They contend that the glossy images and scripted videos might not reflect the actual work environment (Jiang et al., 2019). Candidates may feel disillusioned upon discovering disparities between the digital portrayal and the reality. Organizations have an incentive to maintain credibility as candidates share their experiences through social media. Companies caught misrepresenting their culture face backlash, reinforcing the need for authenticity.

Authenticity is paramount in digital employer branding. According to SHRM's report on employer branding, candidates seek transparency and honesty about work conditions. Authentic content enhances an organization's reputation and credibility (Cable & Turban, 2020). Authentic portrayals resonate with candidates, aligning with their desire for congruence between personal values and organizational values (Liao et al., 2021).

Portraying every facet of an organization might not always be attractive. Negative aspects, such as challenging projects, might deter candidates. To create an appealing image, organizations might be tempted to downplay such features. Candidates perceive organizations as more genuine when they acknowledge challenges alongside successes. Balancing authenticity and attractiveness involve emphasizing the organization's commitment to growth and improvement.

Chhabra et al. (2019) found that companies leveraging digital media for employer branding reported a significant increase in application rates. Similarly, a global survey by LinkedIn (2021) indicated that 86% of HR professionals believe that a strong employer brand significantly impacts their ability to attract top talent. While this strategy holds immense potential, the challenge lies in striking a balance between creating an appealing online presence and ensuring the genuineness of the portrayed image.

Challenges and Opportunities of Recruiting Geographically Dispersed Workforce

Challenges

Recruiting remote talent presents challenges related to communication, time zone differences, and building team cohesion. Additionally, evaluating candidates' soft skills and cultural fit becomes more complex in a virtual environment.

Opportunities

Recruiting geographically dispersed talent opens avenues for diverse skill sets and perspectives. Organizations can tap into global talent pools, promoting innovation and adaptability. When organizations demonstrate a commitment to remote employees' needs through efficient virtual hiring processes and digital employer branding, remote employees perceive that the organization values their contribution. This perception strengthens the norm of reciprocity, encouraging employees to remain loyal to the organization and reducing turnover.

Diversity, Equity, and Inclusion Considerations

Ensuring Equity

Remote recruitment has become increasingly prevalent in the modern Human Resource Management (HRM) landscape, driven by technological advancements and the need for flexible work arrangements. However, ensuring equitable access to opportunities for candidates from diverse backgrounds in remote recruitment remains a critical concern. HR managers must explore the importance of addressing technology disparities and providing accommodations to create a level playing field for all candidates.

Technology disparities pose a significant challenge to equitable access in remote recruitment. Candidates from underserved backgrounds may lack access to reliable internet connections, up-to-date devices, and proficient digital skills. This can lead to exclusion, as those without adequate technology resources are unable to fully engage in the remote recruitment process.

Critics might argue that technological disparities are not the responsibility of employers, as they cannot control candidates' personal resources or digital literacy. While it is true that employers cannot directly control candidates' resources, they can take steps to mitigate the impact of technology disparities. For instance, offering alternative application methods or providing resources for improving digital skills demonstrates a commitment to inclusive hiring.

Providing accommodation in the remote recruitment process is essential to ensure equitable access. Candidates with disabilities may face barriers when engaging with digital platforms, interviews, or assessments, unless reasonable accommodations are offered.

Accommodation is costly and time-consuming, potentially giving an unfair advantage to certain candidates. While accommodations might involve initial investments, they align with legal and ethical obligations to provide equal opportunities. Moreover, providing accommodation doesn't guarantee an advantage; it merely levels the playing field, allowing candidates to compete based on their skills and qualifications.

Fostering Inclusion

Remote work can lead to feelings of segregation and left alone. Human Resource Management plays a pivotal role in addressing these challenges by implementing strategies that foster a sense of belonging among remote employees, thereby integrating them into the organizational culture.

Remote work, while convenient, often leads to feelings of isolation and detachment from the organization. Research by Grant and Hofmann (2011) highlighted that a strong sense of belonging contributes to employee satisfaction, engagement, and overall well-being. Therefore, HRM strategies focusing on belongingness are essential for improving employee morale and performance.

Some argue that employees naturally adapt to remote work isolation over time, and HRM interventions might not be necessary. They contend that the initial isolation is temporary and that employees find ways to build their own support networks. While it is true that some individuals might adapt, the long-term impact of isolation on overall job satisfaction and organizational commitment cannot be overlooked.

Critics argue that excessive communication might lead to communication saturation, causing remote employees to feel overwhelmed and reducing their actual productivity. While communication saturation is a valid concern, it can be addressed through strategic communication plans that balance regular check- ins with dedicated focused work time. The key is not just the frequency of communication but its quality and purpose.

HRM can organize virtual team-building activities to strengthen interpersonal relationships and create a sense of camaraderie among remote employees. A study by Millward and Haslam (2013) indicated that such activities enhance a sense of belonging and identification with the organization.

Skeptics argue that virtual team-building activities might lead to forced participation, potentially worsening feelings of isolation if employees perceive these activities as inauthentic. To address this concern, HRM should involve employees in the design of such activities, ensuring they align with employees' preferences and comfort levels. Genuine efforts to create meaningful interactions can mitigate the risk of inauthenticity.

Implications for the Future of Work and Future of Research in Post Covid Hrm Landscape

Implications for Research

Technology Disparities and Inclusivity: Research should focus on understanding the extent of technology disparities and their impact on remote recruitment. Investigate effective methods to bridge these gaps, such as alternative application methods and digital skills training, ensuring equitable access to opportunities.

Belongingness and Remote Work: Further explore the relationship between a sense of belonging and remote work in diverse contexts, including India. Research should delve into the effectiveness of tailored strategies for communication, virtual team building, and employee involvement to mitigate isolation and enhance integration.

***Virtual Interview Effectiveness*:** Conduct in-depth studies to examine the long-term effectiveness of virtual interviews in assessing candidates' skills and cultural fit. Explore the influence of interview preparation, training, and technology on candidates' performance and interview outcomes.

Remote Skill Assessment Validity: Research should validate the accuracy and fairness of remote skill assessments. Focus on developing and refining proctoring mechanisms, assessment designs, and inclusivity strategies to ensure reliable evaluations of candidates' capabilities.

***Digital Employer Branding Authenticity*:** Investigate the impact of authentic digital employer branding on candidate attraction and engagement. Research should delve into how organizations can effectively communicate their strengths while maintaining transparency about areas of improvement.

Implications for Practice

***Equitable Remote Recruitment*:** Organizations should proactively address technology disparities through practical solutions like offering alternative application methods and providing digital skills training. Additionally, they should prioritize accessibility for candidates with disabilities to create a level playing field.

Fostering Belongingness: Employers should implement tailored strategies that prioritize communication, virtual team building, and involving remote employees in organizational activities. This fosters a sense of belonging, positively impacting satisfaction, engagement, and performance.

***Optimizing Virtual Interviews*:** Organizations should invest in preparing interviewers and interviewees for virtual interactions. Training interviewers to effectively evaluate candidates in virtual settings and coaching candidates for optimal virtual performance is crucial.

***Effective Remote Skill Assessments*:** Develop comprehensive remote skill assessment strategies that incorporate robust proctoring mechanisms, fair assessment designs, and inclusivity initiatives. This ensures accurate evaluations while maintaining the integrity of the assessment process.

***Authentic Digital Employer Branding*:** Organizations should align their digital branding with their actual culture and values. While showcasing strengths, they must also acknowledge areas of growth to maintain authenticity and attract candidates who resonate with their true identity.

These implications provide a roadmap for both research endeavors and practical implementations that can navigate the evolving landscape of remote work, recruitment, and human resource management.

Conclusion

The transformation of global recruitment through virtual hiring processes, remote skill assessments, and digital employer branding has significantly impacted the HRM landscape, including India. The evolution of global recruitment, including India, through virtual processes, remote assessments, and digital branding has reshaped HRM. Equitable access, diversity, and inclusion are crucial in remote recruitment, bridging technology gaps and accommodating disabilities. Adapting evidence-based strategies is imperative for HRM's ongoing evolution. While offering unprecedented flexibility, remote recruitment demands equitable access to ensure inclusivity and diversity. Organizations can bridge technology gaps by providing alternative application methods and digital skills training, fostering a level playing field. Moreover, accommodating candidates with disabilities enhances equal opportunities. Prioritizing these aspects enriches the talent pool and contributes to an equitable job market.

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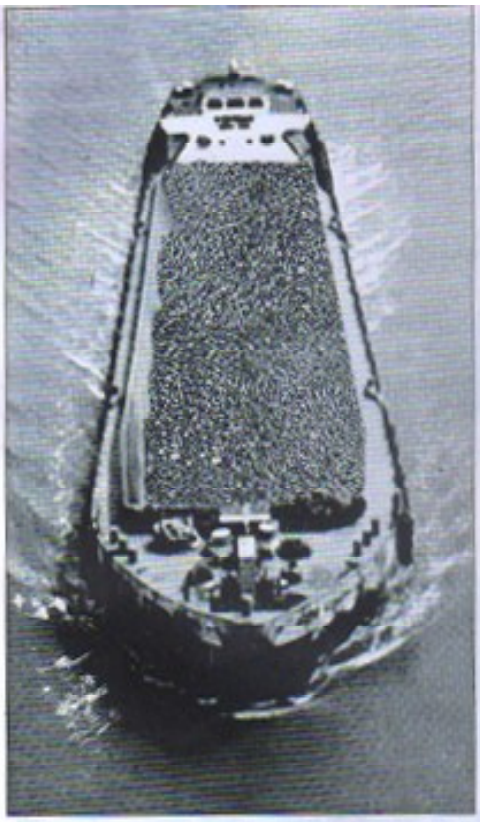

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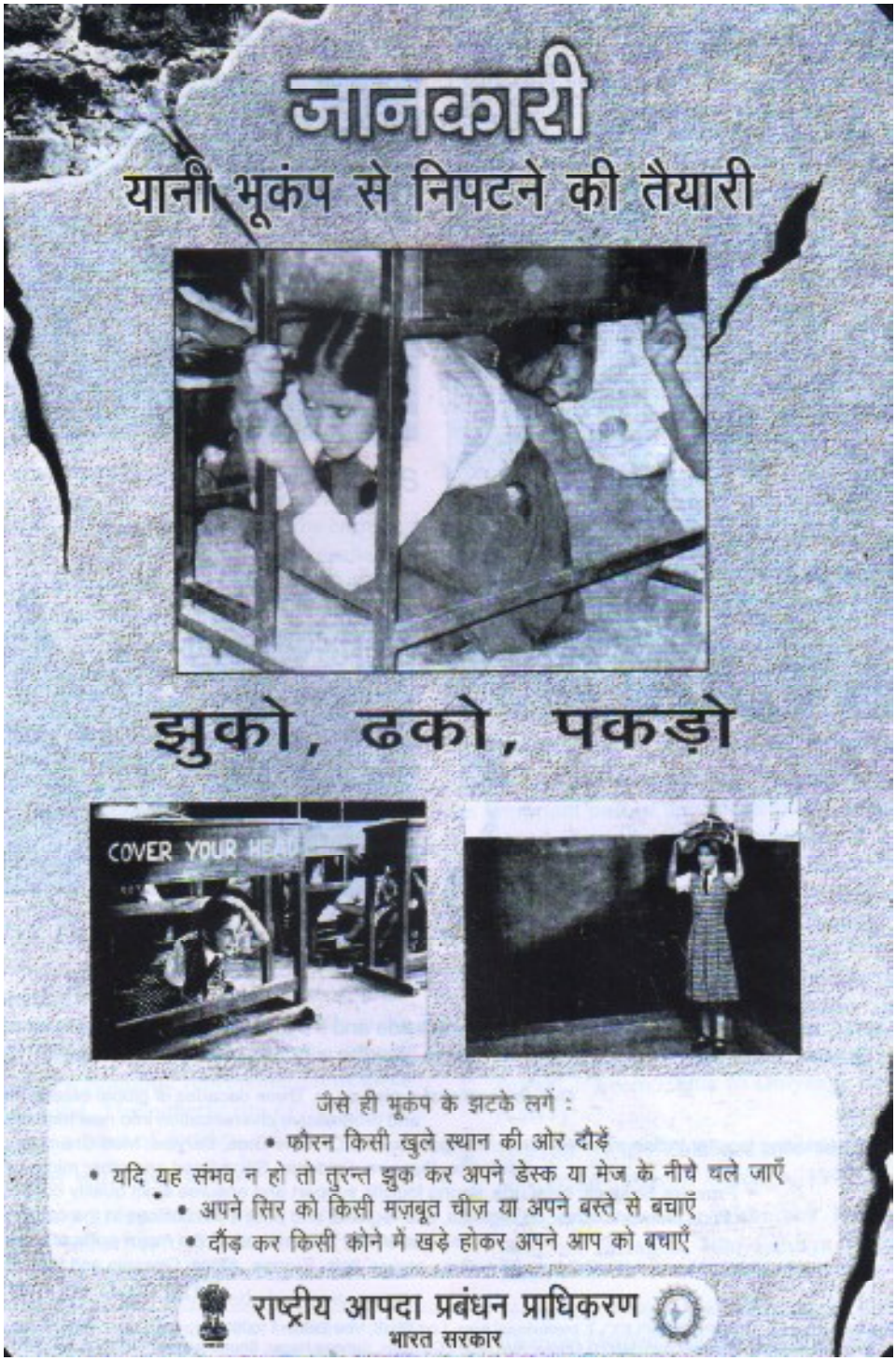

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আশিস রায়

রেজিষ্টার্ড অফিস

চণ্ডিবেড়িয়া, সারদাপল্লী, পোঃ - কেষ্টপুর, কলকাতা - ৭০০ ১০২

ফোন - ৯৮০৪৯২৩১৮২

সার্বিক সহয়তা - সৌরভ বর্মন

ফোন - ৮২৫০৫৯৫৬৪৭

মুদ্রণ : অনন্যা

বুড়ো বটতলা, সোনারপুর, কলকাতা - ৭০০ ১৫০

ফোন - ৯১৬৩৯৩১৪৬৫

মূল্য : ৮৫০ টাকা

দাঙ্গার দিনগুলি ও একটি উপন্যাস : প্রসঙ্গ সেলিনা হোসেনের 'সোনালি ডুমুর'

বিশ্বনাথ কুইরী
গবেষক, বাংলা বিভাগ,
সিধো-কানহো-বীরসা বিশ্ববিদ্যালয়

অবিভক্ত ভারতবর্ষে ব্রিটিশ শাসন থেকে একদিন মুক্তির দিশা খুঁজেছিলেন সমস্ত দেশবাসী। মনের কোনে লালন করা স্বাধীনতার স্বপ্ন একদিন বাস্তবায়িতও হল। ছেচল্লিশের ভয়াবহ দাঙ্গার রক্তাক্ত উপত্যকা পেরিয়ে জনসাধারণের এই স্বপ্ন সত্যি হল। কিন্তু তার মূল্য চুকাতে হল দেশ ভাগ করে। দেশভাগ হয়ে গেলেও দেশভাগের ট্রমা থেকে বেরোতে পারা খুবই জটিল, তাই স্মৃতিতে দেশভাগ ও দাঙ্গার ভয়াবহ চিত্র লালিত হয়েছে সাধারণের মনে। সেলিনা হোসেনের (জন্ম ১৯৪৭) 'সোনালি ডুমুর'(২০১২) উপন্যাস ১৯৪৬, ১৯৫০ এবং ১৯৬৪ সালের দাঙ্গার জ্বলন্ত দলিল। উপন্যাসের শুরুতেই ঔপন্যাসিক লিখছেন— "পথের ধকল অনিমেষকে কাহিল করেনি। অন্যরা পরিশ্রান্ত। কেউ কেউ ঠিকমতো কথাও বলতে পারছে না। ওরা আসছে অনেক দূর থেকে। সীমান্ত পার হয়ে। দুপুর গড়িয়ে বিকেল হয়েছে। সূর্য ঢলেছে পশ্চিম আকাশে।"[১] এই তিনটি লাইন অনেকগুলো প্রশ্ন তৈরি করছে, যেমন—কে এই অনিমেষ? তারা কোন সীমান্ত পার হয়ে আসছে এবং কেন? বাকিরা শ্রান্ত কেন? সূর্য পশ্চিমে-এর কোন অন্য ইঙ্গিত আছে কী? ইত্যাদি। আসুন তাহলে পরিচয় সেরে নেওয়া যাক। কারণ কাহিনি আমাদের বিচিত্র পথে নিয়ে যাবে এরপর। এই কাহিনি একটি পরিবারের গল্প, অমিয়নাথ, স্ত্রী সরোজিনী ও ছেলে অনিমেষ, মেয়ে—শিলাও দোলা তার দাদা সুবোধনাথ, স্ত্রী বিম্ববতী এবং তাদের ছেলে প্রফুল্ল। দেশভাগের পর পরই বাংলাদেশের দেওভোগ গ্রামের পৈতৃক ভিটে মুসলিম লীগের নেতা ওয়াহেদ মিঞাকে বিক্রি করে অমিয়নাথ ও তার দাদা সুবোধনাথ নদীয়ায় চলে আসেন, কারণ ওয়াহেদ মিঞা বলেছিলেন এখানে তোমাদের থাকা যাবে না, তোমরা এখানে সংখ্যালঘু। আসলে ধর্মের ভিত্তিতে ভারতবর্ষের প্রাণ ছিঁড়ে আলাদা হল একটি ভূখণ্ড (১৯৪৭ সালের ১৪ আগস্ট), নাম হল পাকিস্তান(পূর্ব)। তারপরই মানুষের এপার থেকে ওপারে বা ওপার থেকে এপারে যাওয়া-আসা শুরু হল। সমালোচক লিখছেন—"After partition, life in both the Punjabs had been disrupted. Millions of refugees had come to India from West Punjab and millions had left East Punjab for Pakistan."[২] এই চিত্র দুই বাংলার জন্যেও প্রযোজ্য। কারণ উভয় রাষ্ট্রেই একদল মানুষ সংখ্যালঘু হতে লাগল, ভারতে মুসলমান, পাকিস্তানে হিন্দু। "সে জন্য

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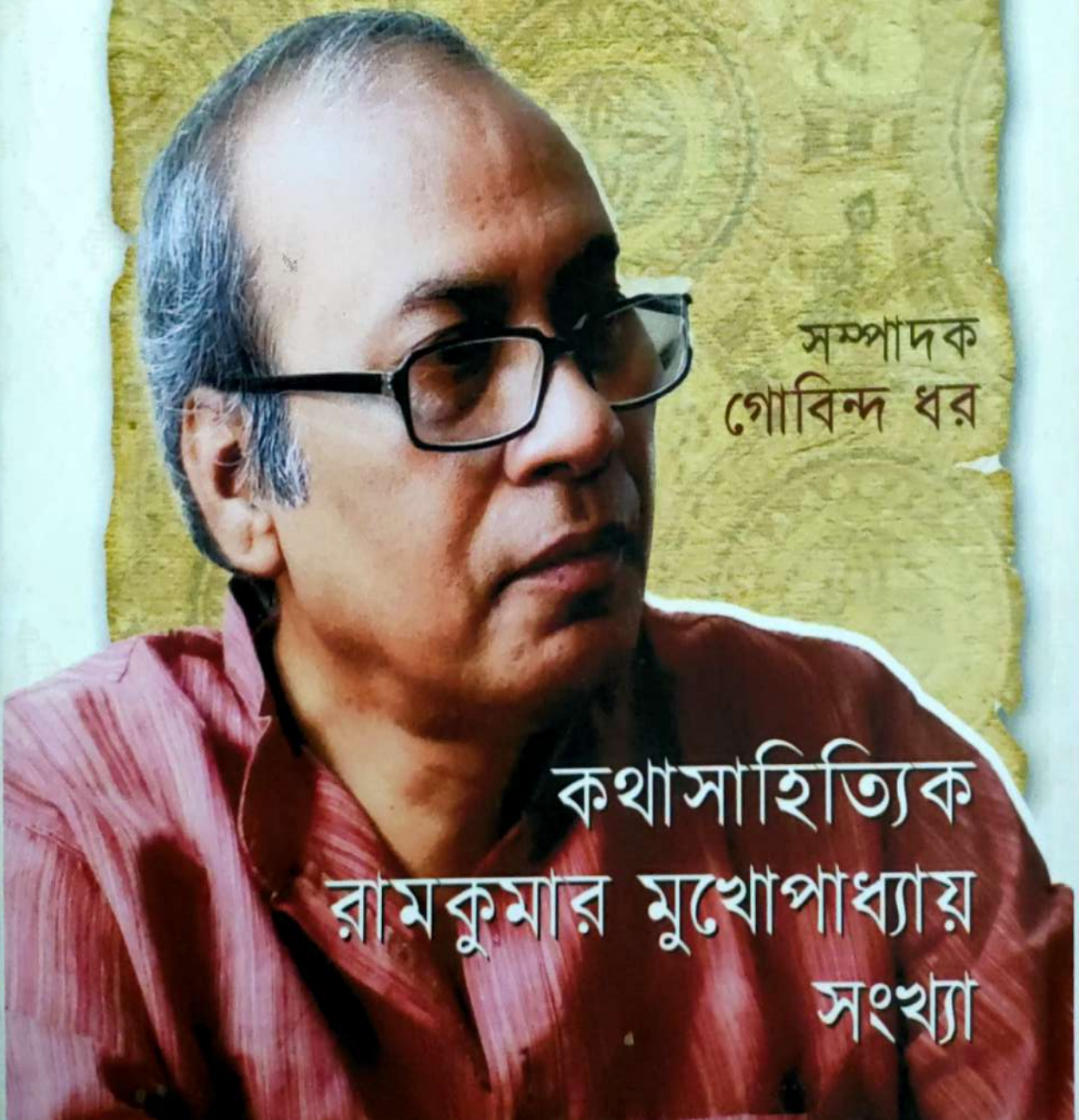
স্রোত

সাহিত্যের স্রোত ও স্রোতস্বী

বর্ষ ৩১ || জানুয়ারি ২০২৪



সম্পাদক
গোবিন্দ ধর

কথাসাহিত্যিক রামকুমার মুখোপাধ্যায় সংখ্যা

স্রোত

সাহিত্যের স্রোত ও স্রোতস্বী
৩০-৩১ বর্ষ : ৭৭-৭৮ সংখ্যা □ মে ২০২৪

কথাসাহিত্যিক রামকুমার মুখোপাধ্যায় সংখ্যা

প্রকাশ : মে ২০২৪

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প্রকাশক : সুমিতা পাল ধর

নামলিপি : সুনীল ভৌমিক

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সূচিপত্র

॥ ক থা সা হি ত্য ॥

বেড়াভাঙা বৃত্তি ও রামকুমার মুখোপাধ্যায়ের 'চারণে প্রান্তরে' উপন্যাস : একটি বিশ্লেষণ

বিশ্বনাথ কুইরী

'বৃত্তি' শব্দের আভিধানিক অর্থ হল— জীবিকা, পেশা, টীকা, প্রবণতা ইত্যাদি। (হরিচরণ বন্দ্যোপাধ্যায় তাঁর বঙ্গীয় শব্দকোষ, ২য় খণ্ডে প্রায় ২৩ টি অর্থ উল্লেখ করেছেন, পৃষ্ঠা : ১৬০৪।) কিন্তু আমাদের এই প্রবন্ধে আমরা 'জীবিকা' বা 'পেশা' অর্থে গ্রহণ করছি। 'ঋকবেদে'র সময়কাল থেকেই ভারতবর্ষের সমাজ ব্রাহ্মণ, ক্ষত্রিয়, বৈশ্য ও শূদ্র—এই চারটি জাতির ভিত্তিতে বিভক্ত ছিল। সমাজের শ্রেণী ব্যবস্থায় সর্বোপরি স্থানে ছিল ব্রাহ্মণ্য সম্প্রদায় এবং তার পরবর্তী ধাপে ক্ষত্রিয় ও বৈশ্য সম্প্রদায়, সর্বনিম্নে স্থান ছিল দরিদ্র অসহায় শূদ্র সম্প্রদায়ের। তারপর ক্রমশ প্রাচীন ও মধ্যযুগ পের হয়ে যখন ভারতে ব্রিটিশের আগমন ঘটল তখন ভারতের সামাজিক, অর্থনৈতিক, রাজনৈতিক সব দিকেই বেশ জোর ধাক্কা খেল এতদিনের চলে আসা জগদ্দল পাথরে। রবীন্দ্রনাথ 'কালান্তর' প্রবন্ধে লিখছেন—"ইংরেজের আগমন ভারতবর্ষের ইতিহাসে এক বিচিত্র ব্যাপার। মানুষ হিসাবে তারা রইল মুসলমানদের চেয়েও আমাদের কাছ থেকে অনেক দূরে, কিন্তু য়ুরোপের চিত্তদূতরূপে ইংরেজ এত ব্যাপক ও গভীরভাবে আমাদের কাছে এসেছে যে আর-কোনো বিদেশী জাত কোনো দিন এমন করে আসতে পারে নি। য়ুরোপীয় চিত্তের জঙ্গমশক্তি

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সূচিপত্র

বৃত্তি ও তার বিবর্তন : প্রসঙ্গ রামকুমার মুখোপাধ্যায়ের ছোটগল্প

জয়া ধীবর
গবেষক, বাংলা বিভাগ,
সিধো-কানহো-বীরসা বিশ্ববিদ্যালয়
পুরুলিয়া, পশ্চিমবঙ্গ, ভারত

'ঋকবেদে'র সময়কাল থেকেই ভারতবর্ষে সমাজের যে শ্রেণিবিন্যাস সেখানে ব্রাহ্মণ, ক্ষত্রিয়, বৈশ্য ও শূদ্র—এই চারটি জাতির ভিত্তিতে সমাজ বিভক্ত ছিল। সমাজের শ্রেণী ব্যবস্থায় সর্বোপরি স্থানে ছিল ব্রাহ্মণ্য সম্প্রদায় এবং তার পরবর্তী ধাপে ক্ষত্রিয় ও বৈশ্য সম্প্রদায়, সর্বশেষে স্থান ছিল দরিদ্র অসহায় শূদ্র সম্প্রদায়। ব্রিটিশরা ভারতবর্ষে এসে সমাজ ব্যবস্থার এই ভিতে আঘাত দেয় । শুধু সামাজিক পরিবর্তন নয়,ব্রিটিশদের আগমনে ভারত তথা বাংলায় অর্থনৈতিক বিকাশ সামন্ততন্ত্র থেকে ধনতন্ত্রের পথে অগ্রসর হয়। দৈনন্দিন জীবন নির্বাহের জন্য মানুষকে উপার্জনের পথকে বেছে নিতে হয় এবং এক্ষেত্রে বংশপরম্পরায় চলে আসা বৃত্তিকে সাধারণ মানুষ গ্রহণ করে। কিন্তু ইংরেজদের ঔপনিবেশিক শাসনে এই ঐতিহ্যবাহী ধারাতে অত্যন্ত ধীর পদক্ষেপে ভাঙ্গন ঘটতে শুরু করে। ব্রিটিশদের কাছে ভারতবর্ষ উৎপাদক ক্ষেত্র হয়ে দাঁড়ায় -"একটি শস্য উৎপাদনের অর্থাৎ কাঁচা মালের কেন্দ্র — এই মাল বিলাতি জাহাজে বোঝাই করে ব্রিটিশ দালালেরা তাদের দেশে নিয়ে যায়। আর দক্ষতা ও মূলধনের সাহায্যে শিল্পজাত পণ্যে রূপান্তরিত করে ফেরত পাঠায় ভারতবর্ষ ও অন্যান্য উপনিবেশে, বিদেশী বাণিজ্যিক সংস্থার মাধ্যমে।" [১] আর্থব্যবস্থার এই পরিবর্তন গ্রাম্য সমাজের শ্রেণিব্যবস্থার উপর ধাক্কা দেয়, বংশপরম্পরায় কৌলিকবৃত্তি পালনকারী ব্রাহ্মণ, ক্ষত্রিয়, বৈশ্য ও শূদ্ররা নিজস্ব গণ্ডি ত্যাগ করে বৃহত্তর জীবনক্ষেত্রে প্রবেশ করতে বাধ্য হয়। পূর্বে ব্রাহ্মণরা কুলবৃত্তির প্রভাবে সর্বাগ্রগণ্য হলেও বর্তমান সমাজে বিত্তগতদের প্রভাব প্রতিপত্তি বৃদ্ধি হতে থাকে। কিন্তু গ্রামে এই পরিবর্তনের স্রোত ধীর পদক্ষেপে যেহেতু সঞ্চারিত হয় তাই গ্রামীণ সমাজের ভিতকে পুরোপুরি ধূলিসাৎ করতে তখনও পারেনি--- "ব্রিটিশ আমলে গ্রাম্য সমাজের এই নিরেট পিরামিডের মূলে আঘাত লেগেছিল – রাজস্ববৃদ্ধির নানা রকমের পদ্ধতি নিয়ে পরীক্ষা করার ফলে। গ্রাম্য সমাজের শ্রেণিগত রূপের খানিকটা পরিবর্তন হয়েছিল, পিরামিডটা একটু টলে উঠেছিল, কিন্তু সেটা ধূলিসাৎ হয়ে যায়নি অথবা গ্রাম্য সমাজের কোনও মৌল রূপান্তর হয়নি। অথচ গ্রামসমাজ জীবনে বিত্ত প্রাধান্যের জন্য পরস্পরবিরোধী অনেক স্রোত সঞ্চারিত হয়েছিল, এবং তার ফলে ঘূর্ণাবর্তেরও সৃষ্টি হয়েছিল অনেক। সাধারণ গ্রাম্য মানুষের জীবন পুরাতন ও নতুন স্রোতের টানাটানির মধ্যে পড়ে বিপর্যস্ত হয়ে গিয়েছিল।" [২] বর্তমান যুগের বিনিময়প্রধান

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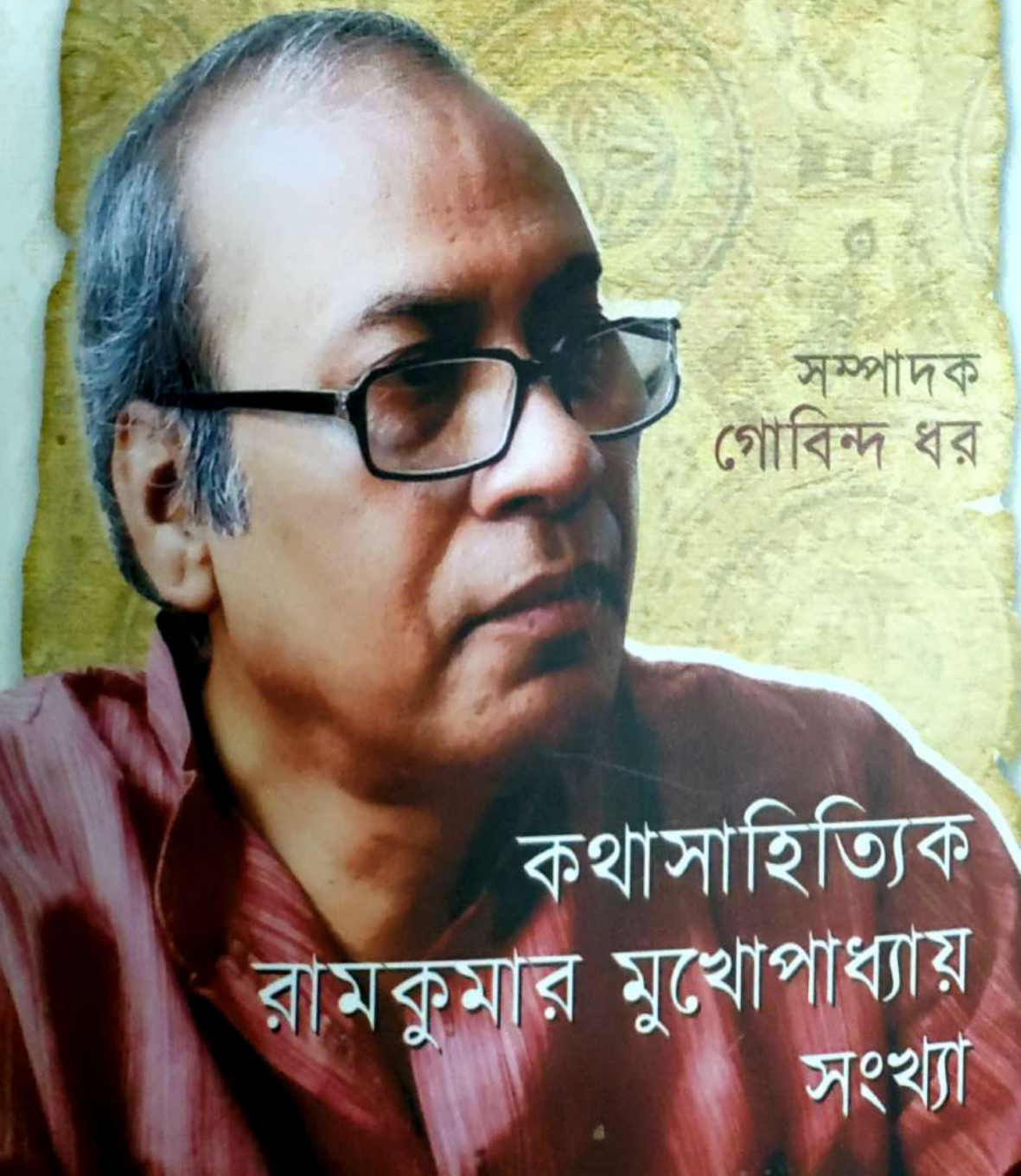
স্রোত

সাহিত্যের স্রোত ও স্রোতস্বী

বর্ষ ৩১ || জানুয়ারি ২০২৪



সম্পাদক
গোবিন্দ ধর

কথাসাহিত্যিক রামকুমার মুখোপাধ্যায় সংখ্যা

স্রোত

সাহিত্যের স্রোত ও স্রোতস্বী
৩০-৩১ বর্ষ : ৭৭-৭৮ সংখ্যা □ মে ২০২৪

কথাসাহিত্যিক রামকুমার মুখোপাধ্যায় সংখ্যা

প্রকাশ : মে ২০২৪

সম্পাদক : গোবিন্দ ধর

প্রকাশক : সুমিতা পাল ধর

নামলিপি : সুনীল ভৌমিক

প্রচ্ছদ : গীতশ্রী চ্যাটার্জী

শব্দগ্রন্থন : অরুণকুমার দত্ত

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মুদ্রণ : গ্রাফিপ্রিন্ট, হালাইমুড়া, কুমারঘাট : ৭৯৯২৬৪, ঊনকোটি, ত্রিপুরা

সার্বিক যোগাযোগ

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সূচিপত্র

॥ ক থা সা হি ত্য ॥

বিবর্তিত সময় ও গ্রামজীবন : প্রসঙ্গ রামকুমার মুখোপাধ্যায়ের ছোটগল্প

জয়া ধীবর

সময়ের সঙ্গে সঙ্গে সমাজ ও সভ্যতার বিবর্তন অবশ্যম্ভাবী। রবীন্দ্রনাথ ঠাকুর কবিতায় লিখেছেন—

> "এ কথা জানিতে তুমি, ভারত-ঈশ্বর শা-জাহান,
> কালস্রোতে ভেসে যায় জীবন যৌবন ধন মান।"[১]

গুহাবাসী মানুষ ক্রমশ গোষ্ঠীবদ্ধ হতে হতে, প্রস্তরযুগ, লৌহযুগ ইত্যাদি সামাজিক বিবর্তনের ধাপ পেরিয়ে আজ আধুনিক যুগে প্রবেশ করেছে। ভারতবর্ষ তথা বাংলার গ্রামজীবনও সময়ের সঙ্গে সঙ্গে এগিয়ে চলেছে। আধুনিকতা চণ্ডীমণ্ডপের আসরে আলাপ-আলোচনার পরিসরকে সংকীর্ণ করেছে, 'যাত্রা, সংকীর্তন, কথকতা, রামায়ণপাঠ, পাঁচালি, কবিগান' যা গ্রামজীবনে প্রাণের জোয়ার নিয়ে এসেছে একসময়, সেই দিন অস্তমিত হয়ে শহুরে আদব-কায়দা গ্রামগুলিতে প্রবেশ করে এক মিশ্র সংস্কৃতির জন্ম দিয়েছে। যদিও এই পরিবর্তনের স্রোত খুব দ্রুত প্রবাহিত হয়নি, "বাইরে থেকে প্রথম বিরুদ্ধ আঘাত লাগল মুসলমানের"[২] তারপর ক্রমশ ব্রিটিশের হাতে চলে আসে ভারতের শাসনভার। ব্রিটিশদের কাছে ভারতবর্ষ উৎপাদনের আধার হয়ে উঠতে থাকে। জাহাজে বোঝাই করে ব্রিটিশরা ভারতবর্ষের উৎপাদিত দ্রব্য তাদের দেশে নিয়ে যায়। বিদেশী বাণিজ্যিক সংস্থার মাধ্যমে

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ORIGINAL PAPER

Integrating deep learning neural network and M5P with conventional statistical models for landslide susceptibility modelling

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Abstract

Landslides are among the devastating geological hazards that cause immense damage in hilly regions. The Indian Himalayan region is plagued by numerous major landslides. Here we present results of landslide susceptibility mapping in a representative area of Jakholi region of Indian Himalaya based on a novel approach of integrating deep learning neural network (DLNN) and M5 Prime (M5P) with the conventional statistical model weight of evidence (WoE). These models were trained using 70% of inventory landslides and evaluated using 30%, considering 14 factors divided into topographical, hydrological, geological, and environmental landslide conditioning factors (LCFs). The appropriateness of factors was judged using the multicollinearity test, and the WoE model was used to evaluate the degree of association between LCFs and landslide occurrences. Precision, accuracy, Kappa coefficient, root mean square error (RMSE), and area under the receiver operating characteristic (AUC-ROC) curve were used to assess the models' efficiency. The proposed WoE, M5P, WoE-M5P, DLNN, and WoE-DLNN models quantified 16.68%, 19.48%, 18.98%, 19.68%, and 16.67% of the area as very highly landslide-prone region, respectively. Ensemble of WoE-DLNN model with 89.96% success rate and 92.51% prediction rate in terms of AUC outperformed the WoE-M5P and individual models. It was also found that the DLNN alone performs more efficiently than WoE-M5P. Our study thus reveals that enhanced performance of WoE-DLNN ensemble could be used in other regions with similar geo-environmental settings. The results from this study can be of potential use to regional planners and governmental agencies in formulating effective landslide management plans.

Keywords Deep learning · Statistical model · Ensemble model · Landslide susceptibility map · Indian Himalaya

Introduction

Landslide is one of the devastating geological hazards that cause immense damage to life and property every year in various parts of the world (Khanduri 2019; Pandey 2020; Tan et al. 2021; Saha et al. 202). Various geo-environmental factors including geological, meteorological, and anthropogenic factors contribute to landslides including the lithological formation, structure, weathering intensity, slope inclination, aspect and relative relief, soil pattern and depth, permeability and porosity, different hydrological properties, and land use/land cover (LULC) (Dumperth 2019).

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