Indian Journal of Research in Homoeopathy

Volume 20 | Issue 1 Article 3

25-3-2026

Investigation of molecular footprints in ultra-high diluted homoeopathic solutions of *Arnica montana* and *Rhus toxicodendron* through combined infrared and impedance spectroscopy

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How to cite this article

Kundu S, Dash UR, RoyChaudhuri C, *et al*. Investigation of molecular footprints in ultra-high diluted homoeopathic solutions of *Arnica montana* and *Rhus toxicodendron* through combined infrared and impedance spectroscopy. *Indian J Res Homoeopathy*. 2026;20(1):17–29.

Investigation of molecular footprints in ultra-high diluted homoeopathic solutions of *Arnica montana* and *Rhus toxicodendron* through combined infrared and impedance spectroscopy

Abstract

Background: The study of ultra-high diluted (UHD) solutions is a compelling and controversial domain in modern science. Despite numerous investigations and hypotheses, there is a lack of rigorous, reproducible empirical evidence supporting the existence of molecular footprints beyond the Avogadro's limit. Objective: This study conducted a detailed investigation of the molecular and electrical properties, focusing on hydrogen bonding and impedance to understand the fundamental nature of UHD solutions. Materials and methods: Combined impedance and infrared spectroscopic investigations were performed to probe the structural behaviour of relevant water networks at the molecular level of UHD alcoholic extract of *Arnica montana* (AM) and *Rhus toxicodendron* (RT). Results: At higher potencies (200C and 1M) of both AM and RT, an interesting correlation was observed between impedance and spectral characteristics. An increase in impedance was observed with potencies for both AM (93.9%) and RT (49%), which was attributed to changes in the hydrogen bonding network and molecular reorganisation during potentisation. This correlates with the Mid-IR spectra, showing increased hydrogen bond length and potential weakening of inter-molecular hydrogen bonds with increasing potency. Also, Far-IR spectra indicate a contrast in the system's enthalpic gain with increased potencies for both AM (29.8%) and RT (65.2%). Conclusion: Distinct variations in spectral and electrical parameters have been observed for AM and RT due to potentisation, suggesting that these solutions retain structural and molecular traits despite extreme dilutions. This notion may revisit traditional homoeopathic treatment approaches by addressing conflicting paradigms regarding the presence of molecular footprints in UHD solutions.

Acknowledgments and Source of Funding

The authors are grateful to the Central Council for Research in Homeopathy (CCRH), Ministry of AYUSH, Govt. of India for their support in this research. They also appreciate the contributions of Mr. Kaustav Ghosh of the School of Biotechnology, KIIT, Bhubaneswar, and Ms. Piyali Mukherjee of the ETC Department of IIEST, Shibpur. Special thanks are extended to Dr. Milan Sengupta, Consultant (Homoeopathy), Virology Laboratory, DACRRI (H), Kolkata, for providing guidance in preparing homeopathic solutions. Financial support: This work was supported by the Central Council for Research in Homeopathy (CCRH), Ministry of AYUSH, Govt. of India (F. No. 17-153/2010-11/CCRH/Tech./Coll/BESU-Kol./Pt.File 2326, dated. 16.12.2016).

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ORIGINAL ARTICLE

Investigation of molecular footprints in ultra-high diluted homoeopathic solutions of *Arnica montana* and *Rhus toxicodendron* through combined infrared and impedance spectroscopy

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ABSTRACT

Background: The study of ultra-high diluted (UHD) solutions is a compelling and controversial domain in modern science. Despite numerous investigations and hypotheses, there is a lack of rigorous, reproducible empirical evidence supporting the existence of molecular footprints beyond the Avogadro's limit. **Objective:** This study conducted a detailed investigation of the molecular and electrical properties, focusing on hydrogen bonding and impedance to understand the fundamental nature of UHD solutions. **Materials and methods:** Combined impedance and infrared spectroscopic investigations were performed to probe the structural behaviour of relevant water networks at the molecular level of UHD alcoholic extract of *Arnica montana* (AM) and *Rhus toxicodendron* (RT). **Results:** At higher potencies (200C and 1M) of both AM and RT, an interesting correlation was observed between impedance and spectral characteristics. An increase in impedance was observed with potencies for both AM (93.9%) and RT (49%), which was attributed to changes in the hydrogen bonding network and molecular reorganisation during potentisation. This correlates with the Mid-IR spectra, showing increased hydrogen bond length and potential weakening of inter-molecular hydrogen bonds with increasing potency. Also, Far-IR spectra indicate a contrast in the system's enthalpic gain with increased potencies for both AM (29.8%) and RT (65.2%). **Conclusion:** Distinct variations in spectral and electrical parameters have been observed for AM and RT due to potentisation, suggesting that these solutions retain structural and molecular traits despite extreme dilutions. This notion may revisit traditional homoeopathic treatment approaches by addressing conflicting paradigms regarding the presence of molecular footprints in UHD solutions.

Keywords: H-O-H bending, Impedance spectroscopy, IR spectroscopy, O-H stretching, Ultra-high diluted solutions

How to cite this article: Kundu S, Dash UR, RoyChaudhuri C, *et al.* Investigation of molecular footprints in ultra-high diluted homoeopathic solutions of *Arnica montana* and *Rhus toxicodendron* through combined infrared and impedance spectroscopy. *Indian J Res Homoeopathy.* 2026;20(1):17–29.

Received 4 January 2025; Accepted 14 February 2026.

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https://doi.org/10.53945/2320-7094.2354

Introduction

Ultra-high diluted (UHD) solutions, often exceeding the point at which no molecules of the original solute are theoretically present, represent a controversial yet intriguing field of modern science, as they challenge established principles of chemistry and physics. Central to this debate is the hypothesis of "molecular footprints," which posits that structural or energetic imprints of the solute may persist in the solvent even at extreme dilutions, thereby supporting claims of retained therapeutic efficacy in practices such as Homoeopathy.[1,2] The homoeopathic remedies are typically prepared through successive centesimal dilutions (1:100), combined with vigorous shaking or succussion—a process termed potentisation or dynamisation—during which considerable mechanical energy (~40.43 Nm per stroke) is imparted to the solution.[3] The potency level is expressed as nC, where n indicates the number of dilutions–succussion steps (e.g., 1C = 10^{-2}, 2C = 10^{-4}, and in general, nC = 10^{-2n}).[4] UHDs may thus be regarded as very low molarity repetitively succussed diluted liquids,[5] distinguished by physicochemical properties markedly different from those of the original solvent.[6]

In this study, we investigated two widely used homoeopathic medicines: *Arnica montana* (AM) and *Rhus toxicodendron* (RT), at ultra-high potencies (200C and 1M; dilution factors of 10^{-400} and 10^{-2000}, respectively), both recognised for their analgesic, anti-inflammatory, and potential anticancer effects.[7–17] The molecular organisation in UHDs is largely governed by the hydrogen-bond (HB) network of water and its interaction with ethanol, which functions as a stabilising co-solvent. In Fourier-transform infrared (FTIR) spectroscopy, the mid-infrared (MIR) spectral features—specifically the O–H stretching and H–O–H bending modes—are primarily sensitive to intra-molecular hydrogen bonding and reflect local HB environments within water molecules. By contrast, the far-infrared (FIR) region, particularly the librational modes, captures inter-molecular HB structure and dynamics through collective, out-of-plane molecular motions. Complementing these vibrational insights, impedance spectroscopy probes dielectric and conductive properties, offering an indirect yet sensitive marker of molecular structuring and charge-transport behaviour across potencies.

Spectroscopic investigations have been instrumental in elucidating the physicochemical properties of UHDs, aiming to capture molecular-level changes induced during potentisation and to probe possible mechanisms of action.[18] IR and Raman spectroscopy provide complementary insights into vibrational modes and scattering patterns, revealing modifications in hydrogen-bonded networks stabilised by ethanol.[19,20] Given water's central role as a solvent, its extensive HB network is crucial for solute behaviour,[21] and numerous computational and experimental studies have examined bulk water structure and vibrational dynamics,[22] although solute–water interactions remain less well understood.[23] Recent work combining TEM and Raman spectroscopy with deep learning has differentiated highly diluted gold solutions across potencies.[24] Similarly, potentisation of *Aurum metallicum* up to 10^{200} has been shown to form a stabilising hydrocarbon layer on nanoparticles,[25] further highlighting the potential for structural modifications even at extreme dilutions. These investigations, however, were confined to potencies around 200C and did not extend to higher scales such as 1M, nor did they systematically examine HB network organisation or impedance responses. FTIR spectroscopy distinguishes intra- and inter-molecular HB features in the MIR and FIR regions,[26] while impedance studies reveal dielectric and conductivity variations linked to molecular interactions.[27,28] Dielectric dispersion analyses have revealed structured solvent vehicles, and electromagnetic induction studies have demonstrated frequency-dependent effects.[29] Potentisation has also been suggested to induce structural alterations in water,[30] while electric fields in UHDs may modulate cellular interactions,[31] pointing to a potential physicochemical basis for their biological activity. Nevertheless, robust mechanistic evidence is still lacking, as many studies face methodological limitations, with most impedance-based investigations remaining limited to narrow frequency ranges.

Systematic investigations of hydrogen bonding and impedance, particularly at potencies beyond 200C, remain essential for advancing the fundamental understanding of UHD solutions. In this regard, we integrate impedance spectroscopy with FIR- and MIR-resolved FTIR to probe intra- and inter-molecular HB features alongside dielectric and conductive properties. Since the dielectric environment governs molecular interactions and signal transmission in biological systems, impedance variations provide indirect yet meaningful indicators of medicinal activity. Applied at potencies beyond conventional limits (200C–1M), this combined approach reveals structural features not previously resolved at such extreme dilutions. To our knowledge, this is the first study to directly correlate hydrogen-bond network organisation with dielectric response in UHD medicines, offering new mechanistic insights into their potential action.

Materials and methods

Sample preparation

Ethanolic whole plant extract of AM (in 60% Ethanol) and leaf extract of RT (in 80% ethanol) were prepared as mother tinctures in accordance with the revised and augmented guidelines of the Homoeopathic Pharmacopoeia of India.[32] The crude tinctures were subsequently dynamised by standard serial dilution in dispensing alcohol (91% ethanol), with succussion at each step as prescribed by HPI, to obtain successive potencies. All medicines, along with succussed ethanol controls at corresponding potencies, were procured as commercially available remedies in sealed glass bottles from M. Bhattacharyya and Co. (Kolkata, India), a long-established, GMP-certified licensed manufacturer operating under applicable regulatory frameworks, with all samples originating from the same batch. In addition, unsuccussed dispensing alcohol used for potency preparation was obtained from the same manufacturer for appropriate comparison. To ensure reproducibility, none of the medicines were prepared in-house, thereby minimising variability, human-induced errors, and potential contamination; all samples were manufactured within the same batch. Ultrapure water with a resistivity of 18MΩ ·cm and absolute ethanol (99.9%, Merck, Product ID: 100983) were included as additional solvent controls. In the present study, both succussed and unsuccussed alcohol controls were employed. However, for clarity and consistency, only data corresponding to the succussed ethanol controls were included in the main analysis. Representative impedance spectra of 200C and 1M succussed ethanol–water solutions are provided in Fig. S1(A).

FTIR measurements

FTIR measurements were conducted using the single reflection type attenuated total reflection (ATR) attachment (Miracle 10) equipped with a ZnSe crystal (SHIMADZU, Japan), which has a refractive index of 2.59, and a spectrometer featuring a DLaTGS detector. A He-Ne laser with an excitation wavelength of 632.8 nm was employed. Spectral acquisition and background noise elimination were performed using the LabSolutions IR software (SHIMADZU, Japan). Data were collected in transmission mode over the 400–4000 cm^{-1} range, covering both the FIR and MIR regions. A total of 45 scans were performed in 1 minute at a resolution of 4 cm^{-1}. Spectrum for each dynamised solution was obtained in triplicate. Additionally, a sample of ethanol (91% v/v), the matching solvent, was subjected to FTIR analysis. All the measurements were performed in a room at controlled temperature of 25 ± 1°C.

Electrical impedance spectroscopy

Electrical Impedance Spectroscopy (EIS) of the samples were conducted using an Electrochemical Workstation (CH Instruments, CHI660E) with screen-printed electrodes or SPE (Zensor, TE100) serving as the measurement platform. Measurements were performed by applying a 250 mV AC signal across the 50 Hz to 1 MHz frequency range. A drop of 20 μL solution was placed on the top of SPE strip for each measurement. The SPEs were changed prior to any measurement.

Data analysis

The observed FTIR spectra for each solution were merged to generate average spectrum in OriginPro 2018 (OriginLab, USA). The spectral output, initially obtained in percentage transmission (%Transmission), was subsequently converted into absorbance using the following relationship:

$$\text{Absorbance} = 2 - \log(\%\text{Transmission}) \quad (1)$$

The obtained absorbance profiles were subsequently fitted with Gaussian peak function after performing the baseline correction:

$$y = y0 + \frac{Ae^{\frac{-4ln(2)(x-xc)}{w^2}}}{w\sqrt{\frac{\pi}{4ln(2)}}} \quad (2)$$

where, y0, A, w, xc correspond to base, area, FWHM, and the central frequency value. The peak height (yc) was determined by the following formula:

$$yc = y0 + \frac{A}{w\sqrt{\frac{\pi}{4lnln\ (2)}}} \quad (3)$$

The pertinent fitting parameters are compiled in Table S1, S2 and S3.

To determine the solution resistance RS for studying the impedimetric variations in the selected samples, the Bode magnitude plots were fitted by equivalent circuits, discussed in subsequent section.

Results

The impedance spectra (50 Hz to 1 MHz) for different potencies (200C and 1M) of both samples are illustrated in Fig. 1(A) and (B). Fig. 1(A) shows the

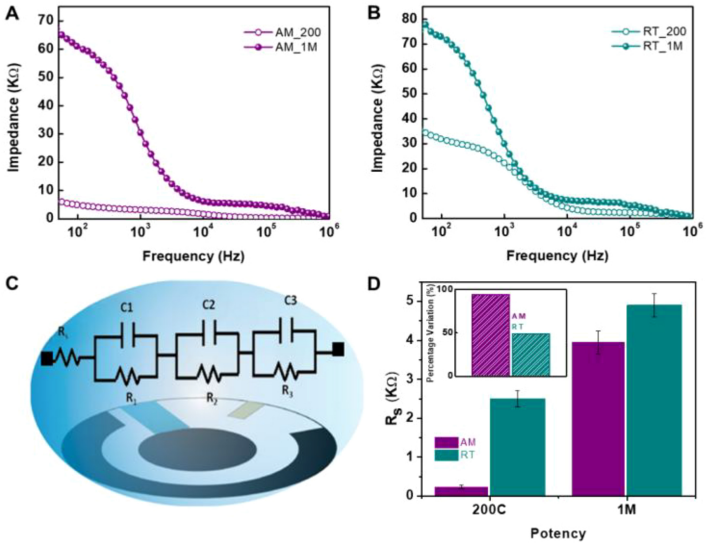

Fig. 1. **(A)** Electrical impedance spectra of AM and **(B)** RT for 200C and 1M potencies. **(C)** Schematic representation of the setup with the 3-electrode screen-printed electrode and a representative equivalent circuit. **(D)** Solution resistance for AM and RT for different potencies. Inset shows the percentage variation of impedance due to potentisation.

Bode magnitude spectra for AM, while Fig. 1(B) displays the same for RT. Within the frequency range considered, the impedance values exhibit notable variations for both AM and RT at different potencies. For AM, the impedance ranges from 6.2 KΩ to 0.27 KΩ with varying frequency at 200C potency and from 67.1 KΩ to 1.04 KΩ at 1M potency. In contrast, for RT, the impedance spans from 35.5 KΩ to 0.7 KΩ at 200C potency and from 75.5 KΩ to 0.71 KΩ at 1M potency in the aforementioned frequency window. These findings underscore distinct impedance behaviors as the potency increases for both AM and RT, indicating the influence of potentisation on their electrical properties. Fig. 1(C) schematically depicts the setup with the screen-printed 3-electrode and a representative equivalent circuit used to calculate the solution resistance RS. It was observed that the solution resistance increases with higher potencies for both samples, as depicted in Fig. 1(D). Notably, the percentage variation in RS due to potentisation is 93.9% for AM, compared to 49% for RT (inset of Fig. 1(D)). This significant difference highlights the presence of distinct molecular traits and structural responses in these UHD solutions. In addition, Fig. S1(A) presents representative impedance spectra for 200C and 1M succussed ethanol-water solutions, both in the absence and presence of medicinal samples, thereby delineating the intrinsic dielectric signatures arising from succussion-induced solvent structuring and their modulation upon incorporation of AM and RT. The accompanying solution resistance analysis Fig. S1(B) further highlights systematic, potency-dependent differences between control and medicinally potentised solutions, underscoring the medicine-specific perturbation of the solvent network superimposed on the baseline solvent response.

Fig. 2 (A-D) presents the MIR spectra (3000–3600 cm^{-1}) focusing on the O−H stretching modes of water. A consistent blue shift (toward higher wavenumbers) of the O−H stretching modes is observed for both samples. For AM, the stretching frequency shifts from 3331 cm^{-1} at 200C potency to 3336 cm^{-1} at 1M potency. Similarly, for RT, the shift is observed from 3322 cm^{-1} at 200C to 3336 cm^{-1} at 1M potency. Fig. 2(E) displays the characteristic frequency values for the cumulative O−H stretching peaks for both AM and RT at different potencies. The cumulative spectra have been deconvoluted into three sub-modes representing strong, weak and broken H-bonded O−H stretching modes. These deconvoluted peaks also exhibit similar blue shifts for the respective samples, indicating consistent changes in H-bonding dynamics with varying potencies. Additionally, with the increased potencies of AM and RT, a decrease in strong HB population (3.53% in AM and 2.02% in RT) and an increase in weak and broken HB population (2.42% in AM and 1.00% in RT) have been observed.

The MIR vibrational spectra (1550–1750 cm^{-1}) relevant to the H−O−H bending modes are shown in Fig. 3. For both AM and RT, a red shift (shift toward lower wavenumbers in the bending mode) is observed as the potencies increase. However, this shift is more pronounced for AM compared to RT. This significant observation highlights the distinct behavior of UHD solutions, particularly in terms of H−O−H bending

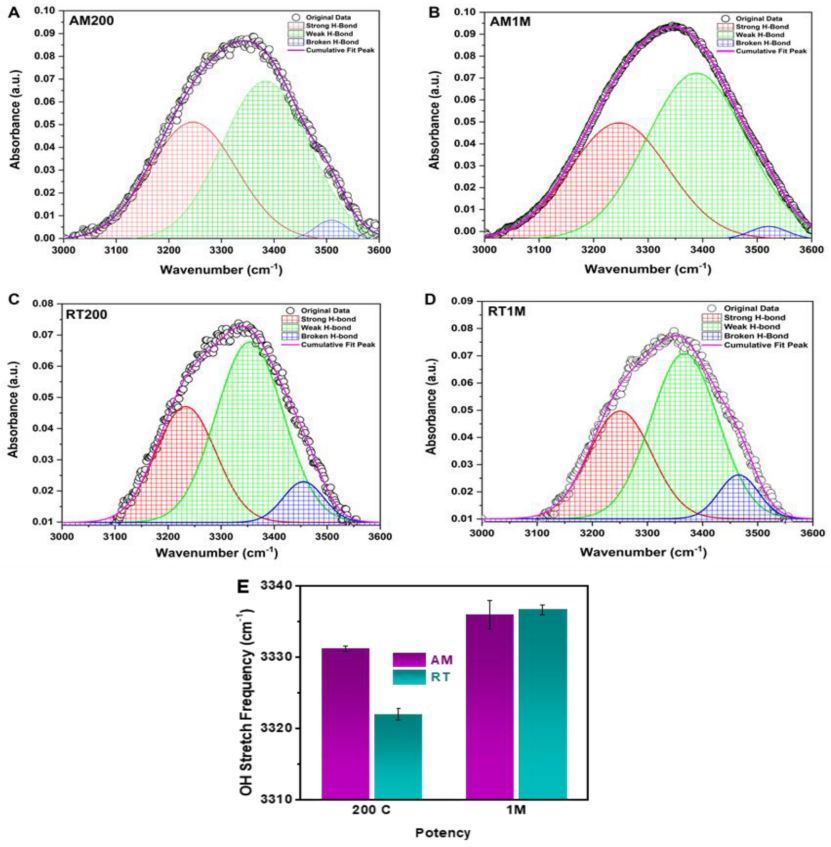

Fig. 2. **(A, C)** IR spectra of O-H stretch vibration for AM and RT for 200C and **(B, D)** 1M potencies. The cumulative peaks have been deconvoluted in three sub-modes. **(E)** The characteristic frequency values for the cumulative O−H stretching peaks for both AM and RT at different potencies.

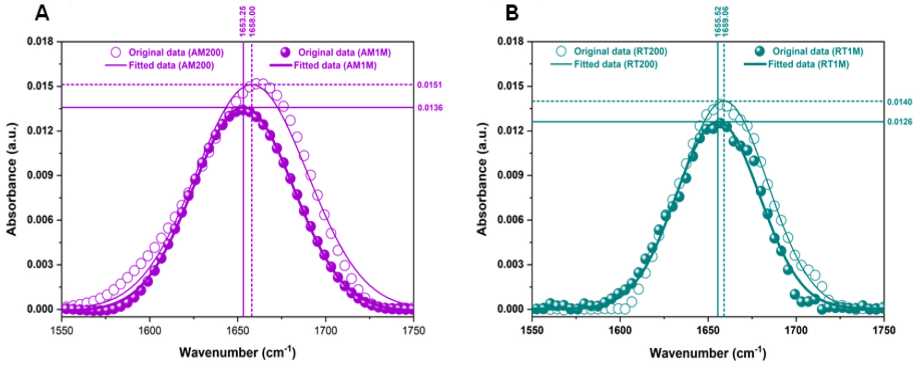

Fig. 3. IR spectra of H−O−H bending vibration for **(A)** AM and **(B)** RT for 200C and 1M potencies.

dynamics. The variations in the (a)symmetric H−O−H bending and O−H stretching modes, and the corresponding changes in HB lengths across different potencies are schematically depicted in Fig. 4.

The FIR spectra (500–600 cm^{-1}) for both samples with varying potencies are shown in Fig. 5(A) and (B), where the characteristic peak corresponds to the inter-molecular libration modes of water molecules. The area under the curve relevant to the librational mode, indicative of the system's enthalpy,[33,34] is depicted in Fig. 5(C). The inset highlights the percentage variation in the area due to potentisation (29.8% for AM and 65.2% for RT), further emphasising the enthalpic gain observed in the systems as potencies increase. The differing percentage variations, and consequently the distinct enthalpic gains observed for AM and RT, further reinforce the presence of molecular traces even in UHD solutions. In addition, complete IR spectra (500–4000 cm^{-1}) for selected medicines have been illustrated in Fig. S2.

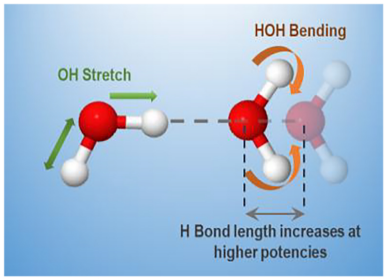

Fig. 4. Schematic representation of (a)symmetric O−H stretch, H−O−H bending modes, and the corresponding changes in hydrogen bond lengths across different potencies.

Discussion

Increase in impedance with potencies for both AM and RT may be attributed to changes in the HB network and the overall molecular structure of the solutions as they are further diluted and potentised. Additionally, the molecular reorganisation during potentisation and reduced ionic mobility may contribute to the higher impedance. The differing variations in impedance observed during the potentisation of AM and RT suggest distinct molecular footprints for each solution. As these UHD solutions (200C) are further potentised (1M), the unique impedance responses indicate that despite extreme dilutions, specific molecular characteristics or residual structures are retained in each solution. These variations reflect how the potentisation process affects the molecular organisation and HB dynamics differently for each substance, providing evidence that these solutions maintain distinct molecular imprints, or footprints, even at high dilutions. Such notions on the electrical properties can be further validated by an in-depth analysis of the IR spectral traits in the MIR and FIR regions.

Intra-molecular O−H stretch of water facilitates to probe the local HB environment. The frequency of the O−H stretch vibration is inversely related to the strength of intermolecular HBs.[35] Thus, a strong HB results in a red shift, while a weaker bond causes a blue shift in O−H stretch frequency, which follows the Novak-Mikenda relationship.[36]

In this study, a consistent blue shift in the cumulative O−H stretch frequency with increasing potencies for both AM and RT suggests that, with higher potencies, the HBs in the water structure become longer and possibly weaker, indicating significant changes in the molecular organisation at these extreme dilutions.[37,38] To gain a more detailed understanding, the broad O−H stretch peak was further deconvoluted into three distinct frequency peaks,[39] each corresponding to strong, weak, and broken H-bonded O−H stretch modes. These spectral features are commonly referred to as "icelike" for strong H-bonded OH modes and "liquid-like" for weak H-bonded OH modes.[37] Notably, all the deconvoluted peaks exhibit a blue shift, which aligns with the overall blue shift observed in the cumulative broad peak, indicating a consistent trend of increasing HB length and a possible weakening of the inter-molecular HBs as potency increases. Consequently, a decrease in strong HB population and an increase in weak and broken HB population with the increased potencies of AM and RT was observed. This is particularly significant as it suggests a structural rearrangement in the water molecules, possibly reflecting the residual molecular effects hypothesised in UHD solutions. The electrical properties of these solutions, as measured by impedance spectroscopy, further support these findings. The impedance data show a clear trend where increased inter-molecular HB length leads to higher impedance, which is in alignment with a previous report.[40,41] Progressive weakening and elongation of hydrogen bonds, as probed by OH stretching features, hence, translates into higher electrical resistance and altered dielectric behavior detected through impedance spectroscopy. This correlation highlights the sensitivity of the system's electrical conductivity to changes in H-bonding, providing another layer of evidence for the structural alterations induced by potentisation.

The unique H−O−H bending mode of water molecules, which is highly responsive to the HB strength of the system and crucial in understanding the subtle yet significant changes occurring in UHD solutions was focused on. It has been well-established that a higher O−H stretch mode frequency correlates with a lower H−O−H bending mode frequency, indicating a weaker inter-molecular O··H bond.[38,42] This behavior is also evident in the study results, where the H−O−H bending frequency shifts towards lower energy (red shift for bending mode) as we move to higher potencies of both AM and RT. This red shift further indicates a weakening of the inter-molecular O−H bonds with increasing potency. This notion provides crucial insights into the H-bonding dynamics within the UHD solutions. The weakening of the inter-molecular O−H bonds induces a higher rate of kinetic depolarisation inside the system.[26,33] Such depolarisation, linked to the weakening of HBs, is more pronounced in AM than in RT, as reflected synergistically in both MIR (corresponding to H−O−H bending) and impedance measurements. This observation is crucial not only for understanding the structural changes in UHD solutions but also for differentiating between the solutions of different molecules. Such differentiation is essential for comprehending the broader implications of extreme

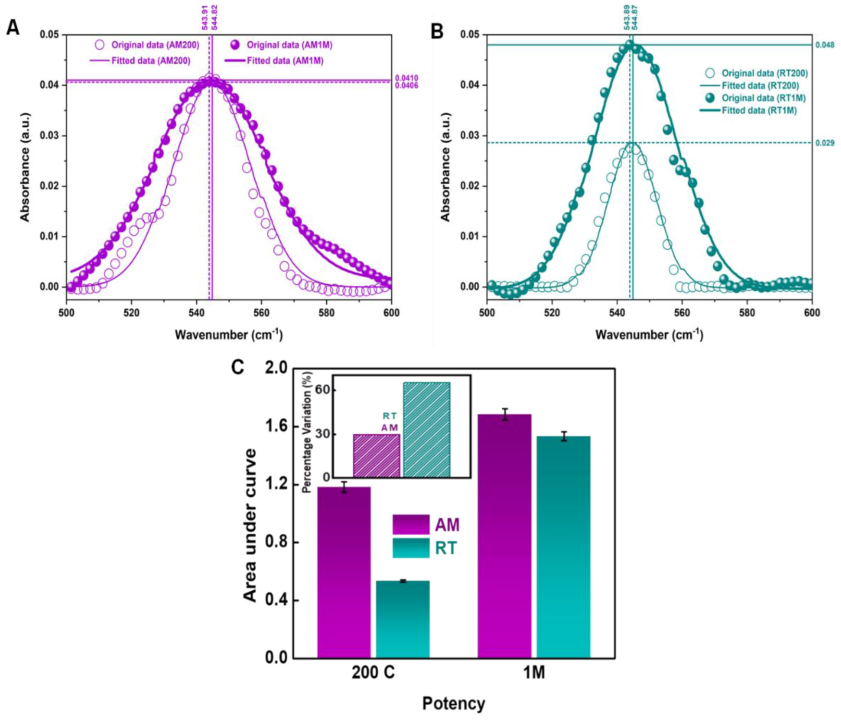

Fig. 5. FIR spectra for **(A)** AM and **(B)** RT samples with varying potencies. **(C)** Area under the curve relevant to the librational mode for the samples. The inset signifies percentage variation for AM and RT due to potentisation.

dilutions on the physical and chemical characteristics, potentially offering empirical support for their distinct properties and effects.

In the FIR region, the inter-molecular out-of-plane librational modes, which provide insights into the collective dynamics of water molecules was focused on. It has been previously concluded that this region provides the direct spectroscopic signature of bound water molecules with an additional enthalpic effect contributing to the overall HB dynamics of the system.[33,34] Significant variations in the area under the curve relevant to the librational mode were observed across different potencies, which are indicative of different system enthalpies.[34] It has been observed that RT exhibits a higher enthalpic gain compared to AM as the potency increases. This enthalpic gain is crucial because it suggests that RT undergoes a different kind of structural rearrangement, one that is energetically more favorable. Previous studies have shown that a higher enthalpic gain (ΔH) is associated with a smaller change in the projection of the total dipole moment (ΔM) of the system on the electric field ($\vec{E}$) direction.[43] Such decremental variation in ΔM results in a lower rate of dielectric, and consequently, impedimetric dispersion. This observation is consistent with our impedance data, where RT demonstrates lower impedance alteration compared to AM while moving towards higher potencies. Overall, impedance variations align closely with FTIR evidence of hydrogen-bond reorganisation and the corresponding solvation enthalpy, indicating that potency-dependent O-H interactions (both intra- and intermolecular), rather than size, charge, or bandgap effects, dominate the observed electrical response. Our findings show that UHD solutions of AM and RT undergo progressive hydrogen bond reorganisation, evidenced by O–H stretching blue shifts, H–O–H bendiFng red shifts, and impedance variations. These spectral and electrochemical markers indicate weakened intermolecular HBs, reduced ionic mobility, and preserved structural traits despite extreme dilutions.

These findings provide compelling evidence to challenge conventional understanding by opening new avenues for further exploration, especially in HB network modulation. Future research could expand on how such molecular reorganisation influences biological systems, potentially contributing to drug design focused on HB networks. Additionally, potentised substances may alter peri-cellular environments and gene expression mechanisms, offering novel therapeutic applications for influencing cell behavior and function. This line of inquiry may play a role in understanding how UHDs impact biochemical pathways, with potential applications in advanced therapeutic interventions. Nevertheless, the present study is

limited by the absence of direct molecular identification, and the observations are confined to two remedies and selected potencies within ultra-high diluted systems; these limitations may be addressed in future investigations through broader sampling and advanced molecular-level characterisation approaches.

Conclusion

This study integrates FTIR and impedance spectroscopy to elucidate molecular and structural dynamics in ultra-highly diluted AM and RT at 200C and 1M potencies. The observed homoeopathically medicines increase in impedance with potency is attributed to modifications in the hydrogen-bond network and molecular reorganisation during potentisation. Correlative MIR and FIR analyses indicate increased hydrogen-bond length and weakened intermolecular interactions, even at extreme dilutions. Distinct potency-dependent variations in the librational mode further suggest differences in system enthalpy between AM and RT. Collectively, these findings support the presence of residual molecular effects in UHD solutions and highlight hydrogen-bond network modulation as a key factor warranting further investigation.

Acknowledgement

The authors are grateful to the Central Council for Research in Homeopathy (CCRH), Ministry of AYUSH, Govt. of India for their support in this research. They also appreciate the contributions of Mr. Kaustav Ghosh of the School of Biotechnology, KIIT, Bhubaneswar, and Ms. Piyali Mukherjee of the ETC Department of IIEST, Shibpur. Special thanks are extended to Dr. Milan Sengupta, Consultant (Homoeopathy), Virology Laboratory, DACRRI (H), Kolkata, for providing guidance in preparing homeopathic solutions.

Funding

This work was supported by the Central Council for Research in Homeopathy (CCRH), Ministry of AYUSH, Govt. of India (F. No. 17-153/2010-11/CCRH/Tech./Coll/BESU-Kol./Pt.File 2326, dated. 16.12.2016).

Conflict of interest

Yes.

Rathin Chakravarty, Debadatta Nayak, and Subhash Kaushik disclose their affiliations with the Central Council for Research in Homeopathy, Ministry of AYUSH, Government of India, as a Scientific Advisory Board Member, Research Officer (H), and Director General, respectively. The other authors have declared no competing financial interests or personal relationships that could have influenced the work reported in this paper.

Author contribution

Sharbadeb Kundu: Concepts, Design, Literature search, Experimental studies, Data acquisition, Data analysis, Statistical analysis, Manuscript preparation, Manuscript editing, Manuscript review, Validation.

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Data availability

Data can be provided upon request.

Supporting information

Supporting information in this article can be found online.

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Étude des empreintes moléculaires dans des solutions homéopathiques ultra-diluées d'Arnica montana et de Rhus toxicodendron par spectroscopie infrarouge et d'impédance combinée

Contexte : L'étude des solutions ultra-diluées (UHD) est un domaine fascinant et controversé de la science moderne. Malgré de nombreuses recherches et hypothèses, il manque des méthodes rigoureuses, Preuves empiriques reproductibles étayant l'existence d'empreintes moléculaires au-delà de la limite d'Avogadro. **Objectif :** Cette étude a mené une investigation détaillée des propriétés moléculaires et électriques, en se concentrant sur les liaisons hydrogène et l'impédance, afin de comprendre la nature fondamentale des solutions UHD. **Matériels et méthodes :** Des investigations combinées par spectroscopie d'impédance et infrarouge ont été réalisées pour sonder le comportement structural des réseaux d'eau pertinents à l'échelle moléculaire des extraits alcooliques UHD d'*Arnica montana* (AM) et de *Rhus toxicodendron* (RT). **Résultats :** Aux concentrations élevées (200 C et 1 M) d'AM et de RT, une corrélation intéressante a été observée entre l'impédance et les caractéristiques spectrales. Une augmentation de l'impédance a été observée avec les concentrations pour AM (93,9 %) et RT (49 %), ce qui a été attribué à des modifications du réseau de liaisons hydrogène et à une réorganisation moléculaire lors de la potentialisation. Ceci est en corrélation avec les spectres infrarouges moyens, montrant un allongement des liaisons hydrogène et un affaiblissement potentiel des liaisons hydrogène intermoléculaires avec l'augmentation de la concentration. De plus, les spectres infrarouges lointains indiquent un contraste dans le gain enthalpique du système avec l'augmentation de la puissance, tant pour l'AM (29,8 %) que pour le RT (65,2 %). **Conclusion :** Des variations distinctes des paramètres spectraux et électriques ont été observées pour l'AM et le RT en raison de la potentialisation, suggérant que ces solutions conservent des caractéristiques structurales et moléculaires malgré des dilutions extrêmes. Cette notion pourrait remettre en question les approches thérapeutiques homéopathiques traditionnelles en abordant les paradigmes contradictoires concernant la présence d'empreintes moléculaires dans les solutions UHD.

Untersuchung molekularer Spuren in ultrahochverdünnten homöopathischen Lösungen von *Arnica montana* und *Rhus toxicodendron* mittels kombinierter Infrarot- und Impedanzspektroskopie

Hintergrund: Die Untersuchung ultrahochverdünnter (UHD) Lösungen ist ein faszinierendes und kontroverses Gebiet der modernen Wissenschaft. Trotz zahlreicher Untersuchungen und Hypothesen mangelt es an rigorosen, Reproduzierbare empirische Belege für die Existenz molekularer Spuren jenseits der Avogadro-Grenze. **Ziel:** Diese Studie untersuchte detailliert die molekularen und elektrischen Eigenschaften von UHD-Lösungen, insbesondere Wasserstoffbrückenbindungen und Impedanz, um deren grundlegende Natur zu verstehen. **Material und Methoden:** Mittels kombinierter Impedanz- und Infrarotspektroskopie wurde das Strukturverhalten relevanter Wassernetzwerke auf molekularer Ebene von UHD-Alkoholextrakten aus *Arnica montana* (AM) und *Rhus toxicodendron* (RT) untersucht. **Ergebnisse:** Bei höheren Konzentrationen (200 C und 1 M) von AM und RT wurde eine interessante Korrelation zwischen Impedanz und spektralen Eigenschaften beobachtet. Mit steigender Konzentration nahm die Impedanz sowohl bei AM (93,9 %) als auch bei RT (49 %) zu. Dies wurde auf Veränderungen im Wasserstoffbrückennetzwerk und eine molekulare Reorganisation während der Potenzierung zurückgeführt. Dies korreliert mit den Mittel-IR-Spektren, die eine Zunahme der Wasserstoffbrückenlänge und eine potenzielle Schwächung intermolekularer Wasserstoffbrückenbindungen mit steigender Konzentration zeigen. Des Weiteren deuten Ferninfrarotspektren auf einen Kontrast im Enthalpiegewinn des Systems mit erhöhten Wirkstärken sowohl für AM (29,8 %) als auch für RT (65,2 %) hin. **Schlussfolgerung:** Aufgrund der Potenzierung wurden deutliche Variationen der spektralen und elektrischen Parameter für AM und RT beobachtet. Dies legt nahe, dass diese Lösungen trotz extremer Verdünnung strukturelle und molekulare Eigenschaften beibehalten. Diese Erkenntnis könnte traditionelle homöopathische Behandlungsansätze neu bewerten, indem sie widersprüchliche Paradigmen bezüglich des Vorhandenseins molekularer Spuren in UHD-Lösungen aufgreift.

***अर्निका मोंटाना* और *रहस टॉक्सिकोडेंड्रोन* के अति-उच्च तनु होम्योपैथिक विलयनों में आणविक पदचिह्नों का कमबाईड इन्फ्रेड और इम्पीडेंस स्पेक्ट्रोस्कोपी द्वारा अध्ययन**

पृष्ठभूमि: अति-तनु तनु (यूएचडी) विलयनों का अध्ययन आधुनिक विज्ञान में एक आकर्षक और विवादास्पद क्षेत्र है। अनेक अनुसंधानो एवं परिकल्पनाओं के बावजूद, अवोगाद्रो सीमा के परे आणविक पदचिन्हों के अस्तित्व का समर्थन करने वाले कठोर एवं पुनरुत्पाध अनुभवजन्य प्रमाणों का आभाव है |

उद्देश्य: इस अध्ययन में यूएचडी विलयनों की मूलभूत प्रकृति को समझने के लिए हाइड्रोजन बॉन्डिंग और प्रतिबाधा पर ध्यान केंद्रित करते हुए आणविक और विद्युत गुणों की विस्तृत जांच की गई। **सामग्री और विधियाँ:** *अर्निका मोंटाना* (एएम) और *रहस टॉक्सिकोडेन्ड्रोन* (आरटी) के यूएचडी अल्कोहलिक अर्क के आणविक स्तर पर प्रासंगिक जल नेटवर्क के संरचनात्मक व्यवहार की जांच करने के लिए संयुक्त इंपीडेंस और इन्फ्रेड स्पेक्ट्रोस्कोपिक जांच की गई। **परिणाम:** एएम और आरटी दोनों की उच्च क्षमता (200C और 1M) पर, इंपीडेंस और स्पेक्ट्रल विशेषताओं के बीच एक दिलचस्प सहसंबंध देखा गया। एएम (93.9%) और आरटी (49%) दोनों की में वृद्धि देखी गई, जिसका श्रेय हाइड्रोजन बॉन्डिंग नेटवर्क में परिवर्तन और क्षमता बढ़ाने के दौरान आणविक पुनर्गठन को दिया गया। यह मध्य-आईआर स्पेक्ट्रा के साथ सहसंबंधित है, जो बढ़ती क्षमता के साथ हाइड्रोजन बॉन्ड की लंबाई में वृद्धि और अंतर-आणविक हाइड्रोजन बॉन्ड के संभावित कमजोर होने को दर्शाता है। इसके अलावा, फार-IR से पता चलता है कि AM (29.8%) और RT (65.2%) दोनों के लिए पोटेंसी बढ़ने के साथ सिस्टम के एन्थैल्पिक वृध्दि में अंतर को इंगित करते है । **निष्कर्ष:** शक्तिवर्धन के कारण AM और RT के लिए स्पेक्ट्रल और विद्युत मापदंडों में स्पष्ट भिन्नताएं देखी गई हैं, जिससे पता चलता है कि ये विलयन अत्यधिक तनुकरण के बावजूद संरचनात्मक और आणविक विशेषताओं को बनाए रखते हैं। यह धारणा UHD विलयनों में आणविक पदचिह्नों की उपस्थिति के संबंध में परस्पर विरोधी प्रतिमानों को संबोधित करके पारंपरिक होम्योपैथिक उपचार दृष्टिकोणों की पुनर्समीक्षी का अधर प्रदान कर सकती है |

Investigación de huellas moleculares en soluciones homeopáticas ultradiluidas de Arnica montana y Rhus toxicodendron mediante espectroscopia infrarroja y de impedancia combinadas

Antecedentes: El estudio de soluciones ultradiluidas (UHD) es un campo fascinante y controvertido en la ciencia moderna. A pesar de las numerosas investigaciones e hipótesis, existe una falta de rigor en su aplicación.
Evidencia empírica reproducible que respalda la existencia de huellas moleculares más allá del límite de Avogadro**.** **Objetivo:** Este estudio realizó una investigación detallada de las propiedades moleculares y eléctricas, centrándose en los enlaces de hidrógeno y la impedancia para comprender la naturaleza fundamental de las soluciones UHD. **Materiales y métodos:** Se realizaron investigaciones combinadas de impedancia y espectroscopia infrarroja para sondear el comportamiento estructural de las redes de agua relevantes a nivel molecular del extracto alcohólico UHD de *Arnica montana* (AM) y *Rhus toxicodendron* (RT). **Resultados:** A potencias más altas (200C y 1M) tanto de AM como de RT, se observó una correlación interesante entre la impedancia y las características espectrales. Se observó un aumento en la impedancia con potencias tanto para AM (93,9 %) como para RT (49 %), lo que se atribuyó a cambios en la red de enlaces de hidrógeno y reorganización molecular durante la potenciación. Esto se correlaciona con los espectros de infrarrojo medio, que muestran un aumento en la longitud del enlace de hidrógeno y un posible debilitamiento de los enlaces de hidrógeno intermoleculares con el aumento de la potencia. Además, los espectros de infrarrojo lejano indican un contraste en la ganancia entálpica del sistema con potencias aumentadas tanto para AM (29,8 %) como para RT (65,2 %). **Conclusión:** Se han observado variaciones distintivas en los parámetros espectrales y eléctricos para AM y RT debido a la potenciación, lo que sugiere que estas soluciones conservan rasgos estructurales y moleculares a pesar de las diluciones extremas. Esta noción podría replantear los enfoques tradicionales del tratamiento homeopático al abordar paradigmas contradictorios con respecto a la presencia de huellas moleculares en las soluciones UHD.

利用紅外光譜和阻抗光譜聯用技術研究山金車和毒漆樹超高稀釋順勢療法溶液中的分子特徵

背景：超高稀釋（UHD）溶液的研究是現代科學中一個引人入勝且頗具爭議的領域。儘管已有大量研究和假設，但仍缺乏嚴謹的、
可重複的經驗證據支持阿伏伽德羅極限之外的分子足跡的存在。**目的：**本研究對超高濃度（UHD）溶液的分子和電性質進行了詳細研究，並著重於氫鍵和阻抗，以了解其基本性質。**材料與方法：**採用阻抗和紅外光譜聯用技術，在分子水平上探測了山金車（Arnica montana，AM）和毒漆樹（Rhus toxicodendron，RT）超高濃度醇提取物中相關水網絡的結構行為。**結果：**在AM和RT的較高濃度（200°C和1M）下，阻抗和光譜特徵之間觀察到有趣的關聯。隨著AM（93.9%）和RT（49%）濃度的增加，阻抗也隨之增加，這歸因於濃度增加過程中氫鍵網絡的變化和分子重組。這與中紅外光譜的結果相符，顯示隨著濃度的增加，氫鍵長

度增加，分子間氫鍵可能減弱。此外，遠紅外光譜表明，隨著AM（29.8%）和RT（65.2%）效價的提高，系統的焓增益也發生了變化。**結論：**由於效價提高，AM和RT的光譜和電學參數均出現了顯著變化，這表明這些溶液即使在極度稀釋的情況下仍保留了其結構和分子特**徵。這項發現或許能**夠透過解決關於超高稀釋度溶液中分子特徵存在的相互矛盾的範式，重新審視傳統的順勢療法治療方法。