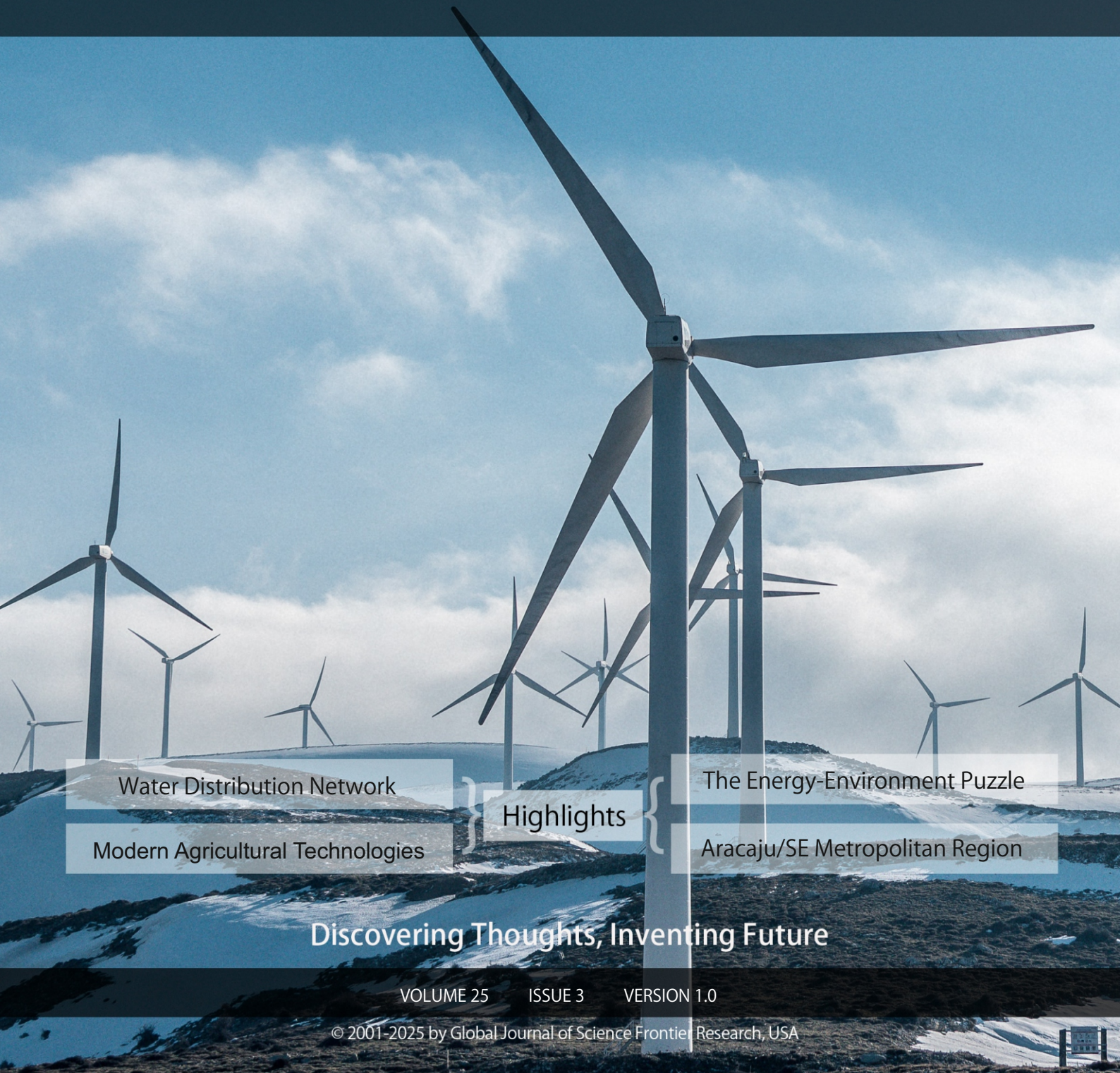


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Water Distribution Network

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Highlights

The Energy-Environment Puzzle

Aracaju/SE Metropolitan Region

Discovering Thoughts, Inventing Future

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The Energy-Environment Puzzle – Reconciling Conflicting Goals

By Miguel Schloss

Abstract- Unpacking knotty performance issues.

We are in the midst of profoundly significant, changing and challenging times. By now it should be clear that various technologies (such as geothermal, renewables, green hydrogen) to decarbonize energy generation and overcome our global warming issues don't appear to have generated the much-needed global carbon emission reductions, despite heavy early investments in decarbonization to generate major savings in climate costs. Adding all up, the evidence strongly suggests that our progress doesn't seem to add much. Could it be that we are running faster, only to stay in place — and in the end despite all the alleged efforts, our progress is bound to fall short of the agreed decarbonization and global warming goals?

Clearly, developments so far, while helpful and promising, are just too limited to meet the mark. We need much faster or, better yet, more effective efforts to achieve tangible progress to meet the global demand at the pace the world is growing. To this end, we must become increasingly aware that we are seeking competing(if not conflicting) objectives between economic development, environmental improvement and affordability. This paper, which is aimed at explaining for skeptics and believers alike the need for a more “strategic” way of planning, to assess every step of the way the trade-offs we are making between the competing goals to achieve maximum impact with reasonably minimum or manageable input.

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The Energy-Environment Puzzle – Reconciling Conflicting Goals

Miguel Schloss

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To do so, we must ourselves wean out of the tendency to emphasize process over actions and results. International gatherings too often become vanity shows to celebrate the issuance of more rules and regulations that in the end make the investment processes more complex and expensive, which deflect us from focusing on substantive actions and results on the ground. For too long, international for a have pressed for combating symptoms, not causes, focusing on processes, not results. A reorientation *from words to deeds* and closer attention on what we are achieving is now in order.

I. INTRODUCTION – MANAGING TRANSFORMATIONS

Zhou Enlai, the Chinese statesman who served as the first Premier of the People's Republic of China, was once asked what he thought of the French

Revolution. Popular lore has it that he responded that it was too early to tell.

Whether this is an accurate depiction of his thought or not, this cautious evaluation of such distant events could certainly apply to most revolutions, as he certainly must have learned -- as for that matter in any major change in structures and practices needed in recent developments on energy transition and environmental implications. A lot of assertions have been made on the role that growth of renewable sources of energy sources can play, the contamination that fossil fuels generate, and ultimately the type of energy mix one has to build –but, as in well-meaning revolutions, reality has shown to be more challenging to tame to produce the desired outcomes.

Conversely, limited attention seems to have been focused on the structural changes taking place in world economies and their impact on aggregate energy demand, affordability and reliability of different sources of energy. Ultimately, what matters is how all sources, put together, affect the trajectory of aggregate demand and their impact on carbon emissions and climate change.

After all, modern civilization, has acquired the power to prevent famines, contain epidemics, and mitigate natural disasters, such as hurricanes and even earthquakes. Energy, in its different forms is no different and ultimately is part of this evolution. In general, the acquisition of power and its different forms, the management among them, has enabled more effective management of risks, while simultaneously increasing the dangers that power systems may pose to themselves. For this reason, we must abandon both the naïve and populist views of imposing some arbitrary standards, and put aside our fantasies of infallibility, to commit ourselves to the hard and rather mundane work of building institutions and policies with strong self-correcting mechanisms to avoid misguided or ineffective efforts. This is perhaps the most important takeaway of development over the last decades, where the decarbonization efforts and the associated energy transition investments were ultimately aimed at reducing global warming that, for the time being at least, doesn't appear to be even near.

II. SO, WHAT IS HAPPENING?

Technology is rarely deterministic, and the same technology can be used in various ways. While it

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has always been a catalyst for major historical changes -- sometimes positive ones, often not so, but it invariably creating new developments – oftentimes revolutions included side effects alongside. For this reason alone, such developments need concurrent tracking to ensure timely and proper corrective actions if such changes start generating undesirable or insufficient impact.

This, of course, is more easily said than done. Oftentimes, technological developments and associated institutional changes are more than capable of promoting distorted worldviews, enabling egregious abuses of power. Such developments have tended to instigate single-minded militant and promotional views, which have repeatedly throughout history generated extreme circumstances, with their share of terrifying new witch hunts.

III. WHAT IS THE ACTUAL RECORD? – PROJECTIONS VS. OUTCOMES

Broadly speaking, leaving fine points aside, here is a broad-brush record and outlook of global supply and demand for energy of the last ten years and how we are headed into the future.

An international outlook serves multiple purposes. First and foremost, it establishes the basis for long-term business planning of all actors concerned. In general, the energy industry is capital intensive and long term by nature. We thus need to understand what the world could look like in coming decades to plan and deploy capital wisely. Emerging markets alone (where the bulk of growing energy demand is taking place as a result of economic growth and urbanization) developing countries will need to spend an additional \$1 trillion per year on climate-related goals by 2025 and around \$2.4 trillion per year by 2030.

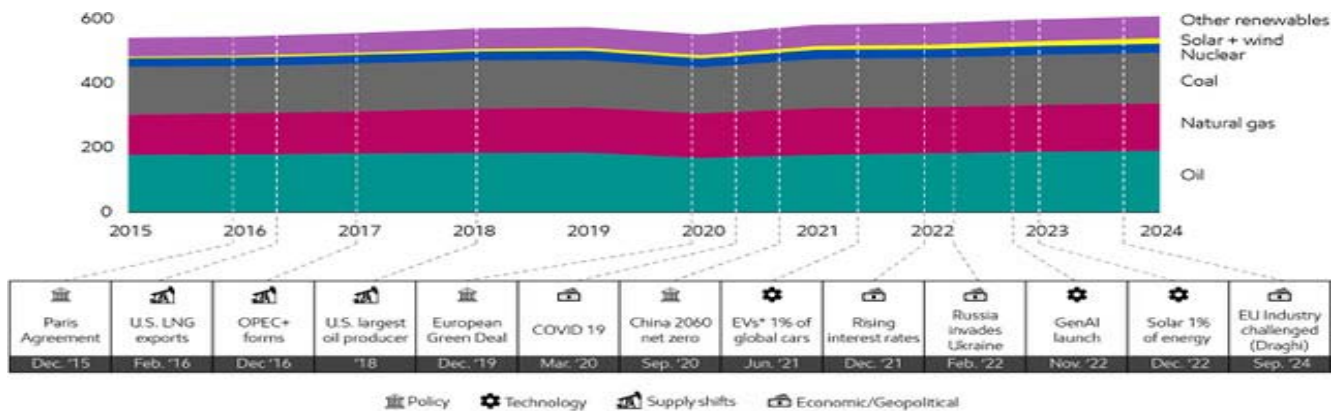
Yet the global outlook serves a broader purpose as well. Energy and products are inseparable from modern life. Access to affordable and reliable energy drives unprecedented economic progress and improved living standards. They also contribute to global emissions. A global outlook provides essential insights into the economic advantages and environmental considerations that play a part in the future of energy.

The projections at the heart of the outlook represent a most likely (not single-minded) view of the world in 2050. It is generally scientifically grounded, based on detailed analysis of a variety of data sources and long-term assessments of market fundamentals, economic trends, technology advancements, consumer behavior and climate-related public policy. It is not an endorsement of a particular outcome, nor is it advocating for what any single source hopes will happen.

There is uncertainty inherent in any future projection, and it is essential to constantly learn and improve our insights and models – and adjust and plan accordingly. Think about it; over the last 10 years we've seen the signing of the Paris Agreement for climate action, a global pandemic, Russia's invasion of Ukraine significantly altered global gas flows, the reemergence of the U.S. as an oil exporter, and huge growth (yet limited in overall terms) in deployment of renewable energy.

These are just a few examples, and yet as can be seen in the graph below, there hasn't been a year where there haven't been some significant macro development affecting energy development. Yet, through all of this, rising prosperity and energy demand have remained inextricably linked, and the global energy mix has mainly remained essentially unchanged.

Global energy mix has remained largely constant in a dynamic world (2015-24)



Sources: UNFCC, EIA, OPEC, EU Commission, EIA, US Federal Reserve, Grantham Institute

*EVs include Battery Electric and Plug-in hybrids – Quadrillion BTU.

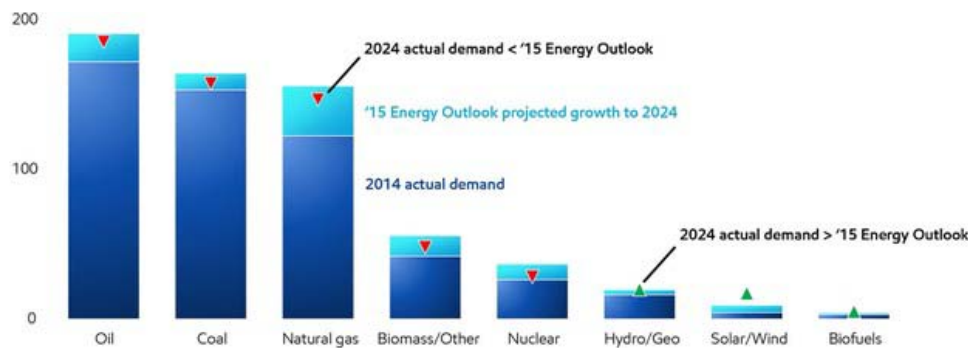
Looking back at outlooks prepared by important energy sector actors, like oil, gas or coal companies, or relevant research institutions, we can see that while

projection weren't perfect, by and large they provided a sound basis for strategies and plans. Even so, these "look-backs" also highlighted the immense scale and

inertia of the energy system. Significant economic and geopolitical events had either near-term or localized

impacts, but in the big scheme of events, only minor impact relative to the projections made ten years ago.

Energy trends over the past decade validate 2014 projections



Exxon Mobile (2015-2024 Energy Global Outlook)

Quadrillion BTU;

Low carbon includes Biomass, Biofuels, Nuclear, Hydro, Geothermal, Solar, and Wind.

Oil excludes biofuels.

Most striking of all is the marginal change in the energy mix over this decade, as traditional hydrocarbon sources (oil and coal) declined by just 1 percentage point each, while solar and wind grow by 2 percentage points, though from a very low basis to reach 3 % of

total sources and natural gas 1 percentage point increased to reach close to a quarter of total (though contributing a lower emission footprint than traditional hydrocarbons):

Decarbonized energy sources increased marginally in energy mix in past decade

	2014 (actual)	2024 share	
		'15 Energy Outlook projection	Actual
Oil	31%	30%	30%
Coal	27%	26%	26%
Natural gas	23%	24%	24%
Biomass / Other	9%	9%	8% ↓
Nuclear	5%	6%	5% ↓
Hydro / Geo	3%	3%	3%
Solar / Wind	1%	1%	3% ↑
Biofuels	1%	1%	1%
*Low carbon	19%	20%	20%

Oil excludes biofuels

Digging deeper into this look-back analysis, there are several insights that inform our current Outlook and highlight some of the challenges society faces as it works to lower emissions while providing affordable, reliable energy that underpins economic growth. In 2024, for instance, global energy demand was ~4% lower than projected in the 2015 Outlook. Some of this difference is related to the pause in growth during the pandemic, but a bigger driver was slower economic

development in Latin America and Sub-Saharan Africa. The 2015 Outlook had assumed rising prosperity in these regions, but income per capita was stagnant over the past ten years. These trends reinforce that rising prosperity and energy demand are inextricably linked.

Oil demand (excluding biofuels) was 2% lower than projected, with the shortfall again due to slower economic development in emerging economies. Oil demand in high income OECD countries and China

grew stronger than projected a decade ago, led by higher demand for transportation fuels.

Natural gas demand grew the most over the last decade, but 2024 demand was 6% lower than 2015 Outlook projection. The developing world, excluding China, contributed, as did Europe, where the loss of pipeline gas and higher prices following Russia's invasion drove Europe's gas demand nearly 20% below 2015 Outlook projections. Low-cost domestic gas resources in the United States and the Middle East drove stronger demand growth than the 2015 Outlook projection.

One can also see that solar and wind grew nearly twice as much as projected in the 2015 Outlook projections, with over half of the difference occurring in China. The combination of policy incentives and technology cost declines encouraged faster deployment. But even with the more rapid growth, solar and wind still only made up ~3% of the world's energy mix in 2024. This illustrates the massive scale of the global energy system.

Looking more broadly at low carbon sources, including nuclear and renewables, we see low carbon sources gained 1% share over the past decade, aligned with the 2015 Outlook projection. The faster solar and wind growth was offset by a significant decline in nuclear energy, led by reactor shutdowns in Europe.

Given the uncertainty inherent in any projection, a range of sensitivities and scenarios – including those we view as remote – must be included to help inform strategic thinking. No future projection could exactly predict every new government policy, its effectiveness, or its unintended consequences. Similarly, the pace of technology advancements and extent of public support for more expensive, lower-emission solutions can influence how quickly or cost-effectively different energy pathways might develop.

All in all, the Global Outlook is made publicly available because it makes an important contribution to a variety of policy discussions – about energy, about economic development, and about the environment. By offering a clear-eyed, thoughtful view, the Outlook can enhance those discussions and – hopefully – lead to better decisions and policy outcomes.

IV. KEY TAKEAWAYS WHEN RENEWABLES SOAR – JUST AS FOSSIL FUELS DO...

In a year when average air temperatures consistently breached the 1.5°C warming threshold, global CO₂-equivalent emissions from energy rose by 1%, marking yet another record, the fourth in as many years. Here are key factors explaining this overall outcome:

- Wind and solar energy alone expanded by an impressive 16% in 2024, nine times faster than total energy demand. China was responsible for 57% of

new additions, with solar almost doubling in just two years (from an admittedly low level). Yet this growth did not fully counterbalance rising demand elsewhere, with total fossil fuel use growing by just over 1%, highlighting a transition defined as much by disorder as by progress. In part, the results could be aligned with a better understanding of business conditions across countries to develop better energy investment responses to the different economic prospects among various jurisdictions.

- Crude oil demand in OECD countries remained flat, following a slight decline in the previous year. In contrast, non-OECD countries, where much of the world's energy demand growth is concentrated and fossil fuels continue to play a dominant role, saw oil demand rise by 1%. Notably, Chinese crude oil demand fell in 2024 by 1.2%, indicating that 2023 may have reached a peak. Elsewhere, global natural gas demand rebounded, rising by 2.5% as gas markets rebalanced after the 2023 slump. India's demand for coal rose 4% in 2024 and now equals that of the CIS, Southern and Central America, North America, and Europe combined.
- These trends underscore a stark truth: while renewable energy is scaling faster than ever, global demand is rising even faster. All-time *records were reached across ALL forms of energy (coal, oil, gas, renewables, hydro and nuclear)*. Rather than replacing fossil fuels, renewables are adding (and till marginally) to the overall energy mix. This pattern, marked by simultaneous growth in clean and conventional energy illustrates the structural, economic, and geopolitical barriers to achieving a truly coordinated global energy transition.
- This year's data reflects a complex picture of the global energy transition. Electrification is accelerating, particularly across developing economies where access to modern energy is expanding rapidly. However, the pace of renewable deployment continues to be outstripped by overall demand growth, 60% of which was met by fossil fuels. The result is a fourth consecutive year of record emissions, highlighting the structural challenges in aligning global energy consumption with climate goals.
- All primary energy sources, including nuclear and hydro, hit record consumption levels (for the first time since 2006), a reflection of surging global demand. No country has shaped this outcome more than China. Its rapid expansion of renewable capacity, alongside continued reliance on coal, gas, and oil, is driving global energy trends. The scale and direction of China's energy choices will be pivotal in determining whether the world can deliver a secure, affordable, and low-carbon energy future.

- Record-high GHG emissions and soaring temperatures in 2024 are a serious wake-up call. We have the strategies, technologies, and know-how to deliver the energy transition with potentially an integrated, secure, and people-centred approach. Now, we must move from action, at scale and at speed. With greater attention to investments in energy storage and transmission, there is potential to overcome the lower load factor and heavy weather- and location-reliance of renewables, thereby levelling their competitiveness with traditional sources of energy.
- Several countries have come forth with new climate plans and announcements at the UN High-Level Event on Climate Action. These lay out emissions targets through 2035, as waypoint on the path to net zero by mid-century. Yet, despite the commitments made many times in the past, even with the more ambitious goals compared to previous climate commitments, the targets announced to date, the trajectory and results fall far short of what's needed to stay within critical warming thresholds. By 2035, the world needs to cut 31.2 gigatons of emissions to stay on track for 1.5 degrees C, or 20.2 Gt for 2 degrees. By now, more than new goals, what is needed concrete strategies, action programs, proper economic and sector policies that provide the necessary conditions and incentive structures, so that productive sectors undertake the necessary investments to achieve this order of change and necessary resilience.
- Globally, we are still not at the pace required, as energy demand continues to rise. This year's data highlights how Europe has been facing a reality check, with rising effective interest rates and supply chain costs slowing progress on renewables, at the same time China and other emerging markets continue to drive growth at scale. What's emerging is not a uniform transition, but a need to address a highly diverse set of local conditions.

V. WHERE DO WE GO FROM HERE – WITH FOSSIL FUELS AT THE HEART OF A BURNING ISSUE?

Rather than aiming to achieve artificial aggregate goals, and build more, costly and time-consuming oversight mechanisms, emphasis must shift towards practical strategies built for resilience, recognizing that energy security and affordability remain central concerns -- competing and in need to be reconciled with climate action.

In a world with greater volatilities and structural changes, policy-makers and business leaders must increasingly seek to navigate an uneven energy transition, one shaped by diverging regional trends,

infrastructure constraints, policy fragmentation and institutional capabilities. Key questions to be henceforth considered in the investment process by business and policy leaders may have to include:

- What does it mean for a strategy when the energy mix is shifting, but not in the way many expected, with gas, oil and coal continuing to play significant roles?, and thus, how we can tilt incentives towards lower emitting hydrocarbons – i.e., towards gas and disincentivize coal?
- How does one respond when electricity demand surges, renewables can't keep up everywhere, and energy systems are already straining under the pressure?
- Are strategies focused where progress is happening –not just where it's expected?, and are we focusing on institutional and other constraints to open up investment opportunities, risk intermediation arrangements in other forms of energy not yet as widely in use, such as geothermal, green hydrogen, etc.?
- How does one prepare for a market where trade flows are shifting, policy signals are mixed, and volatility is here to stay?
- Can one's business thrive in a world where complexity, fragmentation, and disruption are now the norm?. If so, how can we shift attention from processes, target-settings and other intermediary concerns to outcome, and results.

With world primary energy demand projected to increase by more than half over the next 25 years, we are facing the formidable twin challenges of finding secure and affordable supplies of energy while addressing the environmental impacts of that increased consumption. The geographic dislocation between the sources of energy supply and demand and the heightened geopolitical risk in some of the traditional energy-supplying regions is also encouraging consuming nations to cast their nets wider for alternative supplies of energy. The US, the world's largest consumer of energy, and China and India, the fastest-growing consumers, are all characterised by relatively low or declining oil and gas reserves. They all possess substantial reserves of coal... but coal is the most carbon-intensive of the fossil fuels.

There are important drawbacks with the current path and constraints, but there important efforts among companies leading the field in green-technology development. This is bound to take time, and the fact remains that most electricity is generated from fossil fuels and until it can be produced on a huge scale from economically feasible alternatives including renewable resources, the production, storage and transportation of hydrogen and other such sources on a commercial

scale affect the climate no less than the refining of crude oil.

So, in the 21st century, the world faces twin energy-related threats: that of not having adequate and secure supplies of energy at affordable prices and that of environmental harm caused by consuming too much energy in inappropriate ways.

A solution to either of these threats is relatively straight forward; however, a solution to both simultaneously is one of the great challenges of our times. With global energy demand expected to rise by 53% over the next 30 years, and fossil fuels accounting for 83% of the overall increase, simply calling for a cut in consumption is not a sufficient solution to the challenges we face.

Accordingly, in the short term, fossil fuels, including coal have an important role to play in enhancing energy security and fuelling both economic growth and poverty alleviation globally. Looking towards the medium term, however, greater efforts must shift towards: (i) technological development, including deployment of enhanced information technology for more rational use of scarce energy sources; and (ii) trimming energy demand through proper pricing (and taxation) of carbon emissions, to reflect the cost of environmental externalities in energy sources, thereby dampening energy demand to help reduce above-mentioned gap in the energy scenery. There are some 50 countries that have such initiatives in different (though mostly early) stages of development.

In the end, a more determined effort is needed to change the incentive structure and move such initiatives into implementation. This will be indispensable to narrow the gap to embed these costs into consumer behavior, and eventually meeting the global emission and climate change objectives.

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Monitoring Losses in the Water Distribution Network in the Metropolitan Region of Aracaju/SE in DMC's

By Wendell Valença Bittencourt de Jesus, Marcos Luciano Alves Barroso, Leandro Barros de Santana, José Franco de Azevedo & Zacarias Caetano Vieira

Abstract- Real losses are inevitable in water distribution; however, efficient network management can lead to minimum acceptable values. The occurrence of leaks indicates a lack of maintenance of the pipelines, inadequate installations, and large variations in pressure and flow in the network. Thus, the study aims to compare data from Measurement and Control Districts, DMCs (32 and 33), which are part of the water distribution network of the Aracaju Metropolitan Region, with regional and national data, with the perspective of identifying opportunities for improvement that aim to reduce loss rates. The Water Loss Reports of the Sergipe Sanitation Company (DESO) were utilized, adopting seven parameters that were examined in the period from 2017 to 2022, where we sought to identify trends and significant correlations. In which the DMC 32 correlation matrix demonstrated high agreement, particularly showing 66.66%, which indicates a strong correlation between the parameters.

Palavra-chave: água, DMC, perdas, saneamento.

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Monitoring Losses in the Water Distribution Network in the Metropolitan Region of Aracaju/SE in DMC's

Monitoramento De Perdas Na Rede De Distribuição De Água Na Região Metropolitana De Aracaju/Se Em Dmc's

Wendell Valença Bittencourt de Jesus ^α, Marcos Luciano Alves Barroso ^σ, Leandro Barros de Santana ^ρ, José Franco de Azevedo ^ω & Zacarias Caetano Vieira [¥]

Abstract- Real losses are inevitable in water distribution; however, efficient network management can lead to minimum acceptable values. The occurrence of leaks indicates a lack of maintenance of the pipelines, inadequate installations, and large variations in pressure and flow in the network. Thus, the study aims to compare data from Measurement and Control Districts, DMCs (32 and 33), which are part of the water distribution network of the Aracaju Metropolitan Region, with regional and national data, with the perspective of identifying opportunities for improvement that aim to reduce loss rates. The Water Loss Reports of the Sergipe Sanitation Company (DESO) were utilized, adopting seven parameters that were examined in the period from 2017 to 2022, where we sought to identify trends and significant correlations. In which the DMC 32 correlation matrix demonstrated high agreement, particularly showing 66.66%, which indicates a strong correlation between the parameters. In DMC 33, the correlation matrix demonstrated low agreement (42.85%). Meanwhile, the values of the loss indexes in the DMCs (31.82 and 40.82%) showed an unsatisfactory average variation in the period, and if we compare 37.78% (Brazil), 46.67% (Northeast), and 57.60% (Sergipe) in the year 2022, they are lower but not ideal. Demonstrating that the DMCs studied reflect how distribution management operates and how the parameters taken into consideration can estimate operational losses in the water distribution network and direct the actions of sanitation companies.

Palavra-chave: água, DMC, perdas, saneamento.

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I. INTRODUÇÃO

Água é um bem essencial para a vida, mas sua disponibilidade está cada vez mais ameaçada. Historicamente, a crescente demanda por água, a poluição dos recursos hídricos e as mudanças climáticas são alguns dos fatores que contribuem para essa constante vigilância sobre a imensidão das águas (FERREIRA e GARCIA, 2017). Diante desse cenário, a promoção de pesquisas cujos resultados são processos de gerenciamentos eficientes dos recursos hídricos nos sistemas de abastecimento, são vitais.

Muitas estratégias podem ser adotadas para reduzir o desperdício e promover uma adequada administração dos recursos hídricos, no entanto o estudo deve ser embasado por meio de análises e discussões do controle e segurança da água, dos parâmetros para análise de perdas e na identificação das oportunidades mais adequadas para reduzir ou até mitigar esse desperdício. A gestão deste insumo essencial para a sociedade torna-se tão importante sobre os desafios de distribuição quanto se pensa (PEREIRA e TINOCO, 2021).

Barroso (2019), em seus estudos alega que, apesar da existência de certo nível de planejamento para gestão da distribuição, muitos fatores ainda não são considerados. No parâmetro equidade de acesso, as gestões falham no quesito assertividade entre reparo e aumento de distribuição (FRITZ, GIMENES, PINA, 2020).

Uma má gestão da rede de distribuição pode levar a perdas significativas de água potável, por meio de vazamentos e tubulações danificadas (CASTRO, 2022). A ocorrência de vazamentos apresenta como causas mais frequentes a ausência de manutenção da tubulação (PEREIRA e TINOCO, 2021).

Para o planejamento do controle de perdas, companhias responsáveis pela distribuição de água utilizam os Distritos de Medição e Controle (DMC), que são subáreas, de parte da rede, delimitadas e isoladas com controle de vazão na entrada. Os DMC's são

importantes para uma distribuição mais eficiente, pois com auxílio de equipamentos e de pessoal treinado permitem a agilidade na identificação de vazamentos, analisam de forma mais criteriosa o consumo de água da área delimitada por meio da macro e micromedição, controlam a pressão de água na rede, melhoram o acompanhamento das perdas (Real e Aparente). E assim, facilitando o controle de uma determinada área e fazendo com que a companhia consiga desenvolver ações com mais foco no problema.

II. OBJETIVOS

Coletar dados da rede de distribuição de água da Região Metropolitana de Aracaju (RMA)/SE, em dois DMC's, e comparar a dados regionais e nacionais, buscando identificar oportunidades de melhoria, fortalecimento de práticas que visem à redução dos índices de perdas na rede distribuição de água.

III. METODOLOGIA

Com acesso aos Relatórios dos Quantitativos de Perdas Hídricas no sistema de distribuição de água, fornecido pela Diretoria de Operação e Manutenção, da Companhia de Saneamento de Sergipe (DESO) que tratam de informações da rede de distribuição de água da Região Metropolitana de Aracaju, os dados foram consolidados de dois DMC's, no período de 2017 a 2022, e foi realizada uma análise estatística.

Caracterização da cidade de Aracaju/SE - Na cidade de Aracaju, capital do Estado de Sergipe, os serviços estruturantes foram realizados apenas no começo do século XX, como água e esgoto encanados. Atualmente, já tem 602.757 habitantes, com Índice de desenvolvimento Humano de 0,770 e predominam como atividades econômicas setor de serviços e indústria, respondendo por um terço do PIB do Estado (SEPLAG, 2023).

Caracterização da rede de distribuição de água - A rede engloba, além da cidade de Aracaju, as cidades sergipanas de Nossa Senhora do Socorro, Barra dos Coqueiros e parte da cidade de São Cristóvão. A rede existente é alimentada por 4 Estações de Tratamento de Água, e é uma rede predominantemente de traçado misto, e fisicamente dividida e interligadas por 10 Setores, que são redes menores que acomodam uma gestão mais decidida.

Caracterização dos Distritos de Medição e Controle (DMC's) - São sub-áreas específicas de manobras, pequenas redes, onde são instalados Macromedidores, e Válvulas Redutoras de Pressão (VRP) para proteger as tubulações de grandes pressões, evitando seu rompimento e possibilitando assim detectar os vazamentos.

Uma das características mais marcantes da tecnologia que utiliza VRP é que sua implantação

requer, uma área de atuação bem definida na rede de distribuição de água, isolada por registros limítrofes, configurando um subsetor ou um DMC (ZANIBONI, 2009). Os projetos de setorização devem buscar o equilíbrio hidráulico do sistema de distribuição de modo a se obter um sistema com pressões controladas buscando a ocorrência de perdas mínimas (MOTTA, 2010).

Para Gonçalves (1998), a primeira atividade de controle de perdas é a setorização da rede. Pode-se utilizar como forma de controle, a implantação simples do distrito de medição da vazão de entrada do setor.

A rede da Região Metropolitana de Aracaju possui cadastrados 59 DMC's, que foram definidos depois de uma avaliação técnica. E escolhidos aleatoriamente dois (DMC's), denominados DMC 32 e 33 para fazer o estudo. Sendo que o DMC 32, localizado no conjunto habitacional Santa Lúcia/Aracaju, faz parte do Setor 6 da rede, é abastecido pelo reservatório denominado R6, do tipo apoiado, possui um perímetro de rede de aproximadamente 16.105 m, tem apenas um VRP, e possui uma topografia relativamente plana.

Já o DMC 33 é localizado no bairro Siqueira Campos/Aracaju, faz parte do Setor 1, é abastecido pelo reservatório denominado R1, do tipo apoiado, com o perímetro de 10.859 m, não possui VRPs, e de topografia bastante irregular. A partir desse volume de entrada, é possível realizar um comparativo com os volumes micromedidos, de forma a proporcionar o cálculo dos volumes de água perdidos no DMC (JÚNIOR e VATAVUK, 2023).

O monitoramento dos DMC's é realizado diariamente, por meio de um programa (GRAFANA), que recebe os dados do macromedidor, nas quais os pulsos são convertidos em vazão e enviados através do Datalogger, gerando relatórios.

Tratamento estatístico e parâmetros de avaliação - Foram utilizados os dados mensais de 7 parâmetros dos dois DMC's no período de 2017 a 2022. Foram adotados seguintes parâmetros de avaliação conforme o SNIS (Brasil, 2022): Número de economias; Número de ligações; Volume distribuído; Volume micromedido; Volume faturado; Dias faturados e Índice de perdas: Porcentagem de água perdida que sai do reservatório, chega até a entrada do DMC, mas que após a micromedição, esse volume de água não retorna financeiramente a companhia. Para o cálculo do Índice de Perdas (IP) foi utilizada a razão entre a diferença do Volume Distribuído (Vd) pelo Micromedido (Vm) e o Volume Distribuído (Vd) (Equação 1):

$$IP = \frac{Vd - Vm}{Vd} \quad (1)$$

Desta forma os dados coletados foram tabulados e alinhados numa planilha (Excel), dentro do

intervalo observado, foram identificadas as tendências e as correlações significantes entre os parâmetros. Os indicadores são apresentados de forma anualizada, ou seja, totalizados por ano, para diluir o efeito da sazonalidade no abastecimento e as diferenças entre os períodos de leitura dos volumes fornecidos e consumido na área (SANTOS, 2013).

IV. RESULTADOS E DISCUSSÕES

Tabela 1: Número de economias nos DMC's (32 e 33), no período de 2017 a 2022

Ano	Número de economias (Unid) DMC's	
	32	33
2017	2.744	1.533
2018	3.094	1.512
2019	3.719	1.507
2020	3.786	1.487
2021	3.839	1.503
2022	3.964	1.503
Média	3.524	1.507

Nota-se um comportamento diferente entre os DMC's no decorrer dos anos, onde no DMC 32, houve um aumento de 12,75% entre os anos de 2017 e 2018, e entre os anos de 2018 e 2019 houve um aumento mais considerável de 20,20%. Nos anos subsequentes, o aumento foi menos intenso, não ultrapassando 6,59%, representando menos de 150 economias instaladas. O resultado encontrado é condizente uma das características do local, ou seja, franco crescimento, recebendo novos domicílios. Já para o DMC 33, tendo uma pequena queda entre os anos de 2017 e 2020 (4,0%) e permanecendo inalteradas nos anos seguintes, isto é, um local consolidado, de poucas áreas para serem ocupadas, não houve grandes alterações. Vê-se também que no DMC 32 a média do número de economias ficou em torno de 3.524 unidades, enquanto no DMC 33 foi de 1.507 unid., praticamente tem-se o dobro de unidades instaladas.

Quanto ao Número de ligações- Visando melhorar a contabilização do volume consumido, recomenda-se que todas as ligações sejam hidrometradas, e o período de contabilização do volume produzido coincida com o período da leitura dos hidrômetros, permitindo assim comparações coerentes (GONÇALVES, 1998).

A Tabela 2 expõe os dados de número de ligações ativas existentes nos DMC's. Assim, pode-se perceber que no DMC 32 houve uma crescente no número de ligações ativas, ao longo dos anos, sendo mais notável entre os anos 2017/2018 (18,87%) e 2018/2019 (23,18%), que pode estar ligado ao crescente número de imóveis na região, tendo um aumento de mais de 52,63% no período, no número de

ligações, mantendo-se uma média de 3.188 ligações ativas.

Tabela 2: Número de ligações ativas nos DMC's (32 e 33), no período de 2017 a 2022

Ano	Número de ligações (lig.) DMCs	
	32	33
2017	2.337	1.321
2018	2.778	1.305
2019	3.422	1.301
2020	3.482	1.287
2021	3.543	1.302
2022	3.567	1.313
Média	3.188	1.305

Diversos autores como Gomes (2011) e Lambert & Taylor (2010) relatam que em áreas urbanas a dimensão média para, DMC's deve estar compreendida entre 500 e 3.000 ligações, porém, não se recomenda valores acima das 5.000 ligações, pelo fato de se tornar mais difícil a localização de vazamentos. Segundo Motta (2010) em muitos centros urbanos, que experimentaram crescimento populacional acelerado, as redes de distribuição avançam para atender às novas ocupações sem preocupação com a setorização dos sistemas de água. Já no DMC 33 aconteceu o inverso onde entre os anos de 2017 e 2020 houve uma pequena queda no número de ligações (2,64%), que pode ter acontecido devido a supressões de água sem solicitação de religação, além de ser uma região já densamente povoada com menos áreas para crescimento, e nos anos seguintes voltou a crescer o número de ligações (2,02%), ficando com uma média de 1.305 ligações ativas no período.

Ainda quando analisamos a relação economias/ligações nos dois DMC's, tem-se 1,10 econ./lig. pouco abaixo da média nacional, 1,28 econ./lig. (BRASIL, 2022), e no mesmo ano tem-se 1,54 econ./lig. para o DMC 32 acima da média nacional.

Quanto ao Volume distribuído de água- No DMC 32 com vazão média de entrada de 95,90 m³/h (DESO, 2022), apesar de ter uma queda no volume distribuído entre 2017/2018 representando 2,25% (Tabela 3), houve no geral, uma crescente tendo uma média de aumento de 5.000 m³ por ano a partir de 2018, sendo entre 2018 e 2019 foi o mais acentuado de 7.125 m³ (15,40%) e o menor entre 2019/2020 de 1.887 m³ (3,53%) que pode ter sucedido, assim como no número de ligações, e ao pico da Pandemia (COVID 19) onde foi consumido mais água para fins higienização mais assídua, e possíveis perdas na distribuição com uma média no volume distribuído (54.577 m³) no período, representando um aumento de 17.687 m³.

Tabela 3: Variação do volume distribuído de água nos DMC's (32 e 33), no período de 2017 a 2022

Ano	Volume distribuído (m³) DMCs	
	32	33
2017	47.320	23.849
2018	46.253	30.919
2019	53.378	27.816
2020	55.265	26.229
2021	60.237	30.712
2022	65.007	29.145
Média	54.577	28.112

No DMC 33 com vazão média de entrada de 40,55 m³/h (DESO, 2022) diferentemente DMC 32, houve um aumento do volume distribuído (29,64%) entre 2017/2018, já entre 2018/2020 houve uma redução do volume (15,16%), voltando a crescer entre 2020/2021 em 17,09%, assim como no DMC 32, devido também ao pico da Pandemia (COVID 19) ou aos possíveis vazamentos, e reduzindo entre 2021/2022, final da pandemia (5,10%), tendo uma média entre os anos (2017/2022) de 28.112 m³ de água distribuída para os consumidores do bairro. Outra questão importante para ser verificada no DMC é a vazão mínima noturna. Segundo Farley *et.al* (2008), a vazão mínima noturna é a menor vazão de entrada no DMC, e quando como o consumo é mínimo e as perdas por vazamentos atingem os níveis máximos.

Quanto ao Volume micromedido- Analisando a Tabela 4 a seguir que trata do volume micromedido de água, que é aquele medido nos hidrômetros instalados em ligações prediais têm-se que, no DMC 32 houve um aumento de 13.402 m³ (46,08%) em sua micromedição ao longo do período estudado, assim como o volume distribuído, mas em maior intensidade, sendo os aumentos mais consideráveis do volume micromedido entre 2017/2018 (2.724 m³), 2018/2019 (6.367 m³) e entre 2019/2020 (3.051 m³), nos anos restantes os aumentos foram menos expressivos (< 950 m³).

Tabela 4: Variação do volume micromedido nos DMC's (32 e 33), no período de 2017 a 2022

Ano	Volume micromedido(m³) DMC's	
	32	33
2017	29.082	16.912
2018	31.806	16.132
2019	38.173	16.949
2020	41.224	16.356
2021	41.545	15.885
2022	42.484	16.643
Média	37.386	16.480

No DMC 33 foram constatados que não houve grandes alterações do volume micromedido de água, valendo ressaltar o que aconteceu entre 2017/2018 e 2020/2021 que o volume distribuído aumentou (29,64 e

17,09%) e o volume micromedido reduziu (4,61 e 2,88%), o que causou um provável prejuízo a companhia devido à queda de faturamento, já em 2018/2019 e 2021/2022 houve uma diminuição do volume distribuído e um aumento no micromedido (5,06 – 4,77%) fazendo com que a companhia tivesse um aumento no faturamento e reduzisse a perda.

A base de cálculo do índice do consumo médio *per capita* diário do SNIS-AE é o volume de água consumido, micromedido (BRASIL, 2022a). Segundo o diagnóstico do SNIS o consumo médio *per capita* de água no Brasil, foi de 148,20 l/hab.dia (BRASIL, 2022). No entanto, no mesmo documento informa que foi de 133,57 l/hab.dia na cidade de Aracaju/SE, 16,63 litros menores.

Quanto ao Volume faturado- Verifica-se, de acordo com as medições da Tabela 5, nos dois DMC's, que o comportamento do volume faturado, mostrou-se realista, pois os valores são maiores que o do volume micromedido. Isso se deve ao fato que, as companhias adotam parâmetros de consumo mínimo ou médio, que podem ser superiores aos volumes efetivamente consumidos.

Tabela 5: Variação do volume faturado nos DMC's (32 e 33), no período de 2017 a 2022

Ano	Volume Faturado (m³) DMC's	
	32	33
2017	34.440	20.772
2018	38.443	20.176
2019	45.946	20.784
2020	48.113	19.968
2021	48.737	19.757
2022	49.797	20.543
Média	44.246	20.333

Nota-se no DMC 32, que o volume anual de água debitado ao total de economias, houve no decorrer dos anos, uma crescente (15.357 m³) no volume faturado, sendo os maiores aumentos entre os anos 2017/2018 e entre 2018/2019 de 7.506 m³ (19,52%). Nos anos subsequentes não foram constatados sobressalentes aumentos no volume faturado e a média de 44.246 m³, com um aumento significativo de 44,59% no período. Esse percentual representa a fração do volume de água disponibilizado que foi faturado por ter sido contabilizado como volume utilizado pelos consumidores.

Já no DMC 33, assim também como no volume micromedido, não foram constatadas grandes alterações, apresentando uma pequena queda (1,10%), e uma média de 20.333 m³ no período analisado. Assim, como a tendência é de sempre existir algum nível de inadimplência, é provável que os valores realmente faturados sejam maiores que os informados.

Segundo Freire (2017) é importante salientar que volume não-faturado é diferente do componente perda.

Quanto aos Dias faturados- Com relação aos dias faturados não se percebe grandes oscilações, o que se nota é que no DMC 32 na maioria dos anos a média de consumos entre os meses foi de 31 dias, e no DMC 33 a média foi de 30 dias. Estes dados de maneira geral não influenciam os demais parâmetros.

Quanto aos Índices de perdas- É importante ressaltar que, não existe perda nula. As perdas de água ocorrem em todos os sistemas de abastecimento, apenas a quantidade perdida é que varia (MELATO, 2010). Na Tabela 6 abaixo, tem-se os índices percentuais de perdas dos DMC's.

Tabela 6: Desempenho do Índice de Perdas nos DMC's (32 e 33), no período de 2017 a 2022

Ano	Índice percentual de perdas (%) DMC's	
	32	33
2017	37,98	32,70
2018	34,10	44,03
2019	28,36	38,98
2020	25,40	38,47
2021	30,99	48,21
2022	34,15	42,51
Média	31,82	40,82

Pode-se notar que no DMC 32, existe uma diminuição das perdas, relevante ao longo dos anos 2017/2020 (37,98% para 25,40%), e dentre esses os anos de 2018/2019 tiveram a maior redução, gerando assim menos desperdício de água. A partir de 2020 até 2022 o índice de perdas voltou a crescer (8,75%) encerrando com 34,15% e tendo uma média no período de 31,82%. No período analisado (2017-2022) o índice de perdas teve uma redução de 3,83 pp. Em termos quantitativos, o índice significa que, de cada 100 litros disponibilizados pela companhia apenas 68,18 litros são contabilizados como utilizados pelos consumidores.

Já no DMC 33 o comportamento foi bem diferente, onde houve uma forte alta entre os anos 2017/2018 (32,70% - 44,03%) e logo após vieram duas reduções entre 2018/2020 (5,56 pp). Após isso entre 2020/2021 aconteceu uma forte alta (9,74 pp) e em seguida uma queda de (5,70 pp), terminando 2022 com 42,51% de perdas e na média entre os anos 40,82% sendo um aumento de 9,81 pp no período (2017/2022) e uma perda de 9,0 pp maior, se comparado com o DMC 32.

Os dados se comparamos aos 37,78% (Brasil), 46,67% (Nordeste) e 57,60% (Sergipe) do BRASIL (2022), são menores, porém não ideais, isto é, indicam que os investimentos em curso não conseguiram reduzir, de maneira significativa as perdas. A atualização do cadastro comercial também é de grande

importância para o combate as perdas aparentes, por isso devem ser feitas em caráter permanente (SANTOS, 2013).

Os índices de perdas na distribuição de água no Estado de Sergipe nos anos de 2021 e 2022 foram altíssimos de 57,6% e 48,4% com uma variação absoluta de 9,2 (BRASIL, 2022). O que se observa, é a paridade com a média regional, em face dos desafios socioeconômicos serem similares, análise já vista por SILVA (2014). Reduzir essas perdas é uma das atividades que vai além de oferecer retorno financeiro imediato (MORAIS, CAVALCANTE, ALMEIDA, 2010).

Para Motta (2010) o controle de pressões na rede de distribuição tem impacto imediato nos volumes de perdas. Através de análises de históricos de vazões antes e depois da implantação de uma válvula redutora de pressão é possível observar claramente o ganho em volume, uma vez que as vazões de vazamentos são reduzidas a partir da entrada em operação da válvula. A manutenção preventiva e a adoção de procedimentos operacionais e treinamento de pessoal para a realização de manobras adequadas é vital para que se evitem rompimentos causados por aumentos súbitos de pressão (DA SILVA, DELLA, BACK, 2014).

Estudo de matrizes de correlação dos dados dos DMC's- A análise de correlação foi realizada utilizando os dados médios dos 7 parâmetros medidos nos DMC's, sendo correlacionadas as variáveis físicas e o indicador para a determinação de correlações estatisticamente significantes.

Assim a matriz de correlação originaria dos dados médios do DMC 32 (Tabela 7) demonstrou, de um modo geral, elevada concordância, particularmente representando 66,66%, que indicam uma forte correlação ($> 0,50$) entre os parâmetros. Dessa matriz, é possível a observação de correlação significativa positiva ($> 0,88$) entre Volume faturado e os parâmetros N° de Economias, N° de ligação, Volume Distribuído e Volume Micromedido.

Tabela 7: Matriz de correlação dos parâmetros com base nos dados médios, no DMC 32

DMC 32	N° de Economias	N° de Ligações	Volume Distribuído	Volume Micromedido	Volume Faturado	Dias Faturados	Índices de Perdas
N° de Economias	1						
N° de Ligações	0,9956943	1					
Volume Distribuído	0,8754953	0,8332077	1				
Volume Micromedido	0,9875349	0,9786852	0,9031343	1			
Volume Faturado	0,9968859	0,9917520	0,8870240	0,99656955	1		
Dias faturados	0,0212627	-0,0328591	0,3696542	0,15262126	0,0825138	1	
Índices de Perdas	-0,6668382	-0,7162438	-0,2687742	-0,64894643	-0,6663048	0,3503853	1

O que reflete a importância do acompanhamento do volume faturado, pois, de acordo com a análise pode-se constatar que existe uma associação muito ampla entre eles. E, portanto, quando o Volume Faturado aumenta, os outros parâmetros têm

uma forte tendência a aumentar, indicando que esses parâmetros estão relacionados e que podem variar juntos.

Uma forte correlação entre Volume Distribuído e Volume Micromedido ($> 0,90$) indica que, na maioria dos casos, quando o Volume Distribuído aumenta o Volume Micromedido também aumenta de forma substancial. Isso significa que um parâmetro pode ser utilizado para prever o outro, mas que não necessariamente uma variável irá acarretar a outra, observando-se também o aumento do Volume Faturado devido à forte correlação positiva com os dois parâmetros ($> 0,88$ e $> 0,99$). Já as correlações significativas negativas ($< -0,64$) dos Índices de Perdas com os 4 parâmetros, N° de Economias, N° de ligação, Volume Micromedido e Volume faturado indicam que os parâmetros se deslocam em sentidos opostos destacando que, quando o Índice de Perdas aumenta, os outros 4 parâmetros tendem a reduzir fazendo com que menos imóveis sejam atendidos, menos água seja distribuída, micromedida e faturada sendo um grande desafio para a melhora do sistema de distribuição de água.

Já a matriz de correlação originária dos dados médios do DMC 33 (Tabela 8) demonstrou, de um modo geral, baixa concordância, particularmente 42,85%.

Tabela 8: Matriz de correlação dos parâmetros com base nos dados médios, no DMC 33

DMC 33	N° de Economias	N° de Ligações	Volume Distribuído	Volume Micromedido	Volume Faturado	Dias faturados	Índices de Perdas
N° de Economias	1						
N° de Ligações	0,8635312	1					
Volume Distribuído	-0,3700231	-0,2138052	1				
Volume Micromedido	0,4291956	0,4277748	-0,6966519	1			
Volume Faturado	0,5993748	0,6185473	-0,5148708	0,9475834	1		
Dias faturados	-0,4145780	-0,0233152	0,2674593	-0,0817899	-0,0587257	1	
Índices de Perdas	-0,4703762	-0,2977106	0,9510190	-0,8115598	-0,6900001	0,195023	1

Embora essa correlação negativa só tenha ocorrido fortemente ($< -0,81$) entre o Índices de Perdas com Volume Micromedido demonstrando que quanto maior a água micromedida menor a será a perda, quando comparado com os outros parâmetros o Índice de Perdas teve correlação negativa (com maior ou menor intensidade) com praticamente todos, exceto Volume Distribuído, mostrando que eles estão opostamente relacionados e que o Índice de Perdas só diminuiu quando os outros parâmetros se elevaram.

Ao mesmo tempo uma forte correlação positiva ($> 0,95$) entre o Índice de Perdas e o Volume Distribuído constatando-se que quanto mais água foi distribuída pela companhia, mais água foi perdida. Torna-se possível concluir, pela associação do desperdício de água com a dinâmica de combate as perdas, que apesar de um maior Volume Distribuído não houve contribuição para o aumento do Volume Faturado, pois o mesmo só obteve acréscimo quando

comparado com o Volume Micromedido onde obtiveram alta correlação ($> 0,94$).

V. CONCLUSÃO

Após avaliação dos dados dos Relatórios dos Quantitativos de Perdas Hídricas (DESO, 2022) em dois DMC's da rede de distribuição de água da Região Metropolitana de Aracaju, conclui-se que: A instalação dos DMC's não traz nenhum tipo de prejuízo a rede de distribuição de água da Região Metropolitana de Aracaju; Os DMC's estudados são um reflexo de como as gestões de distribuição atuam, e quais os parâmetros são levados em consideração para estimar as perdas operacionais; Tornou-se importante atualizar os dados consolidados sobre percentuais de perdas, e estratifica seus desdobramentos, seja em arrecadação, em volume de água distribuída, frente ao aumento de economias e as dinâmicas sociais; As perdas de água nesses locais representam uma parcela significativa do total de perdas, o que impacta negativamente a eficiência operacional e financeira da companhia; As perdas de água nos distritos de medição e controle são atribuídas aos vazamentos em equipamentos de medição, falhas em válvulas e registros, além de problemas de calibração e manutenção inadequada; A falta de tecnologias avançadas de monitoramento e detecção de vazamentos dificulta a identificação e correção desses problemas de forma rápida e eficiente.

Por tudo, abaixo redução das perdas de água nos distritos de medição requer mais esforços conjuntos das autoridades públicas, companhias de água e comunidades locais.

E para novos estudos e projetos da companhia recomenda-se que: Seja implantado para os DMC's o Sistema de Informação Geográfica (SIG), pois será uma ferramenta de suporte à gestão de perdas; Sejam implantados os sistemas de telemetria, pois permitem a agilidade na obtenção de informações e a tomada de decisões na operação da distribuição de água; Nos relatórios da companhia incluam o parâmetro, vazão de entrada no DMC, a medição de vazão em redes, é um fator importante no controle de perdas, pois sua correta utilização tem influência direta nos índices de perdas (TSUTIYA, 2004); Nos relatórios da companhia incluam o parâmetro, pressão mediana DMC. Pois, o gerenciamento de pressões pode ser definido como uma prática de gestão das pressões do sistema de abastecimento (THORNTON & LAMBERT, 2005).

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Enhancing Sustainable Poultry Farming through Modern Agricultural Technologies: Bridging the Adoption Gap in Southwest Nigeria

By Dr. Victoria Madedor

Abstract- The poultry industry in Nigeria, the largest in Africa, plays a vital role in national food security, rural livelihoods, and the supply of raw materials to industries such as pharmaceuticals, hospitality, and agriculture. Despite its potential, the sector remains constrained by persistent challenges including high mortality rates, frequent disease outbreaks, and limited technological integration, particularly with respect to real-time monitoring and automated systems. While modern agricultural technologies such as the Internet of Things (IoT) offer promising solutions for enhancing productivity and sustainability, their adoption in Nigeria remains limited. However, the empirical gap in understanding the specific barriers to technology adoption among small and medium-scale poultry farmers in Southwest Nigeria has received little attention. This study addresses this gap by investigating the awareness, perceptions, and adoption challenges of IoT-based agricultural technologies among poultry farmers in Oyo, Ogun, and Lagos States. Anchored in Production Theory and employing a descriptive survey design, primary data were collected from 240 poultry farmers using structured questionnaires.

Palavra-chave: sustainable poultry farming, internet of things (IoT), agricultural technologies, technology adoption, nigeria.

GJSFR-H Classification: LCC: S671.5, S494.5.I57



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Abstract- The poultry industry in Nigeria, the largest in Africa, plays a vital role in national food security, rural livelihoods, and the supply of raw materials to industries such as pharmaceuticals, hospitality, and agriculture. Despite its potential, the sector remains constrained by persistent challenges including high mortality rates, frequent disease outbreaks, and limited technological integration, particularly with respect to real-time monitoring and automated systems. While modern agricultural technologies such as the Internet of Things (IoT) offer promising solutions for enhancing productivity and sustainability, their adoption in Nigeria remains limited. However, the empirical gap in understanding the specific barriers to technology adoption among small and medium-scale poultry farmers in Southwest Nigeria has received little attention. This study addresses this gap by investigating the awareness, perceptions, and adoption challenges of IoT-based agricultural technologies among poultry farmers in Oyo, Ogun, and Lagos States. Anchored in Production Theory and employing a descriptive survey design, primary data were collected from 240 poultry farmers using structured questionnaires. Descriptive statistics and Likert-scale analysis were used to evaluate respondents' perceptions. Results show that 58.21% of farmers believe IoT technologies can significantly enhance profitability, and 41.79% consider them user-friendly. However, 54.73% identified financial constraints and system integration issues as major obstacles to adoption. The perception index of 2.33 suggests moderate awareness and a cautiously positive attitude toward these technologies. The study concludes that while awareness and positive perceptions exist, financial and infrastructural barriers hinder broader adoption. It recommends targeted interventions, including subsidized access, financial support mechanisms, and tailored training programs, to bridge the technological adoption gap and promote sustainable poultry farming in the region.

Keywords: sustainable poultry farming, internet of things (IoT), agricultural technologies, technology adoption, nigeria.

1. INTRODUCTION

The poultry industry is a pillar of Nigeria's agricultural economy, playing a crucial role in food security, employment generation, and the supply of essential raw materials to ancillary industries including hospitality, pharmaceuticals, and textiles (Ajala et al., 2021). With approximately 180 million birds and an estimated net worth exceeding 300 billion Naira, the

sector contributes about 25% to the agricultural GDP and supports the livelihood of 14 million Nigerians (Olutumise et al., 2023). This growth is fueled by broiler production, particularly concentrated in Southwest Nigeria, where cultural and religious acceptance, coupled with intensive production systems, have made poultry an attractive venture for smallholders and commercial investors alike (Chiekezie et al., 2022).

Globally, the demand for animal protein has risen, with projections indicating a 60% increase in poultry product demand in Africa by 2030, positioning Nigeria as the continent's largest market (Nkukwana, 2019). Yet, despite its economic significance and growth potential, the sector is constrained by persistent challenges such as high mortality rates, disease outbreaks, substandard chick quality, limited veterinary access, high feed costs, and inadequate extension services (Wongtangintharn et al., 2025). Notably, the COVID-19 pandemic exposed the fragility of existing food systems, highlighting the need for resilient and sustainable models.

To address these inefficiencies and promote sustainable intensification, there is a need to harness the potential of disruptive agricultural technologies (DATs), particularly the Internet of Things (IoT) (Harsanto et al., 2025), which can empower farmers by accelerating agri-food outcomes by multiple folds. IoT enables real-time monitoring of environmental conditions, disease symptoms, and animal behavior via sensor-based data collection and automated responses. Applications range from regulating temperature and humidity in poultry houses to early detection of diseases such as Avian Influenza and Newcastle Disease, both of which have been endemic and devastating in Nigeria (Ojo et al., 2022).

However, while the theoretical and practical benefits of IoT in poultry farming are well-documented, adoption remains limited. The authors acknowledge the promise of smart farming, and base this research on the inadequacy of empirical studies investigating actual adoption dynamics among Nigerian poultry farmers, particularly in Southwest states like Oyo, Ogun, and Lagos. Some of the existing studies focus have focused on general agricultural technology usage, leaving a critical gap in understanding the perceptions, awareness levels, and barriers to IoT adoption in the

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poultry subsector. Afolabi et al. (2021), for instance designed a cloud-based IoT system to monitor temperature and humidity on Nigerian poultry farms and they reported how low-cost sensor technology can help farmers to monitor their farms remotely. Likewise, Kumar et al. (2020) also conducted a systematic review of IoT use in the area of poultry health and welfare management, and they emphasized that these technologies can help to better manage animal welfare and should be integrated into poultry farming practices in Nigeria.

This study aims to bridge the gap between technology use and perception barriers by exploring the socio-economic characteristics, awareness, perceptions, willingness to adopt, and constraints faced by poultry farmers in integrating IoT technologies into their operations. The authors base this study on the Production Theory and the Rational Choice Theory, both of which posit that adoption decisions are influenced by expected gains in productivity, findings provides practical insights that can inform targeted interventions. the result will benefit both farmers and researchers interested in adopting DAT (IoT). Findings will benefit both stakeholders and extension agents on which disruptive technology is most efficient and which is not, and will help smallholder farmers adopt improved poultry production technologies as they aim to expand their current stock and increase productivity.

II. METHODOLOGY

The study was carried out in the south-western part of Nigeria, with a focus on Lagos, Ogun and Oyo states. Apart from agriculture, which is the major economic activity in many of the rural communities of this area, the zone is also known for its commerce and trading activities with a preponderance of micro, small, and medium indigenous industries that are into manufacturing, fabrication, and agro-allied produce. This zone was selected because commercial poultry production is more developed in the south-western part of the nation.

Study population included poultry farmers in Oyo, Ogun and Lagos states and the multi-stage sampling techniques were used to randomly select 40 broiler farmers from 2 Local Government Areas (LGAs) within each state, which was purposively selected using data obtained from the Poultry Association of Nigeria (PAN). Data was collected with the use of a structured questionnaire which was carefully designed to reflect the study's objectives and to capture both qualitative and quantitative responses from poultry farmers.

The focus of the study was on understanding poultry farmers' awareness of and willingness to adopt Disruptive Agricultural Technologies. This was measured using a Likert scale (1-5), which allowed respondents to express varying degrees of agreement or disagreement.

Alongside this, the study also examined several socio-economic factors like age, sex, marital status, education, farming experience and household size that could influence their responses.

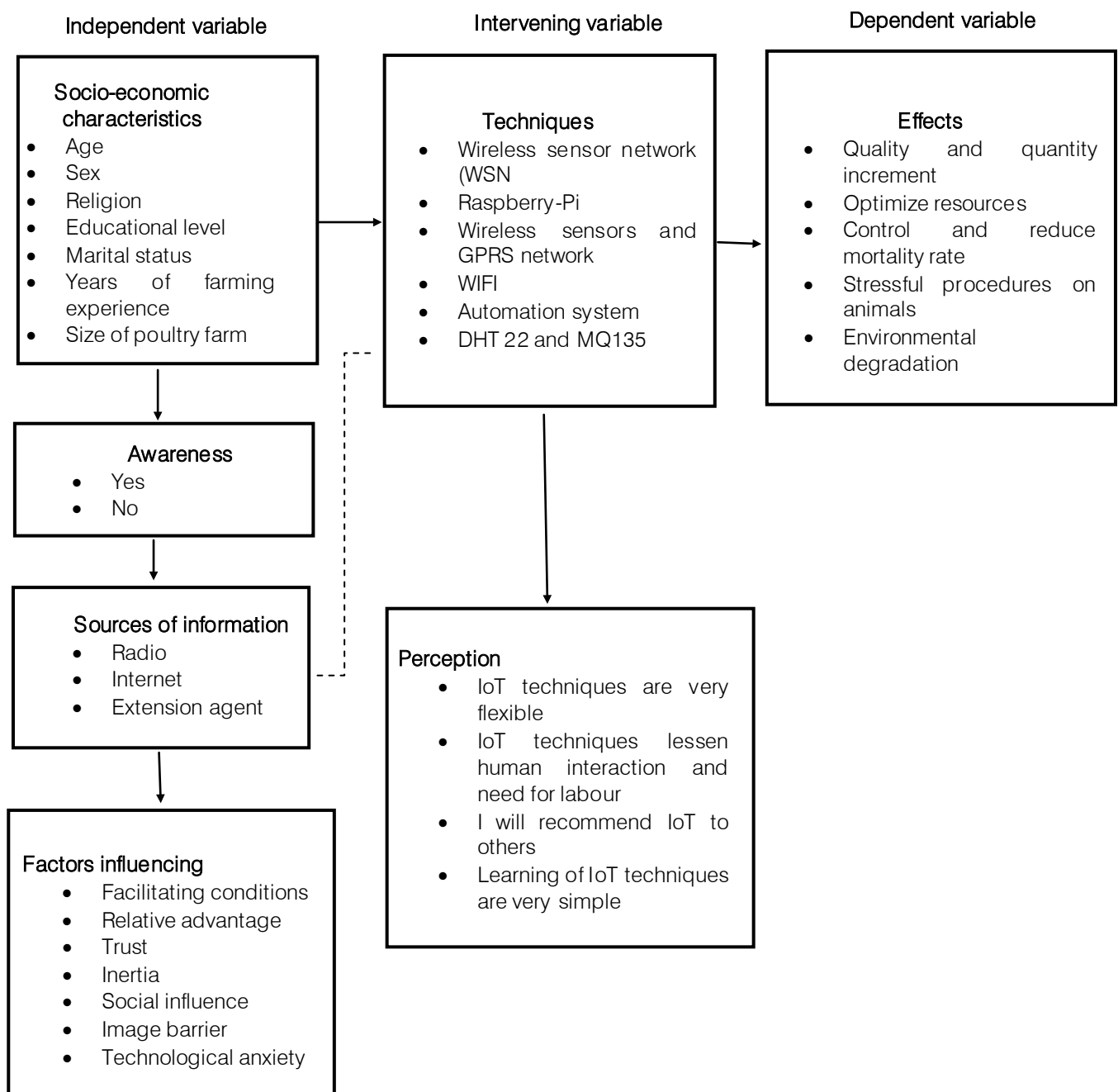


Figure 1: Conceptual Framework

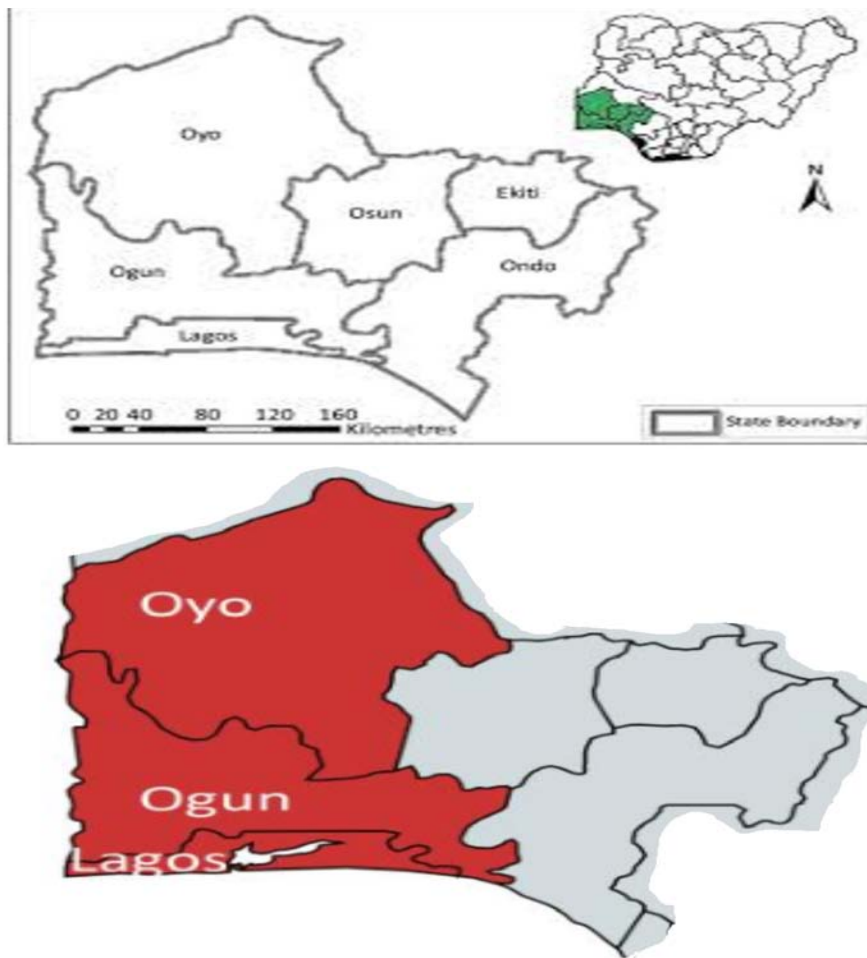


Figure 2

III. RESULTS

A total of 240 questionnaires were distributed across poultry farmers in Southwest Nigeria, with 201 completed and returned, yielding a response rate of 83.75%. Analysis of socio-economic characteristics revealed that most respondents (48.26%) were aged 26–40, followed by 41–60 years (31.84%), with a mean age of 47, indicating a largely active and productive population. The majority were male (70.15%) and married (65.17%), and a significant number (66.67%) had completed tertiary education. In terms of farming experience, 43.28% had 11–20 years of experience, and the average was 19 years.

Regarding size of the enterprise, 38.81% of farmers had fewer than 2,500 birds, 29.35% had 2,501–5,000 birds, and 31.84% had more than 5,000 birds, classifying most as medium-scale farmers. Over half (57.71%) raised both layers and broilers, and 74.13% operated a mix of intensive and extensive systems. For land ownership, 56.22% purchased their land, while others leased (19.40%) or used family land (24.38%). Urban farm locations were more common (61.19%), and 52.24% of respondents were members of the Poultry Association of Nigeria (PAN).

IoT (Internet of Things) technology adoption was fair, with 52.74% of the respondents stating that they were already using IoT solutions, while 47.26% were not. PAN was the main source of IoT information (38.80%), followed by extension agents (33.83%). Most users (62.26%) had less than a year's experience with IoT technologies, while 83.96% expressed willingness to adopt them. In terms of specific technologies, farmers were most aware of biogas (83.58%), automated systems like heaters and feeders (82.09%), and GPRS/mobile systems (74.63%). Awareness was lowest for satellite-enabled remote monitoring (50.75%).

When ranking levels of awareness, respondents were most aware of GPRS and mobile systems, followed by wireless sensors and biogas, with an overall IoT awareness index of 2.09. Perception-wise, most respondents believed IoT could monitor climate (55.72%), detect disease (53.73%), and increase profitability (58.21%). However, constraints such as lack of resources, knowledge, and compatibility were noted. The overall perception index stood at 2.33.

Willingness to adopt specific IoT tools was highest for IoT and WiFi (45.27% very willing), biogas (40.80%), and satellite monitoring (43.29%), with an overall willingness index of 1.83. A logistic regression

analysis found that educational level ($p < 0.05$), stock size ($p < 0.05$), farming experience ($p < 0.1$), and years of IoT use ($p < 0.05$) significantly influenced willingness to adopt disruptive agricultural technologies. For example, a 10% increase in farming experience increased willingness by 17%, and a similar increase in stock size boosted it by 17.7%.

Constraints to poultry farming were categorized into financial, social, institutional, and management. The top constraints included lack of credit facilities (56.72% rated it very severe), poor government support (27.36% very severe), and high feed costs (50.25% very severe). Other notable challenges were pest and disease outbreaks, poor housing, erratic power supply, waste management, and poor veterinary services.

Key barriers to adoption were financial and infrastructural. Specifically, 54.73% of respondents cited

cost of equipment, internet unreliability, and lack of technical knowledge as major obstacles. Additional factors included low trust in technology providers, technological anxiety, and fears of data misuse. Complexity in system setup, high maintenance costs, and limited compatibility with existing infrastructure further dissuaded adoption. Socio-cultural factors such as peer influence, media exposure, and normative pressures also played a role in shaping farmers' perceptions.

Despite these challenges, the majority of respondents expressed willingness to adopt IoT technologies if given adequate support. This willingness was positively influenced by perceived usefulness, ease of use, and potential profitability. Innovativeness and social influence emerged as important determinants of behavioral intention, especially among younger farmers.

Table 1: Socio-economic characteristics of respondents (Demography)

Age (years)	Freq.	Percent
<25	16	71.96
26-40	97	48.26
41-60	64	31.84
>60	24	11.94
Mean	47	
Sex	Freq.	Percent
Male	141	70.15
Female	60	29.85
Marital Status	Freq.	Percent
Single	67	33.33
Married	131	65.17
Divorced	1	0.50
Widowed	2	1.00
Education	Freq.	Percent
Secondary completed	36	17.91
Tertiary attempted	31	15.42
Tertiary Completed	134	66.67
Farming Experience (years)	Freq.	Percent
1-10	54	26.87
11-20	87	43.28
> 20	60	29.85
Total	201	100.00

Source: Field Survey, 2022.

Table 2: Socio-economic characteristics of respondents (Farming System)

Stock Size (birds)	Freq.	Percent
<2500	78	38.81
2501-5000	59	29.35
>5000	64	31.84
Bird type	Freq.	Percent
Layers	22	10.95
Broilers	63	31.34
Both	116	57.71
Production System	Freq.	Percent
Intensive	45	22.39
Extensive	7	3.48
Both	149	74.13
Mode of land acquisition	Freq.	Percent
Outright Purchase	113	56.22
Lease	39	19.40
Family	49	24.38
Location of Poultry Farms	Freq.	Percent
Rural	78	38.81
Urban	123	61.19
PAN Membership	Freq.	Percent
Yes	105	52.24
No	96	47.76
Total	201	100

Source: Field Survey Data, 2022.

Table 3: Distribution of respondents by Practice and Information source of IoT

IOT Practice	Freq.	Percent
Yes	106	52.74
No	95	47.26
Source of IOT Info	Freq.	Percent
Farmers Association	21	10.45
Friends and Family	10	4.98
Extension Agents	68	33.83
Media	24	11.94
Poultry Association of Nigeria	78	38.80
Total	201	100

Source: Field Survey Data, 2022.

Table 4: Distribution of respondents by Years of IoT experience and their willingness to adopt IoT

IOT Experience (Years)	Freq.	Percent
1	66	62.26
>1	40	37.74
Willing to Adopt IOT	Freq.	Percent
Yes	89	83.96
No	17	16.04
Total	106	100

Source: Field Survey Data, 2022.

Table 5: Distribution of Awareness of Internet of Things Technologies

	IOT technologies	Aware		Not Aware	
		Freq	%	Freq	%
1	BIOGAS	168	83.58	33	16.42
2	Wireless Sensors Network	104	51.74	97	48.26
3	GPRS and Mobile System	150	74.63	51	25.37
4	Automated heaters, fans, drinkers, and feeders	165	82.09	36	17.91
5	Temperature and Relative Humidity Sensor and Air Quality Sensor	151	75.12	50	24.88
6	IoT and WiFi	144	71.64	57	28.36
7	IOT and Remote Monitoring (satellite-enabled)	102	50.75	99	49.25

Source: Field Survey, 2022

Table 6: Distribution of Level of Awareness of IoT Technologies

Level of Awareness of IoT	Very Aware		Aware		Slightly Aware		Mean	S.D.	Rank
	Freq	%	Freq	%	Freq	%			
BIOGAS	59	29.35	51	25.37	91	45.27	2.16	0.85	3 rd
Wireless Sensors Network	33	16.42	97	48.26	71	35.32	2.19	0.70	2 nd
GPRS and Mobile System	87	43.28	71	35.32	43	21.39	2.22	0.78	1 st
Automated heaters, fans, drinkers, and feeders	79	39.30	89	44.28	33	16.42	2.05	0.92	4 th
Temperature and Relative Humidity Sensor and Air Quality Sensor	80	39.80	48	23.88	73	36.32	1.97	0.87	6 th
IoT and WiFi	67	33.33	63	31.34	71	35.32	2.02	0.83	5 th
IOT and Remote Monitoring (satellite-enabled)	48	23.88	95	47.26	58	28.86	2.05	0.73	4 th
IOT Awareness Index							2.09		

IV. DISCUSSION

This study found that factors like educational level, stock size and farming experience inform farmers' willingness to adopt IoT technologies in southwest Nigeria, which is similar to the findings of Abioye et al. (2024). This corroborates the theory of rational choice, which suggests that rational producers adopt innovations that improve efficiency and profitability. The demographic profile (largely educated and experienced) also reflects that the study population consisted majorly of farmers with the ability and willingness to engage with digital technologies for more efficient farming.

The moderate adoption rate of IoT technologies and the high willingness to adopt in this study echo the discoveries of Gbadamosi (2023), who demonstrated the technical viability and benefits of IoT monitoring systems based on birds in Nigeria, especially in monitoring environmental parameters such as temperature. However, he described challenges to adoption that were similar to those reported in this study, like financial restrictions, bad infrastructure and limited technical knowledge as great barriers to adoption. These barriers are consistent with findings in broader literature, where costs, lack of internet reliability and digital literacy remain critical.

Shahab et al. (2024), reported that IOT and disruptive technologies can increase disease tracking and prevention through real-time data collection and analysis. However, many farmers' reluctance to adopt these techniques highlight the digital divide that exists in rural, peri-urban and urban environments. Stakeholders like the government, opinion leaders, policy makers and educators must work together to bridge this gap.

The prevalence of endemic poultry diseases such as Newcastle Disease and Avian Influenza further accentuates the importance of timely monitoring systems, yet the inability of farmers to access or operate IoT tools leaves this need unmet (Grace et al., 2024). Although the technical feasibility of IoT applications in poultry production is no longer in question, their viability within different settings, shaped by local infrastructure, economic realities, and user readiness, remains a major concern. Farmers' reliance on informal information networks also implies that peer demonstration and word-of-mouth are instrumental in the diffusion of innovation. In this regard, trust and social proof are as important as cost-effectiveness or system accuracy. Furthermore, the role of government and institutional actors is notably absent in facilitating access to smart technologies. Policy support, such as subsidies, tax waivers for agritech imports, or investment in rural

broadband infrastructure, has the potential to catalyze wider adoption. Countries such as Kenya and South Africa have shown that targeted subsidies, tax incentives, and rural broadband investments can accelerate the adoption of agricultural technologies. For example, Kenya's digital agriculture initiatives, supported by government and private partnerships, have improved small farmers' access to consulting services and mobile-based IoT tools, resulting in higher productivity and market access (Krishna, 2024). Likewise, the integration of IoT training into agricultural extension programs could address existing knowledge gaps.

Socio cultural factors, such as technological anxiety, low confidence in providers and improper use of data, identified in this study point out that adoption is not only a matter of economy or infrastructure, but also of trust, perceived risk and social norms. Younger farmers and those with greater innovation have shown greater behavioral intention to adopt IoT, consistent with global studies on technology acceptance models.

While the willingness to adopt IoT among farmers indicates a readiness for change, their current environment, both physical and institutional, is not sufficiently enabling. The gap between perceived usefulness and actual usage suggests that adoption decisions are shaped as much by systemic enablers as by individual attitudes or capabilities. Thus, for Nigeria's poultry sector to fully benefit from digital transformation, a multi-stakeholder approach that combines infrastructure development, policy incentives, and targeted farmer education must be prioritized.

V. CONCLUSION AND RECOMMENDATIONS

While poultry farmers in Southwest Nigeria are moderately aware of IoT technologies and perceive them as potentially beneficial, their adoption is hindered by financial limitations, poor infrastructure, and insufficient technical support. Nonetheless, the willingness to adopt remains promising, particularly if enabling conditions are improved. To accelerate adoption, it is essential to provide subsidised access to IoT tools, invest in rural digital infrastructure, and incorporate targeted training through extension services. Demonstration farms, public-private partnerships, and clear regulatory frameworks will further support the integration of IoT into poultry farming, ultimately promoting productivity, sustainability, and resilience in the sector.

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Longitudinal and Transverse Dispersion - Diffusion in Streams: Its Effects in "Complete Mixing" Condition, and the Role a New State Function

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Abstract- In environmental impact studies on natural flows, the concept of "complete mixing" linked to the flow's "assimilation capacity" is usually presented in terms of transverse diffusion alone, ignoring the fact that it is a joint mechanism with longitudinal dispersion. This article presents a new approach in which a state function comprehensively describes how the two mechanisms act in unison, facilitating the interpretation and calculation of the "mixing length." The developed equations are applied to the study of three different channels, obtaining satisfactory results, converging with those calculated from Elder's transverse diffusion coefficient.

Keywords: *assimilation capability of streams, state functions, tracers.*

GJSFR-H Classification: LCC: GB659.8



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Alfredo José Constain Aragón

Abstract- In environmental impact studies on natural flows, the concept of "complete mixing" linked to the flow's "assimilation capacity" is usually presented in terms of transverse diffusion alone, ignoring the fact that it is a joint mechanism with longitudinal dispersion. This article presents a new approach in which a state function comprehensively describes how the two mechanisms act in unison, facilitating the interpretation and calculation of the "mixing length." The developed equations are applied to the study of three different channels, obtaining satisfactory results, converging with those calculated from Elder's transverse diffusion coefficient.

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I. INTRODUCTION

a) Paper Size, Margins, Columns and Paragraphs

For environmental impact studies, it is vital to know the dynamics of conservative solutes moving in a flow, which simulate quite well the behavior of the pollutants poured in, and are therefore important for their understanding, control and mitigation. [1] In this perspective, the calculation of the transport coefficients, especially the one that defines the transverse diffusion, is fundamental.

J. W. Elder in his original work [2], based on theoretical considerations, found a definition of the transverse diffusion coefficient, ε_y , which have the following definition, with H as depth, g , as acceleration of gravity and S , as slope of the energy line:

$$\varepsilon_y \approx 0.23 * H * \sqrt{H * g * S} \quad (1)$$

But later, H.B. Fischer [3], who varied this coefficient by about 50%, found better accommodation with the experimental results. This formula is used in this Article as a reference for comparing results due to its simplicity and relative accuracy.

This transverse diffusion coefficient plays a very important role in understanding and defining the so-called "Mixing length", Lo , the distance at which the solute transported in a flow is considered to be "mean

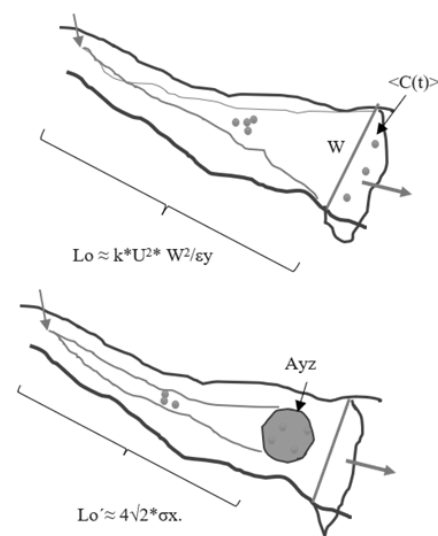
value" distributed in the cross section, and its concentration is a relative minimum, indicating well what the "assimilation capacity of the channel" is reached. With "k" a coefficient that depends on the way the solute is injected into the flow ($k=1$ for central injection), U the average velocity, and W the average width [4,5].

$$Lo \approx \frac{k * U * W^2}{\varepsilon_y} \quad (2)$$

This equation refers to the channel's "width" and is defined when the solute diffuses at an "average" value. Although the physical basis of this equation is sufficiently proven, the fact that it is affected by the "k" factor, which varies between 0.1 and 0.4 and depends on how well the injection point is located, adds an unavoidable component of imprecision.

For this reason, it is interesting to explore an alternative procedure, based on other principles, that provides greater certainty in this critical measurement.

This new procedure may be based on when the solute evenly covers the cross-section of its stream tube with a homogeneous distribution, which may or may not coincide with the channel's width. Figure 1 compares the two procedures: the classic one, corresponding to equation (2), and the new approach.



Source: Author

Figure 1: Two conditions of "complete mixing" in the evolution of a solute

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This new situation occurs when the solute transport distance is long enough for almost all of its mass (99.7%) has lost most of its interactions, and its particles are distributed homogeneously like an ideal gas (losing significantly its interactions), [6] such that, according to Gauss's Theory, there is a corresponding distance of "Six sigma", when $t \approx 4\sqrt{2} \cdot \sigma t$, which if $U \approx \sigma_x / \sigma_t$, it holds. [7]:

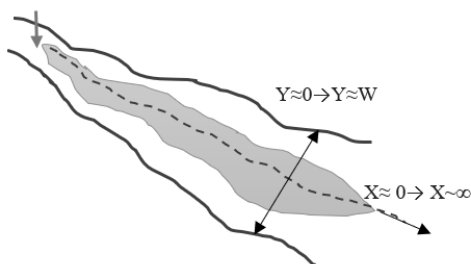
$$Lo' \approx 4\sqrt{2} * \sigma_x \quad (3)$$

Defining transverse diffusion has not been easy, as there is no identifiable velocity distribution along this axis that would allow theoretical manipulation to establish mixing along this axis, as is the case on the vertical axis. [8]

In water quality studies, this "complete mixing" condition is of primary importance, given that monitoring of the variables of interest, they must have optimal representativeness, ensuring that the models run appropriately. [9] This information is typically collected in the field with tracer tests.

On the other hand, it is necessary to distinguish diffusion from dispersion [10]. The former is associated with transport caused by turbulence as a mixing agent, and on a much smaller scale by molecular motion. The second is more directly associated with the mixing and expansion effect of a solute due to the shear effect of longitudinal velocities, arising from the mean advective velocity. The characteristic is that both types of motion are defined as proportional to the concentration gradient. [11]

Thus, while dispersion expands without limit along the longitudinal axis, transverse diffusion has a rather small limit (restricted by a finite width). Figure 2.



Source: Author

Figure 2: Different Spatial Nature of Longitudinal and Transverse Dispersion-Diffusion

This implies that, due to this restriction, diffusion generally progresses much less rapidly than dispersion and can reach a certain equilibrium before its longitudinal portion, covering the cross-sectional area of the flow.

Then, the application of two "complete mixing" criteria must be distinguished: One: When Lo is applicable, the channel width and the transverse

diffusion coefficient must be considered primarily. and Two: When Lo' is applicable, the spatial variance of the solute curve must be considered primarily. Both criteria show important aspects of the tracer advance mechanism. The first criterion is appropriate for channels of not very great width, in which the value of " Lo " is practical for measurement. The second criterion is applied in very large rivers in which the solute behavior is well described by " Lo' ", without needing to refer it to the channel width.

II. STATE FUNCTION TO DESCRIBE THE EVOLUTION OF SOLUTES IN TURBULENT FLOWS

a) Definition of the Function and its Relationship with the Average Flow Velocity

A transport model has been presented based not on the concept of "Dead zones" as the cause of the "non-Fickian bias" of the experimental tracer curves, but rather on the concept of heat exchange in the phenomena of "hydration" and "dilution", supported by the enthalpy of formation of the solute. [12] This evolution is described by a State Function $\Phi(t)$, fulfilling the Pfaff conditions [13] that has been applied to explain numerous experimental cases [14,15].

$$\oint d\Phi = 0 \quad (4)$$

This state function defines a one-dimensional mean flow velocity equation, similar in its quadratic structure to the Chezy-Manning mechanical equation [16]. Here $\beta \approx 0.214$.

$$U \approx \frac{1}{\Phi} \sqrt{\frac{2E}{\beta * t}} \quad (5)$$

b) Definition of the State Function in Terms of Distance

The function Φ itself is defined by clearing it from the previous equation, and putting it into function of the distance, X .

$$\Phi \approx \left(\frac{\sqrt{2E}}{U\sqrt{\beta}} \right) * \frac{1}{\sqrt{X}} \quad (6)$$

Now for two points, with $X1$, and $\Phi1$, and $X2$ and $\Phi2$, the following valid ratio is obtained if E does not vary significantly between each point, from eq. (5), it holds:

$$\frac{\Phi1}{\Phi2} \approx \frac{\sqrt{X2}}{\sqrt{X1}} \rightarrow Lo' \approx \left(\frac{\Phi2}{0.38} \right)^2 * X2 \quad (7)$$

This equation will be useful to find distances of interest ($X2$) to $\Phi2$, when $\Phi1$ and $X1$ are known (this convention would be the other way around), The important thing is that the definitions are consistent with each other.

When $\Phi \approx 0.38$, then the time takes the value $Lo' \approx 4\sqrt{2} \cdot \sigma x$, that is, the "Freedom of interactions" condition for its particles.

c) *Some Thermodynamic Considerations on Interactions in Very Dilute Solutions*

When the solute is suddenly injected into the flow, its mass is transformed from a "solid" compound to a "liquid" compound in a first phase, [17] by means of a heat exchange. In this phase the hydration of the solute particles occurs, by the interaction with the water dipoles. Then there is the formation of structures that respond to the Coulomb interactions between the solute particles, also with a heat exchange, until they disappear when the square root of the concentration will tend to zero, according to the Hückel-Debye law for dilute concentrations. [18] In this last phase, it can be considered that the solute particles behave almost like an ideal gas, which loses its interactions and is distributed homogeneously in the volume considered.

The tendency of these mutual interactions between solute molecules to decrease can be measured in various ways, for example with the thermodynamic equations of internal pressure, "pi" [19]:

$$\left(\frac{\partial E}{\partial v}\right)_T \approx pi \quad (8)$$

This isothermal change in the "internal energy" of the gas, E, corresponds to the interactions (mutual attraction) of the gas particles, which is very small for real gases and zero for ideal gases, if internal pressure is small (low concentrations).

But perhaps the most direct way to estimate this effect is by estimating the "braking" effect that the electrostatic interactions have on the motion of the solute plume flow. In this phase, this degraded compound behaves like "Boltzmann molecular chaos," that is, erratically in all directions and therefore without any particular structure.

d) *Application of the State Function, $\Phi(t)$ to the Calculation of Ratio of Discharge, According to Two Definitions of the Parameter*

If the longitudinal dispersion coefficient, E, is cleared in eq. (5) it holds:

$$E \approx \frac{\Phi^2 \cdot U^2 \cdot 0.214 \cdot tp}{2} \quad (9)$$

And if it is applied to the definition of Concentration (C(t) according to Fick, [20] we have:

$$C(x, t) \approx \frac{M}{Q \cdot \Phi \cdot tp \cdot 1.16} \cdot e^{-\frac{(tp-t)^2}{2 \cdot 0.214 \cdot (\Phi \cdot t)^2}} \quad (10)$$

The peak concentration, Cp, is then:

$$Cp \approx \frac{M}{Q \cdot \Phi \cdot tp \cdot 1.16} \quad (11)$$

Therefore, the discharge, Q, is:

$$Q' \approx \frac{M}{Cp \cdot \Phi \cdot tp \cdot 1.16} \quad (12)$$

And according to the principle of conservation of mass we have:

$$Q \approx \frac{M}{\int_a^b C(t) dt} \quad (13)$$

If the ratio, r, between these two definitions of mass is defined as:

$$r \approx \frac{Q}{Q'} \approx \frac{\left(\frac{M}{\int_a^b C(t) dt}\right)}{\left(\frac{M}{Cp \cdot \Phi \cdot tp \cdot 1.16}\right)} \quad (14)$$

The average value of the solute concentration is:

$$\langle C(t) \rangle \approx 0.441 \cdot Cp \quad (15)$$

Now, if $\Phi \approx 0.38$, when $tp \approx 4\sqrt{2} \cdot \sigma t$, and the solute particles significantly lose their interactions, and considering the mean value theorem, [21], we have:

$$r \approx \frac{\left(\frac{M}{\int_a^b C(t) dt}\right)}{\left(\frac{M}{Cp \cdot \Phi \cdot tp \cdot 1.16}\right)} \approx \frac{Cp \cdot 0.38 \cdot 1.16}{\frac{1}{tp} \int_0^{tp} C(t) dt} \approx \frac{\langle C(t) \rangle}{\langle C(t) \rangle} \approx 1.0 \quad (16)$$

That is, when the "complete mixing" condition is met, the two versions of the flow are equal, that is, when the interactions of the solute particles virtually disappear.

If the solute is considered as an ideal gas, its internal pressure, "pi" must comply with Clapeyron's law, with B as a physical constant. [22]

$$\frac{pi \cdot V}{T} \approx B \quad (17)$$

For the approximate isothermal process, it is found that as the volume of the solute plume increases (which effectively occurs due to the increase in entropy), the internal pressure (and interactions) must decrease. In this way, equation (16) is fully justified since when $\Phi \approx 0.38$ is reached, the solute plume defines a volume such that its passage in time coincides with the definition of discharge in that point.

III. CLASSICAL FORMULAS FOR CALCULATING THE TRANSVERSE DIFFUSION COEFFICIENT, ϵ_y , AND ITS RELATIONSHIP WITH THE LONGITUDINAL DISPERSION COEFFICIENT, E .

The most notable antecedents of these calculations are the formulas proposed by Elder in the middle of the last century, where the two definitions depend on the "shear velocity", $u_* \approx \sqrt{H \cdot g \cdot S}$. [23] The longitudinal coefficient proposed was:

$$E \approx 5.93 \cdot H \cdot u_* \quad (18)$$

And the transversal coefficient, as in eq. (1), corrected by Fischer, was:

$$\epsilon_y \approx 0.6 \cdot H \cdot u_* \quad (19)$$

That is, both transport coefficients depend on the same dynamic factor, u_* . [24] Therefore, in general, the ratio of both coefficients " E/ϵ_y " can be established as a function " G " that depends on factors other than u_* , generally of an empirical, geometric or geomorphological nature, with different values depending on each author, and what factors they consider. [25]

$$\frac{E}{\epsilon_y} \approx G(\text{several factors}) \quad (20)$$

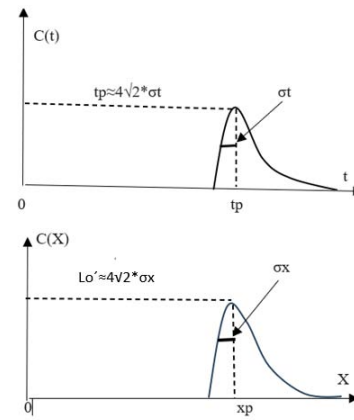
The use of u_* as the universal dynamic root to define transport coefficients is not accidental, since frictional friction is key to understanding and defining momentum transfers between turbulent fluid layers. [26]

On the other hand, it should be considered that turbulence occurs equally along the longitudinal and transverse axes, with shear advection being the predominant differentiating factor in longitudinal dispersion.

IV. RATIO BETWEEN LONGITUDINAL AND TRANSVERSAL TRANSPORTATION AS A FUNCTION OF THE RESPECTIVE VARIANCES

a) "Complete Mixing" Condition for Longitudinal Transport as Function of Longitudinal Variance

Longitudinal dispersion develops in an unconstrained scenario, as in Figure 3, showing how at $t \approx 4\sqrt{2} \cdot \sigma t$, and at $Lo' \approx 4\sqrt{2} \cdot \sigma x$, the solute reaches the condition of loss of interactions. This "complete mixing" condition for the curve is defined from the origin to the point where there is only one time (space) variance.

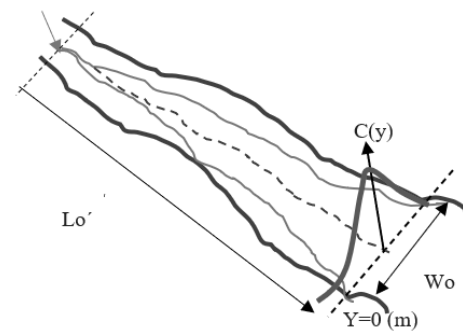


Source: Author

Figure 3: Definition of $4\sqrt{2} \cdot \sigma x$ from 0 to only one space variance

b) "Complete Mixing" Condition for Transverse Transport as Function of Transverse Variance

To establish when the transverse axis transport reach the cross section homogeneously of solute tube, a similar analysis must be performed to determine how many times the transverse spatial variance, σ_y , is in the width, Wo , for the same distance Lo' . Figure 4.



Source: Author

Figure 4: Curve $C(y)$ in Wo , at distance Lo'

The Gaussian expression in terms of the transverse spatial variance for this case is, with C_p equal in $C(X)$ and $C(Y)$, since $t \approx 4\sqrt{2} \cdot \sigma t$ for both distributions, as follows

$$C(y)_i \approx C_p \cdot e^{-\frac{(y - \frac{W}{2})^2}{2 \cdot \sigma_y^2}} \quad (21)$$

The function $C(t)$ in this case corresponds to the inflection points of the curve.

$$C(t)_i \approx 0.608 \cdot C_p \quad (22)$$

Therefore, eq. (21) would be put like this:

$$\frac{C_p}{C(t)_i} \approx e^{+\frac{(y - \frac{W}{2})^2}{2 \cdot \sigma_y^2}} \quad (23)$$

Rearranging:

$$\frac{1}{0.608} \approx 1.64 \approx e^{\frac{(y-\frac{w}{2})^2}{2\sigma_y^2}} \quad (24)$$

And then, with $y=0$:

$$\ln|1.64| \approx 0.50 \approx \frac{(\frac{w}{2})^2}{2\sigma_y^2} \approx \frac{w^2}{8\sigma_y^2} \quad (25)$$

And then:

$$\sigma_y \approx \frac{w}{2} \quad (26)$$

Then, concurrently with eq. (3), the tracer plume, when $\Phi \approx 0.38$, transversely occupies half of the plume width. Figure 5.

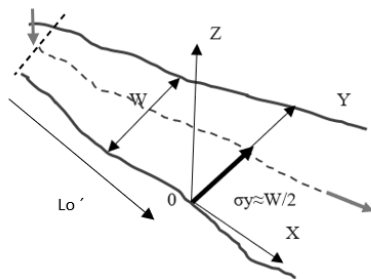


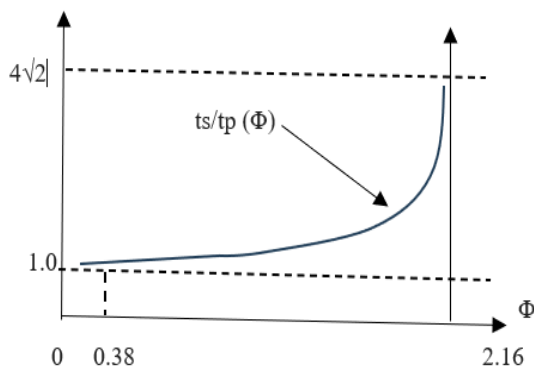
Figure 5: Occupation of $\frac{1}{2}$ Flow Width by Diffusion transverse variance

Therefore, dividing the two displacements, the longitudinal and the transversal, we have:

$$\frac{\sigma_x}{\sigma_y} \sim \frac{4\sqrt{2}}{1} \approx 4\sqrt{2} \quad (27)$$

c) *Quantitative Description of this Dynamic to Find the Ratio of Centroid Time and Peak Time*

The author have already developed a successful approach for calculating the centroid-to-peak time ratio, " t_s/t_p ," based on thermodynamic considerations, [27] as shown in Figure 5.



Source: Author

Figure 5: Curve of the t_s/t_p ratio as a function of $\Phi(t)$

When $\Phi \approx 2.16$, the t_s/t_p ratio is maximum, close to $4\sqrt{2}$, which is the maximum allowed by the homogeneously distributed mass. For $\Phi < 0.38$, it asymptotically approaches 1.0, i.e., there is no delay in the solute centroid when electrostatic interactions between its particles cease. The approximate equation for this trend is:

$$\frac{t_s}{t_p} \approx 0.85 * \Phi^{2.2} + 1 \quad (28)$$

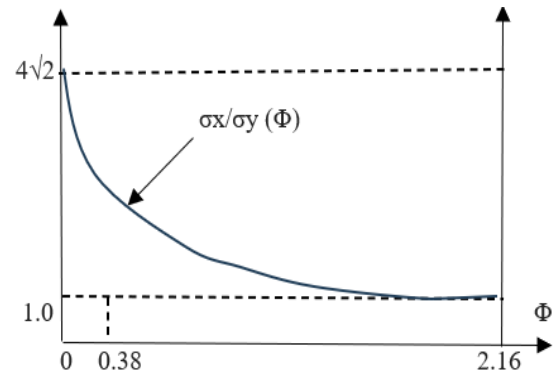
A notable value of this calculation is when $\Phi \approx 0.38$, the moment at which the solute changes to the ideal gas condition, and the electrostatic "braking" effect is reduced to a minimum:

$$\frac{t_s}{t_p} \approx 0.85 * 0.38^{2.2} + 1 \approx 1.10 \quad (29)$$

Which means that the centroid delay is 10%, that is, at the limit of the order of magnitude to not be considered.

d) *Quantitative Description of this Dynamic to Find the Ratio of the Transport Coefficients Σ_x and Σ_y*

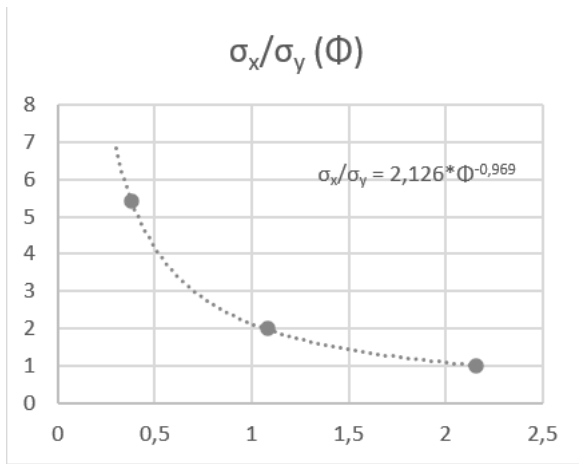
Now, based on results described in 4.2, it is interesting to find the relationship " σ_x/σ_y ", which corresponding curve is as shown in Figure 6.



Source: Author

Figure 6: Curve of the σ_x/σ_y ratio as a function of $\Phi(t)$

A more detailed representation, including notable modeling points, is shown in Figure 7.



Source: Author

Figure 7: Detailed Curve of the ratio σ_x/σ_y as a function of $\Phi(t)$

The approximate equation for this trend is:

$$\frac{\sigma_x}{\sigma_y} \approx \frac{2.126}{\Phi^{0.969}} \quad (30)$$

The notable points here are: For $\Phi \approx 2.16$, at the beginning of the process, the two variances are practically equal, and $\sigma_x/\sigma_y \approx 1$, given that the bias imposed by the advection shear effect is just beginning. For later events, when $\Phi \approx 0.38$, the two values progressively diverges to infinity. For this reason, as a practical limit of the expansion of the function, it is taken no longer to 0.38. Note that this limit is the one of interest, since up to this point, the "Mixing Length" is obtained.

Therefore, the Gaussian ratio of the longitudinal and transverse transport coefficients will be:

$$\frac{\sigma_x}{\sigma_y} \approx \sqrt{\frac{E}{\epsilon_y}} \quad (31)$$

And therefore:

$$\frac{E}{\epsilon_y} \approx \left(\frac{\sigma_x}{\sigma_y} \right)^2 \quad (32)$$

Normally the longitudinal coefficient, E , is known, then the transverse coefficient will be:

$$\epsilon_y \approx \frac{E}{\left(\frac{\sigma_x}{\sigma_y} \right)^2} \quad (33)$$

This value of ϵ_y must be contrasted with the one calculated from the Elder corrected eq. (19), which is considered an acceptable standard for the channel under study.

V. PRACTICAL APPLICATION OF THE METHOD TO REAL CHANNELS IN COLOMBIA AND USA

a) Upper Guavio River, Colombia in 2001

For this study, we consider saline tracer (NaCl) experiments conducted by the Universidad de los Andes in Bogotá in 2001 on the upper Guavio River, a mountain, very roughness river near the town of Arbelaez in the center of the country. [28] Figure 8.



Source: Author

Figure 8: View of Rio Guavio, near Arbelaez. Colombia

The data of this stream experiment is in Table 1.

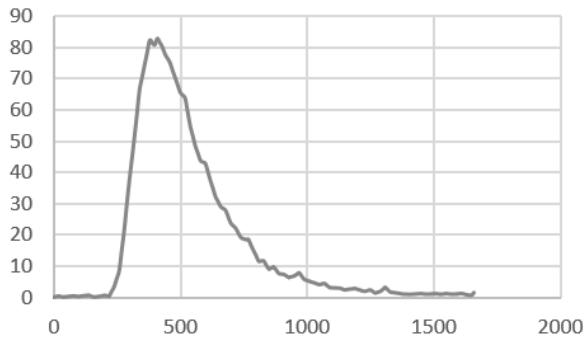
Table 1: Experimental data at Rio Guavio

Date: June 17, 2001. 2n station curve.
2nd curve length: $X = 98.1$ (m)
Width: $W \approx 10.0$ (m)
Depth: $H \approx 0.25$ (m)
Hydraulic radius: $R \approx 0.22$ (m)
Slope: $S \approx 0.045$
Cross-sectional area: $A_{yz} \approx 2.3$ (m ²)
Roughness (Manning): $n \approx 0.32$
Flow rate: $Q \approx 0.550$ (m ³ /s)
Average velocity: $U \approx 0.24$ (m/s)
Mass (NaCl): $M \approx 12233.0$ (g)
Peak time: $t_p \approx 410.0$ (s)
State function: $\Phi \approx 0.55$
Longitudinal coefficient: $E \approx 0.77$ (m ² /s).

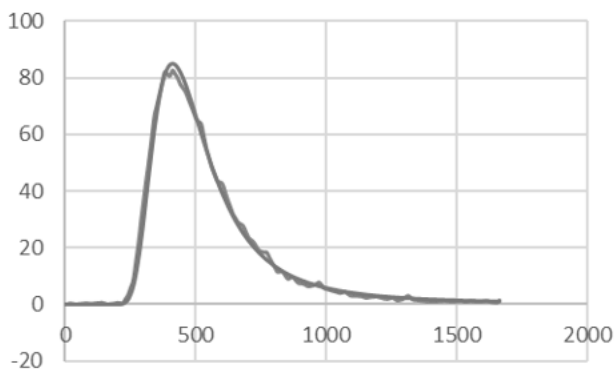
Source: Author

The experimental tracer curve and its model, using equation (9), for that experiment at the second station, are shown in Figure 9.

C(t) E2, Guavio



C(t) E2 Guavio Model,



Source: Author

Figure 9: Experimental curve (broken) and superimposed model (soft), using equation (10)

As can be seen at a distance of $X_1=98.1$ (m) and with a State Function of $\Phi_1 \approx 0.55$, does not yet reach the condition of complete mixing, which occurs at $\Phi \approx 0.38$, then the unknown distance, L_0 , must be estimated approximately with the eq. (7):

$$\frac{\Phi_1}{\Phi_2} \approx \frac{\sqrt{X_2}}{\sqrt{X_1}} \quad (34)$$

Then:

$$\sqrt{X_2} \approx \sqrt{98.1} * \left(\frac{0.55}{0.38} \right) \approx 14.33 \quad (35)$$

So:

$$X_2 \approx L_0' \approx 206.3 \text{ (m)} \quad (36)$$

Now, ratio σ_x/σ_y , eq. (30) is then calculated for $\Phi \approx 0.38$

$$\frac{\sigma_x}{\sigma_y} \approx \frac{2.126}{(0.38)^{0.969}} \approx 5.43 \quad (37)$$

And the transverse transport coefficient, ϵ_y , is as in eq. (33):

$$\epsilon_y \approx \frac{E}{\left(\frac{\sigma_x}{\sigma_y} \right)^2} \approx \frac{0.77}{5.43^2} \approx \frac{0.77}{29.5} \approx 0.026 \left(\frac{m^2}{s} \right) \quad (38)$$

This Coefficient is verified against the value obtained by Elder:

$$\epsilon_y \approx 0.6 * 0.25 * \sqrt{0.25 * 9.83 * 0.045} \approx 0.050 \left(\frac{m^2}{s} \right) \quad (39)$$

The ratio of the two results are 1.92, then, of the same order of magnitude, and are accepted as valid verification. The mixing length L_0 , eq. (2), is then:

$$L_0 \approx \frac{0.1 * 0.24 * 10^2}{0.026} \approx 92.3 \text{ (m)} \quad (40)$$

Comparing with L_0' calculated with eq. (7), it is noted that $L_0' > L_0$ and it is accepted that With a central injection ($k=0.1$) the dispersion covers the width of the channel, but as L_0' is greater, the solute does not yet have a homogeneous distribution in its volume. Although the transverse diffusion coefficient has been calculated with a good approximation to the reference (Elder-Fischer), since there is no strict control over the exact injection, the multiplier "k" may vary. In this case, the L_0' figure can be considered more precise since it does not depend on this factor.

b) Rio Bogota, Colombia in 2024

The Bogota River near the flower farms in the capital is a small to medium-sized plain river with a gentle gradient. In this day were used fluorescent tracer (RWT). Figure 10.



Source: Author

Figure 10: Bogota River, near capital, in Colombia.

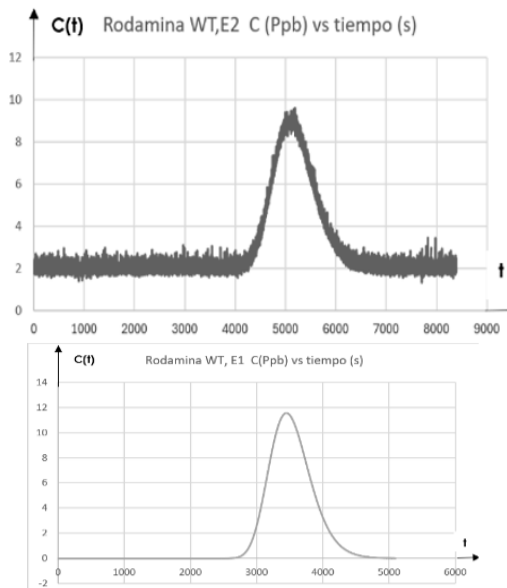
The river experimental data on that day were in Table 2.

Table 2: Experimental data at Rio Bogota

Date: September 5, 2024. 2ond station curve
2ond curve length: $X = 3515.0$ (m)
Width: $W \approx 20.0$ (m)
Depth: $H \approx 2.3$ (m)
Hydraulic radius: $R \approx 1.58$ (m)
Slope: $S \approx 0.0006$
Cross-sectional area: $A_{yz} \approx 38.8$ (m ²)
Roughness (Manning): $n \approx 0.025$
Flow rate: $Q \approx 26.8$ (m ³ /s)
Average velocity: $U \approx 0.69$ (m/s)
Mass (RWT): $M \approx 160.0$ (g)
Peak time Second curve: $t_p \approx 5097.0$ (s)
State function: $\Phi \approx 0.167$
Longitudinal coefficient: $E \approx 7.25$ (m ² /s).

Source: Author

The experimental tracer curve and its model, eq. (10), for that experiment at the second station, are shown in Figure 11.



Source: Author

Figure 11: Experimental curve (red) and superimposed model (gray)

As can be seen, the "Complete Mixing" condition for Dispersion was reached at an earlier point, since $\Phi < 0.38$, therefore equation (7) must be applied to calculate approximately the distance X_1 at which it occurred with $\Phi_1 \approx 0.38$:

$$\sqrt{X_1} \approx \left(\frac{\Phi_2}{\Phi_1} \right) * \sqrt{X_2} \quad (41)$$

And then:

$$\sqrt{X_1} \approx \left(\frac{0.167}{0.38} \right) * \sqrt{3515} \approx 26.1 \text{ (m}^2\text{)} \quad (42)$$

And therefore, $X_1 \approx Lo' \approx 681.0$ (m)

Now, eq. (30) is then calculated for $\Phi \approx 0.38$:

$$\frac{\sigma_x}{\sigma_y} \approx \frac{2.126}{(0.38)^{0.969}} \approx 5.43 \quad (43)$$

And the transverse transport coefficient, ϵ_y , is in eq. (33):

$$\epsilon_y \approx \frac{E}{\left(\frac{\sigma_x}{\sigma_y} \right)^2} \approx \frac{7.26}{5.43^2} \approx \frac{7.26}{29.5} \approx 0.25 \left(\frac{\text{m}^2}{\text{s}} \right) \quad (44)$$

It is verified against the value obtained by Elder-Fischer:

$$\epsilon_y \approx 0.6 * 2.3 * \sqrt{2.3 * 9.83 * 0.0006} \approx 0.160 \left(\frac{\text{m}^2}{\text{s}} \right) \quad (45)$$

The ratio of the two results are 1.56, then, of the same order of magnitude, and are accepted as valid verification.

$$Lo \approx \frac{0.1 * 0.69 * 20^2}{0.25} \approx 662.4 \text{ (m)} \quad (46)$$

Comparing with Lo' , calculated with equation (7), it is noted that $Lo' \approx Lo$ (same order) and it is accepted that the calculation on the width of the channel is equivalent to the criterion of homogeneous distribution of the tracer on the solute current tube.

c) Caltech Channel, USA in 1966

A third example is documented, a tracer experiment carried out by H. B. Fischer [29] on the 40 (m) calibrated channel of the W. M. Keck Laboratory at Caltech, in 1966. In this experiment (Series 2700), Fischer injected NaCl as a tracer, measuring two sequential curves. The objective of the experiment was to test Elder's diffusion theory. Figure 12.



Source : [3]

Figure 12: W.M. Keck 40 (m) channel in Caltech. USA

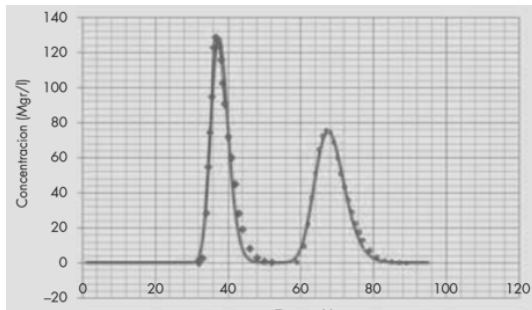
The channel experimental data on that day were in Table 3:

Table 3: Experimental data at Caltech channel

Date: 1966. 2ond station curve.
2nd curve length: $X = 25.06$ (m)
Width: $W \approx 1.09$ (m)
Depth: $H \approx 0.128$ (m)
Hydraulic radius: $R \approx 0.104$ (m)
Slope: $S \approx 0.0002$
Cross-sectional area: $A_{yz} \approx 0.14$ (m ²)
Roughness (Manning): $n \approx 0.009$
Flow rate: $Q \approx 0.053$ (m ³ /s)
Average velocity: $U \approx 0.372$ (m/s)
Mass (NaCl): $M \approx 40.5$ (g)
Peak time 2ond curve: $t_p \approx 67.4$ (s)
State function 2ond curve: $\Phi \approx 0.130$
Longitudinal coefficient: $E \approx 0.0169$ (m ² /s).

Source: Author

The experimental (dotted lines) two tracer curves and the models (thick continuous lines), are shown in Figure 13.



Source: Author

Figure 13: Experimental curves (dotted) and superimposed model (thick continuous line)

As can be seen, the "Complete Mixing" condition for Dispersion was reached at an earlier point, since $\Phi < 0.38$, therefore eq. (7) must be applied to calculate approximately the distance at which it occurred, with $X_2 \approx 25.06$ (m), and $\Phi_2 \approx 0.130$. It is necessary that $\Phi_1 \approx 0.38$ as explained.

$$\sqrt{X_1} \approx \left(\frac{\Phi_2}{\Phi_1} \right) * \sqrt{X_2} \quad (47)$$

And then:

$$\sqrt{X_1} \approx \left(\frac{0.130}{0.38} \right) * \sqrt{25.06} \approx 1.71 \text{ (m}^{\frac{1}{2}}\text{)} \quad (48)$$

And therefore, $X_1 \approx Lo' \approx 2.93$ (m)

Now, eq. (30) is then calculated for $\Phi \approx 0.38$

$$\frac{\sigma_x}{\sigma_y} \approx \frac{2.126}{(0.38)^{0.969}} \approx 5.43 \quad (49)$$

And the transverse transport coefficient, ϵ_y , is in eq. (33):

$$\epsilon_y \approx \frac{E}{\left(\frac{\sigma_x}{\sigma_y} \right)^2} \approx \frac{0.0169}{5.43^2} \approx \frac{0.0169}{29.5} \approx 0.0006 \text{ (} \frac{m^2}{s} \text{)} \quad (50)$$

It is verified against the value obtained by Elder:

$$\epsilon_y \approx 0.6 * 0.128 * \sqrt{0.128 * 9.83 * 0.0002} \approx 0.00122 \text{ (} \frac{m^2}{s} \text{)} \quad (51)$$

The ratio of the two results are 4.92, not so convergent to unit, but of the same order of magnitude, and are accepted as valid verification.

The mixing length Lo , eq. (2), is:

$$Lo \approx \frac{0.1 * 0.372 * 1.09^2}{0.0006} \approx 73.7 \text{ (m)} \quad (52)$$

The two notable distances, Lo and Lo' , differ greatly in their values, indicating that longitudinal dispersion achieves the mixing effect first, rather than transverse diffusion, which has an exaggeratedly high value for the special scope of the channel, indicating that probably in artificial channels, with very small Longitudinal transport coefficient, the indicated method to establish "Complete Mix" is the Lo' calculation.

VI. RESULTS AND DISCUSSIONS

1. This article develops criteria to estimate when a flow reaches the "Complete Mixing" condition. When using the classic Rutherford formula, the transverse diffusion coefficient is calculated from the ratio of longitudinal and transverse variances, using a nonlinear distribution function of Φ , and the value of the longitudinal dispersion coefficient. The values of these calculations are convergent with those found by the Elder-Fischer formula. The alternative criterion is based on finding the distance from the tracer at which $\Phi \approx 0.38$, and the solute is considered homogeneously distributed in the volume covered by the tracer.
2. The first criterion estimates that the tracer fills the channel width, while the second does not.
3. In real streams, the two criteria can sometimes converge, and sometimes not. In very large rivers (with very large widths), where the "mixing lengths" calculated using the classic formula are very long, the other criterion should be preferred, since the interest is often to determine the advection-dispersion characteristics at a certain intermediate point (not across the entire width).
4. To characterize the evolution of the conservative solute in the flow, a state function Φ , is documented, which describes the different notable moments analyzed here.
5. To verify whether this value of ϵ_y is consistent with Elder's classic calculation, taken as a reference, the method is applied to a real field experiment.

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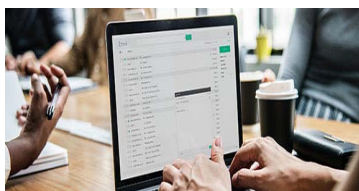
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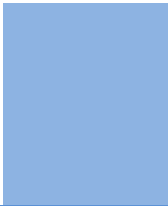
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Acknowledgments

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The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.



Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

- a) A title which should be relevant to the theme of the paper.
- b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
- c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
- d) An introduction, giving fundamental background objectives.
- e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
- f) Results which should be presented concisely by well-designed tables and figures.
- g) Suitable statistical data should also be given.
- h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

- i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
- j) There should be brief acknowledgments.
- k) There ought to be references in the conventional format. Global Journals recommends APA format.

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Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

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A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in a research paper?" Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

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Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

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Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.



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Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

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1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

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5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.



6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

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10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

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19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.



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23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium through which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

INFORMAL GUIDELINES OF RESEARCH PAPER WRITING

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

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To make a paper clear: Adhere to recommended page limits.



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- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

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Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.



The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
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- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

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This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.



Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- o Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- o In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- o Present a background, such as by describing the question that was addressed by creation of an exacting study.
- o Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- o Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- o Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- o Do not include raw data or intermediate calculations in a research manuscript.
- o Do not present similar data more than once.
- o A manuscript should complement any figures or tables, not duplicate information.
- o Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."



Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- o You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- o Give details of all of your remarks as much as possible, focusing on mechanisms.
- o Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- o One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- o Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

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<i>Introduction</i>	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
<i>Methods and Procedures</i>	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
<i>Result</i>	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
<i>Discussion</i>	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
<i>References</i>	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring



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