Liquids Prepared by Serially Diluting and Vigorously Shaking of Aqueous Solutions: Unveiling Effects of the Solute on their Properties

Yinnon, TA 1,2*

1K. Kalia, D.N. Kikar Jordan 90666, Israel
2Reedmace Lake, Enot Tsukim Nature Reserve at Kalia, Israel.

*Correspondence E-mail: lwcdsrc@kalia.org.il

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Abstract

Altering the bioactivity of aqueous solutions via serial dilutions is important for toxicology, medicine and wastewater treatment. Extensive research has shown that serially diluting aqueous solutions beyond a threshold concentration, combined with vigorous shaking after each dilution step, has several notable effects. (a) The solutes may serve as substrates, which facilitate association of water molecules (10^-5 and 10^-7 m sized associates). (b) The associates and the bioactivity of these liquids persist when these fluids are diluted below 10^-24 mol/liter. (c) The associates and the bioactivity of these liquids disappear when such ultra-diluted fluids are screened from ambient electromagnetic radiation. (d) The structural and physicochemical properties of these liquids are explainable within the context of quantum electrodynamics (QED). Hitherto, relations between the physicochemical properties of these liquids and their substrates have not been unveiled. There are no reports of statistically significant data that reflect physicochemical aspects of these liquids attributable to specific characteristics of substrates. Moreover, the aforementioned relations have not been theoretically derived. In this study, the relations are analyzed within the context of QED. The analyses have helped elucidate the challenge of observing the impact of the substrate on the associates. The analyses also indicate that measuring the quantum Hall effect of these liquids holds the promise of unveiling the aforementioned relations.

Introduction

Over the last decades, the physicochemical and bioactive properties of serially diluted aqueous solutions have been extensively studied [see reviews by Konovalov et al. (2014), Bellavite et al. (2014) and Elia et al. (2015)]. These solutions are serially diluted from a solution with a concentration (C) of ~4 - 10^-3 mol/liter (M). The dilutions continue up to and beyond 10^-24 M. Such dilutions, combined with vigorous shaking after each dilution step, may affect these liquids’ bioactive, structural and physicochemical properties. These properties may differ in a statistically significant way from those of liquids with the same chemical composition but which were not serially diluted and vigorously shaken after each dilution step. The differences only occur when the solu-
solutions are diluted beyond a solute dependent threshold concentration ($C_{\text{thr}}$) on the order of $10^{-6}$-$10^{-10}$ M. The differences have been observed for solutions of many solutes, but not for all kinds. Impurities released by containers, contaminants and bubbles affect the properties of serially diluted liquids but cannot fully account for the differences in properties. The denotation SDVSAS will be used for a serially diluted vigorously shaken aqueous solution for which its properties are altered by serial dilutions and vigorous shaking after each dilution step.

To the best of my knowledge, no experiments have produced statistically significant data revealing relations between the physicochemical properties of SDVSASs diluted beyond $10^{-24}$ M versus the characteristics of the solutes (substrates) with which these liquids were prepared. Moreover, the relations have not yet been theoretically derived.

The goals of this paper are to analyze the relations and to propose an experimental technique that has the potential of revealing these relations. These goals are important, because SDVSASs are relevant for toxicology, medicine, wastewater treatment and power generation (Konovalov et al., 2014; Ryzhkina et al., 2011; van Wassenhoven et al. 2017, 2018; Bandyopadhyay et al., 2017). To pursue these goals, firstly, I summarize the facets of the empirical and the quantum electrodynamic (QED) models of SDVSASs, i.e., only those facets required for analyzing the abovementioned relations. Subsequently, I analyze these relations and propose an experimental technique that holds the promise of verifying them. A list with abbreviations is presented at the end of this paper.

**Models of SDVSASs**

According to the empirical model of Konovalov et al. (2016), SDVSASs are disperse systems. They are not liquids (solutions) in the customary sense. For $10^{-24}$ M<$C$<$C_{\text{thr}}$, associates composed of water (H$_2$O) molecules and a few solute (substrate) molecules constitute the disperse phase. At each dilution-shaking step, the prevalence of the substrate decreases but associates composed of H$_2$O molecules persist. Upon crossing the $10^{-24}$ M threshold, a disperse system of associates of H$_2$O molecules surrounded by water (the medium) emerges. The model is mainly based on the experimental data of Konovalov et al. (2014, 2015), e.g.:

- ~$10^{-5}$ m and ~$10^{-7}$ m sized associates, mainly composed of H$_2$O molecules, are present in SDVSASs with $C$< $C_{\text{thr}}$. The associates are self-organized, substrate-induced, entities stabilized during the preparation of SDVSASs. These fluidic associates are surrounded by randomly moving liquid molecules.

- The associates only form in the presence of ambient or artificial EM radiation. On screening such radiation, the associates disintegrate.

- The electronic structure and ordering of the associates’ H$_2$O molecules are determined by the substrate.

- The associates constitute a phase which is different from the bulk liquid.

The empirical model of Elia et al. (2014, 2015), besides emphasizing the molecular association, addresses the solid residue (phase) obtainable by isolating associates through evaporating of the SDVSASs. The

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a For a partial overview of the experimental techniques used for studying SDVSASs see Yinnon (2017).

b Lenger et al. (2014) observed that information indicating characteristics of the substrates of SDVSASs is contained in these liquids’ megahertz resonant frequencies. However, these frequencies often are too close to enable differentiating between SDVSASs prepared with different substrates. Bázár et al. (2015) and Gowen et al. (2015) demonstrated that near infrared spectroscopy, coupled with aquaphotomics, can only reveal molecular changes in water caused by different solutes for solutions with $C$>$10^{-5}$ M.
residue is soluble in water. After dissolving it in water, the liquid’s physicochemical parameters are almost exactly like those of the original SDVSAS from which the solid was extracted.

The presence of ~10\(^{-5}\) m and ~10\(^{-7}\) m sized molecular associates in SDVSASs with C\( < C_{\text{thr}} \), which only stabilize with EM radiation, signifies strong interactions between the molecules and the radiation. Therefore, modeling of SDVSASs necessitates a QED approach (Yinnon et al., 2015a).

Indeed, the associates have properties resembling those of two types of QED domains (Yinnon et al., 2015b&c) — \( \text{CD}_{\text{rot}} \) and \( \text{CD}_{\text{H,O elec}} \) (see Fig. 1 & 2). Stabilization of these domains, during the SDVSAS preparation procedure, is schematized in Appendix Figs. A1 and A2. The QED model of SDVSASs (see Fig. 3) is congruent with the abovementioned empirical models and data (Yinnon et al., 2011, 2013, 2015b&c, 2017, 2018). Properties of \( \text{CD}_{\text{rot}} \) and \( \text{CD}_{\text{H,O elec}} \) pertinent to the goals of this paper are summarized below. For more details, and recent references to the experimental verification

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**Fig. 1.** Schematic drawing of a \( \text{CD}_{\text{rot}} \) revealing its internal structure. Light-blue colored balls symbolize the \( \text{H}_2\text{O} \) molecules constituting the domain. Their blue arrows symbolize the electric dipole moments of the \( \text{H}_2\text{O} \) molecules. The large blue arrow symbolizes the electric dipole moment of the domain, resulting from the ferroelectric ordering of its molecules.

**Fig. 2.** Schematic drawing of a \( \text{CD}_{\text{H,O elec}} \) and its internal structure. Light-blue and yellow colored balls symbolize its \( \text{H}_2\text{O} \) molecules residing, respectively, in their ground and excited electronic states. The electric dipole moments of the \( \text{H}_2\text{O} \) molecules, symbolized by arrows, are randomly oriented.

**Fig. 3.** Schematic picture of a SDVSAS diluted beyond \( 10^{-24} \text{M} \) according to its QED model. \( \text{CD}_{\text{rot}} \) and \( \text{CD}_{\text{H,O elec}} \) are dispersed in bulk water. \( \text{CD}_{\text{rot}} \), with their electric dipole moments, are depicted as ovals with a blue arrow. \( \text{CD}_{\text{H,O elec}} \) are depicted as yellowish-brownish balls. The domains’ sizes are not presented according to their realistic scale ratios. Some of the domains are organized in supradomains: supra-\( \text{CD}_{\text{rot}} \), supra-\( \text{CD}_{\text{H,O elec}} \) and supra-\( \text{CD}_{\text{rot}} \) containing supra-\( \text{CD}_{\text{H,O elec}} \) (see Appendix-paragraph ix & x). These supradomains are not ensembles of molecules but agglomerates of domains, like domains in liquid crystals.

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\(^c\) QED models explicitly describe QED forces, such as the interactions between the dipole moment or electrons of \( \text{H}_2\text{O} \) molecules and the external EM field (Del Giudice, 1988, Preparata, 1995). These forces may lead to association of part of the \( \text{H}_2\text{O} \) molecules in aqueous liquids. The various domains that may form and their concentration dependencies are summarized by Yinnon and Liu (2015a). The QED models of aqueous liquids considerably diverge from the customary ones, which explicitly describe electrostatic forces and assume that QED interactions can be treated as small perturbations (Horne, 1972; Robinson et al., 2002). These models show that \( \text{H}_2\text{O} \) molecules, except for those in solvation shells, move randomly.
of these properties, see the Appendix.

**CD**_rot_ — These domains are composed of H₂O molecules that coherently oscillate between two of their rotational states (Del Giudice et al., 1988, 2006). Their diameter may reach 10⁻⁴ m. A CD<sub>rot</sub> has an electric dipole moment due to the ferroelectric ordering of its H₂O molecules. CD<sub>rot</sub> may order in supradomains, wherein their electric dipoles are about parallel, anti-parallel or randomly aligned. CD<sub>rot</sub> are superfluidic domains (see Appendix, paragraph IX). Just as in superfluidic Helium, whirlpools (vortices) may be created in CD<sub>rot</sub>. Collisions between a CD<sub>rot</sub> and its surrounding randomly moving molecules may cause part of its molecules to whirl into vortices. Also, EM radiation may excite H₂O molecules within a CD<sub>rot</sub> and create vortices. The vortices cannot decay thermally, i.e., they are cold. Therefore, their lifetimes are very long (months – years) (Yinnon et al., 2013).

Information can be stored in supra-CD<sub>rot</sub>. Due to their ferroelectric properties, information can be stored in a manner analogous to that in materials consisting of domains with magnetic moments. Moreover, information can be stored in their cold vortices.

**CD**<sub>H₂O</sub>_<sub>elec</sub> — These domains consist of H₂O molecules that coherently oscillate between their electronic ground state |0> and an excited electronic |b> state (Preparata, 1995). The energy of the |b> state is 12.07 eV. Since the ionization threshold of H₂O molecules is 12.62 eV, the electrons in the |b> state are weakly bound. Therefore, a CD<sub>H₂O</sub>_<sub>elec</sub> contains many coherent quasi-free electrons (QFEs). The diameter of a CD<sub>H₂O</sub>_<sub>elec</sub> is ~10⁻⁷ m.

CD<sub>H₂O</sub>_<sub>elec</sub> are superfluidic domains (see Appendix, paragraph vi). Therefore, interactions between CD<sub>H₂O</sub>_<sub>elec</sub> and the surrounding, randomly moving, molecules or EM radiation may excite the whole CD<sub>H₂O</sub>_<sub>elec</sub> , i.e., cause their molecules to whirl in cold vortices.

QFEs do not collide with each other, as they are coherent, and a single collision would destroy their coherence. Thus, QFE are superconducting. Exciting a CD<sub>H₂O</sub>_<sub>elec</sub> may lead to cold coherent vortices in its pool of superfluidic QFEs. The energy spectra of these vortices are typified by a lowest lying excited state with a frequency of ~1000 Hz (Del Giudice, 1998, 2010). The energy spacing of the spectra is on the order of ~1000 Hz. The magnetic dipoles of these vortices may become aligned by external magnetic fields, e.g. the terrestrial magnetic field (Del Giudice et al., 2002; Montagnier et al., 2011). The QFE’s cold vortices constitute “long-term information storage devices.” The same holds for the cold vortices of the H₂O molecules in CD<sub>H₂O</sub>_<sub>elec</sub>.

Information on the Substrate Imprinted in SDVSASs

The processes leading to stabilization of CD<sub>rot</sub> and CD<sub>H₂O</sub>_<sub>elec</sub> in SDVSASs diluted below C<sub>thr</sub> have been specified by Yinnon et al. (2011, 2015 b & c). They pointed out that, for a SDVSAS at C< C<sub>thr</sub>, vigorous shaking excites or breaks up its CD<sub>rot</sub>. Subsequent dilution of the SDVSAS transfers excited or broken CD<sub>rot</sub> pieces, as well as CD<sub>H₂O</sub>_<sub>elec</sub>, to the diluted liquid. The excited or broken CD<sub>rot</sub> pieces stabilize new CD<sub>rot</sub> and CD<sub>H₂O</sub>_<sub>elec</sub>. Hence, these domains are present in SDVSASs with C< C<sub>thr</sub>, including SDVSASs diluted beyond 10⁻²⁴ M.

**Information on the substrate imprinted in CD**<sub>rot</sub> — In SDVSASs with C< C<sub>thr</sub>, the solutes are located within CD<sub>rot</sub> (see Appendix, paragraph X). An object present in an ensemble of H₂O molecules adds a term H=−d.E to the potential energy of the ensemble [see Appendix - Eq. (A1)]. d is the electric dipole moment of an H₂O molecule. E is the electric field due to the object. Analogously, each solute molecule adds a term to the potential energy of such
an ensemble. The term is a function of the electric field $E_s$ of the solute molecule. Thus, solutes affect the wavefunction describing CD$_{rot}$ ($\Psi_{CD_{rot}}$) and the polarization $P_n$ of the liquid in direction $n$ [see Appendix –Eq. (A2)].

For SDVSASs at $10^{-24}$ M $< C < C_{thr}$, it can be assumed that just one solute molecule is present in each of its CD$_{rot}$. On vigorously shaking this SDVSAS, part of its broken CD$_{rot}$ pieces will not contain any solutes, yet, after breakup of a CD$_{rot}$, the polarization within its broken pieces ($P_n$ broken-CD$_{rot}$) is reminiscent of the “mother domain.” Moreover, after subsequent break up of broken pieces, $P_n$ broken-CD$_{rot}$ is reminiscent of its “grandmother domain,” “great-grandmother domain” and so on. A broken piece’s memory of the polarization of its “ancestors” is due to the extremely slow dynamics of the superfluidic CD$_{rot}$ and their cold vortices. The dynamics occur over days and even years (see Appendix-paragraph V). Accordingly, solute reminiscent $P_n$ broken-CD$_{rot}$ pieces persist for macroscopic times scales. Thus, on serially diluting aqueous solutions and vigorously shaking after each dilution step, even in SDVSASs diluted beyond $10^{-24}$ M, CD$_{rot}$ and their broken CD$_{rot}$ siblings are present along with their substrate reminiscent polarization.

The number of solute molecules that can be contained in a CD$_{rot}$ is small (see Appendix - paragraph X). Hence, the impact of the solutes on the polarization of these domain ($\Delta P_n$) is small. It can be treated as a small perturbation. Of course, $\Delta P_n$ will have some effect on the physicochemical properties of SDVSASs, e.g., its dielectric permittivity. For many types of solutes, the differences between their $E_s$ are small. Therefore, the difference between their $\Delta P_n$ will be tiny. Hitherto, measurements of physicochemical variables reflecting $\Delta P_n$ have not revealed differences in SDVSASs prepared with different substrates. Seemingly, $\Delta P_n$ is negligible compared to the effects of thermal fluctuations or ambient factors.

Vortices created in CD$_{rot}$ by radiation will affect their $P_n$. When the stimulating frequency does not match that of the system, and the radiation energy transferred to the domain is less than the cohesion energy of an H$_2$O molecule in a CD$_{rot}$ (about ~0.025 eV), the effects of the vortices on $P_n$ will just be tiny perturbations $\Delta E P_n$. The energy of these vortices is on the order, or less than that, of thermal fluctuations. Therefore, these vortices cannot have a statistically significant impact on the physicochemical variables of SDVSASs, like dielectric permittivity. However, when the frequency of the radiation matches that of the system, the impact on $P_n$ may be significant.

The tininess of $\Delta E P_n$ suggests that we should continue searching for an observable variable which will enable distinguishing between SDVSASs prepared with different solutes.

**Information on characteristics of the substrate imprinted in CD$_{elec}$ —** Solutes cannot locate within CD$_{elec}$ (Del Giudice et al., 2000, 2010). In SDVSASs, solute molecules imprint their characteristics in CD$_{elec}$ in the following ways:

1. Solutes affect CD$_{elec}$ through their impact on $P_n$. The electric field $E_s$ of a solute molecule located in CD$_{rot}$ impacts the polarization $P_n$, as discussed above. $P_n$ affects the polarization of H$_2$O molecules, as well as the cloud of QFEs of each CD$_{elec}$. It is likely that thermal fluctuations blur the variations in $\Delta P_n$ induced by different solutes. Such blurring would explain why no impact of solutes on CD$_{elec}$ via $P_n$ has been detected.

2. Ions or polar solutes are attracted by the fields of the photons condensed in CD$_{elec}$ (Del Giudice et al., 2002). The attraction affects the wavefunction describing CD$_{elec}$, i.e., $\Psi_{CD_{elec}}$.

3. Whenever the motion of ions does not
get altered by collisions with other molecules, they orbit around their nearest neighbor CD\textsubscript{H\textsubscript{2}O}\textsuperscript{e\textsubscript{lec}} (Del Giudice et al., 2002).\textsuperscript{d} In SDVSASs, at 10\textsuperscript{-24} M<C\textsubscript{thr}, solutes incorporate in CD\textsubscript{rot} (see Appendix – paragraph X). The motion of these solutes does not get altered by collisions, because CD\textsubscript{rot} are superfluidic. In SDVSASs, part of the CD\textsubscript{H\textsubscript{2}O}\textsuperscript{e\textsubscript{lec}} are localized in CD\textsubscript{rot}. Hence, ionic solutes present in CD\textsubscript{rot} may orbit around CD\textsubscript{H\textsubscript{2}O}\textsuperscript{e\textsubscript{lec}}. The circular speed of ions orbiting around a CD\textsubscript{H\textsubscript{2}O}\textsuperscript{e\textsubscript{lec}} is proportional to the cyclotron frequency (ν\textsubscript{c}) (Del Giudice et al., 2002)\textsuperscript{d}. ν\textsubscript{c} is defined such that ν\textsubscript{c}=(qB)/(2\pi m) where q and m are the electric charge and the mass of the ion, respectively, and B is the strength of the static magnetic field (e.g. the terrestrial magnetic field). An alternating magnetic field, with a frequency matching the orbit frequency, extracts the ions from their orbits (Del Giudice et al., 2002). Due to the conservation of angular momentum, this extraction causes rotational excitation of the H\textsubscript{2}O molecules and the QFEs of the CD\textsubscript{H\textsubscript{2}O}\textsuperscript{e\textsubscript{lec}}, i.e., the formation of coherent vortices. When the solute concentration is about uniform in a mesoscopic region, and the external field also spans over mesoscopic distances, the excitation energy of the vortices of many CD\textsubscript{H\textsubscript{2}O}\textsuperscript{e\textsubscript{lec}} may be uniform (Montagnier et al., 2011, 2015). Since ν\textsubscript{c}=(qB)/(2\pi m), the vortices are a function of the charge distribution of the ions.

4. Polar solutes in SDVSASs can indirectly affect the excitations of the QFE cloud. Such solutes affect the spontaneous dissociation of H\textsubscript{2}O molecules. These solutes also affect the charge distribution of the hydronium or hydroxyl ions resulting from such dissociation. These ions orbit around CD\textsubscript{H\textsubscript{2}O}\textsuperscript{e\textsubscript{lec}}, and the extraction of these ions by ambient radiation is thus affected by E\textsubscript{s}.

The effects described in paragraphs 1-4 all impinge on the wavefunction Ψ\textsubscript{CD\textsubscript{H\textsubscript{2}O}\textsuperscript{e\textsubscript{lec}}}. The general wavefunction Ψ, describing matter interacting with EM fields, has been derived by Preparata (1995, ch. 2 & 3). In these chapters, the excitations of Ψ due to perturbations are also presented. The details of Ψ relevant to an ensemble of H\textsubscript{2}O molecules are presented in Arani et al. (1995).

Without going into detail about the effects of the solutes’ E\textsubscript{s} on Ψ\textsubscript{CD\textsubscript{H\textsubscript{2}O}\textsuperscript{e\textsubscript{lec}}}, it suffices to note that E\textsubscript{s} at least perturbatively, affects the excited states of CD\textsubscript{H\textsubscript{2}O}\textsuperscript{e\textsubscript{lec}}, i.e., their molecular vortices and the vortices of their QFEs. Despite these vortices constituting memory devices for E\textsubscript{s}, extracting information on E\textsubscript{s} by analyzing its impact on physicochemical properties of SDVSASs (e.g. electric conductivity) has failed. The failure is attributable to the energies of the vortices being on the same order, or less than that, of the thermal fluctuations of water at ambient conditions.\textsuperscript{e} The latter is on the order of \~10\textsuperscript{-2} eV.

\textsuperscript{d} The orbit of noncolliding ions around CD\textsubscript{H\textsubscript{2}O}\textsuperscript{e\textsubscript{lec}} is an aspect of the explanation, provided by Del Giudice et al. (2002), for the Zhadin effect (Zhadin et al., 1998), which has been confirmed by Pazur (2004).

\textsuperscript{e} Spectroscopic data taken from SDVSASs diluted far beyond C\textsubscript{thr} do not provide information E\textsubscript{s}. The intensities of some UV-visible bands of such SDVSASs are correlated with the prevalence of their nano-associates (Ryzhina et al., 2018). CD\textsubscript{H\textsubscript{2}O}\textsuperscript{e\textsubscript{lec}} affects the ultraviolet (UV), visible (vis) and infrared (IR) spectra of aqueous systems (Yinnon et al., 2016, 2018; Elia et al., 2017). The UV absorption and UV-vis fluorescence spectra of water containing CD\textsubscript{H\textsubscript{2}O}\textsuperscript{e\textsubscript{lec}} typically contain broad featureless bands. Differences have been observed in UV transmission intensities of SDVSASs with C<<C\textsubscript{thr} and prepared with different solutes (Klein et al., 2013). The featureless broad UV-vis spectral bands have not revealed any differences between SDVSASs at C<<C\textsubscript{thr} attributable to specific characteristics of their substrates. Spectral measurements cause slight changes in the electronic, vibrational and rotational states of H\textsubscript{2}O molecules. Likely, these changes blur the tiny differences between the excited states (vortices) of the QFEs. These tiny differences also cannot be imprinted, in a statistically significant manner, in those physicochemical variables of SDVSASs that are affected by thermal fluctuations. The energy of the vortices in QFEs is \~1000 Hz (10\textsuperscript{-10} eV), i.e., many orders less than that of the thermal fluctuations of water at ambient conditions.
Studying Quantum Hall Effects for Exposing Variations between SDVSASs Prepared with Different Substrates

The above presented analyses accentuate the need for directly measuring details of the vortices in the superfluidic QFEs. Vortices in ensembles of superfluidic electrons have been extensively studied during the last decades (Abrikosov et al., 2002; Jain, 2015). Superfluidic electrons underlie the superconductivity of superconductors, and vortices in ensembles of superfluidic electrons can be studied by measuring the quantum Hall effect (Matsuda et al., 2002).

The Hall effect is the voltage difference \( V_H \) across an electrical conductor, which appears transverse to an electric current \( I \) on applying a magnetic field \( B \) perpendicular to the current (Purcell, 1963). Immediately after applying the magnetic field, the charge carriers are deflected towards a rim of the conductor. As a result, at some distance from the current-introducing contacts, for example, positively charged particles pile up on the upper rim of the conductor and become depleted from its opposite lower rim. See Fig. 4. The piling up and depletion of these particles creates an electric field, which underlies \( V_H \). At steady state, the induced electric force exactly cancels the magnetic force, so that the charge carriers are no longer deflected. The Hall coefficient \( (R_H) \) is the ratio of the magnitude of the induced electric field at steady state \( (E) \) to the product of the current density \( (j_x) \) and the magnitude of the applied magnetic field \( (B) \), that is, \( R_H = E / (j_x B) \). The Hall coefficient is a characteristic of the material from which the conductor is made. \( R_H \) depends on the type, number, and properties of the charge carriers that constitute the current.

The quantum Hall effect is the quantum analogue of the above described classical Hall effect. It appears in two-dimensional electron systems (Prange et al., 1990). According to quantum physics, when a two-dimensional electron system is subjected to a magnetic field, its electrons follow circular orbits with discretely valued energy levels. As a result, the Hall conductance \( (\sigma) \) is quantized: \( \sigma = I / V_H = \nu e^2 / h \), where \( e \) is the elementary charge and \( h \) is Planck’s constant. The dimensionless value of the filling factor \( \nu \) is either an integer \((1, 2, 3, \ldots) \) or a fractional \((1/3, 2/5, 3/7, 2/3, 3/5, 1/5, 2/9, 3/13, 5/2, 12/5, \ldots) \) number. Correspondingly, the quantum Hall effect is denoted as the integer or fractional quantum Hall effect. The latter can be regarded as an integer quantum Hall effect, albeit not of electrons but of charge-flux composites (Jain, 2015). Interactions between electrons, resulting in highly correlated quantum states, underlie these composites. The quantum Hall effect reflects details of quantum states of the electron system and impurities present in

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**Fig. 4. Schematic drawing of the Hall effect.** A voltage \( V_x \) applied to a conductor (the pinkish rectangle) leads to the current \( z \). After adding a magnetic field in the y-direction \( (B) \), the charge carriers become deflected towards an edge of the conductor. As a result, the charge carriers pile up on the upper rim of the conductor and become depleted from the lower rim, creating an electric field. This underlies the Hall voltage \( V_{H} \), as indicated by the Voltmeter. At steady state, the induced electric force exactly cancels the magnetic force, so that the charge carriers are no longer deflected.

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\( \text{1 Until 2007, the quantum Hall effect was solely observed in systems at cryogenic temperatures (below ~30 K) and at sufficiently high magnetic fields (a few Tesla). In 2007, the effect was observed in graphene at room temperatures and magnetic fields of about 30 Tesla (Novoselov et al., 2007; Parmentier et al., 2016).} \)
the conducting material.

Vortices present in ensembles of superfluidic electrons impact on their quantum Hall effect (Matsuda et al., 2002). For example, a vortex motion perpendicular to the transport current corresponds to a dissipative longitudinal electric field, while parallel motion impacts the Hall electric field \( E \). Measuring the quantum Hall effect enables extracting information on energy dissipation processes. Such processes reflect the electronic structure of the vortices, the characteristics of the ensemble of superfluidic electrons and the low energy excitations out of the condensate.

I propose to study the vortices of QFEs by measuring quantum Hall effects in SDVSASs, or in the solid residue left over after evaporating these liquids. Some properties of SDVSASs are preserved in the residue (Elia et al., 2014; Klein and Wolf, 2016). Such studies might reveal properties of SDVSASs diluted beyond \( 10^{-24} \) M, which are related to the \( E_s \) of their substrate.

It is beyond the scope of this paper to specify techniques for measuring the quantum Hall effect of SDVSASs. Vortices in ensembles of superfluidic electrons are still extensively studied (Abrikosov, 2002; Jain, 2015). Assessing implications of the superfluidic QFEs, for detailing techniques, will be left to those specialized in quantum Hall effects. It is likely that the quantum Hall effects of SDVSASs will be more discernible after aging of these liquids. On aging of SDVSASs, their physicochemical properties become more distinct, because they are far from equilibrium self-organizing systems (Elia et al., 2008).

Discussion and Conclusion

The above analyses indicate that for SDVSASs with \( C<C_{\text{thr}} \), the degree to which their substrates impact on their properties is similar or less than that of thermal fluctuations. Therefore, variables affected by such fluctuations cannot reveal the impact. The QED model indicates that the vortices in the superfluidic domains (CD\(_{\text{H}_{2}O}\) and CD\(_{\text{rot}}\)) present in these liquids are a function of the electronic characteristics of their substrates but are not affected by thermal fluctuations. Accordingly, I propose to study the vortices of the superfluidic QFEs by measuring their impact on the Quantum Hall effect. Such a study promises to unveil variations between SDVSASs prepared with different substrates, even when their serial dilutions combined with vigorous shaking continued beyond \( 10^{-24} \) M.

Revealing substrate dependent quantum Hall effects in SDVSASs will support the QED interpretation of these liquids. It will also provide additional evidence that QED domains may play roles in aqueous systems. Moreover, it will show that outcomes of chemical or biological processes, which involve SDVSASs diluted close to or far beyond \( 10^{-24} \) M, \( (i.e., \) outcomes attributable to properties of their substrates) are real phenomena. In addition, it would indicate that measuring the quantum Hall effects might be an effective method for studying other aqueous systems. Phenomena in various systems have been attributed to stabilization of QED domains at ambient conditions (Del Giudice et al., 2010, 2013; De Ninno et al., 2011, 2013, 2017; D’Emilia et al., 2015; Elia et al., 2015, 2017; Yinnon et al., 2009). For example, the \( 10^{-3} - 10^{-4} \) m wide exclusion zone (EZ), which forms adjacent to hydrophilic membranes (Zheng et al., 2006), has been attributed to stabilization of CD\(_{\text{H}_{2}O}\) and CD\(_{\text{rot}}\) (Del Giudice et al., 2010, 2013; De Ninno, 2017). The attribution has been supported by experiments on water iteratively brought in contact with such membranes. The contact may rupture clumps of EZ and disperse these in the bulk liquid.

\(^8\) The electric conductivity of water is enhanced in the presence of CD\(_{\text{H}_{2}O}\) (Yinnon et al., 2013, 2016; Elia et al., 2017).
The iteratively perturbed water (IPW) has physicochemical properties commensurate with its clumps containing CD\textsubscript{elec}\textsuperscript{H\textsubscript{2}O} and CD\textsubscript{rot} (Elia et al., 2015, 2017; Yinnon et al., 2016). Some of these properties, e.g., the optical activity or pH, are perturbing membrane specific (Elia et al., 2018, 2019). Accordingly, it is plausible that water flowing adjacent to various types of hydrophilic cellulose (a common phenomenon in nature) contains CD\textsubscript{elec}\textsuperscript{H\textsubscript{2}O} and CD\textsubscript{rot}, with perturbing membrane specific vortices. Studying perturbing membrane dependent quantum Hall phenomena in IPW may have implications for revealing effects of such liquids on organisms. It has been hypothesized that the aqueous phase in cells entirely consists of EZ water (Zheng et al., 2006). Perturbing membrane specific vortices in IPW might alter the CD\textsubscript{elec}\textsuperscript{H\textsubscript{2}O} and CD\textsubscript{rot} of cellular water. Alterations in the properties of these domains might affect biological processes. Modes of interactions between biological molecules and CD\textsubscript{elec}\textsuperscript{H\textsubscript{2}O} and CD\textsubscript{rot} have been proposed by De Giudice et al. (2010).

Appendix

Properties of CD\textsubscript{rot} — The properties of CD\textsubscript{rot} described below are derived \textit{ab initio} by Del Giudice et al. (1988, 2013, 2006) and Sivasubramanian et al. (2005).

I. CD\textsubscript{rot} are composed of H\textsubscript{2}O molecules that coherently oscillate between two of their rotational states. Analyses of Raman and IR spectroscopic data by Elton et al. (2016) indicate the presence of coherent long-range dipole–dipole interactions in water. Dielectric dispersion measurements by Mahata (2013) indicate that association of molecules in SDVSASs involve the electric dipole rotations of the H\textsubscript{2}O molecules (Yinnon, 2017).

II. Interactions between the electric dipole moment of H\textsubscript{2}O molecules and EM radiation underlie the formation of CD\textsubscript{rot}, as corroborated by experimental data on SDVSASs (Yinnon et al., 2015c).

III. The ferroelectric ordering of the H\textsubscript{2}O molecules within CD\textsubscript{rot}, as well as that of the CD\textsubscript{rot}, are corroborated by dielectric permittivity measurements of SDVSASs (Yinnon et al., 2015c).

IV. The conditions for formation of CD\textsubscript{rot} have been derived \textit{ab initio} with classical electrodynamics and with QED. These conditions [summarized by Yinnon et al. (2016)] include: These domains cannot auto-organize, because the energy an H\textsubscript{2}O molecule gains by joining a CD\textsubscript{rot} (~0.025 eV) is on the same order as the energy of the water’s thermal fluctuations. However, objects with sizable asymmetric charge distributions (e.g., polar solutes, polar macromolecules or hydrophilic membranes) may stabilize CD\textsubscript{rot}. The presence of such an object adds a term

$$H=-dE$$

(A1)

to the potential energy of a H\textsubscript{2}O ensemble. \(d\) is the electric dipole moment of a H\textsubscript{2}O molecule. \(E\) is the electric field due to the object. \(H\) augments the energy an H\textsubscript{2}O molecule gains on its inclusions within CD\textsubscript{rot}. Hence, near the object, \(H\) may induce H\textsubscript{2}O molecules to order into CD\textsubscript{rot}. The ordering results in a permanent polarization \(P_n\) in direction \(n\) with magnitude:
where \( \tan(\zeta) = \left[ \omega_0 - \left(\omega_0^2 + 4H^2\right)^{\frac{1}{2}} \right] / (2H) \). Here \( A_0(t) \) and \( A_1(t) \) represent the amplitudes of the collective modes of the \( \text{H}_2\text{O} \) molecules in their ground state (angular momentum \( l=0 \)) and their excited state (\( l=1 \)) respectively at microscopic time \( t \). \( \omega t \) signifies the difference in phases of these modes. \( \omega_0 \) is the frequency of the \( l=0 \leftrightarrow l=1 \) transition. The time average of the polarization is:

\[
\overline{P}_n = \frac{1}{\sqrt{3}}(\sin 2\zeta)(\overline{A}_0^2 - \overline{A}_1^2)
\]

with \( \overline{A}_0^2 \) and \( \overline{A}_1^2 \), respectively, the time average of \( [A_0(t)]^2 \) and \( [A_1(t)]^2 \).

Eq. (2) shows that a net polarization implies a nonzero difference in the \( l=0 \) and \( l=1 \) populations, i.e., a state different from the \( [A_0(t)]^2 \approx [A_1(t)]^2 \) typifying the equilibrium Boltzmann distribution of bulk water.

V. After \( \text{CD}_{\text{rot}} \) are stabilized, and the object is removed, these domains still may persist for macroscopic times (years) (Yinnon et al., 2013, 2016). Water containing \( \text{CD}_{\text{rot}} \) is a far-out-of-equilibrium dissipative system. Its \( \text{CD}_{\text{rot}} \) continuously realign on a macroscopic time scale.

VI. Thermogravimetry indicates that isolated \( \text{CD}_{\text{rot}} \) may persist up to \( \sim 650^\circ \text{C} \), which agrees with \textit{ab initio} derived predictions (Yinnon et al., 2016).

VII. \( \text{CD}_{\text{rot}} \) reaching dimensions of \( 10^{-4} \) m is commensurate with Atomic force microscopy revealing \( 10^{-5} \) m sized domains in SDVSASs with \( C<C_{\text{thr}} \) (Ryzhikina et al., 2012) and Fluorescence microscopy revealing \( 10^{-4} \) m sized domains in water perturbed by Nafion (Elia et al., 2013). These domains have characteristics resembling those of \( \text{CD}_{\text{rot}} \) (Yinnon et al., 2015c, 2016).

VIII. Serially diluting an aqueous solution with \( C>10^{-3} \) M, and vigorously shaking it after each dilution, may stabilize \( \text{CD}_{\text{rot}} \) when \( C \) drops below \( C_{\text{thr}} \) (see Figs. A1 & 2) (Yinnon et al., 2015c).

IX. \( \text{CD}_{\text{rot}} \) are superfluidic domains. A single collision between the \( \text{H}_2\text{O} \) molecules constituting a \( \text{CD}_{\text{rot}} \) would destroy their rotational coherence. The superfluidity implies that exciting \( \text{CD}_{\text{rot}} \) may create vortices within these domains. Collisions of \( \text{CD}_{\text{rot}} \) with surrounding molecules or EM radiation may excite \( \text{CD}_{\text{rot}} \). When the excitation energy is larger than the energy an \( \text{H}_2\text{O} \) molecule gains by joining a \( \text{CD}_{\text{rot}} \) (\( \sim 0.025 \) eV), an \( \text{H}_2\text{O} \) molecule desorbs. When the excitation energy is smaller, the whole domain becomes excited and vortices are created. These vortices cannot decay thermally. The coherence of the rotations of the \( \text{H}_2\text{O} \) molecules within the
CD$_{rot}$, which surround the vortices, prevents random thermal fluctuations, i.e., the vortices are cold.

X. Solutes are pulled into CD$_{rot}$ yet many solutes destroy CD$_{rot}$. The critical concentration below which CD$_{rot}$ persist ($C_{crit}^{CDrot}$) depends on the solute. Typically, $10^{-10} \text{ M} < C_{crit}^{CDrot} < 10^{-6} \text{ M}$. $C_{crit}^{CDrot}$ equals $C_{thr}$ (Yinnon et al., 2015b & c).


i. Interactions between H$_2$O molecules and ultraviolet (UV) radiation underlie formation of CD$_{H_2O}^{elec}$, as corroborated by experiments of SDVSASs and other structured waters (Elia et al., 2017; Ryzhkina et al., 2018; Yinnon et al., 2017, 2018).

ii. The $\sim10^{-7}$ m dimension of CD$_{H_2O}^{elec}$ is corroborated by experiments (Yinnon et al., 2015b&c).

iii. The energy an H$_2$O molecule gains by joining a CD$_{H_2O}^{elec}$ ($E_{coh}$) results from its participation in the coherent oscillations of the domain’s molecules. At ambient conditions, $E_{coh} \approx 10^{-1}$ eV, as corroborated by experiments (De Ninno et al., 2013).

iv. CD$_{H_2O}^{elec}$ are superfluidic domains. A single collision between the H$_2$O molecules constituting a CD$_{H_2O}^{elec}$ would destroy their coherence. The impact of a randomly moving liquid molecule bordering on a CD$_{H_2O}^{elec}$ colliding with it depends on the collision energy. When the collision energy is larger than $E_{coh}$, an H$_2$O molecule may desorb from the CD$_{H_2O}^{elec}$. Otherwise, superfluidity implies that the collision excites the whole CD$_{H_2O}^{elec}$, i.e., vortices are created. These excited CD$_{H_2O}^{elec}$ states may also be induced by irradiation.

v. The formation of CD$_{elec}^{H_2O}$ is a central aspect upon condensation of a liquid from its vapor.

vi. CD$_{elec}^{H_2O}$ only form at temperatures below 500 K (at ambient pressures), as corroborated by experiments (Yinnon et al., 2016).

vii. In bulk water at ambient conditions, the energy of thermal fluctuations is about an order of magnitude smaller than $E_{coh}$. Therefore, in bulk water, CD$_{elec}^{H_2O}$ are metastable. The competition between QED interactions and collisions resulting from thermal noise causes a continuing adsorption and desorption of H$_2$O molecules from CD$_{elec}^{H_2O}$. In other words, in bulk water there are everlasting transitions of H$_2$O molecules between a coherent and a noncoherent phase. The transitions are like those in superfluidic Helium. The transitions produce a continuously changing space distribution of the coherent and noncoherent fractions of H$_2$O molecules. At room temperature, $\sim$20 percent of the H$_2$O molecules belong to the former (Preparata, 1995 ch. 10), as corroborated by experiments (Yinnon et al., 2012). The time scale of the transitions is below $10^{-14}$ seconds. Therefore, observation of CD$_{elec}^{H_2O}$ requires very fast probes.

viii. Ensembles of CD$_{elec}^{H_2O}$ can be stabilized by CD$_{rot}$, membranes, macromolecules, CD$_{plasma}$ or IPD$_{plasma}$. The latter two are QED domains consisting of H$_2$O molecules and solvated solutes (Del Giudice et al., 2000; Yinnon et al., 2012). Solvated solutes organize in CD$_{plasma}$ for C larger than a solute dependent transition concentration ($C_{trans}^{IPDplasma}$). For $C < C_{trans}^{IPDplasma}$, solvated solutes may organize in IPD$_{plasma}$. The solutes in CD$_{plasma}$ perform coherent plasma oscillations, while those in IPD$_{plasma}$ participate in in-phase plasma oscillations. Experimental data indicating stabilization of
**CD\textsubscript{\textit{H}_2\textit{O}}** by **CD\textit{rot}**, membranes, **CD\textit{plasma}** or **IPD\textit{plasma}** have recently been forwarded (Yinnon et al., 2015b,c, 2016, 2017, 2018; Elia et al., 2015, 2017, De Ninno, 2017).

**ix.** When a **CD\textsubscript{\textit{H}_2\textit{O}}** is stabilized by a **CD\textit{rot}**, the former is located within the latter. The **H_2O** molecules of a **CD\textsubscript{\textit{H}_2\textit{O}}** located within a **CD\textit{rot}** reside in a superposition state. These **H_2O** molecules simultaneously participate in the coherent electronic and coherent rotational oscillations typifying the molecular ensembles constituting these domains.

**x.** **CD\textsubscript{\textit{H}_2\textit{O}}** agglomerate into supra-**CD\textsubscript{\textit{H}_2\textit{O}}**, as corroborated by experiments (Yinnon et al., 2015c).

**xi.** Fingerprints of the QFEs, rendering **CD\textsubscript{\textit{H}_2\textit{O}}** electrically charged, have been revealed by experiments (Yinnon et al., 2015c).

**xii.** The ~1000 Hz spacing of the spectra of the vortices of QFEs has been corroborated by experiments (Montagnier et al., 2015).

**xiii.** **CD\textsubscript{\textit{H}_2\textit{O}}** cannot contain solutes.

**Fig. A1.** Schematic picture of serially diluted solutions of weak electrolytes or nonelectrolytic compounds. Solutions diluted onto a solute dependent critical concentration **C\textsuperscript{\textit{C\textsubscript{\textit{CDrot}}}c\textsubscript{\textit{crit}}}** are pictured. The top rows (a) and bottom rows (b) series pertain to solutions which, respectively, were not vigorously shaken and those which were vigorously shaken after each dilutions step.\(^h\)

Figure ia illustrates that, for **C** larger than a transition concentration \(**C\textsuperscript{\textit{CDplasma}trans}**\), all solvated solutes move randomly, i.e., do not organize in a QED domain. The tiny blue balls represent randomly moving ~10\(^{-9}\) - 10\(^{-8}\) m solvated solutes. The irregularly shaped bunches of black hexagons represent aggregates of nonsolvated solutes. Figure iia illustrates that, on dilution below **C\textsuperscript{\textit{CDplasma}}**, solvated solutes organize in a QED domain type denoted **CD\textsubscript{\textit{plasma}}** (symbolized with purple-blue colored balls). The yellow-brown balls and their agglomerates represent, respectively, ~10\(^{-7}\) m sized QED domains denoted **CD\textsubscript{\textit{H}_2\textit{O}}** and supra-**CD\textsubscript{\textit{H}_2\textit{O}}**, which are both stabilized by **CD\textsubscript{\textit{plasma}}**. Figures iia and iia illustrate the transformation of **CD\textsubscript{\textit{plasma}}** into another type of QED domain denoted **IPD\textsubscript{\textit{plasma}}**. The transformation occurs at the transition concentration \(**C\textsuperscript{\textit{CDplasma}trans}**\). Figures ia-iiia illustrate that on dilution the nonsolvated solutes diminish, i.e., solvate. Figures iiia-iv illustrate that, on dilution, the diameter of **IPD\textsubscript{\textit{plasma}}** does not change, but the number of **IPD\textsubscript{\textit{plasma}}** diminishes.

\(^h\) The sizes of the various domains, their broken pieces and the sizes of the solvated solutes with their hydration shells are not presented according to their realistic scale ratios. The picture is based on the analyses presented by Yinnon et al. (2011, 2013, 2015b&c). The figure is a reprint of Fig.1 in Yinnon and Liu (2015c). The schematic picture of serially diluted solutions of strong electrolytes is similar. It appeared in Fig. 1 of Yinnon and Liu (2015b).
In the b series, the blue zigzag curves symbolize that shaking excites or cracks domains and aggregates. Figure iib illustrates that excitations or cracking does not significantly alter the internal structure of CD$_{\text{plasma}}$, which just as in Figure iiia are represented with purple-blue colored balls. Figures iib and iiib illustrate the transition from CD$_{\text{plasma}}$ to IPD$_{\text{plasma}}$, with the latter pictured as blue-crystalline balls just as in Figure iiiia. Figures iib and iiib illustrate that shaking excites or breaks up IPD$_{\text{plasma}}$. The excited or broken IPD$_{\text{plasma}}$ pieces are electric dipole aggregates (EDA$_{\text{IPDplasma}}$). These are pictured as irregularly shaped aggregates in figure iib. Their aligned black arrows orderings symbolize EDA$_{\text{IPDplasma}}$’s distorted ferroelectric H$_2$O molecules orderings. The purple arrow in the EDA$_{\text{IPDplasma}}$ symbolize these domains’ dipole moments.

**Fig. A2.** Schematic picture of serially diluted solutions of weak electrolytes or nonelectrolytic compounds. Solutions diluted beyond a solute dependent critical concentration $C_{\text{crit}}^\text{CDrot}$ are pictured.

The top rows (a) and bottom rows (b) series pertain to solutions which, respectively, were not vigorously shaken and those which were vigorously shaken after each dilutions step.

Fig. va illustrates that at very low concentrations, the prevalence of IPD$_{\text{plasma}}$ becomes negligible. Figures via-viiia illustrate that below a certain concentration there are insufficient solutes to form IPD$_{\text{plasma}}$. The concentration below which no IPD$_{\text{plasma}}$ form has not yet been theoretically derived. Figures via-viiia illustrate that, whenever there are too few solutes to form IPD$_{\text{plasma}}$, the solution has the characteristics predicted by the customary models, i.e., all solvated solutes move randomly and their number diminishes on dilution.

In the b series, the blue zigzag curves symbolize that shaking excites or cracks domains and aggregates. Figure vb illustrates that on diluting below a solute type dependent critical concentration ($C_{\text{crit}}^\text{CDrot}$), a QED domain denoted CD$_{\text{rot}}$ becomes stabilized by EDA$_{\text{IPDplasma}}$, i.e., the irregular shaped EDA$_{\text{IPDplasma}}$ are located within the elongated ovals representing CD$_{\text{rot}}$. The dark blue arrows symbolize the dipole moment of CD$_{\text{rot}}$. Figure vb shows that vigorous shaking excites or breaks up CD$_{\text{rot}}$, thus creating entities (electric dipole aggregates) denoted EDA$_{\text{CDrot}}$. The lump outlined with an irregular shaped broken curve, located at the bottom of one of the left CD$_{\text{rot}}$, represents the EDA$_{\text{CDrot}}$. Figures vb-viib show that at certain concentrations both EDA$_{\text{IPDplasma}}$ and EDA$_{\text{CDrot}}$ are present within CD$_{\text{rot}}$, though the sizes of EDA$_{\text{IPDplasma}}$ diminish with concentration. Figure viib shows that on diluting further, no EDA$_{\text{IPDplasma}}$ persist, i.e., there are too few solute particles to sustain EDA$_{\text{IPDplasma}}$. At these concentrations, vigorous shaking just breaks up CD$_{\text{rot}}$ and creates new EDA$_{\text{CDrot}}$. These, in turn stabilize, new CD$_{\text{rot}}$, as pictured in Figure viib. Figures vb-viib illustrate that CD$_{\text{rot}}$ may align with their dipole moments parallel. Figure viiib illustrates that at certain concentrations their dipoles may be aligned antiparallel.
Dedication

I dedicate this paper to Dr. Suzanne S. D. Kleinberger. Her many years’ long devoted patient support, combined with her gift of distinguishing between the medical efficacy of SDVSAAs prepared with different substrates, made this study possible.

Acknowledgements

I express my gratitude to Prof. A. M. Yinnon for his continuous support and manuscript review. I also express my appreciation and thankfulness to Jesús Aguilar for his careful literature search.

References


Montagnier L, Aissa J, Del Giudice E, Lavallee C,


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**Table 1**

List of abbreviations in alphabetic order, followed by Greek symbols abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>B</strong></td>
<td>Magnetic Field</td>
</tr>
<tr>
<td><strong>C</strong></td>
<td>Concentration</td>
</tr>
<tr>
<td><strong>C&lt;sub&gt;crit&lt;/sub&gt;</strong></td>
<td>Critical concentration</td>
</tr>
<tr>
<td><strong>C&lt;sub&gt;CDrot&lt;/sub&gt;</strong></td>
<td>Critical concentration below which CDrot may form</td>
</tr>
<tr>
<td><strong>C&lt;sub&gt;CDplasma&lt;/sub&gt;</strong></td>
<td>Transition concentration for CDplasma formation</td>
</tr>
<tr>
<td><strong>C&lt;sub&gt;IPDplasma&lt;/sub&gt;</strong></td>
<td>Transition concentration for IPDplasma formation</td>
</tr>
<tr>
<td><strong>C&lt;sub&gt;thr&lt;/sub&gt;</strong></td>
<td>Threshold concentration below which no domains are present in SDVASS samples screened by Permalloy</td>
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<tr>
<td><strong>CD</strong></td>
<td>Coherence domain</td>
</tr>
<tr>
<td><strong>CD&lt;sub&gt;elec&lt;/sub&gt;</strong></td>
<td>Coherence domain composed of coherent electronically excited water molecules</td>
</tr>
<tr>
<td><strong>CD&lt;sub&gt;plasma&lt;/sub&gt;</strong></td>
<td>Coherence domain composed of few solvated solutes performing coherent plasma oscillation and numerous polar solvent molecules</td>
</tr>
<tr>
<td><strong>CDrot</strong></td>
<td>Coherence domain composed of ferroelectric ordered polar solvent molecules</td>
</tr>
<tr>
<td><strong>EDA&lt;sub&gt;CDrot&lt;/sub&gt;</strong></td>
<td>Excited or broken CDrot piece, which has an electric dipole moment and therefore is denoted electric dipole aggregate (EDA)</td>
</tr>
<tr>
<td><strong>EDA&lt;sub&gt;IPDplasma&lt;/sub&gt;</strong></td>
<td>Excited or broken IPDplasma piece, which has an electric dipole moment and therefore is denoted electric dipole aggregate (EDA)</td>
</tr>
<tr>
<td><strong>EM</strong></td>
<td>Electro-magnetic</td>
</tr>
<tr>
<td><strong>eV</strong></td>
<td>Electron Volt</td>
</tr>
<tr>
<td><strong>E</strong></td>
<td>Electric field</td>
</tr>
<tr>
<td><strong>E&lt;sub&gt;s&lt;/sub&gt;</strong></td>
<td>Electric field of solute molecule</td>
</tr>
<tr>
<td><strong>H&lt;sub&gt;2&lt;/sub&gt;O</strong></td>
<td>Water molecule</td>
</tr>
<tr>
<td><strong>Hz</strong></td>
<td>Herz</td>
</tr>
<tr>
<td><strong>IPDplasma</strong></td>
<td>In phase domains composed of few solvated solutes and numerous solvent molecules performing in phase plasma oscillation.</td>
</tr>
<tr>
<td><strong>I</strong></td>
<td>Electric current</td>
</tr>
<tr>
<td><strong>IR</strong></td>
<td>Infra red</td>
</tr>
<tr>
<td><strong>j&lt;sub&gt;x&lt;/sub&gt;</strong></td>
<td>Current of density in x direction</td>
</tr>
<tr>
<td><strong>M</strong></td>
<td>Molarity in mole per liter</td>
</tr>
<tr>
<td><strong>m</strong></td>
<td>Meter</td>
</tr>
<tr>
<td><strong>mol / l</strong></td>
<td>Mole per Liter</td>
</tr>
<tr>
<td><strong>NaCl</strong></td>
<td>Sodium Chloride</td>
</tr>
<tr>
<td><strong>QED</strong></td>
<td>Quantum electro-dynamics</td>
</tr>
<tr>
<td><strong>QFE</strong></td>
<td>Quasi free electrons</td>
</tr>
<tr>
<td><strong>R&lt;sub&gt;II&lt;/sub&gt;</strong></td>
<td>The Hall coefficient</td>
</tr>
</tbody>
</table>
Abbreviation | Explanation
--- | ---
SDVSAS | Serially diluted vigorously shaken aqueous solution
Supra-CD | Agglomerate of coherence domains
UV | Ultra-violet
$V_{HI}$ | Hall Voltage
Vis | Visible light
$\Sigma$ | Hall conductance
$\Psi$ | Quantum wavefunction describing matter
$\Psi_{CD_{elec}}^{\text{H}^{\text{Ih}}}$ | Quantum wavefunction describing $\text{CD}_{\text{elec}}^{\text{H}^{\text{Ih}}}$
$\Psi_{CD_{rot}}$ | Quantum wavefunction describing $\text{CD}_{\text{rot}}$

**Discussion with Reviewers**

**Reviewer**

In the paper, the acronym SDVSAS refers to a process originating in the work of Samuel Hahnemann devoted to the preparation of homeopathic remedies. A dog should be named and identified as a dog and not as a barking bunch of hair (BBH). If authors are afraid of speaking frankly of “homeopathic preparations,” the best is to publish on other less controversial subjects. Accordingly, other groups have taken their responsibility by publishing very good scientific papers on the science involved behind the preparation of homeopathic remedies, a subject that is in direct relationship with SDVSAS.

**TA Yinnon**

“SDVSAS” is just an abbreviation, as customarily in scientific papers. There are several reasons for me sticking to this custom and not denoting such liquids as homeopathic remedies.

- The study of serially diluted liquids is important for advancing basic science.

For example, it enabled discovering concentration dependent phase transitions, which seems to imply a paradigmatic shift in chemical reactivity and solution structure research (Kononov et al., 2002, 2015).

- Some scientists use the denotations “highly diluted” or “extremely diluted” solutions for SDVSASs. I deem it important to emphasize that the liquids are vigorously shaken.

- SDVSASs are not just used in homeopathy. SDVSASs are of importance for other technological fields, e.g., wastewater treatment or power generation (Ryzhkina et al., 2011; Bandyopadhyay et al., 2017).

- Homeopathic remedies generally contain alcohol. As emphasized by Van Wassenhoven et al. (2018): “Following the European pharmacopoeia, [...] to avoid precipitates, first dilutions of soluble MT must be prepared using the same alcohol concentration as the MT, but alcohol is not required for higher dilutions when producing homeopathic medicines. When a homeopathic medicine is made for bulk storage in a pharmacy, 62% w/w alcohol is added as a preservative, but intermediate dilutions are always prepared in pure water and then discarded. All Korsakov intermediate preparations are similarly prepared using pure water, and alcohol is added only for the final dynamisations. The homeopathic manufacturing tradition expects that the homeopathic information is carried by the water and not by the alcohol.”

- To advance knowledge on the physicochemical properties of serially diluted liquids, I deem it wisest to stick to customarily scientific methods and to publish in peer reviewed physics or chemistry journals. I trust that science-
based evidence will eventually erase the controversies around homeopathy.

**Reviewer**

The EZ-water concept developed by Gerald Pollack’s research group (Zheng et al., 2006) obviously has a relationship with SDVSASs.

**TA Yinnon**

In my open access paper (Yinnon, 2018 p. 27), I pointed out:

(a) EZ water might be a source of CD$_{\text{rot}}$ and CD$^{\text{H}_2\text{O}}_{\text{elec}}$ in SDVSASs prepared in vessels of glass or other hydrophilic materials.

(b) The available experimental data were insufficient for delineating the relative contribution of EZ water or that of other mechanisms to the prevalence of CD$_{\text{rot}}$ and CD$^{\text{H}_2\text{O}}_{\text{elec}}$ in SDVSASs.

After I submitted the manuscript of the current paper, new relevant data have been published. So, I thank you for your remark, which provides me with an opportunity to readdress the issue.

Montagnier et al. (2009, 2011, 2015, 2017) have shown that aqueous SDVSASs, with some types of DNA as substrate, may emit 500-3000 Hz radiation. They prepared and kept the SDVSASs in Eppendorf plastic tubes. They digitally recorded the radiation, sent the record to a distant laboratory, transformed it into an analog form and sent the electric vector of the analog signal to a solenoid, which generated a magnetic field in a test tube of water. They added enzymatic proteins to the water, to allow polymerase chain reaction processes to occur. DNA molecules identical to the DNA substrate materialized in the water. They explained their results with the QED formalism of aqueous systems developed by Kurian et al. (2018). Recently, Tang et al. (2019) examined factors affecting the aforementioned processes. For example, they showed that on using hydrophilic quartz cuvettes instead of the hydrophobic plastic Eppendorf tubes, the success rate of the processes increased (a rate of 38.5% for the quartz cuvettes versus 8.7% for the plastic tubes). EZ water forms adjacent to hydrophilic membranes (Zheng et al., 2006), but is not known to stabilize adjacent to hydrophobic surfaces. The finding that the success rates of the processes are significantly less on using the hydrophobic tubes than on employing the hydrophilic cuvettes indicates that also in the absence of EZ water, SDVSAS have the properties discovered by the group of Montagnier. However, the results also hint that entities in EZ water (likely its CD$_{\text{rot}}$ and/or CD$^{\text{H}_2\text{O}}_{\text{elec}}$) contribute to the aforementioned processes.

**Reviewer**

My concern is how energy generated by mechanical shaking can be high enough to excite water domains? As far as I understand, excitation requires electronic transitions. How can such energy be provided by shaking? And what is the cohesion energy of the coherent domain? Is mechanical shaking able to induce its breakage?

**TA Yinnon**

Since the water domains CD$_{\text{rot}}$ and CD$^{\text{H}_2\text{O}}_{\text{elec}}$ are superfluidic, these are excitable by collisions with surrounding molecules (see Appendix – paragraphs IX and iv). When the collision energy is larger than the energy a H$_2$O molecule gains by joining a domain (the cohesion energy), a H$_2$O-molecule desorbs from the domain. When the excitation energy is smaller, the whole domain becomes excited and vortices are created. The cohesion energy of the H$_2$O molecules constituting CD$^{\text{H}_2\text{O}}_{\text{elec}}$ is ~0.1 eV and that of CD$_{\text{rot}}$ is ~0.025 eV. Since the latter is of the order of that of thermal fluctuations of water at ambient conditions, CD$_{\text{rot}}$ cannot auto-organize in bulk water. However, once these domains become stabilized by objects
with sizable asymmetric charge distributions, these may persist for macroscopic times (see Appendix - paragraphs IV and V).

In water at ambient conditions, collisions between $\text{H}_2\text{O}$ molecules do not excite these from their ground electronic states to their excited electronic states. In section “Properties of CD$^{\text{H}_2\text{O}}$” on page 4 is written “These domains consist of $\text{H}_2\text{O}$ molecules that coherently oscillate between their electronic ground state $|0\rangle$ and an excited electronic $|b\rangle$ state .... The energy difference between the $|0\rangle$ and $|b\rangle$ states is 12.07 eV.” Collisions among molecules, even induced by vigorous shaking, cannot excite $\text{H}_2\text{O}$ molecules from their $|0\rangle$ to their $|b\rangle$ state. Instead, QED processes underlie the coherent oscillations between the $|0\rangle$ and $|b\rangle$ states of the molecules constituting CD$^{\text{H}_2\text{O}}$.

According to the QED model of SDVSASs, for $C<C_{\text{thr}}$, break-up of CD$\text{rot}$ is a crucial process in the preparation of these liquids (see the main text’s first paragraph in section “Information on the substrate imprinted in SDVSASs”). As to whether mechanical shaking of SDVSASs may break up its CD$\text{rot}$, Yinnon et al. (2015b footnote g) have pointed out that the energetics of processes induced by vigorous shaking of SDVSASs have not been quantified. Therefore, these authors roughly estimated the energy available for break-up of molecular associates in an aqueous liquid after it has been shaken. They followed the approach of Raine et al. (1993). They noted: On stirring water in a glass vessel, more than 95% of the applied energy heats the system and dissipates to the surroundings. After stirring one liter of water for one minute, the energy available for excitation or break-up of molecular associates is of the order of one Joule, i.e., $10^{18}$ - $10^{19}$ eV. Elia et al. (2010) estimated that in a 45-times decimally diluted SDVSASs, about $10^{23}$ - $10^{24}$ molecules are associated. Thus, the stirring provides maximal $\sim 10^{-4}$ eV per associated molecule. In other words, the stirring cannot lead to a total disintegration of CD$\text{rot}$, but only to some local break up.

I thank the anonymous Reviewer-1 for pointing out: “From a fluid dynamics viewpoint, the afore-mentioned approach is not convincing, as it does not take into account the Richardson-Kolmogorov cascade for energy dissipation through turbulence. Taking into account the well-known laws of turbulence shows that for manual shaking the Kolmogorov dissipation scale cannot be lower than about 10 $\mu$m (Henry, 2016).” Henry (2016) has estimated: Vortexing water in a manual Wasserwirbler with a height of 30 cm and capacity of about one liter, the Richardson-Kolmogorov cascade enables the applied energy to split up entities with sizes larger than 21 $\mu$m; while the most efficient mechanical commercial machines, (which can vortex 20 liters of water over a height of 50 cm), enable the applied energy to split up entities with sizes larger than 343 nm.

CD$\text{rot}$ may reach dimensions of hundreds of $\mu$m. The group of Konovalov has observed molecular associates with sizes of the order of $10^{-5}$ m in SDVSAS with $C<<C_{\text{thr}}$ which were prepared with a lab dancer or by vortexing. The properties of these associates resemble those of CD$\text{rot}$ (Yinnon et al., 2015b&c). Thus, on vortexing SDVSASs, the Richardson-Kolmogorov cascade should enable the applied energy to split up these associates. The 0.1 $\mu$m sized CD$^{\text{H}_2\text{O}}$ are smaller than the Kolmogorov dissipation scale. However, in the QED model of SDVSASs, neither is it assumed nor concluded that CD$^{\text{H}_2\text{O}}$ break up.