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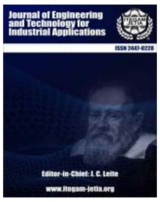

RESEARCH ARTICLE OPEN ACCESS

NATURE OF DISPERSION: ITS RELATIONSHIP WITH SOME FRACTAL AND THERMODYNAMIC PHENOMENA

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ABSTRACT

Water quality studies, vital for the development of human civilization, critically depend on the reliability and accuracy of the environmental and geomorphological data fed by the models. Nowadays, tracers are widely used to obtain this kind of data, however, many methodological and technical problems persist about they, which make it difficult for the specialist to properly manage time and costs. This article presents an alternative methodology, based on a state function, which accurately describes the phases of evolution of the solutes in the flow. From their analysis it is clear that the "abnormal bias" observed in the tracer curves correspond not to effects of flow (as stated in the dead zone theory) but to effects of the chemistry of the solute dissolving in water. This different approach allows to improve the corresponding interpretations and calculations of tracers used in field. Experiments are presented at the end that are interpreted with the proposed state function.

I. INTRODUCTION

Water Quality studies have become essential tools for the control and improvement of the conditions of use of water resources, so threatened by a growing anthropic activity. However, currently, and despite spectacular advances in digital computing, theoretical tools suffer from great backwardness, since they correspond to complex models, developed in the last quarter of last century.

This article presents new developments in the understanding of the Advection-Diffusion phenomenon, especially with the development of a state function, $\boldsymbol{\phi(U,E,t)}$, which describes the evolution of the tracer cloud at different stages. This function connects with certain contemporary notions, corresponding to Feigenbaum's infinite bifurcation model, and also puts into play experimental results of great importance, such as the Svedberg constant, obtained in his investigations of Brownian particles in aqueous media, carried out with ultra-centrifugation, at the beginning of the 20th century.

These new concepts put in mutual connection, allow us to have new and powerful tools to properly interpret the complex phenomena of water pollution in the modern world. In this article, the word "solute" and "tracer" are used interchangeably. on the understanding that current engineering techniques used almost exclusively saline tracers, or fluorescent tracers, which dissociate into charged units (ions) as a result of their interaction with water.

II. DISPERSION AS A MOLECULAR PHENOMENON

II.1 ELEMENTARY DIFFRACTION OF PARTICLES IN THE FLOW, AND ITS MEANING

The molecular vision of dispersion has been defined by the author [1] as the random separation of any pair of particles, **N** and **W**, by the effect of a "diffraction" element, $\boldsymbol{D}$, (which can be a physical obstacle or a velocity differential in the shear dynamic field of the flow), which generates a characteristic separation, $\boldsymbol{\Delta}$, at a characteristic time, $\boldsymbol{\tau}$, valid for multiple scales. Figure 1.

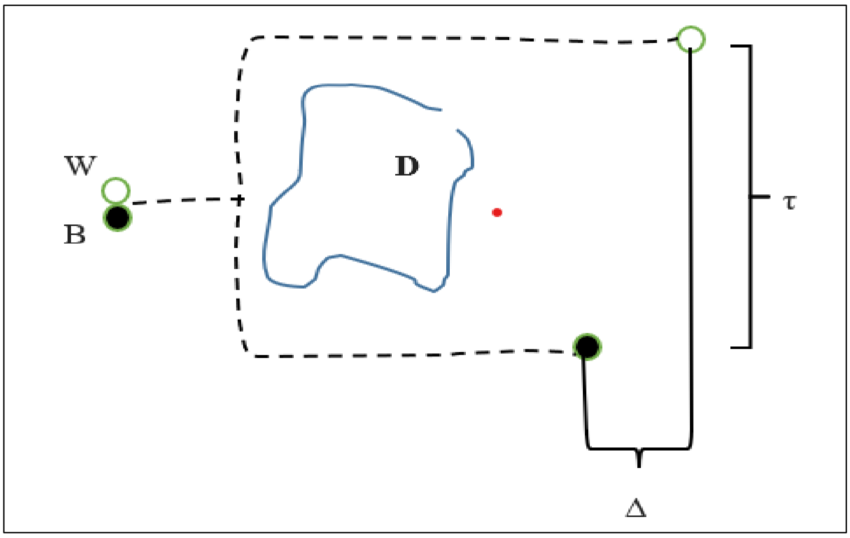

Figure 1: Random separation of a couple of particles.
Source: Authors, (2023).

It is now necessary to give a more precise meaning, both to Δ, and to τ, from concepts of the kinetic theory of liquids [2] developed by Y. Frenkel, as follows [3]:

Let be a group of tracer particles you inject suddenly into a flow, generating a concentration gradient between its center of mass and the liquid environment. The one-dimensional motion of each particle is random, insofar as it is immersed in a thermal environment, with equal probability of going left or right. Despite the individual randomness of motion of each particle, at each point of the distribution there will be a "previous point" at which the concentration is greater than at a "posterior point", Farther from the center of mass, therefore there will be more mobile particles at that first point than at the second, which generates an imbalance in the number of particles that move away from the center, from those that move away. The average displacement of the set, called "Diffusion", must be calculated by means of the squares of the individual displacements, xj^2 for its definition to make experimental sense:

$$< x^2 > \approx \frac{x1^2 + x2^2 + \cdots + xn^2}{N} \tag{1}$$

Since the number of observed displacements is proportional to time, the following one-dimensional proportionality can be written as:

$$< x^2 > \approx 2 * D * t \tag{2}$$

If the motion of the particles of the solute within the fluid is interpreted as in sequence of jumps, whose number is precisely "N", then for a single hop ($N = 1$) one can write, with "τ" the characteristic time for a jump:

$$\Delta^2 \approx 2 * D * \tau \tag{3}$$

Therefore:

$$\Delta \approx \sqrt{2 * D * \tau} \tag{4}$$

And one can then define a "dispersion" velocity, related to Figure 1, as follows: [4].

$$Vdisp \approx \frac{\Delta}{\tau} \approx \frac{\sqrt{2 * D * \tau}}{\tau} \approx \sqrt{\frac{2 * D}{\tau}} \tag{5}$$

It is useful then to define a dimensionless function of the form:

$$\phi \approx \frac{Vdisp}{U} \tag{6}$$

This function can be shown to be a "thermodynamic potential" since it satisfies Schwartz conditions [5]:

$$\oint d\phi = 0 \tag{7}$$

In addition, its expanded form is:

$$U \approx \frac{1}{\phi} \sqrt{\frac{2 * D}{\tau}} \tag{8}$$

Equation for the mean velocity of flow, which has an analytic form similar to the Chezy-Manning equation for uniform flow.

II.2 BALANCE OF ENERGIES IN THE TRACER SYSTEM AND ITS RELATIONSHIP WITH THE CURVE OF THE STATE FUNCTION AND THE PROCESSES OF EVOLUTION OF THE TRACERER PLUME

When the tracer suddenly enters the turbulent flow, it is accompanied by an energy of its structure, called "enthalpy of formation", ΔHo [6].

This energy is used to configure the different interactions of the particles of the solute, and are of two types:

A.- Initial energy associated with the static crystal itself, $\Delta xtal$ at the beginning of the process;

B.- Energy associated with the distribution of the chemical potential, in the later stage, ΔChe.

$$\Delta Ho \approx \Delta Xtal + \Delta Che \tag{9}$$

In the initial process, called "solvation", the dipole particles of water act electrically on the ions of the solute, surrounding them and forming complex units, destroying their initial structure. In a second process, with the solvated particles already "loose", a distribution is established in the flow that is associated with a gradient of chemical potential.

In this process of destruction, water uses a certain thermal energy, ***Δq ext***, which equals ***Δxtal.*** [7]

$$\Delta q\ ext \approx \Delta xtal \qquad (10)$$

In addition to this balance, energies enter the system from outside, consisting of a kinetic part, ***ΔK***, (flow velocity), and a potential part, ***ΔE***, which constitute the gravitational part (of the slope of the flow), and also heat is expelled to the outside, ***ΔQ***, product of all the processes of irreversible degradation. Figure 2. [8].

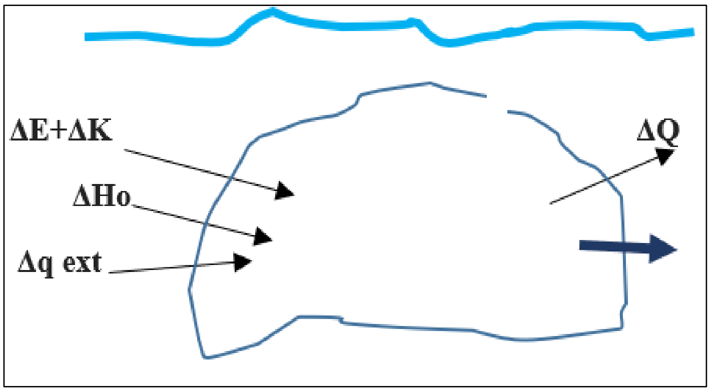

Figure 2: System´s energies and in its surroundings.
Source: Authors, (2023).

The general balance is:

$$\Delta E + \Delta K \approx \Delta Q \qquad (11)$$

To represent the evolution of the plotter cloud, one has that the variation of the State function, ϕ(t) is. Figure 3:

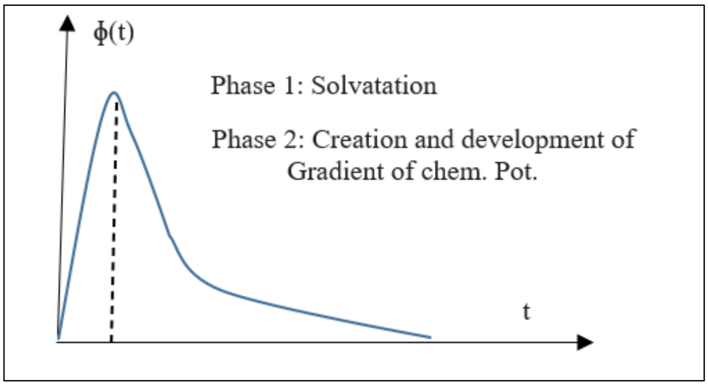

Figure 3: Variation of state Function.
Source: Authors, (2023).

The first process (Phase 1) is relatively fast and ***ϕ(t)*** goes from 0 to ***ϕmax ≈2.16***, and the second (Phase 2) is much slower and goes from the peak of the state function to its extinction at equilibrium. Phase 1 (ascending) corresponds to the "dipole-ion" interaction that is associated with solvation, while phase 2 (descending) corresponds to the "ion-ion" interaction, which represents the formation of an "ionic cloud" that surrounds each ion, and that is diluted as time passes [9-10].

In phase 2, the "ionic clouds" generate an extra volume to each particle, which offers an additional effect of resistance by viscous friction, called "Einstein-Stokes", which is diluted over time by gradual destruction of these clouds. This effect leads to a "delay" of the plotter that moves with a velocity, ***u***, less than that of the flow, ***U***.

As the tracer plume advances in the flow, the gradual destruction of the aforementioned "ionic clouds" decreases the effective radii of the tracer particles, that is, decreasing the viscous resistance, and therefore increasing the effective speed of these particles. When a point is reached where the "clouds" disappear, the plotter particles are coupled in speed to the flow itself. Figure 4.

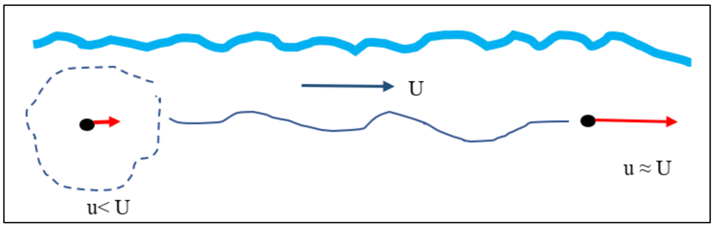

Figure 4: Retardant effect of the ionic atmosphere by the Einstein-Stokes effect.
Source: Authors, (2023).

II.3 THE "EINSTEIN-STOKES" EFFECT AS A REAL CAUSE OF "NON-FICKIAN" BIAS IN REAL TRACER CONCENTRATION CURVES

From the Fick Advección-Dispersion transport equation, (12) the following analysis can be made with respect to the pronounced "bias" that is detected in the experimental curves, but which does not correspond to this theoretical model, therefore called "non-Fickian bias":

$$\mathrm{C}(x,t) \approx \frac{M}{Ayz*\sqrt{4\pi*E*t}} * e^{-\frac{(Xo-U*t)^2}{4*E*t}} \qquad (12)$$

While a certain "normal" bias effect of the Galileo transformation must appear in this equation, (Black Curve) Figure 5.

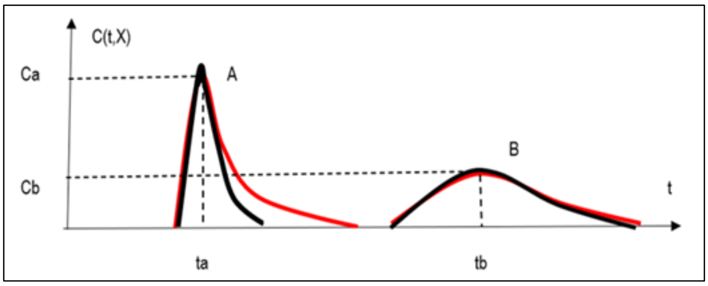

Figure 5: Decreasing bias over time of sequential Fickian tracer curves in the flow.
Source: Authors, (2023).

Represented with the difference ***(Xo-U*t)*** in the exponential quadratic argument, seen by a fixed observer on the banks of the channel (Beiser, 1977), the degree of "asymmetry" of this bias in the experiments (red curve) [11-12], has been much greater than expected, especially in the initial phase of the evolution of the tracer in the flow, forming a long "unexplained" tail (Curve A) that becomes more symmetrical over time. (Curve B).

At the same time, several alternatives have been proposed to solve this enigma, generally derived from the reactor models of chemical engineering. among them the theories ("Aggregated Dead zone", ADZ, and Transient storage" TS), which base the existence of non-Fickian "bias" in the operation of the so-called "Dead Zones", Those located on the periphery of the channels, perform a "trapping" of the particles of the solute, and then release this mass, and thus configure a supposed mechanism that delays the tracer. [13-14].

This mechanism operates on the basis of a mass exchange between the central zone (Bulk zone) with Concentration "***Cb***", completely mixed, and the peripheral zones, with concentrations "***Cd***", and therefore bases the nature of the anomaly of the "long tails" in an exclusive defect of the flow, Figure 6.

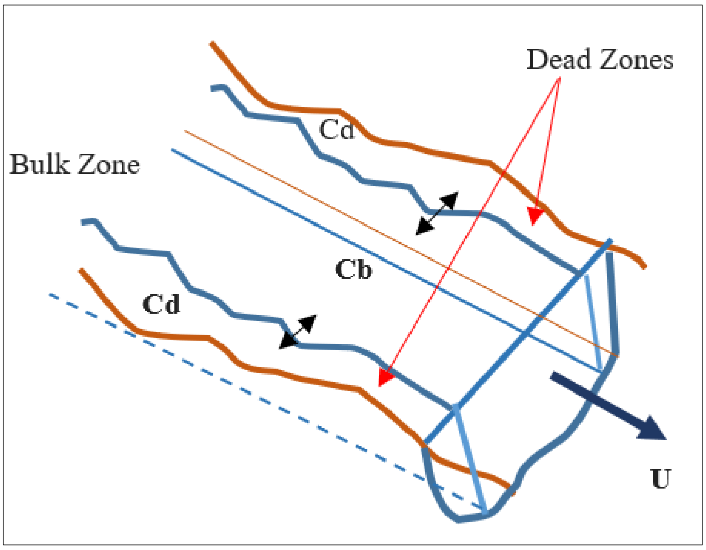

Figure 6: Geometric model of "Dead Zones".
Source: Authors, (2023).

The truth is that although they yield correct results, their mechanisms suffer from great mathematical complexity, and present the problem that the "trapping" of tracer particles in the peripheral zone necessarily requires the realization of a certain work against the forces of interaction, which the system cannot perform because being a "totally irreversible" process, all the energy that is delivered from the outside is transformed into heat, as the 2nd Principle preaches. The only alternative would be to provide this work from the outside, but this is not feasible either because it is assumed that the tracer is totally conservative, and nothing can hold it back.

Additionally, the results of the equations of the ADZ and TS methods are supported by computer programs (of the Monte Carlo type) that greatly obscure their analytical effectiveness. [15-16]. These methods give the flow (and not the tracer) the very mechanics of scattering with pronounced biases.

As seen earlier in this article, if the "Einstein-Stokes" effect is considered, due to the dependence of the speed of the tracer cloud (of its centroid), ***u***, with this effect, it gradually couples its velocity with the velocity of the flow, ***U***, until finally all the mass of the tracer is transported with this average velocity. It is evident that the "non-Fickian bias" is due not to a defect of the flow, but to the physico-chemical of the solute in the water, dependent that if on the turbulence of the medium.

II.4 THE MECHANISM OF IRREVERSIBILITY: BROWNIAN MOTION, AND ARROW OF TIME

The nature of the motion of solute particles in a flow undergoing a concentration gradient (actually of chemical potential) has a double facet: At the basic (individual) level each particle, "***P***", has the possibility of going "back" or "forward" (contrary arrows), but at the collective level there is a net movement of the tracer pen, expanding radially, relative to its center of mass Figure 7.

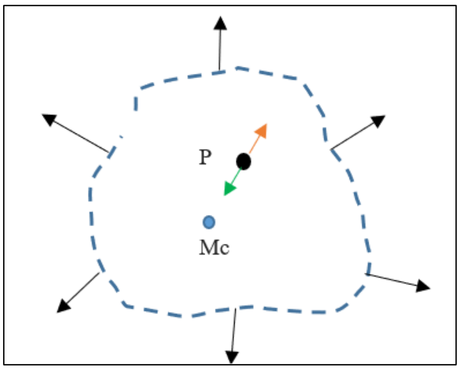

Figure 7: Complex movement of the tracer plume.
Source: Authors, (2023).

It can be seen then that at the same time that there is the basic randomness in each step of the Brownian motion (zigzag, forward backward), of each particle, there is an "arrow of time" (unidirectional) related to the increase in volume of the tracer with time.

This behavior can be put graphically as a tree of bifurcations in time and space, indicating that the individual random "decisions" of each particle are made in very short, medium and large times (distances), and the advance of the whole was getting bigger and bigger, Figure 8.

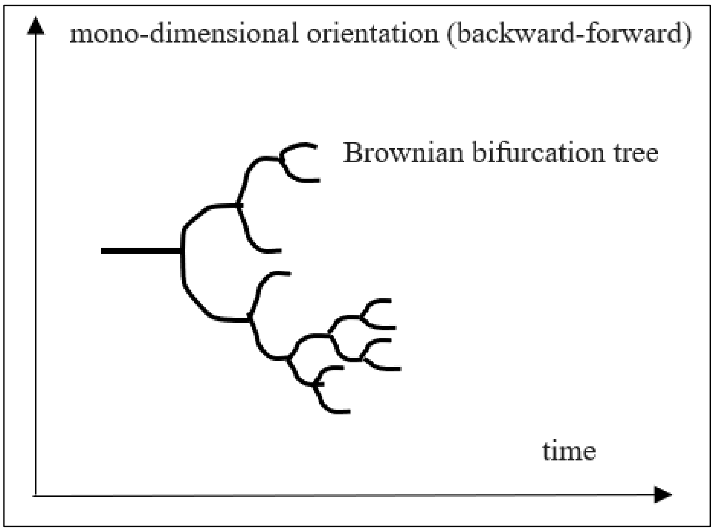

Figure 8: Brownian branching tree of the tracer.
Source: Authors, (2023).

As can be seen, these bifurcations occur on all scales, that is, it is a fractal phenomenon, mathematically defined by a "Law of powers", also called "Law of self-similarity". For this reason, it can be accepted that both the characteristic distance and time, Δ and τ of the Brownian jumps in Figure 1, *they occur at all scales*.

II.5 RELATION BETWEEN "τ" and "t", FEINGENBAUM'S CONSTANT, AND SVEDBERG'S CONSTANT

Since the mid-1960s the foundations of the nonlinear theory of phase transitions were established through the technique of "renormalization", and from which R. Feingenbaum developed the concept of "period doubling" in nonlinear physical systems (monomodal), such as the logistic function of growth [17], arriving at the definition of the ratio of "scaling", with a definition of geometric progression of the type:

$$\delta = lim\frac{\lambda(n)-\lambda(n-1)}{\lambda} \approx 4.6692 \tag{13}$$

The adjacent values of "λ" are getting closer and with shorter branches, progressing geometrically, accumulating duplications towards chaos, being strictly an "eigenvalue" of an operator. For this case, values of "λ" correspond to the independent variable, which defines the points at which the bifurcations occur, and when "λ" is the time, we speak of "period doubling". Since Feingenbaum presented his formula, it has been proven that this ratio is a universal value of self-equal phenomena (fractals) including turbulence and diffusion.

It can then be proposed that the times involved in the tree of Brownian bifurcations will be subject to a pattern of geometric progression of the Feingenbaum type. For this it must be remembered in principle, that Brownian motions are normally distributed, and therefore fulfill the probabilistic function of Gauss. In this sense, an arbitrary particle that runs through a Brownian system will spend different "residence times", ***Θσ*** and ***Θ∞*,** depending on whether it travels the curve between -***σ*** and +***σ***, or that it travels from -∞ to +∞, as shown in Figure 9.

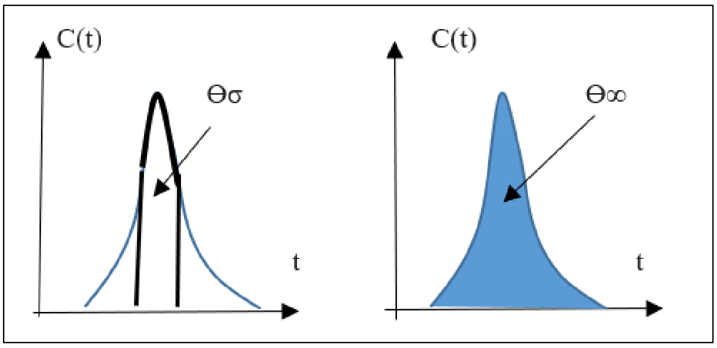

Figure 9: Two residence times of the particle.
Source: Authors, (2023).

Their ratio is, in terms of notable areas and values of concentration [18]:

$$r = \frac{\theta\sigma}{\theta\infty} \approx \frac{\frac{\int_{-\sigma}^{+\sigma} c(t)dt}{<C>}}{\frac{\int_{-\infty}^{+\infty} c(t)dt}{Cp}} \approx \frac{\frac{\int_{-\sigma}^{+\sigma} c(t)dt}{\int_{-\infty}^{+\infty} c(t)dt}}{\frac{<C>}{Cp}} \approx \frac{\frac{0.683}{0.997}}{0.442} \approx 1.54 \tag{14}$$

This is an average value found by T. Svedberg in his studies of the distribution of Brownian particles in the ultracentrifuge, being a characteristic value of these distributions. [19] Now, if one considers that the Poisson probabilistic distribution is widely used in physics for counting "rare" events in infinite succession. [20] The count of the arrival time of Brownian particles, as "rare" particles (scarce in the flow) can then be performed with this distribution, around the mean value ***"r"≈1.54***, and from the characteristic time, ***τ***, and ***n≈∞:***

$$t \approx \tau\left(1 + 1.54 + \frac{1.54^2}{!} + \cdots + \frac{1.54^n}{n!}\right) \approx \tau * 4.669 \tag{15}$$

This result is remarkable, because it shows the intimate relationship between Brownian motion (fractal) and the geometric progression of Feingenbaum bifurcations, establishing that time in the Brownian sequence is an infinite process towards chaos, [21].

III. ADVECTION-DISPERSION AS A MACROSCOPIC PHENOMENON

Based on previous theoretical developments, it is proposed to analyze different aspects of Adveccion-Dispersion as a phenomenon on a human scale, especially the explanation of the effect of "bias" in the experimental curves of tracer, and the relationship between the different magnitudes in the evolution of the conservative solute cloud.

III.1 SCOPE OF THE CALCULATION OF DISTANCE, Δ AND VARIANCE, σ, FOR DISPERSION

As we have seen, the characteristic distance, Δ, has a "local" meaning, closer to molecular concepts of Brownian motion, and likewise the characteristic time, τ, which of course has an essential nature, of passage from one equilibrium point to another equilibrium point in the quasi-crystalline lattice of the liquid, [22]. These equilibrium points are places of "vacancy" that fill the tracer ions, before and after the jump, Figure 10.

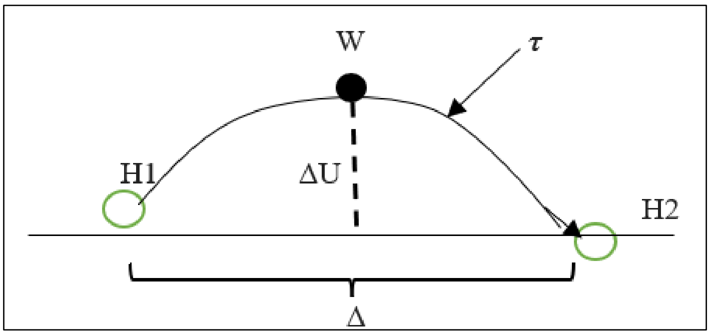

Figure 10: Jump of the particle, from one hole to another.
Source: Authors, (2023).

This passage of a particle from one point to another of the liquid of the flow is actually made from "energy jumps," from one "hole" to another, for which the particle must have sufficient energy to cross the "potential barrier", ***ΔU***, which separates one "hole" from the other, [23]. That energy needed for that jump is called "***W***," and it's called "activation energy".

When talking about diffusion in macroscopic domains, the "local", Brownian approach is transcended, and the concept of Statistical Distribution must be used, in which "local" events add to infinity. There operates the probabilistic distribution "Normal" (Gaussian), Figure 11.

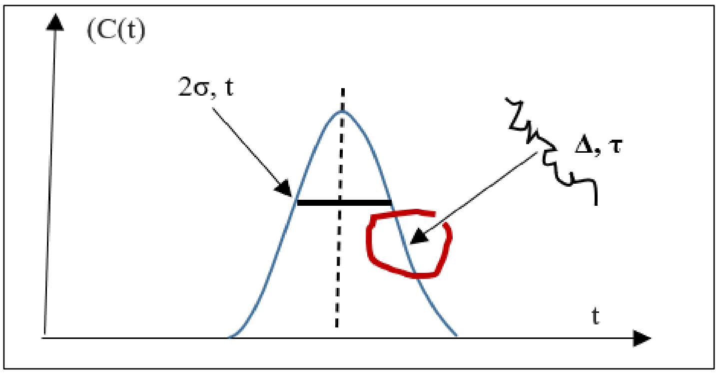

Figure 11: Macro and micro vision in dispersion.
Source: Authors, (2023).

For the macroscopic field the following expression is valid, in which due to its general character the Longitudinal transport coefficient, E, and the macroscopic time, ***t***: [24].

$$\sigma_x \approx \sqrt{2 * E * t} \tag{16}$$

It must be compared with the expression "local", equation (4), and the relationship between $\boldsymbol{\sigma_x}$, and $\boldsymbol{\Delta}$ is:

$$\Delta \approx \frac{\sigma x}{\sqrt{\delta}} \tag{17}$$

Now, to estimate the temporal variance, $\boldsymbol{\sigma_t}$, the average velocity of the flow must be used.

$$\sigma_t \approx \frac{\sigma x}{U} \tag{18}$$

Combining equation (4) with the previous ones, from (16) to (18), we have:

$$\tau \approx \frac{\sigma t}{\phi * \sqrt{\delta}} \tag{19}$$

In this way we have the definitions that allow to elucidate the mechanics of the Dispersion in turbulent natural flows, including "local" and general parameters.

III.2 APPLICATION OF THE "COMPLETE MIXTURE" CRITERION BASED ON THE "EINSTEIN-STOKES" EFFECT

It is interesting to apply the above criterion in the experimental tracer curves. As an exercise it would be calculated as follows.

A.- The value of $\boldsymbol{\phi}$ for the most initial condition, moments after injection, when the solute has been solvated in a first phase of the evolution of the tracer pen. This occurs when the macroscopic time, "***t***", is worth $\boldsymbol{tp \approx \sigma t}$, which is the smallest possible value, Figure 12.

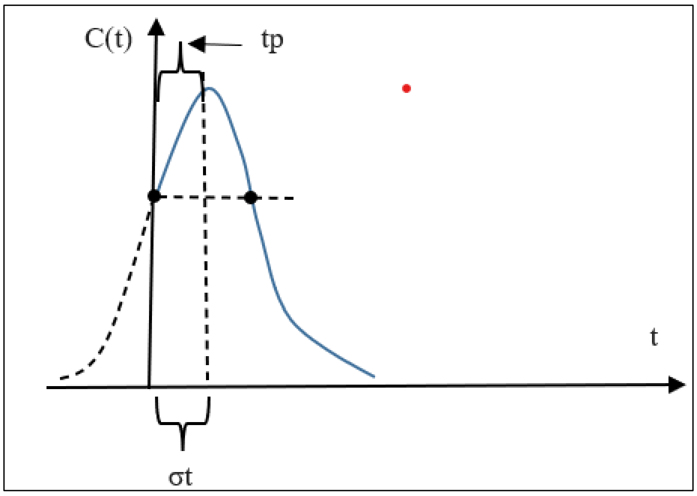

Figure 12: Minimum time in the evolution of the plume.
Source: Authors, (2023).

In this case. At the very beginning of the evolution of the pen, we will have:

$$\tau \approx \frac{tp}{\delta} \approx \frac{tp}{\phi * \sqrt{\delta}} \tag{20}$$

Therefore, at the very beginning of Phase 2: $\boldsymbol{\phi \approx \sqrt{\delta} \approx 2.16}$

B.- The value of $\boldsymbol{\phi}$ when there is "Complete mixture", that is, when the tracer cloud has achieved a time $\boldsymbol{tp \approx 4\sqrt{2} * \sigma t}$, since for that circumstance approximately 99.7% of the mass of the solute is "free" to participate in transport with a speed equal to that of the flow itself, that is, the effect of additional viscous friction has practically disappeared. This situation is shown in Figure 13.

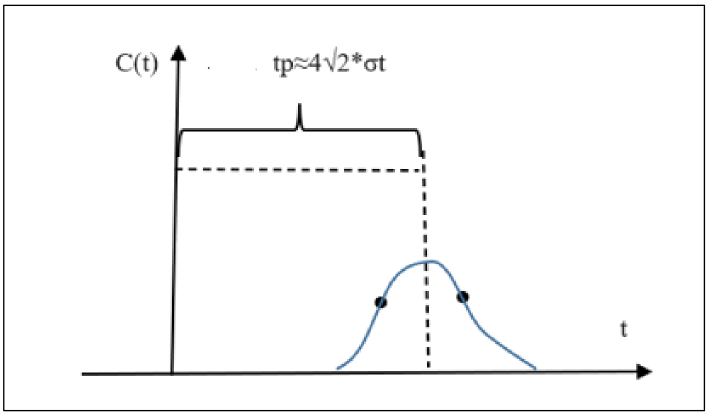

Figure 13: "Complete mix" condition on tracer.
Source: Authors, (2023).

If we replace the value of the longitudinal dispersion coefficient of equation (8) into Fick's classical equation (12) an extension of that equation remains, containing the Flow, the Feingenbaum fractal constant, and the State function [25]:

$$C(x,t) \approx \frac{M}{Q * \phi * t * 1.16} * e^{-\frac{(to-t)^2}{2 * \left(\frac{1}{\delta}\right) * (\phi * t)^2}} \tag{21}$$

Note how this new longitudinal tracer transport equation includes both the state function, the Feigenbaum's number and the flow, likewise, it is verified that this new equation adequately represents the experimental tracer curves with the appropriate bias, even under medical conditions close to the time of injection.

IV. VERIFICATION OF THE CALIBRATION OF TRACER MEASUREMENT EQUIPMENT

One of the recurring themes in the experimental work is the verification of the calibration of the equipment, that is, to have technical criteria that indicate when a team is out of specification in terms of its precision and accuracy [26].

IV.1 ECUACIONES PARA VERIFICAR LA CALIBRACION DE EQUIPOS DE FLUORIMETRIA

The authors have previously proposed formulas to estimate $\boldsymbol{\phi(t)}$**,** and $\boldsymbol{Cp(t)}$**,** linked as basic data to perform such verifications. As follows: [27].

$$Cp(t) \approx \alpha * tp^{-b} \tag{22}$$

Where "b" is an exponent that is chosen in such a way that the equations agree but is usually set around $\boldsymbol{b \approx 2/3}$ [28].

$$\phi(t) \approx \frac{M}{Q * \alpha * 1.16} * \frac{1}{t^{(1-b)}} \tag{23}$$

Note that equation (22) actually defines the envelope of concentrations at subsequent points in time. Note also, that the numerical value of "***α***" is a common element to magnitudes that depend only on time "(horizontal"), as well as magnitudes that depend only on the Concentration ("vertical"), so in principle, when calculated "independently", and if they converge to the expected common result, the Measurement (and therefore the Calibration) can be considered adequate. Figure 14.

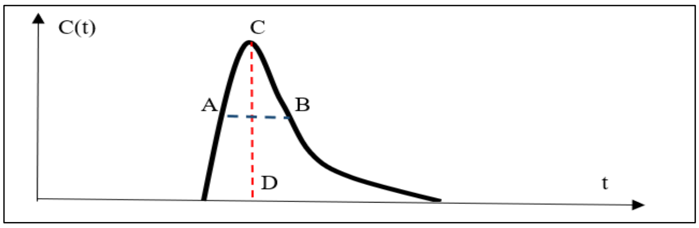

Figure 14: Independent "horizontal" and "vertical" measurements. Source: Authors, (2023).

For a case being studied, ***ϕ(t)*** is a "horizontal" magnitude (which depends EXCLUSIVELY on time, and is measured between the two inflection points A and B, (blue), while ***Cp(t)*** is a "vertical" magnitude, which depends EXCLUSIVELY on the Calibration, and is measured between points ***C*** and ***D***, (red), and therefore its analysis can yield clues as to whether the calibration is correct, or eventually if there is a problem with the sensor.

Then, if calculated ***Cp*** (***C-D***) with the data of ***ϕ*** (***A-B***) and do not match experimentally, it must be investigated if it is a problem of CALIBRATION, or if for any other reason the sensor is not measuring properly, and it should be relocated.

IV.2 DOCUMENTED EXPERIMENTS ON THE RIVER SEVERN, IN THE UNITED KINGDOM[29] IN 1986 WITH RHODAMINE WT. ANALYSIS OF THE BEHAVIOR OF "α"

This experimental study of scattering using fluorescent tracers was conducted in the River Severn (Wales) by T.C. Atkinson, P.M. Davies, and T.M. L. Wingley of the United Kingdom (Davis et al, 2000). For the original study, tracer measurements are made over a long stretch of 14 kilometers (between Llanidloes and Caersws) using six gauging points (stations ***A*** to ***G***) placed one behind the other at this distance.

The tracer used is Rhodamine WT 20% (***M≈1kg in 5 Liters***, ***H20 distilled***). The area of the mean cross section is ***Ayz≈12.72 m2***, the average velocity of flow is ***<U>≈0.70 m/s***, so the average estimated flow rate is ***<Q>≈7.54 m3/s***. Appearance of the channel in Caersws is shown in Figure 15.

Figure 15: Aspects of the River Severn (Caersws, Wales). Source: Authors, (2023).

The experimental curves of Rhodamine WT of ***Cp(tp)*** for the different distances are shown. Figure 16.

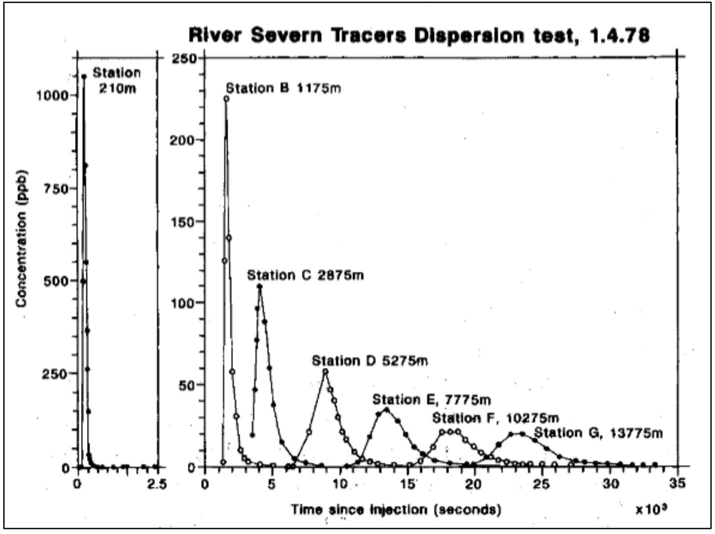

Figure 16: Distribution of ***Cp vs tp*** in the river Severn. Source: Authors, (2023).

The following Table 1 condenses the basic data of these 7 experiments with RWT, which are plotted with a potential experimental modeling of EXCEL in Figure 17.

Table 1: Main data on 7 tracer experiments in River Severn.

	A	**B**	**C**	**D**	**E**	**F**	**G**
Cp (Ppb)	1050	225	110	58	34.5	21	20
tp (s)	300	1740	4140	8880	13440	18120	23533
X (m)	210	1175	2875	5275	7775	10275	13775

Source: Authors, (2023).

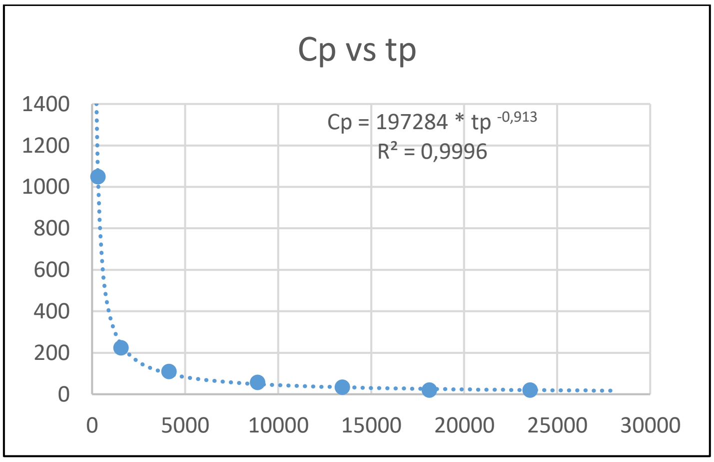

Figure 17: ***Cp vs tp***, Severn River, with 1kg RWT injection. Source: Authors, (2023).

The potential relationship in Excel of the ***Cp(tp)*** values is:

$$Cp(tp) \approx 197284 * tp^{-0.913} \tag{24}$$

This means that approximately ***α≈197284***, for the RWT, and the parameter "***b***" is ***b≈0.913.***

To determine the state function, ***ϕ*** (***tp***), equation (23) is used:

$$\phi \approx \frac{10^9\,(\mu g)}{7540\left(\frac{L}{s}\right)*197284*1.16} * \, tp^{-0.087} \approx 0.58 * tp^{-0.087} \qquad (25)$$

The resulting values of ***ϕ (tp)*** are shown in the following Table 2:

Table 2: Resulting values of equation (25).

Site	tp (s)	ϕ
A	300	0.35
B	1740	0.30
C	4140	0.28
D	8880	0.263
E	13440	0.254
F	18120	0.247
G	23533	0.242

Source: Authors, (2023).

Now, using equation (21) for the peak concentration as a function of ϕ, the ***Cp*** values are calculated for the curves from **A** to **G**:

$$Cp \approx \frac{M}{\phi * Q * tp * 1.16} \qquad (26)$$

The following data are then left, Table 3:

Table 3: Comparison of measured vs calculated values of Cp(t) in each site.

	A	B	C	D	E	F	G
Cp (Ppb) measured	1050	225	110	58	34.5.	21	20
Cp (Ppb) calculated	1080	217	95.5	49.0	33.5	25.5	20.1
Δ%	3%	4%	16%	18%	3%	21%	0.5%

Source: Authors, (2023).

With these results within compatible error percentages as acceptable for hydraulics, it is shown that the calibration of the instruments in the tracer measurements, are compatible in this case for RWT in the Welsh channel.

V. CONCLUSIONS

1. In this article it is noted that diffusion as a phenomenon of random diffraction of tracer particles, corresponds to "jumps" between "gaps" (vacancies) in the semi-crystalline structure of the liquid, according to the model of J. Frenkel, but that these jumps occur at all scales, in a fractal way, and regulated by the sequence of bifurcations towards the chaotic state, according to Feigenbaum's model.

2. The dispersive evolution of tracers in turbulent flows, from the molecular point of view, can be seen as a process in two phases that depend on the tracer itself and not so much on the flow itself, unlike what is maintained by contemporary models that propose a trapping of the tracer in the peripheral zone (ADZ and TS) with thermodynamic questions.

A first phase corresponds to the "ion-dipole" interaction of the solute and water, which destroys the solid configuration of the tracer. And a second phase dependent on the "ion-ion" interaction, in which the "ionic clouds" of the electrolyte itself, slow down its movement, thanks to the "Einstein-Stokes" effect, which adds additional viscous friction, delaying the σtracer cloud of the flow itself. This mechanism directly explains the "non-Fickian bias" of experimental curves.

3. Based on the existence of a state function, ϕ(t), these interactions can be explained, from the definition of a relationship between "residence times" of the plotter particles, for a Normal distribution, covering the Gaussian curve only between ***-σ*** and ***+σ***, and another between -∞ and +∞**,** which leads to define the Brownian process in terms of the Svedberg constant, ***a≈1.54***, which connects to Feigenbaum's constant.

4. Several equations are developed, based on "ϕ" and "α", a factor that relates "horizontal" and "vertical" magnitudes in the dynamics of the tracers, and therefore allows to analyze the reliability of the measurements, since if they are calculated separately, and if they coincide appropriately, they give a vision of the goodness of the calibration of the measurements.

5. These equations are applied to Fluorimetric tracer (RWT) measurements in Wales, and the results of which are documented with great precision in articles reviewed in the literature. The results are satisfactory, and allow to open an interesting door to the analysis of Water Quality studies.

VI. AUTHOR´S CONTRIBUTIONS

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