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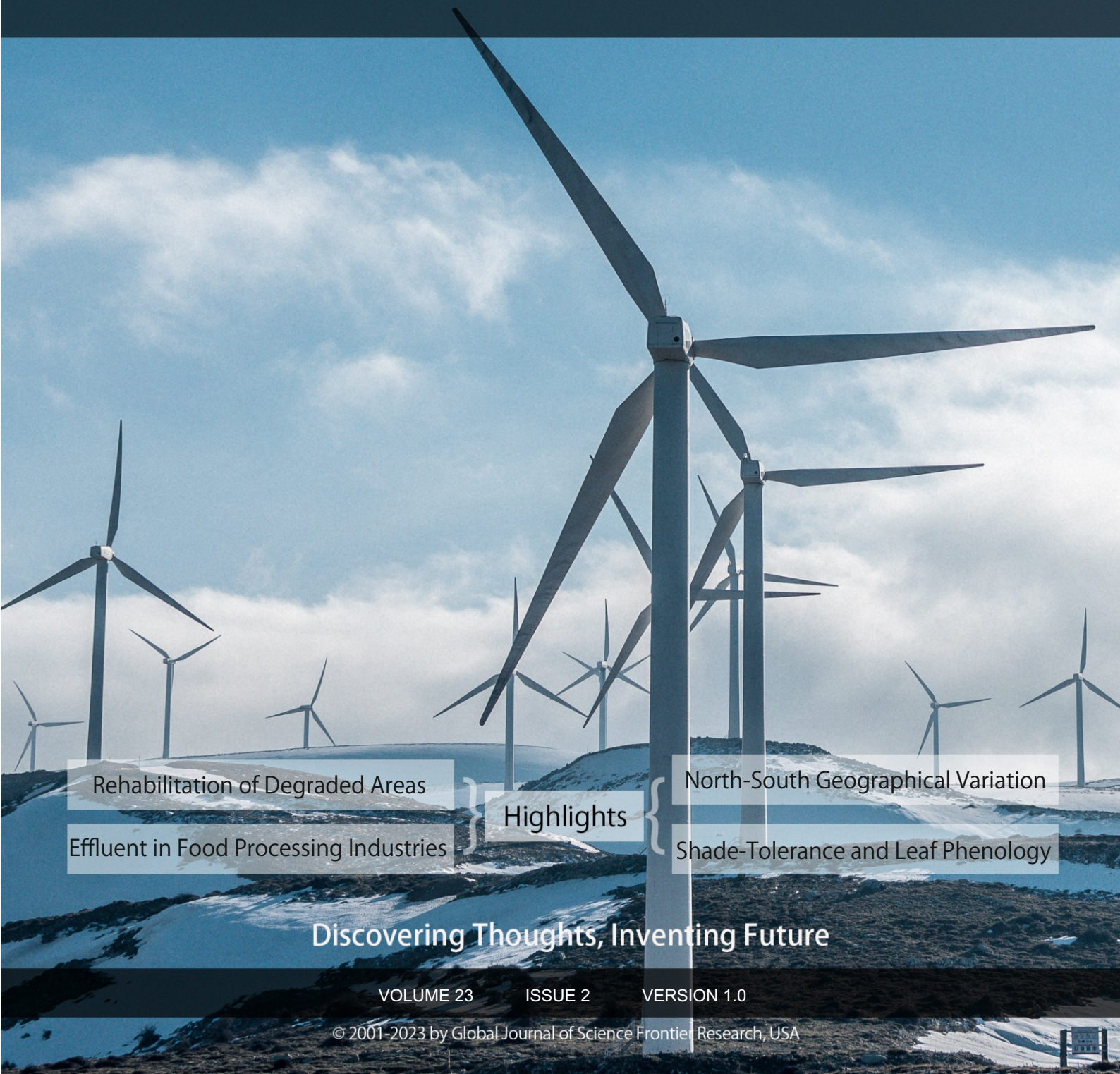

Rehabilitation of Degraded Areas

Effluent in Food Processing Industries

Highlights

North-South Geographical Variation

Shade-Tolerance and Leaf Phenology

Discovering Thoughts, Inventing Future

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Systemic Approach and use of Models for Rehabilitation of Degraded Areas

By Juarês José Aumond, Carlos Loch & Jucinei José Comin

Universidade Regional

Abstract- Based on general systems theory, in Optical Chaos Theory and aided by the Systems Engineering has developed an ecological model system for the environmental recovery treating the area as a complex dynamic system, hypersensitive to initial conditions to prepare the ground. Assuming that the degraded areas are hypersensitive to the initial conditions of soil preparation, we applied the technique to trigger the roughness over time emergent properties that speed up the process of environmental recovery. Was evaluated in the process of the evolution of environmental restoration components, soil, vegetation, wildlife, water and microclimate under the effect of roughness, as auxiliary components in the internalization of matter and energy in the degraded area. We compared the evolution of biotic and abiotic environmental variables in the model preparation of rugged terrain with the conventional model, consisting of flat surfaces and more regular. It was confirmed that the roughness behave as gravitational attractor generated islands of diversity, the system incorporates a dynamic hypersensitive to these initial conditions and act as nucleation triggering effect amplified by the feedback, which increase and accelerate the recovery environment.

Keywords: *environmental recovery, ecological model and systems general theory.*

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SYSTEMICAPPROACHANDUSEOFMODELSFORREHABILITATIONOFDEGRADEDAREAS

Strictly as per the compliance and regulations of:

Systemic Approach and use of Models for Rehabilitation of Degraded Areas

Abordagem Sistêmica e o uso de Modelos Para Recuperação deÁreas

Juarês José Aumond [σ], Carlos Loch [ρ] & Jucinei José Comin [ω]

Resumo- Com base na Teoria Geral dos Sistemas, na "Ótica da Teoria do Caos" e auxiliada pela Engenharia de Sistemas se desenvolveu um modelo ecológico de sistema para a recuperação ambiental tratando a área como um sistema dinâmico complexo, hipersensível às condições iniciais de preparação do terreno. Partindo da hipótese de que as áreas degradadas são hipersensíveis às condições iniciais de preparação do terreno, aplicou-se a técnica das rugosidades para desencadear ao longo do tempo propriedades emergentes que aceleram o processo de recuperação ambiental. Avaliou-se, no processo de recuperação ambiental a evolução dos componentes, solo, vegetação, fauna, água e microclima sob o efeito das rugosidades, como componentes auxiliares na internalização da matéria e energia na área degradada. Comparou-se a evolução das variáveis ambientais bióticas e abióticas no modelo de preparação do terreno irregular com o modelo convencional, formado por superfícies planas e mais regulares. Confirmou-se que as rugosidades se comportam como atratores gravitacionais que geram ilhas de diversidade, incorporando ao sistema uma dinâmica hipersensível a essas condições iniciais e funcionam como nucleadoras que desencadeiam efeitos amplificados pela retroalimentação, que potencializam e aceleram a recuperação ambiental. Todas as variáveis biométricas da espécie *Mimosa scabrella* (altura, diâmetro do colo, DAP e área da copa) e altura da vegetação espontânea apresentaram crescimento mais acelerado nas áreas irregulares, resultando em mudanças ambientais dos fatores abióticos. Concluiu-se que o modelo ecológico proposto e os resultados práticos obtidos validam o diagrama de influência como ferramenta importante para entender as relações de causalidade e retroalimentação das variáveis e sua evolução temporal no processo de recuperação ambiental.

Palavras-chave: recuperação ambiental, modelo ecológico e teoria geral dos sistemas.

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Abstract- Based on general systems theory, in Optical Chaos Theory and aided by the Systems Engineering has developed an ecological model system for the environmental recovery treating the area as a complex dynamic system, hypersensitive to initial conditions to prepare the ground. Assuming that the degraded areas are hypersensitive to the initial conditions of soil preparation, we applied the technique to trigger the roughness over time emergent properties that speed up the process of environmental recovery. Was evaluated in the process of the evolution of environmental restoration components, soil, vegetation, wildlife, water and microclimate under the effect of roughness, as auxiliary components in the internalization of matter and energy in the degraded area. We compared the evolution of biotic and abiotic environmental variables in the model preparation of rugged terrain with the conventional model, consisting of flat surfaces and more regular. It was confirmed that the roughness behave as gravitational attractor generated islands of diversity, the system incorporates a dynamic hypersensitive to these initial conditions and act as nucleation triggering effect amplified by the feedback, which increase and accelerate the recovery environment. All biometric variables Mimosa scabrella species (height, stem diameter, DBH and crown area) and height of the spontaneous vegetation had faster growth in irregular areas, resulting in environmental changes of abiotic factors. It was concluded that the ecological model proposed and the practical results obtained validate the influence diagram as an important tool to understand the causal relationships and feedback of the variables and their temporal evolution in the process of environmental recovery.

Keywords: environmental recovery, ecological model and systems general theory.

I. Introdução

Os fenômenos naturais, em sua maioria, constituem-se em sistemas dinâmicos complexos que apresentam dinâmica evolutiva determinada pela sua estrutura e pelos fatores externos, principalmente energéticos (radiação solar, luminosidade), materiais (precipitação e CO_2, entre outros) e causas endógenas (MACIEL, 1974; BERTALANFFY, 1975; ODUM, 1988; MATURANA;VARELA, 1997; SOUZA; BUCKERIDGE, 2004).

Para Odum (1988), a análise ecológica de um ecossistema passa necessariamente pelo uso de modelos que são versões simplificadas do mundo real. Os modelos são formulações que imitam um fenômeno real e permitem fazer predições quantitativas, por isso devem ser estatísticos e matemáticos (formais). No entanto, cabe destacar que os modelos podem também ser apenas conceituais. Nesse caso, utiliza-se um modelo gráfico constituído pelos círculos de causalidade para descrever o comportamento e as interações entre as variáveis bióticas e abióticas do sistema em recuperação (GRIFFITH; TOY, 2005).

Os sistemas ambientais são sistemas dinâmicos complexos, formados por grande número de elementos interligados, com capacidade de troca de informações com seu ambiente condicionante e capacidade de adaptar sua estrutura interna como consequência das interações entre seus elementos. De sua complexidade resulta a necessidade de uso de modelos para análise e interpretação (CRISTOFOLETTI, 2004).

Considerar um sistema como constituído de subsistemas e estes, por sua vez, pertencentes a um subsistema maior, na literatura da Teoria Geral de Sistemas ele é denominado ordem hierárquica (BERTALLANFFY, 1975). A modelagem começa com a construção de um diagrama. Para um modelo funcional de uma situação ecológica existem no mínimo quatro ingredientes: uma fonte de energia; propriedades, chamadas de variáveis de estado; vias de fluxo; e as interações ou funções interativas, em que as forças e as propriedades interagem para alterar, amplificar ou controlar os fluxos ou criar novas "propriedades emergentes" (ODUM, 1988).

Daenzer e Huber (1994) recomendaram a Engenharia de Sistemas (*Systems Engineering*) como modelo para análise e interpretação de sistemas complexos. De acordo com esses autores, é necessário que se identifiquem quais as entradas ou efeitos (*inputs*) e quais as saídas (*outputs*) relevantes do ambiente que geram influências sobre o sistema. Deve haver concentração especial orientada para a estrutura de fluxos do sistema, estruturas de processos e mecanismos. Tal enfoque é útil para interpretar e explicar como o *output* decorre do *input* ou como o *input* deve ser transformado no *output* desejado. É ainda relevante no procedimento de análise partir do geral para o detalhe (*top-down*), o que permite deslocar-se ora no âmbito do sistema mais abrangente, ora no âmbito de um subsistema, sem perder de vista o conjunto das inter-relações.

Griffith e Toy (2005), considerando que todo movimento de desencadeamento é sistêmico, recomendaram usar os círculos de causalidade para modelar processos de recuperação ambiental. Esses círculos se constituem na ferramenta principal do pensamento sistêmico e mostram a relação de causalidade e retroalimentação entre variáveis por meio de sequência cíclica. Para esses autores, o conjunto dos círculos de causalidade pode ser chamado de "diagrama de influências". Essa forma de modelagem ajuda entender os ecossistemas, porque geralmente seguem padrões circulares e não modelos lineares (ODUM, 1988).

Os círculos de causalidade consistem de variáveis interligadas por conectores, representados por arcos com setas. O *feedback* de reforço corresponde a pequenas ações que podem evoluir, transformando-se em grandes consequências positivas (círculos virtuosos) ou negativas (círculos viciosos), e o *feedback* de equilíbrio (círculos de balanceamento) é mecanismo para se atingir a homeostase (SENGE, 1999).

Entre as principais características dos sistemas dinâmicos complexos (sistemas caóticos) está o processo de retroalimentação (*feedback*), em que pequenas mudanças podem ocasionar efeitos dramáticos, pois podem ser amplificadas pela realimentação. A segunda propriedade é a existência de níveis críticos, ou patamares, a partir dos quais o sistema se desequilibra. Essa mudança de estado geralmente é causada por pequeno aumento no fluxo de matéria e energia (GLEICK, 1989; SOUZA; BUCKERIDGE, 2004).

A Teoria do Caos e a "matemática da complexidade", também denominada "Teoria dos Sistemas Dinâmicos", são ferramentas importantes para análises dos fenômenos naturais (GLEICK, 1989; SOUZA; BUCKERIDGE, 2004). Os sistemas caóticos se afastam da previsibilidade inicial, e o acaso é característica-chave (GLEICK, 1989; RUELLE, 1993; CAPRA, 1996; LORENS, 1996; SOUZA; BUCKERIDGE, 2004; CAMARGO, 2005). De acordo com esses autores, as principais características dos eventos caóticos são: hipersensibilidade às suas condições iniciais; só ocorrem com mais de três variáveis e, quanto mais complexo for o sistema, maior será sua possibilidade de caos; em seu estado inicial, os sistemas caóticos possuem previsibilidade zero e ocorrem sempre em espaço limitado. A Teoria do Caos é um caminho para se entenderem os fenômenos naturais que apresentam comportamento aparentemente aleatório, mas que, analisados estatisticamente, são, na realidade, gerados por sistemas estocásticos.

Estudos realizados por Anand e Desrochers (2004) utilizando modelos e conceitos de sistemas complexos para avaliar o processo de restauração

ambiental sugerem a validação da teoria do caos (sistemas dinâmicos complexos) para compreender e quantificar os processos de recuperação ambiental. Consideram conceitos de atratores e padrões de comportamento das comunidades no lugar de focalizar medidas de espécies bióticas individuais. A análise dos componentes principais, embora seja técnica linear, pode ajudar a detectar trajetórias não lineares da recuperação ambiental. Com base na teoria do caos, duas fases na recuperação foram detectadas: uma fase linear inicial com a evolução da comunidade e a consequente redução da área desmatada e uma segunda fase na qual a restauração evolui em resposta a um atrator estranho, e o seu estado final é de difícil previsão, mas representa as circunstâncias necessárias para que o sistema ecológico siga suacomplexa trajetória natural.

Entre os vetores que têm gerado significativa degradação ambiental na esfera global estão a mineração, a agricultura, a urbanização e a pecuária. As principais alterações ambientais provocadas pela mineração são a supressão da vegetação, a mudança da superfície topográfica, o impacto visual, a indução de escorregamentos, a destruição da fauna, a aceleração dos processos erosivos, o assoreamento e entulhamentode cursos d'água e a mudança no nível freático, entre outros (GRIFFITH, 1980; BITAR, 1997; ZIMMERMANN; TREBIEN, 2001).

Os avanços das técnicas de recuperação, conseguidos isoladamente, ainda carecem de modelo ecológico integrador, e, para que esses avanços ainda circunscritos nas várias áreas do conhecimento possam somar esforços, é necessária uma abordagem sistêmica.

Considerando a área degradada como um sistema dinâmico complexo, hipersensível às condições iniciais de preparação do terreno, o objetivo deste trabalho foi avaliar os componentes solo, rugosidades (pequenas variações do relevo alternando superfícies côncavas e convexas), vegetação (*Mimosa scabrella*, herbáceas e arbustivas), fauna (invertebrados), água e microclima(radiação) no processo de recuperação ambiental em uma área de mineração de argila.

II. Material e Métodos

A área objeto deste estudo situa-se no Município de Doutor Pedrinho, SC, na localidade de Campo Formoso, encravada no Médio Vale do Itajaí, com predomínio de Cambissolos Húmicos Alumínicos (UBERTI, 2005). As coordenadas geográficas da área são: latitude sul (26° 39' 15") e longitude oeste (49° 29' 15"). De acordo com Köppen (1948), o clima é classificado como mesotérmico úmido (Cfb), sem estação seca definida, apresentando temperatura média anual de 19,7 °C e precipitação total anual entre 1.600 e 1.700 mm (ATLAS DE SANTA CATARINA, 1986). A área é formada por altiplanos sedimentares com vegetação rasteira e fragmentos de Floresta Ombrófila Mista, ladeados inferiormente por escarpas abruptas de arenitos que circundam vales, onde se desenvolvem fragmentos de Floresta Ombrófila Densa (AUMOND, 2007).

Os principais componentes de um ecossistema eleitos para o experimento, baseados na literatura (ODUM, 1988; VIVAN, 1998; KHATOUNIAN, 1999; AUMOND, 2003; RICKLEFS, 2010), que integram o modelo de sistema para a recuperação da área degradada,incluem solo, água, vegetação, fauna (invertebrados), microclima e rugosidades do terreno. As rugosidades são pequenas variações do relevo com profundidades variando de 40 a 75 cm e largura de 100 a 500 cm, as quais foram executadas com o auxílio de uma escavadeira hidráulica. Vale salientar que, na mineração, as rugosidades do terreno são consequências da própria explotação mineral e da regularização topográfica com máquinas, que é rotina na mineração e provoca a compactação do solo, com consequente aumento da densidade e diminuição da infiltração da água, retardando a recuperação desse solo.

As rugosidades são constituídas por superfícies convexas propícias ao processo erosivo, estando associadas a superfícies côncavas que constituem pequenas depressões que auxiliam na internalização da matéria e energia no próprio sistema. São variáveis do relevo (AUMOND, 2003) que influenciam a água, a vegetação, a fauna e o solo, além de representarem as irregularidades da superfície do terreno, a que Guerra (1999) denominou microtopografias. As rugosidades influenciam o microclima, que é expresso pela radiação, temperatura ambiente, temperatura do solo e umidaderelativa do ar.

No diagrama simplificado da Figura 1, estruturado para avaliar a evolução do experimento, estão representados, no nível A, o sistema ambiente (vizinhança) com seus componentes e o sistema degradado com os componentes selecionados, que estão representados no nível B. A organização dos componentes do modelo (Figura 2), representados hierarquicamente no diagrama simplificado (Figura 1), permite o pesquisador deslocar-se de um nível para outro sem perder de vista o conjunto. Os componentes selecionados dispostos em ordem hierárquica, ao serem analisados no nível B, são os subsistemas da área degradada e constituem

nodos inter-relacionados, formando uma rede. As linhas representam as interações e as setas, o sentido das interações entre duas variáveis (e.g. água e solo), podendo indicar se o efeito é no mesmo sentido ou em sentido oposto. Assim, por exemplo, mais água escoando pela superfície pode representar mais erosão no subsistema solo. Maior cobertura vegetal significa maior amenização ambiental microclimática devido à menor radiação solar que resulta em temperaturas menores do ambiente e do solo e maior umidade relativa do ar. As rugosidades como variações do relevo podem significar mais água, sedimentos (solo) e propágulos retidos no sistemadegradado.

Considerando a eleição dos seis componentes no sistema área degradada, para determinar a intensidade das relações entre si e com o ambiente do entorno e o grau de importância os componentes foram representados numa matriz, em que os elementos foram ordenados em linhas e colunas (Tabela 1). Para determinar

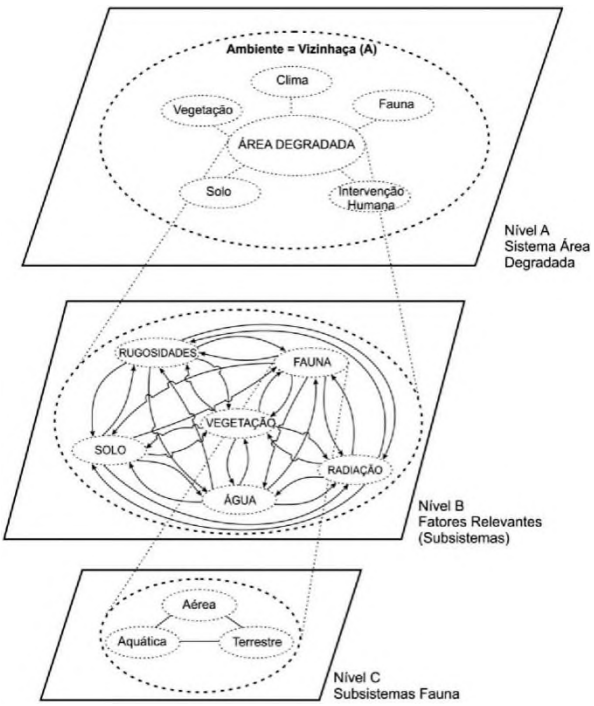

Figure 1: Simplified diagram of the system with degraded components of the environment (level A). At level B are represented elements (subsystems) of the degraded area and level C are represented constituents in the fauna

Figura 1: Diagrama simplificado do sistema degradado com os componentes do ambiente (nível A). No nível B estão representados os elementos (subsistemas) da área degradada e no nível C estão representadosos componentes do subsistema da fauna

a intensidade das relações entre os componentes do sistema e o ambiente, optou-se por aplicar quatro graus de intensidade, variando de 0 a 3, que representam: 0 = a intensidade da relação é nula; 1 = a intensidade da relação é fraca; 2 = a intensidade da relação é média; e 3 = a intensidade da relação é intensa (forte).

A determinação das intensidades das relações foi definida empiricamente através das observações de campo, avaliando-se sempre as quatro alternativas degraus de intensidades.

Partindo da análise da matriz, pode-se estruturar a concepção do modelo do sistema ecológico para recuperação da área degradada, evidenciando graficamente as principais relações e intensidades, existentes entre os subsistemas que o compõem (Figura 2).

A abordagem sistêmica com enfoque mais geral considera a teia complexa das interações de todos os elementos e fatores determinantes do processo e evita a sobrevalorização de um fator específico em detrimento de outros. A recuperação ambiental de uma área não pode ser avaliada apenas pela quantificação biométrica. São das medidas e da análise da interação de todos os elementos e fatores ecológicos que se podem avaliar comparativamente as áreas em processo de recuperação. Nesse projeto, fez-se a análise integrada das inter-relações dos elementos bióticos e abióticos, bem como sua evolução com o auxílio do modelo ecológico para recuperação da área degradada.

Para a pesquisa foram utilizadas mudas de *Mimosa scabrella* que provieram de um mesmo lote de sementes adquiridas de um viveiro localizado em condições ambientais semelhantes às da área do experimento. Para garantir o rigor da metodologia científica, antes do plantio foram realizadas as medidas das alturas das mudas de *M. scabrella*, separando-as por classe de altura, de forma a permitir distribuição de mesma proporção em todas as parcelas.

Devido às condições extremamente adversas do substrato, optou-se por uma densidade de 4.501 mudas de *M. scabrella* por hectare, portanto superior ao recomendado na literatura, que é de 2 m x 2 m, correspondendo a 2.500 mudas por hectare. Por não se tratar de áreas planas e niveladas, não se aplicou a metodologia dos módulos com linhas regulares em forma de quincôncio nas parcelas irregulares. Primeiro foram implantadas nas parcelas irregulares as mudas com espaçamento variável entre si, adaptando-se sua distribuição de acordo com as rugosidades. Após conhecidas as densidades de mudas, isto é, o número de mudas, repetiu-se a mesma densidade nas parcelas planas regulares, porém espacejadas em linhas e comdistribuição espacial em quincôncio. Em razão da dimensão e superfície da área de pesquisa, foram plantadas 1.738 mudas de *M. scabrella* em todas as parcelas do experimento. A abertura das covas foi realizadacom escavadeira manual com 15 cm de diâmetro por 25 cm de profundidade.

Baseado em análises de solos, foram adicionados os nutrientes superfosfato triplo, cloreto de potássio e ureia. A adubação química foi realizada com base no Sistema de Recomendação de Adubação e Calagem do RS e SC (ROLAS, 2004).

Foram monitoradas as seguintes variáveis abióticas: radiação solar (W/m^2); temperatura ambiente (^{o}C); umidade relativa do ar (%); oscilações do gradiente térmico do solo nos vários estádios da sucessão vegetal; variação da umidade, densidade e porosidade do solo; coeficiente de infiltração, coeficiente de

Tabela 1: Representação do grau de intensidade das relações entre os componentes do sistema, representados em forma de matriz

Table 1: Representation of the Intensity of the Relationship between System Components Represented in Matrix form

Componente Que Exerce Influência	Componente Influenciado						
	Solo	Água	Vegetação	Radiação	Rugosidade	Fauna	Ambiente
Solo	0	2	3	1	2	1	1
Água	3	0	3	3	1	3	1
Vegetação	3	3	3	3	1	3	1
Radiação	2	2	2	0	0	2	1
Rugosidade	2	3	3	2	0	2	0
Fauna	2	0	3	0	0	3	2
Ambiente	2	2	3	3	0	3	0

escoamento superficial e conservação da água; e perdas do solo e evolução das características químicas do solo.

Para as medições da temperatura do solo (^{o}C), umidade relativa do ar (%) e radiação solar (W/m^2), foi instalado um sistema de aquisição de sinais acoplados a um computador tipo *notebook*. As medidas de temperatura do solo foram realizadas com 16 sensores do tipo termistores – NTC, com incerteza da medida de 0,2 ^{o}C. As medidas do sistema de aquisição cobriram um período de dois anos.

A umidade do ar foi medida, no mesmo sistema com sensores de umidade do tipo *capacitivo*, com incerteza de 0,5%, instalados a 1,3 m de altura.

O sistema de aquisição de sinais que registra a radiação solar de todo o espectro eletromagnético foi medido por sensores do tipo *termo-elementos* com incerteza de 5%. Esses *termo-elementos* foram inseridos próximos dos sensores da umidade do ar e realizaram as medidas contínuas automaticamente em W/m^2.

As temperaturas foram tomadas por quatro termômetros de máximas e mínimas, colocados nas quatro parcelas na altura de 1,3 m da superfície do terreno. As medidas, em graus centígrados, foram registradas manualmente com o auxílio de termômetros da Incoterm, que mediram as temperaturas máximas e mínimas do ambiente (ar) a cada 24 h, nas quatro parcelas.

Para avaliar a conservação da água e perdas do solo (erosão), foram instaladas canaletas de concreto semicirculares com diâmetro de 30 cm, numa extensão de 15m cada. Na base dessas canaletas foram instalados sistemas coletores de

água e solo erodido. Os coletores consistem de quatro tanques pré-fabricados de concreto com 80 cm de diâmetro, o primeiro funcionando como decantador das partículas maiores. O excesso de escoamento passava por divisores Geib de alumínio, cuja função era dividir o fluxo do escoamento e obter apenas uma fração; por isso possuíam número ímpar de janelas verticais. A água que passava pela janela central era conduzida para o tanque seguinte para ser coletada, e as demais janelas conduziam a água para um sistema de deságue (BERTONI; LOMBARDI, 1985). Esses equipamentos permitiram a determinação da concentração dos sedimentos, as análises granulométricas do solo e o tratamento estatístico com a série de dados da precipitação.

Para avaliar a capacidade de infiltração do solo, aplicou-se o teste de infiltração de água no solo de acordo com a norma NBR-7229, da Associação Brasileira de Normas Técnicas (ABNT).

Para monitorar a evolução química e física do solo, foram programadas três fases de coletas de amostras para análises de solo dos primeiros 15 cm de cada parcela. As análises químicas foram efetuadas de acordo com a metodologia descrita por Tedesco et al. (1995). Nos componentes físicos, determinaram-se a densidade aparente, a porosidade total (VTP), a umidade gravimétrica e a temperatura do solo.

As medidas de biometria abrangeram a totalidade dos indivíduos plantados de *M. scabrella* (1.738 indivíduos). As variáveis monitoradas foram: taxa de sobrevivência das mudas; desenvolvimento das mudas (o diâmetro do caule a uma altura-padrão de 5 cm do solo; as medidas do diâmetro à altura do peito - DAP; a altura total dos indivíduos, medida da base até o limite superior do último meristema apical; e a área da copa em sua porção mais desenvolvida). Foram também monitorados os índices de cobertura do solo e a caracterização da composição florística (biodiversidade vegetal: ervas, arbustos e arbóreas que se instalaram espontaneamente). Para obtenção do índice de cobertura do solo, foi utilizado o método de quadrantes.

Para avaliar diferenças significativas de tamanhos (diâmetro, altura e diâmetro de copa) e número de espécies espontâneas colonizadoras, foi utilizado o teste t nas amostras independentes com nível de significância de 5%, conforme Beiguelman (2002).

A caracterização da composição florística foi realizada através da elaboração de uma lista das espécies encontradas no local de estudo, comparando-se o número de espécies (herbáceas, arbustivas e arbóreas) entre as parcelas regulares e irregulares. Foram calculados os índices de similaridade de SΦrensen (MULLER- DOMBOIS; ELLEMBERG, 1974) e de Jaccard (MAGURRAN, 1988).

O subsistema fauna de invertebrados é composto pelos seguintes elementos: fauna aérea, fauna terrestre e fauna aquática. Para caracterização do subsistema fauna de invertebrados, foram instaladas armadilhas, os quais, posteriormente, foram triados em laboratório com o auxílio de microscópio estetoscópio para classificação da fauna aérea e da fauna terrestre. Nesta pesquisa não foi avaliada a fauna aquática de invertebrados. As variáveis medidas nos dois componentes do subsistema fauna foram: riqueza, diversidade, similaridade, dominância, equidade e rarefação. A diversidade faunística foi medida com base no número de ordens e número de indivíduos por ordens identificados nas parcelas.

As análises foram realizadas usando-se o pacote estatístico PAST (HAMMER et al., 2001) e incluíram a diversidade (índice de Shannon), dominância e equidade. Os índices de Shannon foram comparados através do teste t modificado (MAGURRAN, 1988). Para avaliar a variabilidade da riqueza em função das coletas (riqueza x amostras), foram construídos gráficos de rarefação. A riqueza refere-se ao número de ordens identificadas em cada parcela. A abundância refere-se ao número de indivíduos por unidade de área avaliada e varia no espaço (área) de uma comunidade para outra e no tempo em função das flutuações populacionais. A diversidade determina a representação dos indivíduos de cada ordem nas comunidades. A equidade indica como os indivíduos

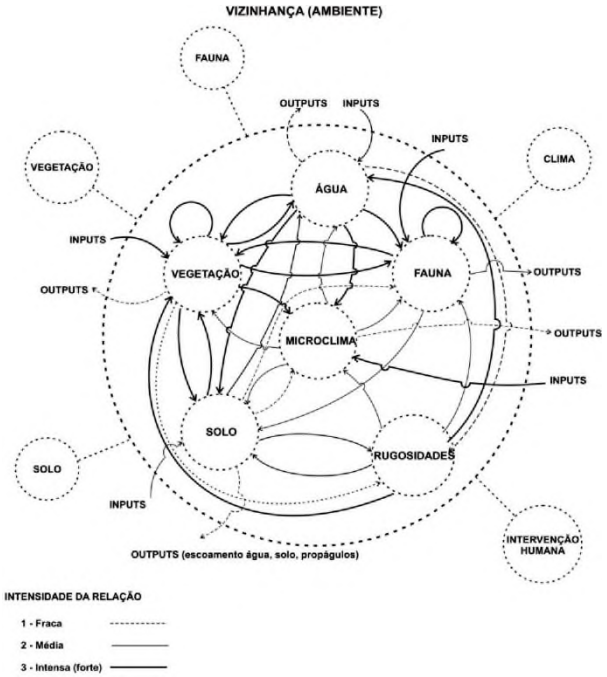

Figure 2: Design of the model system for ecological restoration of a degraded ecosystem

Figura 2: Concepção do Modelo de Sistema Ecológico Para Recuperação de um Ecossistema Degradado

estão distribuídos entre as ordens. A dominância é a proporção dos organismos mais abundantes de um talhão, calculada para cada ambiente.

III. Resultados

A análise dos dados da radiação solar evidenciou o efeito da vegetação na incidência da radiação nas duas áreas, a regular e a irregular (Figura 3a). Verificou- se, ao longo do tempo, aumento da diferença da radiação entre as duas áreas, que seguiu tendência definida pelo estabelecimento da vegetação. A radiação nas áreas irregulares foi menor desde o verão de 2005, após um ano da implantação do experimento. Nesse período, a média da radiação nas áreas irregulares variou de 28,90 a 212,62 W/m^2, enquanto nas áreas regulares, de 93,54 a 405,77 W/m^2. No entanto, as diferenças tornaram-se estatisticamente significativas a partir das medidas efetuadas no inverno de 2005 e continuaram assim até as últimas medidas realizadas no verão de 2006.

Muitos dos atributos inerentes às funções dos ecossistemas podem ser afetados pela mudança da radiação solar, como produção de biomassa, flutuações nas populações das plantas e animais, mudanças no ciclo dos nutrientes, entre outros. Os estudos do efeito do aumento da radiação solar sobre os ecossistemas se iniciaram há poucos anos, e menos de 5% desses estudos foram executados em condições de campo e, menos ainda, sobre as plantas das florestas (CALDWELL et al., 1998). Por isso a importância de se conhecerem melhor as interações entre a radiação solar e as plantas e como esses componentes interagem temporalmente no processo de recuperação ambiental.

A temperatura do solo é fator relevante do ponto de vista ecológico no processo de recuperação ambiental de áreas degradadas. Observaram-se diferenças significativas nos dois tratamentos, nas diferentes profundidades, após o segundo ano do experimento (Figura 3b).

A irregularidade da superfície (rugosidades) provocou maior reflexão difusa da radiação solar na ausência da vegetação. Assim, além de amenizar a temperatura do solo e do ar, criou micronichos diferenciados, estimulando o estabelecimento e produção vegetal, que por sua vez passou a ter efeito de *feed- back* no processo da sucessão vegetal. A temperatura ambiente máxima e a mínima sempre foram superiores nas áreas regulares, confirmando o efeito de amenização da temperatura ambiente provocado pelo estádio mais avançado da recuperação ambiental nas áreas irregulares (Figura 3c).

Na avaliação do diâmetro da *M. scabrella*, as parcelas irregulares apresentaram valores superiores e estatisticamente diferentes daqueles das parcelas regulares (Figura 3d).

A

Período	Radiação Solar (W/m²)		P_{Calc}
	Regular	Irregular	
02 a 07/02/2005	170,60	150,02	0,1466
13 a 18/02/2005	243,22	212,05	0,0938
14/02/2005	248,13	212,62	0,4261
14 a 20/07/2005	93,54	28,90	$5,57x10^{-25}$
02 a 08/11/2005	405,77	171,32	$8,37x10^{-10}$
06/11/2005	336,84	120,19	$1,95x10^{-06}$
22 a 26/02/2006	334,79	84,62	$2,74x10^{-35}$

B

Período	Temperatura do solo (ºC)					
	Profundidade 2,5 cm			Profundidade 7,5 cm		
	Regular	Irregular	P_{calc}	Regular	Irregular	P_{calc}
02 a 07/02/2005	22,39	21,64	$3,36x10^{-29}$	22,52	21,58	$1,83x10^{-29}$
13 a 18/02/2005	22,70	23,11	$9,14x10^{-13}$	23,99	23,15	$1,71x10^{-14}$
14 a 20/07/2005	13,34	14,86	$2,32x10^{-85}$	13,30	14,50	$1,74x10^{-40}$
02 a 08/11/2005	20,68	19,92	$7,15x10^{-36}$	21,05	20,04	$3,14x10^{-54}$
22 a 26/02/2006	21,85	22,58	$1,89x10^{-32}$	22,51	22,79	$3,80x10^{-05}$

C

Período	Temperatura Ambiente (ºC)					
	Máxima			Mínima		
	Regular	Irregular	P_{calc}	Regular	Irregular	P_{calc}
19 a 29/11/2005	30,77	27,82	0,007	15,05	13,77	0,098
04 a 18/02/2006	29,17	26,27	0,036	18,90	18,27	0,258

D

Parcela	Diâmetro basal do caule (mm)								
	Maio de 2004			Dezembro de 2004			Fevereiro de 2006		
	Regular	Irregular	P_{calc}	Regular	Irregular	P_{calc}	Regular	Irregular	P_{calc}
1110	9,39	14,48	$1,69x10^{-43}$	27,53	35,72	$3,47x10^{-19}$	43,74	56,19	$2,51x10^{-21}$
820	7,42	15,03	$2,52x10^{-72}$	20,58	35,92	$4,79x10^{-72}$	37,56	59,56	$1,04x10^{-64}$
Média	8,51	14,73	$1,2x10^{-110}$	24,45	35,81	$3,53x10^{-70}$	40,65	57,73	$5,4x10^{-72}$

*Figure 3: Solar radiation (W/m²) of the Feb/2005 and Feb/2006 treatments regular and irregular (A) Soil temperature of the Feb/2005 and Feb/2006 treatments regular and irregular 2.5 and 7.5 cm depth (B), maximum and minimum temperature 19-29 Nov/2005 and Feb/2006 4-18 in regular and irregular treatments (C), basal diameter (mm) of the stem of **M. scabrella** in May 2004, Dec/2004 and in Feb/2006 irregular and regular treatments (D)*

Figura 3: Radiação solar (W/m²) de fev/2005 a fev/2006 nos tratamentos regular e irregular (A); temperatura do solo de fev/2005 a fev/2006 nos tratamentos regular e irregular a 2,5 e a 7,5 cm de profundidade (B); temperatura ambiente máxima e mínima de 19 a 29 nov/2005 e 4 a 18 fev/2006, nos tratamentos irregular e regular (C) e; diâmetro basal (mm) do caule de *M. scabrella* em maio 2004, dez/2004 e fev/2006 nos tratamentos irregular e regular (D)

A

Parcela	Fevereiro de 2006		
	Regular	Irregular	P_{Calc}
1110	22,04	34,13	$1,21x10^{-26}$
820	15,9	38,52	$2,5x10^{-102}$
Média	19,32	36,14	$8,05x10^{-101}$

B

Parcela	ÉPOCAS DE AVALIAÇÃO								
	Maio de 2004			Dezembro de 2004			Fevereiro de 2006		
	Regular	Irregular	P_{Calc}	Regular	Irregular	P_{Calc}	Regular	Irregular	P_{Calc}
1110	59,5	104,82	$1,9x10^{-54}$	210,16	268,13	$1,2x10^{-22}$	327,64	453,57	$1,4x10^{-41}$
820	45,96	105,51	$2,8x10^{-77}$	163,25	293,09	$3,1x10^{-95}$	270,18	525,77	$3,8x10^{-150}$
Média	50,36	105,13	$7,6x10^{-142}$	176,54	279,43	$3,9x10^{-124}$	279,89	486,69	$2,1x10^{-204}$

C

Parcela	ÉPOCAS DE AVALIAÇÃO								
	Maio de 2004			Dezembro de 2004			Fevereiro de 2006		
	Regular	Irregular	P_{Calc}	Regular	Irregular	P_{Calc}	Regular	Irregular	P_{Calc}
1110	0,09	0,25	$2,12x10^{-50}$	0,95	1,43	$2,85x10^{-12}$	1,83	3,13	$4,03x10^{-24}$
820	0,05	0,25	$7,76x10^{-55}$	0,52	1,67	$6,52x10^{-75}$	1,41	3,66	$2,46x10^{-59}$
Média	0,07	0,25	$1,06x10^{-103}$	0,76	1,54	$2,10x10^{-61}$	1,65	3,37	$2,13x10^{-75}$

D

Parcela	ÉPOCAS DE AVALIAÇÃO								
	Maio de 2004			Dezembro de 2004			Fevereiro de 2006		
	Regular	Irregular	P_{Calc}	Regular	Irregular	P_{Calc}	Regular	Irregular	P_{Calc}
1110	18,18	25,74	0,15	19,74	59	0,0014	91,75	84,38	0,46
820	15,19	28,37	0,012	57,56	62,62	0,27	89	76,88	0,27
Média	16,68	27,06	0,004	38,65	64,31	0,004	90,38	80,63	0,179

*Figure 4: Diameter at breast height (mm) in Feb/2006 irregular and regular treatments (A), overall height (mm) in May/ 2004; Dec/2004 and Feb/2006, irregular and regular treatments (B); area canopy (m^2) in May/2004; Dec/2004 and Feb/2006, irregular and regular treatments of **M. scabrella** (C); coverage ratio (%) of soil by spontaneous vegetation plots in regular and irregular in May/2004; Dec/2004 and Feb/2006, irregular and regular treatments (D)*

Figura 4: Diâmetro à altura do peito (mm) em fev/2006 nos tratamentos irregular e regular (A); altura total (mm) em maio/2004; dez/2004 e fev/2006, nos tratamentos irregular e regular (B); área de copa (m^2) em maio/2004; dez/2004 e fev/2006, nos tratamentos irregular e regular de *M. scabrella* (C) e; índice de cobertura (%) do solo pela vegetação espontânea nas parcelas regulares e irregulares em maio/2004; dez/2004 e fev/2006, nos tratamentos irregular e regular (D)

O DAP da *M. scabrella* após 26 meses da implantação do experimento foi significativamente maior nas áreas irregulares, em comparação com as áreas regulares (Figura 4a).

A análise da altura média da *M. scabrella* demonstrou crescimento contínuo tanto nas áreas irregulares quanto nas regulares. No entanto, ocorreu diferenciação crescente entre a altura dos indivíduos das áreas irregulares em relação às áreas regulares (Figura 4b). Os indivíduos de *M. scabrella* apresentaram maiores valores médios das áreas de copa nas parcelas com solo irregularizado (Figura 4c).

A análise do índice de cobertura do solo pela vegetação espontânea (herbáceas e arbustivas) no período de maio de 2004 a dezembro de 2004 demonstrou um índice de cobertura maior nas áreas irregulares (Figura 4d). No entanto, nas medidas de fevereiro de 2006 houve inversão com maior cobertura nas áreas regulares. O maior índice de cobertura nas áreas regulares decorreu de várias razões ecológicas, entre elas o menor desenvolvimento da *M. scabrella* e maior radiação solar. Nas áreas irregulares, as gramíneas e herbáceas já tinham perecido e cumprido seu papel de pioneiras naquele estádio da recuperação ambiental, enquanto nas áreas regulares ainda cobriam o solo. Nas áreas irregulares, inúmeros fatores como menor irradiação solar, menor temperatura do ambiente, entre outros, resultantes do maior desenvolvimento da *M. scabrella*, provocaram progressivamente diminuição das condições ecológicas propícias às gramíneas e herbáceas.

A elevada riqueza florística estabelecida espontâneamente (151 táxons entre espécies e morfoespécies), bem como a rapidez de colonização, evidencia o pool gênico na área de entorno, além da eficiência e eficácia dos mecanismos de dispersão e da capacidade de instalação das espécies em curto espaço de tempo. O destaque das famílias Asteraceae, Poaceae e Cyperaceae se deve, em grande parte, às estratégias de dispersão e capacidade de instalação que esses grupos de plantas possuem. Regensburguer (2004), em área próxima, após nove meses, constatou o estabelecimento expontâneo de 22 famílias com predominância das Asteráceas (35,7%), seguidas das Ciperaceae e Poaceae, com 10,7%. Em menores proporções, registraram-se as Euphorbiaceae, Rubiaceae, Solanaceae (7,1%), Commelinaceae, Myrsinaceae, Phytolaccacea e Polygonaceae, Solanaceae, Apiaceaee Lamiaceae, com 3,6%.

Para o componente fauna foram coletados nas armadilhas e triados um total de 8.715 indivíduos pertencentes a 12 ordens, dois pertencentes à classe Arachnida e 10 à classe Hexapoda. As ordens com maior abundância foram Diptera (3.004 indivíduos), Collembola (1.766), Coleoptera (1.121), Thysanoptera (1.114) e Hemiptera (819).

A partir da análise do número de espécimes por ordem, constatou-se que, entre as áreas de 820 m^2, a parcela irregular apresentou maior diversidade ($t = -3,5337$ e $p = 0,0004$). A parcela regular obteve maiordominância ($p = 0$). Os índices de riqueza ($p = 0,512$) que definem o número de ordens em cada parcela e a equidade ($p = 0,546$), que indica como os indivíduos estão distribuídos entre as ordens, não mostraram diferenças significativas entre as parcelas com 820 m^2.

Pela análise da rarefação se confirmou a diferença entre as duas parcelas de 820 m^2, evidenciando que, ao aumentar o número de amostragem, aumenta também a riqueza na área irregular. A diferença crescente da riqueza na área irregular (820 m^2), quando comparada com a regular (820 m^2), sugere que nesta se chegou a um patamar de ordem mais cedo, com menor esforço de coleta, estabilizando-se mais rapidamente.

Quando se comparam, entre si, as parcelas regulares e irregulares de 1.110 m^2, observa-se que a parcela irregular teve maior dominância ($p = 0$), no entanto a diversidade foi maior na parcela regular ($t = 7,8277$ e $p < 0,0001$). Não houve diferença significativa entre as áreas no índice de riqueza ($p = 0,883$) e equidade ($p = 0,168$). O teste de rarefação evidênciou que as parcelas regulares e irregulares com 1.110 m^2 são semelhantes entre si. Da análise comparativa entre as parcelas regulares (820 m^2 + 1.110 m^2) e irregulares (820 m^2 +1.110 m^2) conclui-se que, as parcelas regulares apresentaram maior diversidade ($t = 4,1176$; $p < 0,0001$). Os índices de riqueza($p = 1$), dominância ($p = 0,102$) e equidade ($p = 0,507$) não apresentaram diferenças significativas. A curva de rarefação não aponta diferença entre os dois tratamentos.

IV. Discussão

As variáveis abióticas e bióticas avaliadas estatisticamente validaram o uso do modelo de sistema ecológico aplicado na recuperação ambiental. As parcelas irregulares com rugosidades se comportaram como sistemas dinâmicos complexos, hipersensíveis às condições iniciais de preparação do solo.

Todas as variáveis biométricas da espécie *M. scabrella* (altura, diâmetro do colo, DAP e área da copa) e altura da vegetação espontânea apresentaram crescimento mais acelerado nas parcelas irregulares, resultando em mudanças ambientais dos fatores abióticos.

A comparação da altura dos indivíduos das parcelas irregulares com as parcelas regulares evidenciou um crescimento expressivamente maior nas parcelas irregulares. Confirmou-se nesta pesquisa a importância da *M. scabrella* na recuperação de áreas degradadas pela elevada produção de biomassa e por facilitar a sucessão secundária, por se desenvolver mesmo em condições edáficas adversas, conforme defendido por diversos autores (CARPANEZZI; CARPANEZZI, 1992; FRANCO et al., 1992; CALLAWAY, 1995; NAU; SEVEGNANI, 1997; REGENSBURGER, 2004; REGENSBURGER et al., 2008; REIS et al., 1999).

Guilherme (2000), analisando o efeito da cobertura do dossel da regeneração natural de plantas lenhosas em mata de galeria, constatou índices de cobertura que variaram de 57,7 a 77,3%, e a ocorrência de indivíduos da regeneração natural aumentou à medida que o índice de cobertura do dossel foi menor. Valores esses inferiores aos obtidos nesta pesquisa, tanto nas parcelas regulares quanto nas irregulares, após dois anos do plantio.

Como o objetivo prioritário da recuperação de áreas degradadas é proteger o solo com vegetação a fim de interromper os processos erosivos (CAMPELLO, 1996; DIAS; GRIFFITH, 1998; REIS et al., 1999), o percentual de cobertura do solo obtido neste estudo foi elevado, alcançando esse objetivo em apenas um ano e dois meses.

A essência da abordagem sistêmica está em ver inter-relacionamentos em vez de cadeias lineares de causa- efeito, bem como processos de mudança no lugar de simples fatos instantâneos. A elaboração de diagramas ou círculos de causalidade, constituído pelo arranjo dos componentes, facilitou a identificação e análise de padrões de interações. Permitiu reconhecer, no processo de recuperação, os tipos de "estruturas" (padrões de comportamento chamados de arquétipos) continuamente recorrentes, conforme sugeriu Senge (1999).

Verificou-se que os componentes bióticos e abióticos interagiram espacial e temporalmente, gerando padrões e propriedades ambientais emergentes diferenciadas nos dois tratamentos, em função do estabelecimento e desenvolvimento da vegetação. O modelo de sistema ecológico para a recuperação ambiental, tratando a área como um sistema dinâmico complexo, hipersensível às condições iniciais de preparação do terreno, permitiu acompanhar a dinâmica evolutiva diferenciada que foi mais rápida e rica, no tratamento contendo rugosidades. As interações entre os componentes, previstas no modelo, se confirmaram, podendo variar em intensidade ao longo do tempo, como no caso da intensidade das interações entre as rugosidades e a fauna.

As rugosidades, como único diferencial entre os dois tratamentos, desencadearam temporalmente efeitos benéficos para a recuperação ambiental, retendo água, sedimentos, matéria orgânica, nutrientes, sementes e atraindo a fauna de invertebrados. A presença da fauna, por sua vez, retroagiu sobre a vegetação, polinizando-a, predando-a e ampliando as interações.

Nos ecossistemas mais quentes e úmidos, as sete ordens com maior número de espécies (Orthoptera, Homoptera, Hemiptera e Lepidoptera, Coleoptera, Diptera e Hymenoptera) são diversificadas e sensíveis a mudanças ambientais. Essas ordens são indicadores da riqueza e saúde dos ecossistemas, fiéis em acusar qualquer modificação de estrutura, diminuição de fluxo de matéria e energia, ou restrição de recursos, e rápidas em anunciar tendências de degradação, regeneração ou recuperação dos ambientes, em razão de sua grande mobilidade e curto ciclo de vida (BROWN-JUNIOR,2000).

A diversidade de um grupo indicador está relacionada com a diversidade dos seus recursos e ambiente (BROWN-JUNIOR, 1997). Nos sistemas florestais, a diversidade de nichos, recursos e espécies se expande por um volume multidimensional limitado apenas pela heterogeneidade topográfica, disponibilidade de radiação e água, frequência de perturbação branda ou imprevisível e controle pelos ocupantes de níveis tróficos superiores (BROWN- JUNIOR, 2000). Destaca-se que a única espécie arbórea desenvolvida até o final das medições era a *Mimosa scabrella*. As rugosidades (microtopografias) serviram como atrativo para a fauna, pelo acúmulo de água e nutrientes. No entanto, essas microtopografias, apesar de reterem água devido aos longos períodos de estiagem, secaram, diminuindo também o efeito positivo como atratores da fauna.

A radiação na área irregular de 820 m^2 foi sistematicamente mais baixa e pode ter influenciado a maior diversidade. As médias das temperaturas máximas do ambiente também foram significativamente menores na área irregular de 820 m^2. As rugosidades do terreno aumentaram a diversidade e heterogeneidade ambiental, que foram significativa para atração dos insetos nessa escala de tempo. Os resultados obtidos entre as parcelas de 1.110 m^2 foram opostos aos das parcelas com 820 m^2. Na parcela irregular (1.110 m^2), a heterogeneidade não foi determinante em razão, provavelmente, da conexão estabelecida entre essa parcela e a irregular de 820 m^2, em função da distribuição espacial no campo.

Segundo Silveira (1976), a temperatura ideal para o desenvolvimento dos insetos é em média de 25 ^oC, podendo alguns grupos suportar temperaturas que variam de 15 a 38 ^oC. A umidade relativa do ar foi menor na área irregular de 820 m^2, porém foi estatisticamente significativa apenas durante sete meses. A radiação e umidade são fatores que afetam diretamente a comunidade de artrópodes, principalmente para espécimes que necessitam de ambientes mais estáveis. Alguns organismos, como os artrópodes, são muito sensíveis mesmo a mínimas perturbações, mudando a composição da comunidade, diminuindo ou desaparecendo com qualquer modificação ambiental (BROWN-JUNIOR, 1997).

As ordens Collembola e Coleoptera responderam melhor às parcelas irregulares de 820 m^2 e 1.110 m^2, que apresentaram umidade mais elevada, menor radiação solar e menor variação na temperatura, o que supõe que espécies dessas ordens não toleram ambientes instáveis, preferindo microclima mais constante.

A ordem Thysanoptera foi mais abundante nas parcelas regulares de 820 m^2 e 1.110 m^2. Possivelmente essa ordem responda melhor em ambientes com maior radiação e menor umidade. Essa ordem geralmente é considerada praga, porém não há nenhuma informação a respeito das

comunidades naturais no Sul do Brasil (PINENT, 2006).

Lazzari e Lazzarotto (2005) relataram que o maior número de espécies de hemípteros foi coletado nas armadilhas instaladas em local aberto, facilitando a sua atração. O mesmo ocorreu nesta pesquisa, em que a maior abundância de hemíptera foi coletada nas áreas regulares, onde as armadilhas ficavam mais expostas.

Os aracnídeos não foram muito abundantes e predominaram nas parcelas regulares. Possivelmente os indivíduos coletados respondam melhor a ambientesmais alterados.

A comparação entre os dois tratamentos de recuperação mostrou melhor estrutura vegetal e melhores condições microclimáticas nas parcelas irregulares, porém somente na parcela irregular (820 m^2) é que se pode observar maior diversidade dos artrópodes. Como o processo de recuperação é lento e gradativo, a pesquisa com a comunidade de artrópodes foi exígua. Essa constatação evidenciou que o período de avaliação da fauna de invertebrados exige mais tempo de observação. Provavelmente a oferta de recursos não apresentasse ainda diferenças significativas, apesar do crescente desenvolvimento das arbóreas.

As variações do relevo, neste caso representadaspelas rugosidades, influenciaram as interações entre a radiação solar, a umidade e os nutrientes, criando oportunidades diferenciadas para as espécies vegetais e animais. A observação da dinâmica das comunidades confirma que as espécies se substituem ao longo do tempo, refletindo as variações ambientais de uma forma heterogênea e dinâmica, conforme sugeriram Griffithet al. (1994).

A evolução da vegetação desencadeou uma teia complexa de interações com as variáveis, radiação, temperatura do solo, temperatura do ambiente e umidade relativa do ar, que no processo sucessional se refletiram em maior variabilidade das condições microclimáticas. Nas parcelas com tratamento irregular, a mudança da estrutura da composição florística desencadeou alterações nas condições microclimáticas mais intensas e heterogêneas que nas parcelas com tratamento regular. Ao invés de relação linear de causa e efeito da vegetação sobre as condições microclimáticas, na qual o maior desenvolvimento da vegetação resultaria em amenização da radiação, temperatura do ambiente e do solo, o que se constatou foi a emergência de um padrão microclimático complexo de interações entre os componentes bióticos e abióticos. Essa complexidade crescente resultou de um processo de interação entre a vegetação e o microclima, formando um círculo de causalidade de ação e reação que resultou numa cumplicidade coevolutiva cada vez mais rica e variadaentre a vegetação e o meio abiótico.

A revegetação mais rica e acelerada nas parcelas com rugosidades não se refletiu linearmente, por exemplo, amenizando as condições microclimáticas, como sugeriramYarranton e Morrison (1974). No entanto, resultou em aumento da heterogeneidade ambiental, tanto da radiação, da umidade do ar e da temperatura do ambiente quanto do solo. As rugosidades dessas áreas se comportaram, ao longo do tempo, como centros do estabelecimentode Cyperaceae e Juncaceae e fauna aquática e se transformaram, em núcleos para o crescimento de espécies mais exigentes, num fenômeno de nucleação, como sugerido por Yarranton e Morrison (1974), análogo ao encontrado em Física, tal como o crescimento do granizo. A área degradada reagiu como sistema dinâmico complexo e interagiu com o ambiente, adaptando sua estrutura interna em razão dessas interações. Ao potencializar a heterogeneidade ambiental, ampliou ainda mais a diversidade.

Apesar da aparente aleatoriedade desses fenômenos de retroalimentação, evidencia-se certa ordem que emergiu de sua dinâmica evolutiva determinada pela sua estrutura, pelo ambiente e pelas causas endógenas, resultando numa recuperação mais acelerada, complexa e rica nas áreas irregulares. Ao longo do processo, a dinâmica da recuperação tendeu para um estado mais complexo de equilíbrio dinâmico através de mecanismos de autocontrole e autorregulação que entraram em ação como resposta às mudanças ambientais, que Braga et al. (2004) denominam homeostasia. A área degradada em processo de recuperação ambiental, analogamente aos sistemas naturais, se mantém a si própria, evoluindo com mudanças em resposta aos desafios do ambiente (VASCONCELLOS, 2003). Aautocriatividade é uma resposta do sistema às condições do ambiente que não podem ser enfrentadas com a estrutura existente. Os sistemas naturais se auto-organizam diante dos desafios do ambiente, tendendo à maior complexidade.

Ao aumentar a circulação interna de matéria (solo, água e nutrientes) pela criação das rugosidades e consequente incremento da superfície total da área, provocou-se dissipação diretamente proporcional de energia dentro do sistema degradado. Nas áreas irregulares houve tendência de redução do escoamento superficial. Parte da energia da água foi gasta na erosão das superfícies convexas com sedimentação proporcional nas superfícies côncavas, havendo dissipação diretamente proporcional da energia da

água no próprio sistema. Essa internalização da energia e matéria no sistema resultou em enriquecimento ecológico notadamente maior nas microtopografias (concavidades), proporcionando maior variabilidade ambiental e aporte de matéria orgânica.

Ao provocar a erosão e lixiviação das formas convexas, aciona-se, na mesma proporção, a sedimentação nas concavidades, dissipando a energia do fluxo da água, criando-se, assim, a complementaridade no próprio sistema. O aumento da erosão tem correspondente direto de sedimentação e retenção nas concavidades da área. Nas superfícies convexas, os fluxos externos e internos de matéria e energia levam à dissipação de energia e perdas por erosão e por lixiviação. Nas superfícies côncavas, os fatores ecológicos estão voltados para dentro do sistema, levando a uma introspecção da matéria e energia tanto de origem externa quanto interna do sistema. Com a internalização da matéria e energia no sistema houve enriquecimento ecológico e maior variabilidade ambiental nas áreas com tratamento irregular. O fluxo de matéria e energia foi o mecanismo da sustentabilidade desse processo de enriquecimento e crescimento da heterogeneidade ambiental.

No processo de recuperação, as parcelas regulares se comportaram como superfícies dissipadoras, e as precipitações geraram mais escoamentos superficiais para fora do sistema, desencadeando mais degradação. O volume de água escoada para fora da parcela regular foi significativamente superior, correspondendo a 6,8 vezes ao da parcela irregular, e as perdas de solo na parcela regular foram 4,06 vezes superiores, evidenciando introspecção da matéria na parcela irregular prevista por Aumond (2003).

O coeficiente de escoamento médio da parcela regular foi de 0,133, contra os 0,03 da parcela irregular (AUMOND, 2007), o que corresponde a um valor de 4,43% vezes maior que na parcela irregular. O fluxo de matéria e energia na área degradada, como um sistema aberto, teve efeito negativo, tornando-se fonte de perdas irreversíveis e empobrecimento. Isso pode ser comprovado pela perda de solo na parcela irregular, que correspondeu a 0,87 $Mg.ha^{-1}.ano^{-1}$ contra um total de 3,54 $Mg.ha^{-1}.ano^{-1}$ na parcela regular.

Apesar da maior retenção de sedimentos nas parcelas irregulares, partindo da análise da estrutura do modelo do sistema ecológico proposto para recuperação da área degradada, não ficaram muito evidentes a priori a função e potencial de desdobramentos das rugosidades na recuperação. O componente rugosidade, representado no quadrante sudeste do modelo ecológico (Figura 2), apresenta apenas duas relações muito intensas, consideradas fortes e incluídas na categoria 3 (Tabela 1). A maior concentração das relações intensas entre os componentes do sistema ecológico mostram círculos de causalidade entre água, vegetação, solo, radiação e fauna e está representada graficamente a noroeste do componente rugosidade (Figura 2). Todavia, o modelo proposto não deve ser visto pelo observador como imagem estática, pois se trata de um modelo em que estão representadas as relações de causalidade e retroalimentação que evoluem temporalmente. Nos sistemas dinâmicos complexos surgem, ao longo do tempo, propriedades que emergem da interação de suas partes e só podem ser compreendidas em sua dinâmica como um todo integrado e não como coleção de partes dissociadas. Nesse caso, a área degradada se comportando como sistema dinâmico complexo incorporou uma dinâmica hipersensível às condições iniciais, em que as rugosidades desencadearam efeitos que foram amplificados espacial e temporalmente pela retroalimentação ao longo do processo de recuperação. Com o passar do tempo, as rugosidades desencadearam propriedades emergentes, aumentando as interações entre outros componentes do sistema. A intensidade das interações teve comportamento variável, podendo aumentar ou diminuir no tempo, como resposta da retroalimentação entre os componentes e também devido às propriedades emergentes.

As rugosidades, além de afetarem o microclima no primeiro estádio, pela retenção da água, amenização da temperatura e aumento da umidade, influenciaram beneficamente também a vegetação e a fauna pela criação de *habitats* diferenciados e variáveis no tempo. As relações intensas das rugosidades com a água e a vegetação previstas no modelo ecológico se confirmaram ao se transformarem em ilhas de diversidade que, por sua vez, desencadearam outros circuitos de realimentação com os demais componentes: fauna, solo e microclima. As relações das rugosidades com a fauna, previstas originalmente como de intensidade média 2, se mostraram mais efetivas na recuperação porque, ao reterem água e nutrientes, se transformaram em ilhas de diversidade, potencializando o efeito de atração da fauna pela amenização da temperatura e disponibilização de recursos. As interações entre a radiação e a fauna de invertebrados se mostraram variáveis, e sua intensidade dependeu da espécie, confirmando observações de Brown (1997) de que os artrópodes são sensíveis,

mesmo a mínimas perturbações microclimáticas. Nesta pesquisa não houve diferenças significativas nos índices faunísticos entre os dois tratamentos. Com o tempo, as interaçõesentre as rugosidades e os demais componentes do sistema foram diminuindo de intensidade com o estabelecimento da vegetação e a colmatação das microtopografias.

As áreas em recuperação tiveram nas rugosidades seu diferencial por internalizar a matéria e a energia no sistema, potencializando e acelerando a recuperação ambiental. As entradas (*inputs*) no sistema (água, nutrientes e sementes) resultaram em enriquecimento ambiental, que propiciou o estabelecimento da vegetação e o aporte da fauna. As saídas (*output*) do sistema decorreram das entradas (*input*), sendo influenciadas pelas rugosidades, porque o *input* foi transformado no *output* desejado através da retenção de matéria e energia, resultando em maior enriquecimento das áreasirregulares.

Em contraposição, as áreas regulares, por funcionarem como superfícies dissipativas; e as saídas (*outputs*), por levarem a uma degradação ambiental crescente pelo escoamento superficial e consequente erosão, dificultaram o estabelecimento da vegetação. As áreas regulares levaram à dispersão de energia e matéria para fora do sistema e, consequentemente, apresentaram empobrecimento devido ao baixo índice de retenção interno de matéria e energia.

Numa área degradada, o índice de retenção de matéria e energia interna é baixo. Analogamente, nos ecossistemas áridos e semiáridos também pouca energia solar é assimilada e pouco dióxido de carbono (CO_2) do ar é retirado para formar os compostos orgânicos, via fotossíntese. Nos ecossistemas florestais, ao contrário, a energia solar é transformada em energia química, ficando assim armazenada na forma de substâncias orgânicas como carboidratos e proteínas (AUMOND, 2003).

Nessa abordagem a respeito da recuperação de áreas degradadas, os ecossistemas conservados podem ser entendidos como supersistemas do tipo estruturas dissipativas, em analogia às estruturas dissipativas de Prigogine e Stenger (1984) e Prigogine e Glansdorff (1997). Assim posto, os ecossistemas apresentam estrutura organizacional fechada com suas populações de animais e vegetais estabelecidas, estrutura que deve ser almejada nos processos de recuperação. No entanto, seus componentes estão em permanente estado de mudança, e o conjunto operacionaliza a cadeia alimentar cíclica com seus diferentes níveis tróficos, que são alimentados pelo fluxo externo de matéria e energia (CO_2, água e radiação solar, entre outros).

A floresta é um supersistema dissipativo, estruturalmente aberto ao fluxo de matéria e energia, porém é fechado organizacionalmente. Todos os seus componentes – plantas, animais, solo e macro, meso e microfauna–formam uma rede complexa de interações, caracterizando um conjunto de relações entre processos de produção que se mantêm dentro da cadeia alimentar, mantendo o conjunto afastado do estado de equilíbrio (AUMOND, 2003).

Nesse processo, fluem irreversível e continuamente matéria e energia, e a estrutura do ecossistema, como um todo, permanece afastada do estado de equilíbrio. Analogamente em recuperação ambiental, a instabilidade desse processo, associada às técnicas que permitem internalizar parte do fluxo de matéria e energia, conduz à auto-organização resultante da emergência de novas estruturas que funcionam como atratores de uma complexidade crescente, advinda da não linearidade do sistema. As rugosidades, nesses casos, são componentes-chave para desencadear a recuperação e acelerar a complexidade da cadeia alimentar (AUMOND, 2008).

A chave da compreensão do processo de recuperação/restauração ambiental de áreas degradadas está na perspectiva desenvolvida por Prigogine e Glansdorff (1997), partindo-se da concepção de Bertalanffy (1975), que sugeriu que os seres vivos se mantêm graças ao fluxo de matéria e energia num equilíbrio dinâmico e são mantidos pela instabilidade do sistema, à semelhança dos fragmentos florestais. Nessa perspectiva dos sistemas denominados dissipativos, na recuperação das áreas degradadas deve haver contínuo processo de incorporação de matéria e energia, fazendo emergir da instabilidade uma nova estabilidade fluente, da desordem uma nova ordem e do desequilíbrio um novo estado de equilíbrio dinâmico. Na ótica da teoria dos sistemas dissipativos, deve-se, então, ativar o desequilíbrio para reacender os fatores ecológicos e, consequentemente, as condições de instabilidade e o fluxo de matéria para recuperação da vida na área degradada.

Deve-se levar a área ao fechamento organizacional, mantendo a abertura ao fluxo de matéria e energia. A revegetação assim encontrará um estado ecologicamente ativo, estimulando todas as possibilidades e mecanismos para se instalar e criar um estado superior de organização ecológica. Provocando a desorganização espacial da

área degradada através de rugosidades, criando superfícies convexas adjacentes a superfícies côncavas, aumenta-se a superfície total da área e se aciona o movimento vertical e horizontal da água, a erosão e lixiviação de sedimentos, resíduos orgânicos e colóides que irão depositar-se no interior das depressões do terreno. O aumento da superfície do terreno é acompanhado necessariamente de um aumento do fluxo de matéria e energia. Além de aumentar a superfície de contato com oxigênio, dióxido de carbono, água e exposição variável à radiação solar, cria-se um fluxo de macro e micronutrientes numa condição de equilíbrio dinâmico ou "*fliessgleichgewicht*"[5], na expressão de Bertanlanffy (1975), ampliando, assim, as potencialidades ecológicas e acelerando o processo de recuperação ambiental.

Ao criar a instabilidade na área degradada, acionou-se um processo de evolução temporal com dependência hipersensível às condições iniciais, em que atratores gravitacionais representados pelas rugosidades conduziram a uma reorganização da paisagem análoga à metáfora do efeito borboleta de Lorens (1996), ao abordar a teoria do caos. Pequena diferença no estado inicial da recuperação, representado pelas rugosidades, levaram ao longo do tempo a consequências em grande escala, resultando numa aceleração da recuperação ambiental. Confirmando observações de Anand e Desrochers (2004), a dinâmica da recuperação evolui em resposta a um atrator estranho desencadeado nesse caso pelas rugosidades, sendo por isso difícil de prever seu estado final. No entanto, a imprevisibilidade da trajetória da recuperação não impede de prever em seu destino uma tendência de aceleração na recuperação e a uma diversidade crescente ao longo do processo.

Não se podem substituir os processos naturais, mas, sim, estimulá-los na busca de um novo estado. Com a desordem ambiental subjacentemente induzida, emerge mais rapidamente uma nova ordem natural interna, mais rica em micronichos, e com mais interações e nutrientes disponíveis, tornando-a mais dinâmica e produtiva.

A vegetação de determinada área em processo de recuperação deve ser consequência de todo um conjunto de procedimentos ecológicos adequados. A revegetação instalar-se-á mais rapidamente com a sinergia humana, incluindo a irregularização morfológica do terreno, gerando diversidade física e variação dos demais fatores ecológicos, como consequência da maior variabilidade de micronichos disponíveis. Assim, aumentam-se as interações e inter-relações entre os elementos que compõem o ecossistema local.

Quanto maior o número de variáveis físicas, químicas e biológicas mantidas flutuando na área, mais dinâmico será o sistema. Quanto maior a diversidade de microtopografias, incluindo-se formas convexas e côncavas, maior será a erosão e a sedimentação, maior será a variabilidade do padrão de luminosidade e mais intensa será a circulação de nutrientes. Quanto maior a flexibilidade dos componentes do sistema, mais complexa a rede e os padrões de interconexões e, consequentemente, maior sua capacidade de buscade um novo equilíbrio dinâmico.

Nos sistemas degradados, as variáveis ecológicas (luminosidade, temperatura, escoamento de água e ciclagem de nutrientes, entre outros) dificultam o aparecimento e enriquecimento da vida, e o padrão de organização será aberto, com elevada entropia, resultando em perdas progressivamente maiores e irreversíveis. A água escoa para fora do sistema, erode e carreia matéria orgânica, macro e micronutrientes, empobrecendo ainda mais a área degradada. A retenção da água será sempre menor nas áreas desmatadas do que nas áreas em que viceja a vegetação. A insolação direta na superfície do solo provoca oscilações com extremos de temperatura. A transferência de calor solar para o meio via condução, radiação e convecção provoca grandes oscilações térmicas no solo, seguidas de enormes perdas para o espaço.

Nos sistemas organizacionalmente abertos, há grandes perdas de matéria e energia e, por isso, propõe-se internalizar os processos ecológicos. A estratégia adequada é levar o sistema, isto é, a área degradada ao fechamento organizacional, induzindo à introspecção das variáveis ecológicas, de forma a aumentar o fluxo de matéria e energia internamente no sistema. A internalização da matéria e da energia conduz à maior variabilidade ambiental, que facilita o estabelecimento e aumento da biodiversidade, a produção de biomassa e a autossustentabilidade.

Pelo exposto, considera-se que o modelo ecológico constituiu ferramenta importante para entender às relações de causalidade e retroalimentação entre as variáveis no processo de recuperação de área degradada.

V. Conclusões

O arcabouço teórico e os resultados práticos obtidos nesta pesquisa validaram o modelo de

[5] Equilíbrio fluente que expressa à coexistência de equilíbrio, de fluxo, de estrutura e de mudança.

sistema proposto para avaliar a recuperação da área degradada. A hipótese de que as áreas degradadas são sensíveis às condições iniciais de preparação do terreno e se comportam como sistemas dinâmicos complexos se confirmou.

Partindo de condições iniciais semelhantes, à exceção das rugosidades, as áreas irregulares evoluíram diferenciadamente nos dois tratamentos testados. As variáveis abióticas evoluíram, desencadeando melhoria ambiental para as variáveis bióticas e estas retroagiram influenciando as primeiras.

A amenização da radiação solar provocou reflexão difusa e diferenciada, minimizando as variações diárias da intensidade da luz, da temperatura ambiente e da temperatura do solo, que por sua vez exerceram efeito de retroalimentação sobre a vegetação, acelerando a recuperação da área.

A temperatura do solo foi, na maior parte do tempo, menor nas parcelas irregulares. Após o primeiro ano, o padrão de temperatura foi mais heterogêneo, enquanto no terceiro ano, devido ao efeito de proteção exercido pelas herbáceas e arbustivas, que ainda sobreviviam nas parcelas regulares, houve alteração desse padrão, ocorrendo as maiores temperaturas nas áreas irregulares.

As menores radiações e temperaturas nas parcelas irregulares provocaram tendência para maior umidade relativa do ar. Enquanto a umidade do solo foi menor fora das irregularidades, as superfícies côncavas das rugosidades exerceram importante papel na retenção da água, resultando em maior umidade local no solo.

Em relação à densidade, o volume total de poros do solo e as análises químicas deste não foram significativamente diferentes no período analisado, provavelmente indicando que o tempo de avaliação ainda não foi suficiente para mostrar diferenças entre os tratamentos.

As rugosidades comportaram-se como atratores gravitacionais, gerando ilhas de diversidade que incorporaram ao sistema uma dinâmica hipersensível a essas condições iniciais. As rugosidades funcionaram como nucleadoras- retendo água, nutrientes e sedimentos-, atraíram a fauna e desencadearam efeitos que foram amplificados pela realimentação, potencializando e acelerando a recuperação ambiental.

As parcelas regulares se comportaram, no entanto, como superfícies dissipadoras de matéria e energia, e as precipitações geraram mais escoamento para fora do sistema, desencadeando mais degradação. O volume de escoamento da água para fora do sistema foi 6,8 vezes maior, enquanto as perdas de solo foram 4,06 vezes maiores e o coeficiente de escoamento médio da água, 4,43 vezes maior na parcela regular, evidenciando maior internalização de matéria, na área irregular. As superfícies côncavas das rugosidades concentraram matéria e energia tanto de origem interna quanto externa do sistema degradado, tendendo à maior introspecção dos fatores ecológicos, que levaram a área à maior complexidade organizacional.

As variáveis altura, diâmetro do colo, diâmetro à altura do peito e área da copa de *M. scabrella* foram estatisticamente maiores nas parcelas irregulares. A vegetação espontânea, representada por herbáceas e arbustivas, permaneceu vigorando por mais tempo nas parcelas regulares em razão das condições favoráveis a essas espécies dos primeiros estádios da sucessão. Nas áreas irregulares, após o segundo ano, o maior desenvolvimento da cobertura arbórea induziu à eliminação de parte da vegetação rasteira, evidenciando estádio sucessional mais avançado.

A comparação entre os dois tratamentos de recuperação mostra a melhor estrutura vegetal e as melhores condições microclimáticas nas parcelas irregulares, porém somente em uma parcela irregular foi possível observar maior diversidade dos artrópodes, provavelmente porque a oferta de recursos não apresentava, ainda, diferenças significativas, apesar do crescente desenvolvimento das arbóreas. Como o processo de recuperação é lento e gradativo, a pesquisa com a comunidade de artrópodes exige mais tempo de observação.

O modelo ecológico proposto, fundamentado numa metodologia integradora e baseado na inter-relação e interdependência essencial de todos os componentes; os fenômenos físicos, químicos e biológicos; e os resultados práticos validaram o diagrama de influência como ferramenta importante para entender as relações de causalidade e retroalimentação das variáveis e sua evolução temporal no processo de recuperação ambiental.

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North-South Geographical Variation of Chromosome Polymorphism in Mexican Populations of Drosophila Pseudoobscura

By Victor M. Salceda & Carolina Arceo-Maldonado

Abstract- Chromosomal polymorphism in Drosophila pseudoobscura has been extensively studied in USA populations and moderately in Mexico with around 60 localities. The differences that exist between both entities are notorious in terms of the chromosomal constitution of the populations of each region, thus, the northern populations (USA) present as representative inversions the ST, AR and CH sequences while in the southern ones (Mexico) TL, CU, and SC chromosome arrangements prevail. Assuming that a probable mechanism that has allowed this substitution is the flow generated by the presence of clines or gradients, in this case with a North-South orientation, we set out to find out the existence of these clines, with this objective, 29 populations of this species distributed in four North-South transects were studied.

Specimens of D. pseudoobscura captured by attraction with fermenting fruits were transported to the laboratory where an isoline was formed with each female and a larva was extracted from each one, from which the salivary glands were obtained, which once stained revealed the polytenic chromosomes, in which the inversion(s) carried in the third chromosome pair were individually identified, in this way a total of 3439 chromosomes were analyzed.

Keywords: *drosophila pseudoobscura, chromosomal polymorphism, geographic gradients.*

GJSFR-H Classification: *LCC Code: QH430*

Strictly as per the compliance and regulations of:

North-South Geographical Variation of Chromosome Polymorphism in Mexican Populations of Drosophila Pseudoobscura

Variacion Geografica Norte-Sur del Polimorfismo Cromosomico en Poblaciones Mexicanas de Drosophilapseudoobscura

Victor M. Salceda [α] & Carolina Arceo-Maldonado [σ]

Resumen- El polimorfismo cromosómico en *Drosophila pseudoobscura* ha sido ampliamente estudiado en poblaciones de EEUU y moderadamente en México con alrededor de 60 localidades. Son notorias las diferencias que existen entre ambas entidades en cuanto a la constitución cromosómica de las poblaciones de cada región, así, las poblaciones norteñas (EEUU) presentan como inversiones representativas las secuencias ST, AR y CH en tanto que en las sureñas (México) prevalecen los arreglos cromosómicos TL, CU y SC. Asumiendo que un probable mecanismo que ha permitido esta substitución sea el flujo generado por la presencia de clines o gradientes, en este caso con orientación Norte – Sur nos propusimos averiguar la existencia de dichos clines.

Con este objetivo se estudiaron 29 poblaciones de esta especie distribuidas en cuatro transectos Norte – Sur. Especímenes de *D. pseudoobscura* capturados mediante atracción con frutas en fermentación, se transportaron al laboratorio donde con cada hembra se constituyó una isolínea y de cada una se extrajo una larva de la que se obtuvieron las glándulas salivales que una vez teñidas pusieron de manifiesto los cromosomas politénicos en los que se identificaron en forma individual la(s) inversiones portadas en el tercer par cromosómico, de esta forma un total de 3439 cromosomas fueron analizados.

Se identificaron 17 inversiones diferentes y en cada población el número de ellas varió entre tres y once. Para cada localidad se calcularon las frecuencias relativas de cada inversión y con ellas se determinó para cada transecto la presencia o ausencia de gradientes en los diferentes transectos, la presencia de gradientes sólo se pudo observar entre dos o tres poblaciones aledañas pero la clara manifestación de un gradiente a lo largo del correspondiente transecto en ningún caso fue evidente. Nuestros resultados son similares con estudios previos en poblaciones de EEUU. Un mecanismo que explique las substituciones de inversiones de norte a sur permanece aún sin explicación.

Palabras clave: drosophila pseuoobscura, polimorfismo cromosómico, gradientes geográficos.

Abstract- Chromosomal polymorphism in *Drosophila pseudoobscura* has been extensively studied in USA populations and moderately in Mexico with around 60 localities. The differences that exist between both entities are notorious in terms of the chromosomal constitution of the populations of each region, thus, the northern populations (USA) present as representative inversions the ST, AR and CH sequences while in the southern ones (Mexico) TL, CU, and SC chromosome arrangements prevail. Assuming that a probable mechanism that has allowed this substitution is the flow generated by the presence of clines or gradients, in this case with a North-South orientation, we set out to find out the existence of these clines, with this objective, 29 populations of this species distributed in four North-South transects were studied.

Specimens of *D. pseudoobscura* captured by attraction with fermenting fruits were transported to the laboratory where an isoline was formed with each female and a larva was extracted from each one, from which the salivary glands were obtained, which once stained revealed the polytenic chromosomes, in which the inversion(s) carried in the third chromosome pair were individually identified, in this way a total of 3439 chromosomes were analyzed.

Seventeen different inversions were identified and in each population the number of them varied between three and eleven. For each locality, the relative frequencies of each inversion were calculated and with them the presence or absence of gradients in the different transects was determined for each transect. The presence of gradients could only be observed between two or three neighboring populations, but the clear manifestation of a gradient along the corresponding transect was not evident in any case. Our results are similar to previous studies in US populations. A mechanism that explains the substitutions of investments from north to south remains unexplained.

Keywords: drosophila pseudoobscura, chromosomal polymorphism, geographic gradients.

I. Introduccion

La presencia en forma natural de inversiones cromosómicas es un fenómeno detectado indirectamente por Sturtevant en 1917 y ampliamente distribuido en el género *Drosophila.* Más de la mitad de las especies del género hasta ahora analizadas para ello son polimórficas en uno o más de sus brazos cromosómicos. Esos polimorfismos

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muestran una interesante diferenciación geográfica, siendo la primera especie que se estudió a este respecto y probablemente la más estudiada *Drosophila pseudoobscura,* para una revisión detallada ver Dobshanzky y Powell (1975) y Powell (1992). Esta especie es polimórfica para el tercer par de cromosomas y presenta una distribución geográfica que abarca la Columbia Británica en Canadá, todo el Oeste de Estados Unidos, México, Guatemala y una pequeña colonia en las cercanías de Bogotá en Colombia (Dobshansky *et al.* 1963), habita principalmente bosques de coníferas, bosques mixtos de árboles de climas templados y alturas comprendidas desde el nivel del mar hasta 3000 msnm.

El polimorfismo cromosómico de esta especie, según se observa en el tercer par de cromosomas politénicos consta de 40 inversiones paracéntricas hasta el momento descritas. El grado de polimorfismo en poblaciones naturales a lo largo del territorio mexicano ha sido reportado por varios autores entre los que tenemos: Dobshanzky (1939, 1948), Dobshanzky y Epling (1944), Dobshanzky *et al.* (1975), Guzmán *et al.* (2005), Levine*et al.* (1995), Olvera *et al.* (1979, 2005) y Salceda *et al.* (2007a, b).

Otro aspecto concerniente a la distribución geográfica de las inversiones se refiere a la presencia o ausencia de clines o gradientes geográficos, cambios direccionales graduales en la frecuencia relativa de las inversiones en localidades adyacentes. La presencia de estos gradientes se ha puesto de manifiesto en varias especies de *Drosophila,* por ejemplo los estudios en poblaciones europeas de *D. suboscura* realizados por Krimbas y Loukas (1986), Krimbas (1992, 1993) y los de Dobshanzky y Epling (1944) en poblaciones estadounidenses y mexicanas de *D. pseudoobscura.* Otros estudios de esta especie en poblaciones mexicanas con referencia a la presencia de gradientes geográficos son los de Guzmán *et al.* (1993, 2005), Olvera *et al.* (2005) y Salceda y Espinoza-Velázquez (2006 a, b), los tres primeros se refieren a gradientes Este-Oeste en tanto que los dos últimos a variación microgeográfica.

Ahora bien, considerando que en las poblaciones norteñas, según los autores antes mencionados, prevalecen las inversiones denominadas ST, AR y CH y en las del Sur las más frecuentes son TL, CU y SC, nosotros asumimos que el mecanismo que permite esta substitución es la presencia de gradientes Norte-Sur, con esta idea en mente decidimos analizar esa posibilidad utilizando datos referentes a las frecuencias relativas de varias inversiones presentes diferentes poblaciones naturales de esta especie dentro del territorio mexicano y adecuándolas a diferentes transectos Norte-Sur.

II. Materiales y Metodos

Durante los años 2000-2004 se obtuvieron muestras de *D. pseudoobscura* en 29 localidades distribuidas a lo largo de la mayor parte del territorio mexicano ocupado por esta especie. Los sitios se agruparon en cuatro regiones que se corresponden con cuatro transectos Norte-Sur a saber: transecto "A" incluye longitudes 92º - 96º 59´ W; transecto "B" de 97º -98º 59´ W; transecto "C" 99º - 101º- 59´ W y transecto"D" 102º- 106º W, en las tablas 1-4 se muestran estas agrupaciones y se incluyen los nombres de los sitios, frecuencias relativas de cada una de las inversiones más frecuentes en la localidad y el tamaño de la muestra.

Las agrupaciones se de esta manera para facilitar el análisis de los datos y de forma tal que se tuvieran pocos grupos representativos (transectos) y que cada uno de ellos contuviera el mayor número de localidades posible y que compartieran condiciones (meridianos) geográficas semejantes esperando que esta forma de agrupación fuese la mejor opción para analizar y comparar la información recabada.

Para la captura de las moscas se realizaron viajes de colecta con duración de una semana por localidad y a las distancias desde el laboratorio al sitio de colecta y además para asegurar un tamaño de muestra apropiado, sin embargo, las muestras fueron de tamaño variable. Las moscas se capturaron usando como trampas 25-30 botes de plástico que contenían frutas en fermentación, principalmente plátanos, y distribuidas en el sitio de colecta de forma tal que se cubriese una mayor superficie. Cuando las moscas empezaban a visitar las trampas se realizaron rondas de colecta cada 15-20 minutos, las colectas se efectuaron por las mañanas desde la salida del Sol hasta las 9.00 h y por las tardes desde las 17.00 h hasta que la oscuridad impedía la colecta; las moscas fueron atrapadas con la ayuda de una red entomológica y de toda la captura se separaban, con la ayuda de un microscopio estereoscópico, aquellas pertenecientes a la especie *D. pseudoobscura* se colocaban en frascos homeopáticos con alimento fresco en grupos de 20-30 individuos por frasco, hembras y machos por separado para prevenir una posible doble inseminación y así se guardaban para su traslado al laboratorio en Salazar, el resto de las moscas capturadas se liberaban.

Una vez en el laboratorio las hembras fueron colocadas individualmente en un frasco de cultivo con alimento fresco donde se incubaron por una semana, en aquellos casos en que la muestra fue pequeña se utilizaron los machos para ello cada macho fue cruzado individualmente con 2-3 hembras una cepa de laboratorio de constitución cromosómica conocida ya sea EP/EP (Estes Park) o TL/TL (Tree Line).

Una semana después, cuando las larvas comenzaban a reptar en la superficie del medio, los

adultos se transfirieron a un nuevo frasco de cultivo con alimento fresco para servir como reserva y al cultivo original se le añadieron unas gotas de una solución concentrada de levadura viva para asegurar una buena nutrición de las larvas en crecimiento y así obtener larvas saludables con glándulas salivales grandes y consecuentemente cromosomas politénicos grandes que facilitarían su observación e interpretación. Al aparecer larvas del tercer estadio, de cada cultivo se extrajo una larva la cual bajo el microscopio se disecó, se le extrajeron las glándulas salivales mismas que se tiñeron por 3-5 minutos con una solución de lacto-aceto-orceina y se procedió a realizar el aplastamiento que permite la expansión de los cromosomas y listos para su observación y determinación del cariotipo correspondiente de cada larva así tratada; las determinaciones cariotípicas se hicieron con la ayuda de un atlas fotográfico así como con las figuras publicadas por Dobshanzky y Epling (1944), Kastritsis y Crumpacker (1966, 1967) y Olvera *et al.* (1979).

Después de terminadas las determinaciones de cada colecta se calcularon las frecuencias relativas de cada inversión presente en cada localidad y con ellas se elaboraron las tablas correspondientes. El medio empleado para el mantenimiento de los cultivos fue el de uso común en el laboratorio consistente en una mezcla de harina de maíz-agar-azúcar-levadura, los cultivos se mantuvieron a temperatura constante de 25 ± 1^{o} C y a una humedad relativa de 65 %.

III. Resultados

Considerando las 29 localidades muestreadas, un total de 3439 terceros cromosomas fueron analizados, estos son los datos a los que haremos referencia.

En todo el estudio se encontraron 16 diferentes inversiones incluyendo una nueva aún no descrita, estas inversiones fueron previamente descritas por Dobshanzky y Epling (1944) y Olvera *et al.* (1979) a fin de identificarlas sus nombres son Tree Line (TL), Cuernavaca (CU), Santa Cruz (SC), Estes Park (EP), Olympic (OL), Hidalgo (HI), PikesPeak (PP), Chiricahua (CH), Standard (ST), Arrow Head (AR), Tarasco (TA), Ozumba (OZ), Iztaccíhuatl (IZ) y Páztcuaro (PA) aquí listados en orden descendiente de su abundancia global en este estudio y presentados en las Tablas 1-4 y Figuras 1-4. Los datos aquí analizados muestran evidencias para diferencias de las frecuencias relativas de las inversiones cromosómicas entre algunas de las localidades muestreadas. También es importante mencionar que no todas las inversiones están presentes en todas las poblaciones puesto que el número de ellas en cada sitio varió de tres a once por localidad. Tomando esto en cuenta en las tablas sólo se indican las frecuencias relativas de las seis inversiones más representativas e incluyendo las restantes bajo la denominación de "OTRAS".

IV. Discusion

Primeramente debemos señalar que en la mayoría de las poblaciones de *D. pseudoobscura* hasta ahora estudiadas con respecto al polimorfismo cromosómico exhiben un patrón de distribución de las inversiones en el que un par de inversiones son las responsables de hasta un 90 % de la muestra y que constituyen el par dominante, en el que a lo largo de un ciclo anual alternan su abundancia, y el restante 10.5 representado por tres, cuatro o más inversiones presentes en esa población; las poblaciones a las que ahora nos referimos muestran en general ese mismo tipo de patrón con algunas peculiaridades inherentes a cada una de ellas.

Mostraremos ahora cómo se comportan en cada grupo las frecuencias relativas de la inversiones; en el transecto "A" encontramos 4-5 inversiones diferentes y de ellas la inversión TL fue la más abundante y constituyendo el par dominante con la inversión CU esto en la localidad Oaxaca que en este transecto es la norteña, pero conforme nos dirigimos al Sur en Ocosingo esta inversión CU es reemplazada por la SC la que siguiendo al Sur alcanza su máxima frecuencia en San Cristóbal de las Casas donde el par dominante es TL-SC, los arreglos cromosómicos EP y OA complementan la constitución cromosómica de estas tres localidades, la información se presenta en la Tabla 1 y Figura 1.

Tabla 1: Frecuencias relativas de inversiones de *Drosophila pseudoobscura* encontradas en el transecto "A". (TreeLine = TL; Cuernavaca = CU; Santa Cruz = SC; Estes Park = EP; Olympic = OL; Oaxaca =OA; n = tamaño de muestra

	TL	CU	SC	EP	OA	n
Oaxaca	35.7	54.1	7.1	2.0	1.0	98
Ocosingo	45.5	1.6	41.5	9.8	1.6	123
S.C.Casas	33.3	1.3	61.5	3.9	---	78

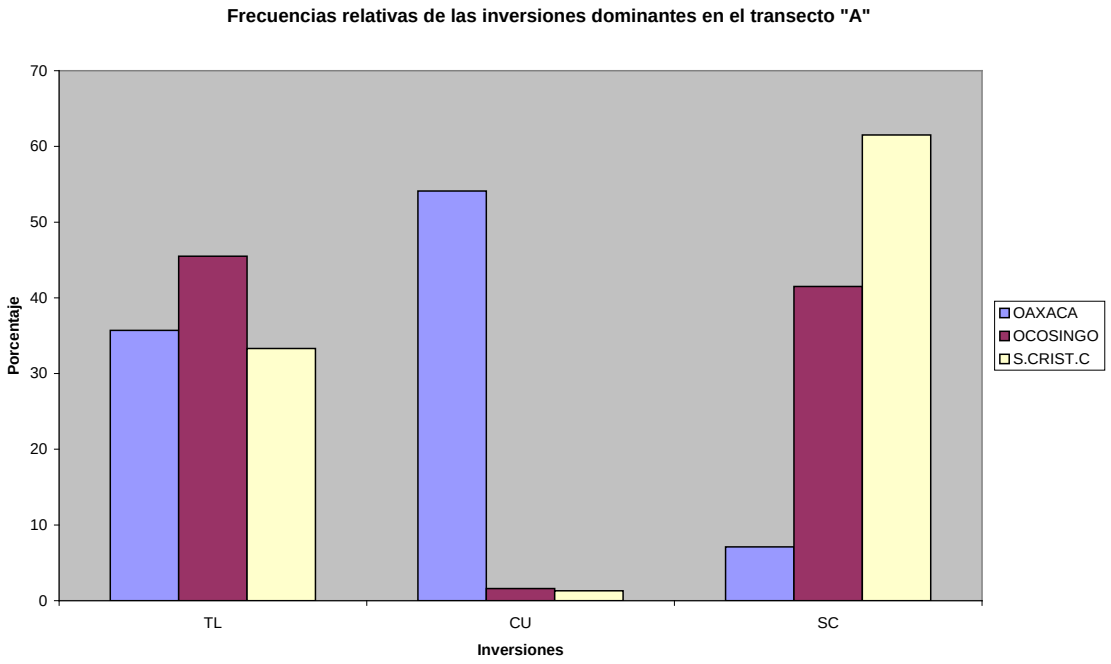

Figura 1: Representación Gráfica de Los Cambios de Frecuencia De Las Inversiones Dominantes de *Drosophila Pseudoobscura en el Transecto "A"*

Transecto "B", en esta zona observamos un promedio de seis inversiones diferentes, de ellas sólo TL y CU, que se complementan mutuamente como par dominante, pero mostraron algunos cambios en frecuencia al desplazarnos de Norte a Sur, estos cambios no fueron consistentes en una dirección como para constituir un gradiente, probablemente debido a diferentes fechas de colecta entre sitio y sitio; el resto de las inversiones no sufrieron cambios considerables manteniendo sus frecuencias relativas a niveles bajos. Su representación se presenta en la Tabla 2 y Figura 2.

Tabla 2: Frecuencias Relativas de Inversiones de *Drosophila Pseudoobscura* Encontradas en El Transecto "B". (Símboloscomoentabla 1)

	TL	CU	SC	EP	OL	OA	others	n
Lobo	54.6	14.6	9.1	1.8	12.7	1.8	5.4	55
Pinal	56.9	6.3	4.9	---	25.0	---	7.0	144
Tulancingo	67.6	22.9	---	6.3	2.5	0.4	0.4	240
C. Nuclear	66.2	21.1	---	12.7	---	---	---	71
Amecameca	39.0	48.0	2.5	8.0	1.0	1.5	---	200
Malinche	66.3	20.2	---	9.0	1.1	2.3	1.1	89
Seco	47.4	39.6	5.8	5.2	1.4	0.4	0.2	515
Perla	59.7	32.2	2.7	4.7	0.7	---	---	149
F. de Caballo	32.7	53.3	7.5	0.9	1.9	2.8	0.9	107

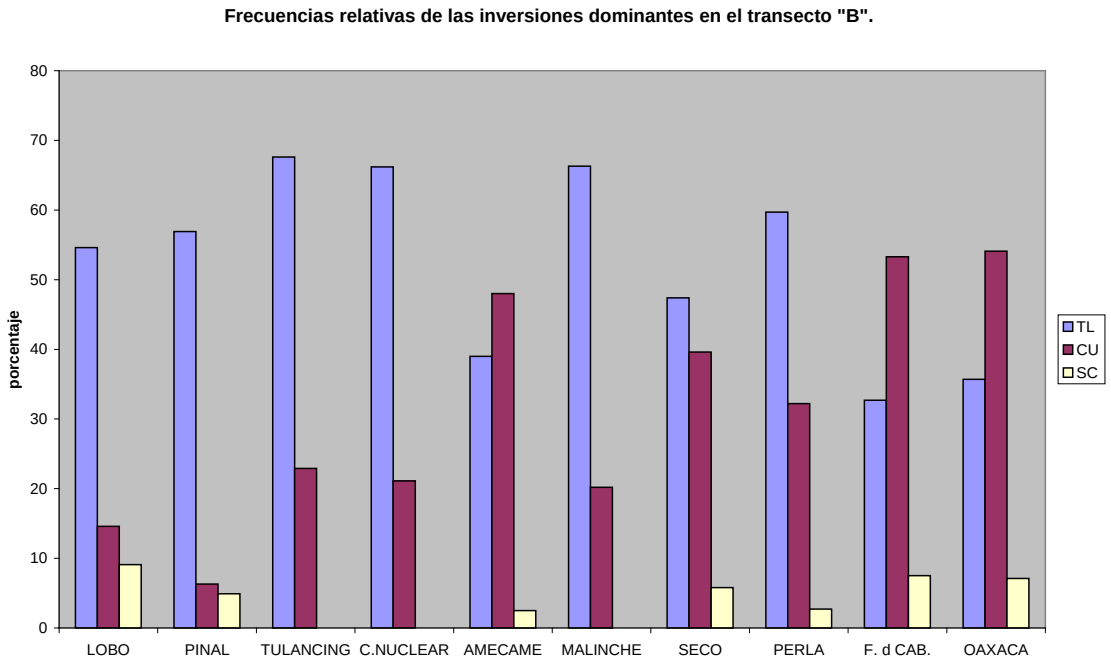

Figura 2: Representación Gráfica de Los Cambios de Frecuencia de Las Inversiones Dominantes de *Drosophila Pseudoobscura en El Transecto "B"*

En el transecto "C" encontramos según la población entre seis y once inversiones diferentes, este tramo presentó cambios notorios conforme nos desplazamos de Norte a Sur, así en la población más norteña las inversiones SC, EP y PP demostraron ser las más abundantes pero al dirigirse al Sur esa condición cambia y fueron substituidos por los arreglos cromosómicos TL, CU y OL, más al Sur ocurre una nueva substitución y las inversiones dominantes son TL, CU y SC luego la secuencia SC es substituida por SC por lo que finalmente en las poblaciones sureñas predominan las inversiones TL, CU y SC; en todos los casos existieron los contribuyentes menores representados por tres o cuatro inversiones. (Tabla 3 y Figura 3).

Tabla 3: Frecuencias Relativas de Inversiones de *Drosophila Pseudoobscura* Encontradas en el Transecto "C". (Símboloscomoen tabla 1)

	TL	CU	SC	EP	OL	OA	PP	others	n
C. de Caballo	9.7	6.4	32.3	22.6	---	9.7	19.4	---	31
Lirios	35.7	23.1	10.5	5.6	23.8	1.4	---	---	143
Matehuala	34.3	14.3	5.7	14.3	20.0	---	8.6	2.9	35
Jerez	30.9	7.1	33.3	11.9	2.4	4.8	---	9.6	42
Congoja	36.3	2.9	42.6	2.1	4.6	2.6	---	9.1	240
Río Verde	59.3	5.4	2.8	7.6	22.4	1.0	---	1.6	317
Reyes	51.6	3.2	16.1	6.5	22.6	---	---	---	31
T. Nueva	57.2	8.7	28.3	---	10.9	---	---	---	46
Huimilpan	45.2	26.2	4.8	4.8	14.3	2.4	---	2.4	42
Victoria	30.9	16.2	29.4	1.5	2.9	7.4	---	11.8	68
Zirahuén	30.5	25.7	20.9	10.5	2.9	9.5	---	---	105

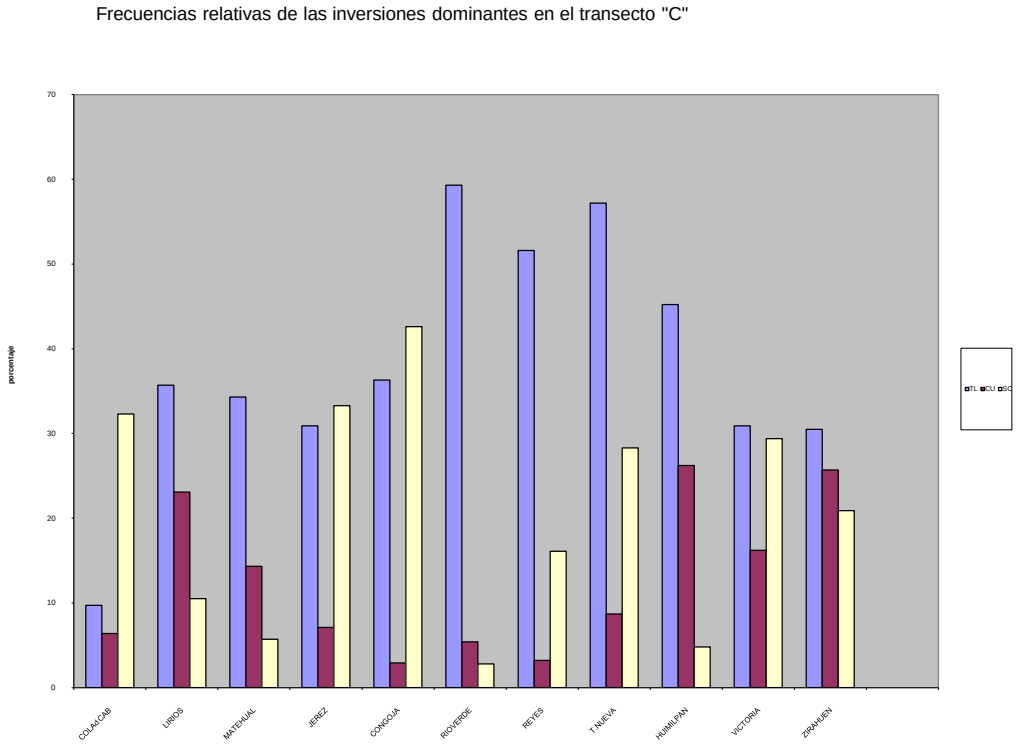

Figura 3: Representación Gráfica de los Cambios de Frecuencia de las Inversiones Dominantes de *Drosophila Pseudoobscura en el Transecto "C"*

En el transecto "D" encontramos como componentes principales en las poblaciones más norteñas las inversiones TL, SC y OL las cuales en la porción media fueron substituidos por los arreglos cromosómicos SC y CH y al finalizar el transecto en las poblaciones sureñas ocurre un incremento de la inversión TL y las cinco restantes presentan valores muy similares entre si pero alejados de TL, según se observa en la Tabla 4 y figura 4.

Tabla 4: Frecuencias Relativas de Inversiones de *Drosophila Pseudoobscura* Encontradas en el Transecto "D". (SímboloscomoenTabla 1)

	TL	CU	SC	EP	OL	OA	CH	others	n
Torreón	36.6	11.6	16.1	9.8	16-1	---	---	9.8	112
Presidio	17.1	7.3	31.7	---	4.9	---	26.8	12.1	41
Diego de A.	8.5	---	48.9	6.4	2.1	---	19.2	14.8	47
Presa	5.6	3.7	55.6	---	---	---	18.5	16.8	54
Valparaiso	34.9	6.8	6.8	2.7	3.4	5.5	---	8.3	146
Cd. Guzmán	21.4	8.6	8.6	5.7	1.4	2.9	---	1.4	70

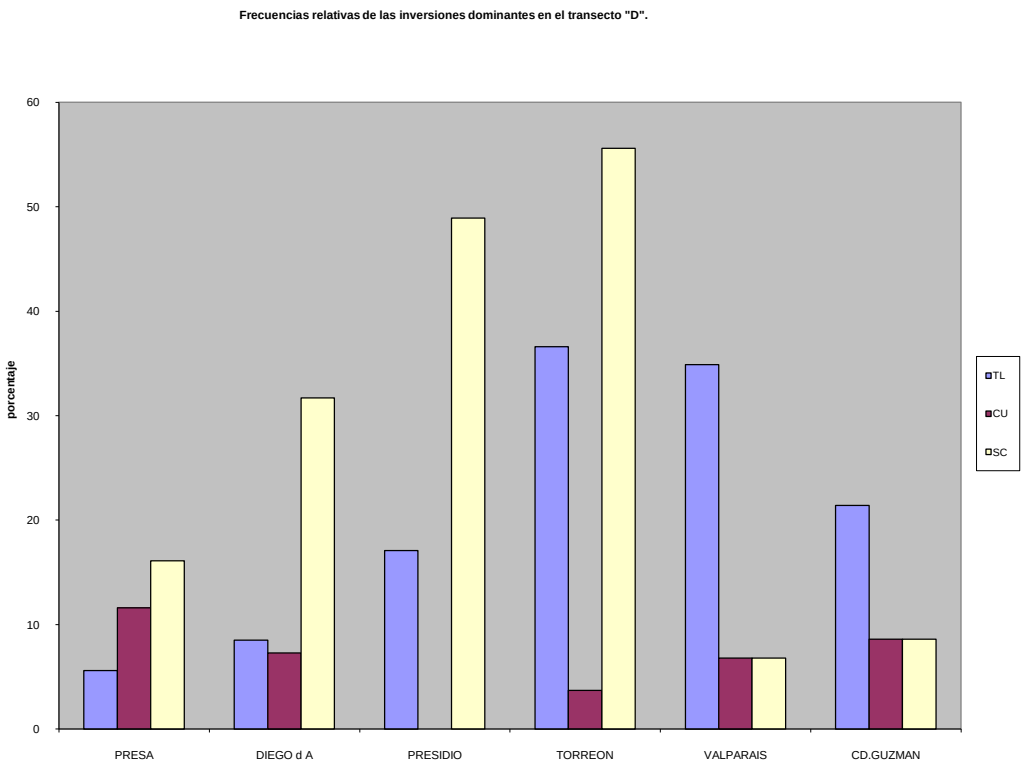

Figura 4: Representación Gráfica de Los Cambios de Frecuencia de Las Inversiones Dominantes de *Drosophila Pseudoobscura en el Transecto "D"*

Esta breve descripción de los cambios diferenciales que ocurren en cuanto a las frecuencias relativas de las diferentes inversiones incluidas en cada transecto, fácilmente visibles en las tablas, muestran cuan complicada es la respuesta de cada inversión a las condiciones ambientales de cada localidad, lo que en consecuencia, el poder determinar la presencia de un gradiente Norte-Sur es difícil, en efecto nosotros no lo encontramos en ninguno de los transectos.

Se sabe que los gradientes observados para la frecuencia relativa de las diferentes inversiones de esta y otras especies de *Drosophila,* como otra característica, pueden ser considerados como un claro ejemplo de selección en respuesta a los cambios diferenciales del medio ambientePowell (1990) y aunque en las poblaciones aquí estudiadas no encontramos una clara evidencia de la presencia de gradientes en la dirección Norte-Sur, al menoscuando consideramos un transecto en su totalidad, puesto que ocasionalmente en algunas secciones de un transecto dado y dirigiéndonos al Sur de una localidad a la siguiente, fue posible observar lo que pudiera mostrar una posible tendencia en cambios direccionales, por ejemplo, el transecto "A" claramente muestra un gradiente en el cual la inversión CU es substituida gradualmente por la inversión SC y en contraste en el transecto "B" nunca notamos evidencia de una tendencia de este tipo y siempre se presentaron sus componentes principales, las inversiones TL y CU con valores similares; en tanto en el transecto "C" si bien no observamos tendencia gradual de cambios en esa dirección si pudimos notar que ciertas inversiones fueron substituidas por otras, por ejemplo, PP y EP fueron substituidas, debido al cambio en sus frecuencias relativas al presentarse incrementos para las inversiones TL, SC o bien OL; por último en el transecto "D" se observó que los componentes dominantes en las poblaciones norteñas, TL, SC y CU conforme nos dirigimos al Sur hubo una substitución de la inversiones TL y CU por la inversión CH esto en las poblaciones medias del transecto para que en las poblaciones sureñas nuevamente fuesen dominantes TL, CU y SC.

Finalmente, debemos mencionar que la presencia de gradientes ha sido obserbada en varias especies de *Drosophila* y que la dirección en que ocurren depende de la especie estudiada, así, Levitan (1990) encontró gradientes Este-Oeste en poblaciones de *D. robusta,* de igual forma lo hicieron Dobshanzky y Epling (1944) en poblaciones de *D. pseudoobscura* en Estados Unidos y lo mismo ocurrió con las poblaciones mexicanas de esta especie estudiadas por Guzmán *et al.* (1993, 2005) y Olvera *et al.* (2005). Por su parte Krimbas (1990) reportó un caso interesante en *D. subobscura* donde encontró tres tipos de gradiente: Norte-Sur, Este-Oeste y centrales-marginales. Por su

parte Soulé (1973) quien estudió la presencia de gradientes en 16 especies de *Drosophila* observó que en 15 de ellas existe gradiente central-marginal. En *D. persimilis,* especie hermana de *D. pseudoobscura*y quienes conviven en buena parte de su distribución geográfica, Dobshanzky y Epling /1944) y Powell (1990) demostraron que la primera especie muestra gradientes Norte-Sur pero curiosamente no lo hace en la dirección Este-Oeste.

En las 29 localidades que nos ocupan para la búsqueda de gradientes Norte-Sur no fue posible encontrar una clara evidencia de ello, sin embargo, estas mismas poblaciones en la mayoría de los casos presentaron gradientes Este-Oeste como se demostró en poblaciones de Estados Unidos.

Por lo anterior asumimos que la presencia de gradientes Norte-Sur no es el factor que ha permitido la substitución de inversiones del Norte por las del Sur es decir el cambio de las inversiones ST, AR y CH predominantes en el Norte por las inversiones TL, CU y SC que prevalecen en el Sur. También debemos considerar que un posible factor que intervino en nuestro estudio es la amplitud de los transectos por nosotros considerados es bastante amplia, dos grados de longitud, y que la organización de los transectos fue en cierta forma azarosa según se hicieron las colectas, por lo que si aún se quiere analizar este fenómeno habrá que tener cuidado en que las poblaciones estén exactamente sobre el mismo meridiano y separadas entre ellas por distancias apropiadas.

De todas formas mostramos que las poblaciones mexicanas de ésta especie se comportan de manera similar a las de Estados Unidos con respecto a ésta característica, ausencia de gradientes Norte-Sur, y queda abierta la pregunta de cual(es)es(son) el(los) mecanismo(s) que han permitido la substitución de unas inversiones por otras específicamente ST, AR y CH por TL, CU y SC.

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An Overview on Engineering Bio-Treatment Methods for Effluent in Food Processing Industries

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Abstract- The highly toxic materials appearing in the food processing effluents are persistent on the natural ecosystem. The resultant effect is magnifying throughout the food chain and adversely affecting both public health and environmental health. So, effluent from food processing industries havereceived extensive research awareness. This review examines the adapted engineering bio-treatment methods for effluent and their treatment mitigations. Effluents from various food processing industries are also discussed. Volatile organic compounds (VOC) are emitted from this effluent and differ in chemical formation, amount, and possible threat. Natural methods used for their reduction have definite advantages and disadvantages. Risk reduction evaluations are the basic step for the treatment methods. Different physical, chemical, and biological treatment technologies have been applied to remove microorganisms from effluent,each having inherent merits and limitations. The simultaneous novelty of bio-energy and bio-treatment of effluent made this work outstanding.

Keywords: *bio-treatment; effluent; food processing; industry; microorganism.*

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I. Introduction

Land and water bodies in almost the world are affected by eutrophication, contamination, and exhaustion. Urbanization encroachment in every nook and cranny of the world has increased contamination due to human and industrial activities. These activities affect agricultural soils and waters by way of contamination. However, because the world has shown more interest in the present environmental issues and sustainable solutions, scientists and engineers face the task of using waste and weak small soil locations. These can realize when the soil locations and water bodies are balanced using bio-treatment methods (1-4). Numerous adverse effects witnessed from these contaminations are from food processing industries. These affect aquatic life negatively. The dissolved substances volatilize into the atmosphere, contribute to acid rain, pose a significant health issue to humans, and cause rust to materials (5-6). Recently, efforts to treat contaminants from gaseous, solid, and wastewater become a major concern. The techniques commonly include engineering bio-treatment (7), chemical methods [8], and biological methods (9-10). Today, the engineering bio-treatment technique is the most widely used for contaminants removal due to its low cost compared to other methods (11-12).

Engineering bio-treatment system (EBS), combined with chemical and biological treatment, has been observed as a successful method for contaminants removal. Liang et al. (13) used a bio-electrochemical system (BES) to remove sulfate from wastewater. Other researchers have also combined several methods for contaminant removal (14-15). Some treatment techniques add another impurity to the treated medium (16), and the impact can harm humans and aquatic life. Therefore, efforts to ensure that adulterations are not observed after treatment guarantee the environment's total safety. Briefly, numerous prerequisites accessible for effluent treatments are summarised in (Fig. 1). PAHs seem to exist in several natural environments, so their influence on the ecosystem is growing due to their toxic impact on humans and aquatic life. Among the numerous PAHs, benzo(a)pyrene is the most dangerous contaminant observed in effluent chiefly from the petrochemical industries and unleashes carcinogenic substances (17). The notable pollutants in the effluent from food industries elucidate in (Table1). Numerous sources of contamination involved the unleashing of unrefined or processed liquid from cities and villages, discharge from processing or industrial plants, flow from farmland, and leachates from waste disposal locations. Insufficiency of water, population growth, energy, and the development of new material technologies have forced researchers to probe into viable effluent treatment and waste recycling (18-20). The fundamental alterable to be observed for the effluent disposal are the odour, colour, oil, grease, pH, nitrogen content, phosphorus content, biological and chemical oxygen demand (BOD & COD), and

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suspended solids, dissolved solids, and metal ion absorption(21-22).

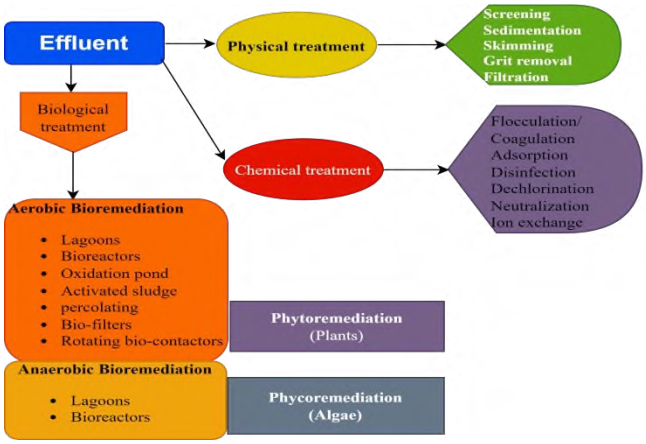

Figure 1: Numerous Prerequisites Accessible for Effluent Treatments

Table 1: Different Types of Environmental Pollutants

Pollutant type	Contaminants name	Reference
POPs	Pesticides, DDT, PCBs, nitrogen oxides, and ozone	[23][24]
PAHs	Naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, pyrene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, etc.	[25][26]
Antibiotics	Trimethoprim, ciprofloxacin, sulfamethoxazole	[27][28]
Metal ions	Arsenic, cadmium, chromium, mercury, lead.	[29][30]
Chlorinated disinfection by-products	Haloacetic acids, trihalomethanes, ketones, hydroxyl, carboxylic acids, nitrosamines, oxoacids, and aldehydes.	[30][31]
Perfluorinated compounds	Perfluorooctane sulphonate, Perfluorooctanoic acid.	[32][33]

II. Current Status of Food Processing Effluents in our Environment

The rising recalcitrant to microbial degradation from food processing effluents (FPEs) in our environment is a source of worry. The data gotten from the web of science papers' reference register of 'Science Direct' and 'SCOPUS' by defining the keywords 'effluents' and 'contaminants' as a subject matter between the year 2004-2022 led to over 800 research articles on emerging pollutants. The large quantity of waste produced during food processing is rich in nutrients and this wastewater can also be recycled to produce value-added goods. These goods include ethanol, 1-butanol, methanol, propanol, and isobutanol which are gotten from food waste via the fermentation process (34). A greater volume of the waste is discarded into landfill after treatment to reduce toxicity (35). The transformation of food waste into organic fertilizer can mitigate its environment effect, enhance nutrient levels of the soil and decrease direct chemical fertilizer application. The microalgae extracted after food waste treatment can be useful in animal feed, biofuel feedstock, and fertilizers (36). Single-cell proteins like bacteria, fungi, algae, and yeast are bred and collected to realize the food provision for man and animals (37-38). The gentle decrease in water quality in Nigeria is due to the disposal of food processing effluents into natural water bodies which are sometimes mixed with faecal material and micro-pollutants.

III. Food Processing Effluents

Liquid wastes from various food processing industries vary in concentration and quantity. The nature of effluent lies in the source and technology of any industry(39-40). It is a mixture of domestic and industrial materials coupled with synthetic items. Existing effluents contaminant includes; fats and oil, sugars, and amino acids (proteins). Amino acids and sugar constitute a crucial portion of organic matter in effluent from food processing industries(41-42). A remarkable quantity of some inorganic materials like potassium, calcium, magnesium, arsenic, sulfur, sodium, phosphorus, ammonium salt, and other heavy metals are mainly found in industrial effluents(43-44). Persistent organic pollutants (POP) from domestic and industrial impurities (mainly from the petroleum industry) are not left out(45-47). Polycyclic aromatic hydrocarbons (PAHs) from POP are from the combustion of non-renewable fuels like petroleum, coal, household heating, biomass

burning, emissions from operational industries, greenhouse gases, and landfills and wildfires. PAHs are organic contaminants mostly found in polymeric products and pollute the ecosystem(48-50).

a) Effluent from the slaughterhouse

Activities like roasting and washing from the slaughterhouse (abattoir) are good sources of contaminants. Disposal of this waste from the abattoir is a worrisome environmental challenge all over the globe. Using waste rubber in roasting slaughtered animals increased pollution in terrestrial, aquatic, and groundwater (51-52). The chemical properties of abattoir wastes are the same as that of municipal sewages, though the former is highly concentrated wastewater with soluble and suspended organic formations. Waste blood from the abattoir contains high chemical oxygen demand (COD) of about 375 000 mg/L, and it is one of the highly dissolved adulterants in abattoir wastewater (53-55). In Nigeria, there is no master plan for the disposal of effluents generated from abattoirs. The solid waste from the abattoir is collected and dumped in the landfills or open fields while the liquid waste finds its way into the water bodies or municipal sewerage system. These activities jeopardize human health coupled with terrestrial and aquatic life (56-57). Effluent from an abattoir can lead to an increase in biochemical oxygen demand (BOD), COD, pH, temperature, and turbidity, which may even lead to a lack of oxygen in the water bodies (58-59).

b) Effluent from the Cassava Industry

Cassava is known by its genus Manihot esculanta crantzcrantz and is mainly consumed in Africa, Asia, India, and South America (60-61). One of the processing methods include direct fermentation to get fufu (62-63), grating and fermentation to obtain garri flakes (64-65),grating and fermentation to obtain garri flakes (66-67), to obtain tapiocca (68). The liquid from cassava processing units contains a dangerous liquid called cyanide which is acidic in nature (69-70). Because of improper disposal of these effluents, the site is left to develop a foul odour while the effluents find their way to the water bodies and some percolates into the groundwater leading to another risk as elucidatedin (Fig. 2). The odour generated from the industry site cannot allow residents living near the factory to breath freely. The effluent from the cassava waste kills all the grasses along its parts due to the acidic content of the wastewater creating artificial soil erosion. Cassava effluent breeds various types of bacteria and fungi in the soil and affects public health when washed into the water(71-72). Some domestic animals and birds feed directly from this cassava effluent and when consumed leads to dangerous health problems. All these could pose an environmental problem shortly due to the lack of effluent treatment facilities.

Figure 2: Effect of Cassava Effluent on the Environment

c) Effluent from Fruit Juice Factory

Fruit is one of the essential nutrients required by man for the maintenance of the body. It is consumed by everybody in one form or the other. Some eat it as raw fruit, while others prefer consuming it as juice after processing. Fruits are the major sources of vitamin C(73-74). A deficiency of vitamin C in our diet can cause scurvy in children and other health implications in adults(75). Effluent from fruit juice factoriesis a source of emerging contaminants that could pollute freshwater easily(76). It is also a breeding ground for mosquitoes, flies, and other dangerous insects. The odour from the

factory wastewater attracts flies and perched in our food can cause dysentery in humans. Those emerging contaminant from the environment seems to be extremely difficult in the interim while trying to remove them. Wastewater from the fruit processing industry is highly polluted and cannot be discharged into the environment or reused without adequate treatment. The presence of COD and BOD needs an integrated chemical and biological treatment method in a bid to obtain the desired efficiency. Policymakers should also help ensure that good legislation on proper disposal of this effluent to avoid endangering the environment.

d) Effluent from Brewery Industries

Beer is made of four components viz; water, malted grains, hops, and yeast. Other flavours as cherries and citrus fruits can be added to it. A good production of water intake during the production of beer will end up as effluent and can be discharged through the sewer system or discharged into the water bodies(22). Stages in the brewing process of beer production (Fig. 3) and summarized in equation 1. The main components of the effluent which contribute to total suspended solids (TSS) comprise spent grain, yeast, and hops (77). Effluent fluids from this factory bear an average COD of 5340.97 mg/L with pH values ranging from 4.0 to 6.7 (78). The disposal of these wastes creates numerous problems for the environment. Discharging the effluent into the water bodies without proper treatment can cause problems for man and aquatic animals. Hence, one of the methods of reduction includes the utilization ofanimal feed, biogas production, and treatment of the effluent before disposal.

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 \quad \text{.....(1)}$$

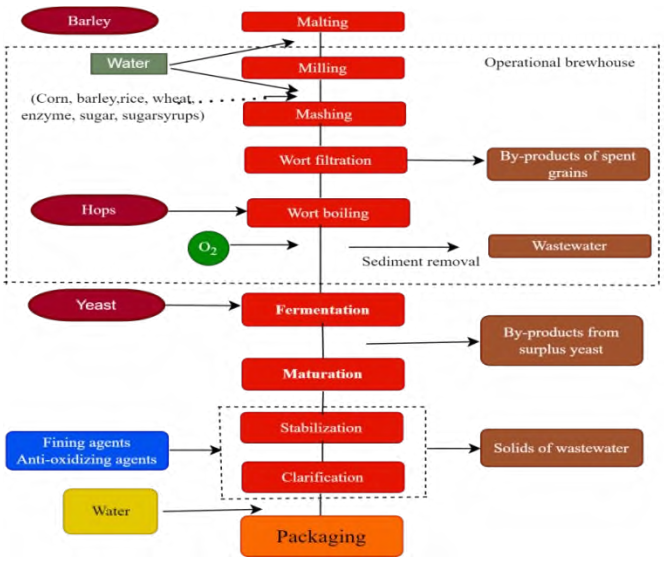

Figure 3: Brewing Process of Beer Production

e) Effluent from Grain Mills Processing Industries

This industry comprises grain processing in many product segments including cereal grain (corn, wheat, guinea corn, rice, etcetera), dried plantain and tubers chips, animal feed, breakfast cereal production, wheat starch and gluten production. There is no form of protection from this factory when humans are predisposed to health risks (Fig. 4). Soaked (moist) grains are also processed in this factory and have implications on the environment and public health. The milling factory for grains generates dust and fine particles that cause air pollution. The polluting process includes washing, spent lube oil from a garage which generates wastewater containing biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), and total dissolved solids (TDS)(79).Noise as pollution is also generated by this industry. Wastewater from grain is harmless and amenable to enzymatic and microbiological bioconversion(80). Most of the effluent is discharged into open water bodies and this can affect the water quality which in turn affects aquatic animals and humans when consumed(81). Discharge of polluted wastewater high in BOD into rivers and oceans can cause eutrophication and adversely impact biodiversity(82). The organic material in wastewater stimulates the growth of bacteria and fungi naturally present in water, which then consume dissolved oxygen(83).

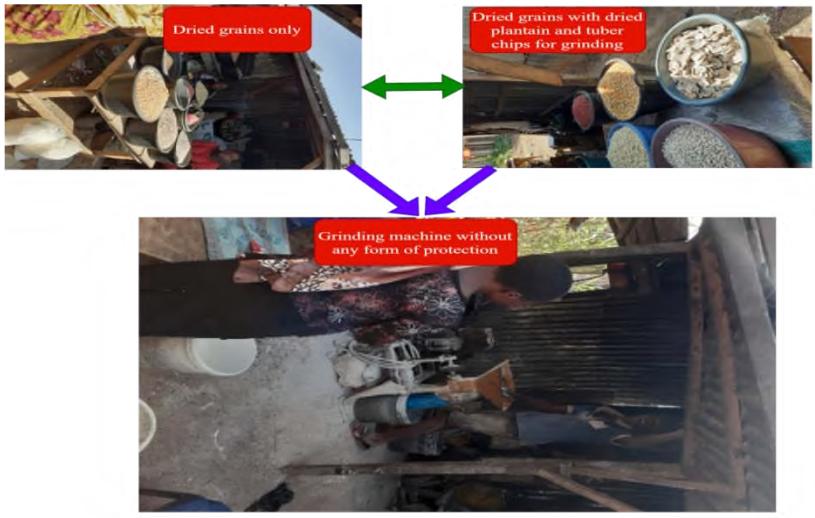

Figure 4: Unprotective Site of Grain Processing Factory in Abakaliki, Nigeria

f) Effluent from the Palm Oil Mill Industry

Pollutant flowing with palm fruit effluent is the most noticeable in agro-industrial wastes (84). The palm oil mill effluent (POME) consists of a large number of suspended solids, organic carbon, oil, and grease. Chemical oxygen demand (COD) and Biological oxygen demand (BOD) values for POME are estimated to be as high as 100,000 mg/L, which risks the environment (85-86). Al Azad et al. investigated the simultaneous incubation period of a purple non-sulfur bacterium in decreasing COD, total nitrogen, and total phosphorus in resolved POME (87). The physicochemical characteristics of raw and treated palm oil mill effluent (POME) as elucidating in (Table 2).The microalgae treatment of POME is essential but creates negative effects if not handled very well (88). Pre-treatment in POME is found effective as it converts lignin into sugar reducing supplement. Efficiencies for pollutant removal arefound in different parameters, for instance, 62.07% for total nitrogen (TN), 47.09% for COD, and 30.77% for total phosphorus (TP) (89). Further research indicated that immobilized microalgae cells exhibited a wonderful biomass concentration of 1.27 g/L and a COD decrease of 71% (90) than other suspended free cells. Dissolved oxygen is relatively higher in effluent from oil processing factories when compared to other industries (91).

Table 2: Physicochemical Characteristics of Raw and Treated Palm Oil Mill Effluent (POME) [87]

Parameter	Raw POME	Resolved POME	Reduction
pH	3.68	3.78	-
Chemical oxygen demand (mg/L)	39,900	21,540	46.2
Total solid (mg/L)	50,782 ± 1215	12,885 ± 40.86	74.6
Total volatile solid (mg/L)	43,099 ± 988	9510 ± 46.78	77.9
Total suspended solids (mg/L)	12,318 ± 265	1624 ± 146	86.8
Oil and grease (mg/L)	4132 ± 70.68	151 ± 26.03	96.3
Total nitrogen (mg/L)	804 ± 53.49	239 ± 100.75	70.3
Total phosphorus (mg/L)	120 ± 5.07	77 ± 3.96	35.8

IV. Adapted Bio-Treatment Methods

Water is a prime component in food processing, the beginning and midway cleaning of roots, an effective shipment of raw materials, and the lead actor for disinfecting plant machinery and work areas. Due to this substantial water usage, food production's main concern is that water and wastewater are controlled in the highest inexpensive method and reused in any way feasible to lower costs and remain environmentally acquiescent. The functional design for any food industry usage should match your plant requirements for the best efficacy. A pre-treatment form is often the most straightforward and inexpensive solution if the main concern is to lower adjusted parts to an acceptable discharge degree. Significant removal of suspended solids, oil, grease, and BOD is possible by executing a system based on the dissolved Air Flotation operation.

a) Electric Discharge Plasma Methods

In foodstuff industries, many volatile organic compounds (VOC) are emitted, which differ in chemical formation, amount, and possible threat. Traditional methods used for their reduction have definite merits

and demerits. The major stumbling block comprised pollutants carried into another stage, generating risk-taking waste and leading to a high cost of treatment. Different types of plasma methods exist for nanowires synthesis (92). Plasma fabricated with an electrical discharge in gases is functional in agriculture and biomedical applications(93). The best-developed VOC plasma treatment is the fusion of pulsed corona discharge with catalytic and photocatalytic treatment(94). As described by the authors, the dielectric barrier is a reactor to generate non-thermal plasma for wastewater treatment(95). A streak camera furnished with a spectrograph has evaluated the optical emission of plasma acquired using machine learning algorithms which roughly calculated the plasma electron structure(96). A high-voltage pulse developed during hydrogen removal from water permits the distillation of wastewater and minimizes its chemical and biological occupation(97). Another research viewed high-voltage electrical discharge plasma reagents as encouraging effluent remediation and reduction of organic/ polyphenol compounds(98). The trimming of polyphenol compounds of 60.32% is at 60 Hz with air $FeCl_3x6H_2O$. Also, the best COD removal of 50.98% and 49.02% is attained with the inclusion of $FeCl_3x6H_2O$ at 120 Hz. In closure, the most remarkable trimming in colour intensity was at 120 Hz with the addition of $FeCl_3x6H_2O$ coupled with nitrogen and air. Mathematical modelling of high-voltage electrical discharge plasma automation has recently been used for pollutant removal(99-101)and seems the most inexpensive and efficient method in effluent treatment. Several other studies on the application of dielectric barrier discharge plasma in uncoupling minerals in wastewater are also making waves(102-103).

b) Disinfection & Ozonation

The blend of chemical disinfectants in food processing apparatus is significant for checking a food-borne disease epidemic. As good as drinking water disinfection, food mills will need to evaluate disinfectant vulnerabilities to stabilize disease discharge upon display to likely toxic disinfection by-products. The growing non-thermal treatment automation novelty has replaced thermal technologies in food industries to manufacture healthy, nutritious, safe, and prolonged shelf-life foods (104). The clarification of several farm-to-fork disease reduction master plans at separate steps in food quality assurance was extensively evaluated (105). The activities that led to the spread of disease infection summarizes in (Fig. 5). Alchemical disinfection has grown in today's research, leading to a growth in scientific publications (106). Cold plasma revealed its efficacy in disinfecting methods for the inactivation of bacteria, viruses, diseases, and other hazardous microorganisms (107). The reduction of biofilm formation requires exceptional strategies by biochemical agents in the food industry while enhancing food quality and safety (108-109). Dripping ozone has displayed effectiveness in foodstuff disinfection, pesticide degradation, and seed germination (110). Water reuse in food processing firms helps to reduce the impact created by water scarcity in some localities (111). The fluid ozone treatment is efficient in dropping a microbial size, keeping standard variables, and growing shelf life in fresh-cut slices of onion (112). The disinfecting capacity of liquid ozone was comparable to 100 ppm chlorine. These show that ozone is a safe disinfecting agent in food processing firms. The effectiveness of ozone treatment capacity on usual microorganisms proved that ozone concentration is adequate, and the time exhibition needed to surrender total microbial removal is 20 ppm and 4 minutes, independently (113). However, the opposition to the tested organisms with ozone gas is in the order of effectiveness. This result is necessary for applying ozone concentration and exposure duration in a large-garment firm for rapid disinfection. The cost of ozone generation integrated with a short-lived period of ozone could lead to wasteful working for the utilization of ozone solo in extensive effluent treatment use (114). Overcoming this barrier means that more research in this area is required to ensure the large-scale application of ozonation.

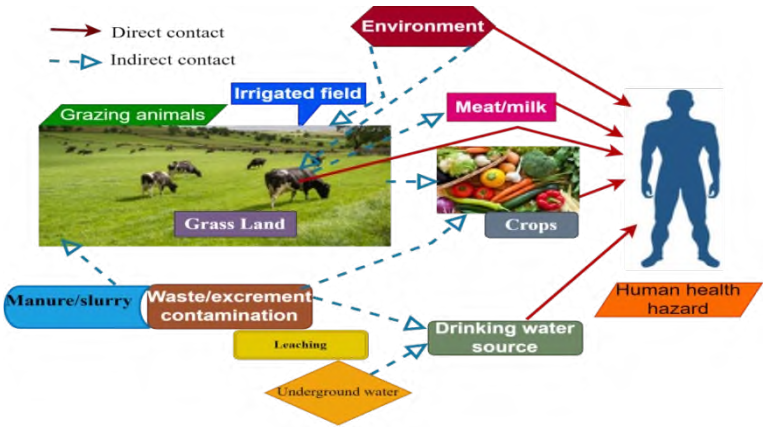

Figure 5: Route to Disease Infection

c) Membrane Bioreactor

Membrane bioreactor (MBR) is a novel and efficient automation that is fast expanding and increasingly applied in municipal and industrial effluent treatment all over the globe. It is also a wastewater treatment process where a perm-selective membrane, for example, microfiltration or ultrafiltration, is combined with biological operation, particularly a suspended advance bioreactor. Most food industries' wastewater contains a lot of oil and grease that require adequate cleaning using various techniques to enhance reuse. By so doing, many scientists have developed an intense use of membrane automation in the tenable recycling of phytochemicals from the agri-food zone (115). For instance, synthetic purification of membranes in food production sewerage chemically improved backwash carried out in an experiment with 6 Lm^{-2} of 2000 ppm (116). NaClO attained an effectiveness of 56.8% inlet unblocking and 60.7% all-inclusive resistance in the absence of these concentrations undergoing any negative outcome on the biomass project. Highly effective removal of fundamental material from high-power food processing effluent showed that 90% of the total COD was removed at an organic loading rate (OLR) of 5.0 g COD/L day (117). A tiny expansion in trans-membrane pressure was noticed, with the growth of volatile fatty acids inside the test span. Virgin membrane took 57 days before fouling and another 75 days to get to dynamic membrane number of years following four cycles with an expanded OLR ranging from 3.5 to 7.5 g COD/L day (Fig 6).

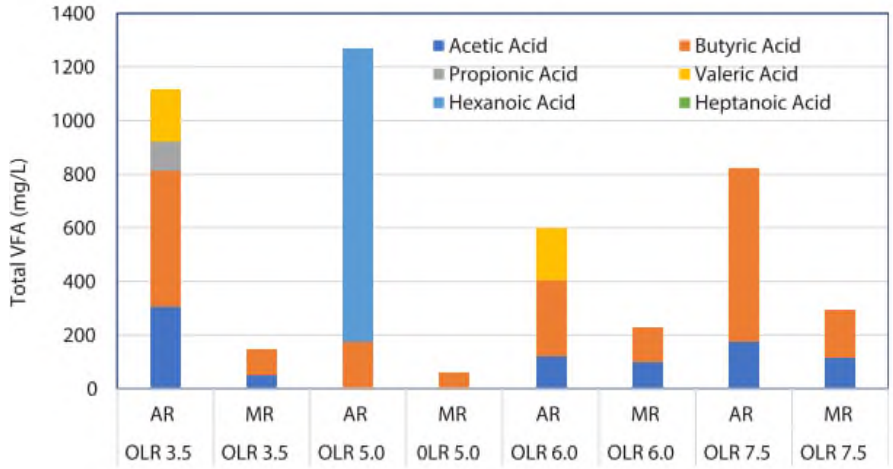

Figure 6: Volatile Fatty Acid Accumulation in the Acidogenic Reactor (AR) and Methanogenic Reactor (MR) at Different Olrs During the Treatment Operation [117]

Inexpensive material support and biogas energy creation made the dynamic anaerobic membrane bioreactor possible operation for force effluent. Meat processing effluent has intensely undergone examination using an anaerobic membrane reactor (118). The technique realized a COD withdrawal of 88 - 95% for 0.4 - 3.2 $kgCOD/m^3$ per day. The outcome of methane gas was moderately low at 0.13 - 0.18 $LCH_4\ g^{-1}$ COD removal, showing the existence of non-biodegradable organics in the effluent. At low OLR, membrane variability is firm but declinesto 3.2 $kgCOD/m^3$ per day. At the highest OLR, the minimum gathering of dissolved methane and saturation index discerns. The organic matter removal and methane manufacturing from food waste-reuse with household wasteshowed a tremendous COD and TOC removal attains during the treatment at a very high organic loading rate of 2.95 kg COD/m^3 d (119). Food waste-recycling incorporation correlates with a mean methane manufacturing of 0.21 ± 0.1 L CH_4/g of COD removal. Incorporating polyvinyl alcohol-gel donated emphatically by cutting off the cake from the exterior membrane led to a reduction in the fouling index value of deep-rooted working. A significant elucidation of organic carbon detection identification and particular grouping of dissolved organic matter (DOM) during the treatment revealed that ceramic membranes are strong for DOMs removal. While variant parts in the DOMs donated to the membrane are dirty, oligomers would assume to be the crucial dirt. The tenable flux at variant high solid clusters showed that the best filtration-to-relaxation ratios were 3:1, 3:1, 3:1, and 3:6.

This agrees with the considerable tenable flux increment at mixed liquor total solid (MLTS) clusters of 10, 15, 20, and 25 g/L, respectively (120). The ultimate MLTS cluster proposes to be about 20 g/L to keep a high tenable flux through the anaerobic digestion of food waste. The achieved regression equation linking the excessive tenable alteration and MLTS cluster applied to forecast the tenable variability at future MLTS cluster, acting as a reference for full-size AnMBR blueprint and functioning. A combination of a micro-

aerobic reactor and membrane bioreactor improved the degradation of extracellular polymeric substances (121). The use of livestock waste for the production of methane and treatment of the same wastewater showed that methane yield was recorded as highest at a hydraulic retention time of 15 days because of the higher microbial operation (122). Some other researchers have investigated the use of membrane bioreactors in food processing industries (123-125). This method can also be applied in pharmaceutical effluent treatment (126) to reduce the growing pathogens in hospitals.

d) Electrochemical Treatment Method

The electrochemical method for treating food-industry effluent generally lowers the concentration of organic pollutants. Effluent from food and beverage factories has a greater drawback on the economy and environment. Tackling this problem means that the impact created should be solved with immediately available technologies. Boron-doped diamond is the best-utilized anode material because of its high performance in discharging hydroxyl radicals and this pushes for higher pollutant removal in the chloride presence (127). The electrochemical process is gaining more popularity because of its effective pollutant removal within a lesser period compared to normal biological treatment (128). Though ultra-stable electrolyte is needed to degrade and avert the build-up of undesired outgrowth (129). This method is also used in the water recycling operation of dissolved air flotation from the food industry (130). Wastewater from maize processing industries can be harvested for cleaner production of electricity (131-132).A study by (133)used integrated technology for sugar factory effluent treatment. The outcome indicated that the single use of ultrasonication and electrocoagulation processes of treatment did not show a promising result in terms of COD removal. Meanwhile, the combination of the dual processes shows better efficiency. This process is purely inexpensive compared to other technologies. A good example of integrating more than one treatment technology is reported (134-135).

e) Bio-Removal of Dyes

The agro-based bio-treatment process could be utilized for the direct removal of dyes and can also act as a co-substrate to invigorate the decolorization of dyes by fungi and bacteria (136). The utilization of biologically activated banana peel waste has demonstrated a great adsorbent for the removal of methylene blue dye at a low cost in a green environment (137). Another bio-removal of methylene blue was successful using yeast with a removal percentage of over 70% at standard conditionsunderthe highest temperature of 35 ^{o}C (138). The application of the Langmuir equation helps to homogenize adsorption on the tops of absorbate and absorbent charge to possess the same proportion of sorption stimulus energy. Under high temperatures, betaine laccase displayed higher decolorization of some recalcitrant organic dyes in wastewater and aqueous solution (139). Other studies have been performed relating to the biosorption of various dyes using leaf-based biosorbents and very reliable findings are reported in the literature, elucidated in Table 3. For example, Alhajali et al. (140)have examined the removal of phosphate and nitrate ions from an aqueous solution using pistacia leave powder as a biosorbent. The authors reported high removal potential at a powder dose of 2 g/L and temperature of 25 ^{o}C. Characterization using SEM, FTIR, and EDX confirmed the efficacy of this natural method. Non-selective utilization of dyes adulterates water bodies and this poses a dangerous threat to public health. The good carbon content of eucalyptus leaves shows its best removal efficiency of adsorbent (methylene blue dye from water) at a higher pH range (141). While the adsorption adopts pseudo-second-order kinetics, the method is inexpensive, available, and eco-friendly.

Table 3: Studies Relating to the Adsorption of Dyes from Aqueous Medium using Leaf-Derived Biosorbents

Source	Adsorbent ppties	Dye	The optimal condition of the experiment(IDC, dose, pH, Temp, rpm, CT.	Removal efficiency/adsorption capacity	Desorption efficiency	Isotherm model	Kinetic model	Ref.
Lemongrass leaf	NaOH	Methylene blue/crystal violet	200 mg/L, 0.005-0.05, 2-9, 25-50 ^{o}C, 60 rpm	76.92 & 35.84 mg g^{-1}	64.35±0.88% for CV and 92.90±1.70% for MB.	Langmuir	Pseudo-second-order	[142]
Cucumis sativus peel	Sodium chloride	Crystal violet	5.0 g/L, 160 – 900 ^{o}C, 1 h	149.25 mg g^{-1}	17.14%	Langmuir	Pseudo-second-order	[143]
Nigella sativa L. herb	Sodium hydroxide	Synthetic dye	1000 mg/L, 30 mg/L, 8, 360 min	136.2 mg g^{-1}	-	Langmuir	PSO	[144]
Seed of Artocarpus heterophyllus &	NaOH & hydrochloric acid	Lead	2 μg/mL, 60 mg, 5.8, 300 rpm, 70 min.	96% for SBAh & 93% for SBSc/4.93 for SBAh & 3.95	-	Temkin	Inter-particle diffusion	[145]

Syzygium cumini				mg/g for SBSc				
Sugarcane bagasse	-	Methylene blue	100 mg/L, 45 ^{o}C, 24 h	98.32%/9.41 mg g^{-1}	-	Sips's three-parame ter	Pseudo-second-order	[146]
Rice husk, cow dung & sludge biochar	-	Methylene blue	1000 gm, 0.6-6.0 g/100 mL,2.0 – 11.0, 500 ^{o}C, 3 h,	99.0% for all the sources	-	Langmuir	Pseudo-first & second-order	[147]
Fique plant	HCl & NaOH	Textile dye	50 mL, 0.5 g, 2.4 – 3.8, 45 ^{o}C, 24 h	66.29%	-	Exponentia l decay	-	[148]
Bilberry leaves	-	Cationic dye	53.34% pH, 12.00% Temp, 22.11% CT,	200.4 mg g^{-1}	-	Sips	General order	[149]
Lemon grass	Activated carbon	Remazol brilliant violet 5R	25 – 500 mg/L, 2-12, 30 – 60 ^{o}C, 0 – 24 h,	125 & 342.9 mg g^{-1}	-	Langmuir & Koble Corrigan	PFO	[150]
Waste wood biomass	-	Congo red	10 -100 mg dm^{-3}, 4 – 9, 5 – 360 min,	71.8%/3.3 mg g^{-1}	18.6%	Langmuir	Pseudo-second-order	[151]
Peels of Trapa natans & citrullus lanatus	Citric acid treated	Cationic dyes	250 mL, 100 g, 30 ^{o}C, 150 rpm, 6 – 10 h	128 & 189 mg g^{-1}	-	Langmuir	Pseudo-second-order	[152]

Note: ppties: properties; IDC: initial dye concentration; Temp: Temperature; rpm: revolution per speed; CT: contact time

f) Bio-Recalcitrant Pollutant Removal

The destructive recalcitrant of organic pollutants from industrial effluent is a major public health challenge to the world. A lot of these contaminants are available in every space of our environment (153). Green-grey technologies amount to a promising pathway for instigating first-hand wastewater treatment and recycling in our cities (154). Fe(III) coagulant-treated colloidal gas aphrons (CGA) are adjudged the most efficient in the removal of bio-recalcitrant colour and dissolved organic carbon (DOC) in cassava distillery wastewater (155). Photocatalytic reactors have helped in the degradation of bio-recalcitrant organics from pharmaceuticals, pesticides, surfactants, and dyes which may escape with treated water (156). Though this method can only be effective in the laboratory setup, effortsto industrialize it are being employed. Combined efforts of hybrid microbial electrochemical systems and photocatalysis exhibitedsubstantial prospects for the degradation of bio-recalcitrant pollutants and improved system production (157). The study to integrate the microbial electrochemical systemwith electro-Fenton oxidation leads to an efficient process to deal with recalcitrant compounds (158). Nitrogen pollution is a major threat to aquatic life. Reduction of this nitrate pollutant could be made possible via a novel system of informally coupled photocatalysis and biodegradation (159). This novelty showed a removal efficiency of 40.3% after a few hours.

g) Photofermentation Using Purple Non-Sulfur Bacteria

Photofermentation is observed virtually in every solid waste and wastewater of numerous food and beverage processing industries. Solid waste and wastewater from food industries are converted to bio-hydrogen via photofermentation using purple non-sulfur bacteria as biocatalysts(160). Two enzymes of nitrogenase and hydrogenase are utilized in the creation of bio-hydrogen (161). The utilization of purple non-sulfur bacteria (PNSB) for single-cell protein is of great help in mainstream protein sources for the production of feed for aquaculture and poultry (162-37). The two-phase bio-refinery operation to waste substrates building ethanol-rich effluents is examined (163). The process allowed microbial consortia held in the winery wastewater to advance through a fermentative ethanol corridor. It is difficult to produce bio-hydrogen due to the metabolic route changes involved but the identification of lignocellulosic feedstock using microbes-dependent to crash the operational cost and reduce waste produced has made it feasible (164). This process is efficient enough to cater to succeeding energy demands. The use of nanomaterial and bioelectrochemical technology is confirmed to be appropriate for fermentative hydrogen production (165). A by-product called furfural is detrimental to the photofermentation production of hydrogen when lignocellulose biomass is undergoing hydrolysis. A better result of hydrogen production is obtained when furfural is in total absence from the production chain (166). A top hydrogen yield of 2.59 ± 0.13 mol-H_2/mol-glucose while a top production rate of 100.64 ± 3.12 mmol-H2/(h.mol-glucose) are gotten in the absence of furfural but a noticeable barrier is recorded in the presence of furfural (Fig. 7). The application of thermosiphon photobioreactor in the production of bio-hydrogen is examined using rhodopseudomonas palustris (167). The result of the response surface methodology models indicated topmost specific

hydrogen production rates of 0.17 mol m – 3h – 1 and 0.21 mmol Gcdw – 1h – 1 at R. palustris concentrations of 1.21 and 0.4 g/L. The computed hydrogen yield falls within the range of 45 to 77% and the glycerol consumption is 8 to 19%, respectively.

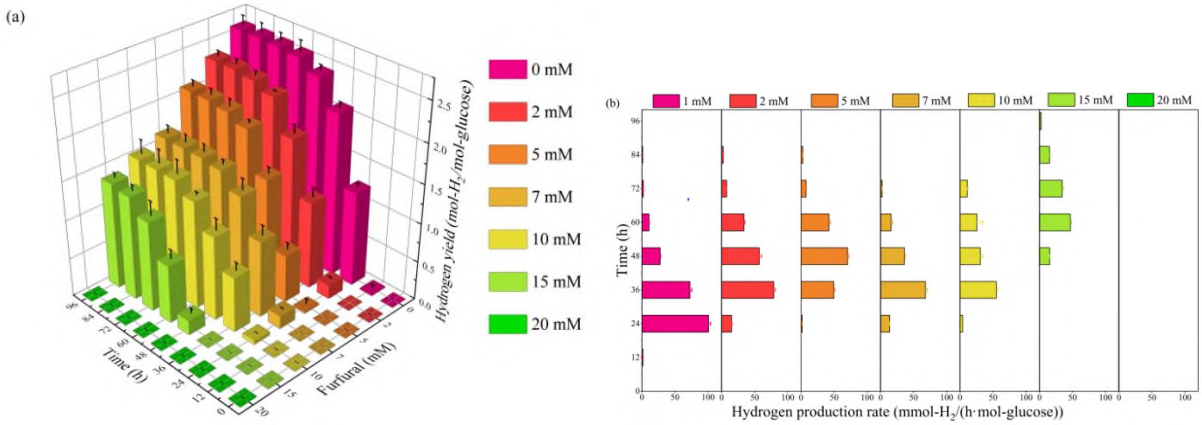

Figure 7: Hydrogen Production from Glucose in the Presence of Furfural (A) Accumulative Hydrogen Yield (B) Hydrogen Production Rate [166]

h) Integrated Treatment Strategies of Effluent in Food Processing Industries

Explosive chemicals get into the environment during manufacturing, firing, loading, assembling, and packaging operations. Contaminated effluent from those operations if released untreated, becomes a threat to the standard of most important environmental constituents of the lithosphere, hydrosphere, and biosphere. Treatment of these hazardous materials from the wastewater before release to the environment is important. A single method may not wholly achieve much but integrated treatment where two or more techniques are employed may go a long way in obtaining adequate results (168). Wastewater from the food processing industry is a good source of energy and a primary source for getting valuable items. The characteristic of food waste effluents is summarized in (Table 4). Reuse and recovery in food processing firmsare aimed at enhancing food productivity while reducing operational costs and avoiding environmental calamity through an integrated approach (169). Tannery effluents contain some chromium materials and their wastewater can be reusable through an integrated process of treatment. The treatment removal efficiency of this chromium-contaminated effluent ranges from 82 to 99.9% which is now safe for irrigation (170). A study by (171) required at least a minimal quantity of microalgae to keep operational stability and expand methane production. A Continuous stirred reactor is the most efficient type of reactor used for the conversion of wastewater to biogas though with challenges (172).

Table 4: Removal Efficiency from Food Processing Effluents

Food firm wastewater	BOD	COD	TSS	pH	Total nitrogen (TN)	Total phosphorus (TP)	Ref.
Cassava	-	88.7±1.2%	-	9.0	72.4±3.2%	74.1±10.8%	[173]
Slaughterhouse	-	97.1%	-	-	90.8%	90.1%	[174]
Fruit juice	99.7%	99%	98.4%	-	-	-	[175]
Brewery	93%	77%	90%	-	87%	89%	[176]
Palm oil	-	90.20%	-	4.3	94.44%	94.24%	[177]

i) E-Beam Radiation of Effluent in Food Processing Industries

The application of e-beam and gamma irradiation to treat food industrial effluents is gaining momentum in recent times. The current challenge of a global health crisis in association with fresh and groundwater pollution demands for safe disposal of effluents. Effluent is made up of heterogeneous suspended particles, dissolved organic, inorganic solids, salt, and some phenolic compound that are recalcitrant to microbial degradation (178). Electron beam treatment of any type of food effluent is noticed to be very efficient in reducing the biological oxygen demand and chemical oxygen demand (79). Remediation of wastewater from the food processing industry using e-beam irradiation is a key to viable smart and green cities across the world (179). For example, a 13 kGy dose of e-beam is used for the reduction of human adenovirus type-5 aggressive titres by almost 100% (180). This shows how effective e-beam

technology is while deploying it for wastewater disinfection. Also, a 35 kGy dose of e-beam irradiation is efficient for the reduction of toxic materials from slaughterhouse effluent (181). Meanwhile, possible organic carbon content after irradiation removal could further be investigated. The use of e-beam irradiation for the post-harvest treatment of cherry tomatoes is investigated (182). The result showed that a 3.6 kGy dose of e-beam irradiation is effective in reducing bacterial population, free filamentous fungi, and foodborne injected pathogens. A high-powered e-beam accelerator is designed to treat not less than 12 million gallons per day of wastewater using 13.5 ¢/ton/kGy during irradiation processing (183). This method can also be extended to pharmaceutical wastewater treatment in real-time (184). For instance, the integration of Gamma rays and E-beam irradiation showcased an assessment of efficiency as aggressive indicators for better healthcare effluent quality control. The irradiation of healthcare effluentwith Gamma and E-beam ionizing irradiation indicated that E-beam technology is more efficient but spores of Clostridium perfringens exhibited the most resistance among studied microorganisms (185). The authors submitted that lower doses of E-beam irradiation are needed for the inactivation of bacteria and bacteriophages than those needed for Gamma rays inactivation. However, a dose of 7 kGy is enough for the total inactivation of bacteria and viruses during inactivation patterns.

j) Electro-Bio Process of Effluent in Food Processing Industries

This is another method of effluent treatment found useful in food processing industries. It involves the integration of electrochemical and biological processes in treatment management. Excellent integration of working variables could give a categorical realization of pollutant removal gotten from the experimental models of apiece procedure. The reduction of COD up to 80% from bleach effluent appears to be inexpensive by using electrocoagulation and biological treatment (186). A hybrid of electrokinetic is effectively used to remove heavy metals, organic and inorganic from the agricultural soil (187-188). Meanwhile, the electro-bio-simulation treatment improved the fertility of agricultural soil while reducing the electrical conductivity drastically lower than 2.0 dS/m (188). Another efficient use of bio-electricity is the developing route for CO_2 consumption and reserved hydrogen fuelwhich involves the combination of microbial blend with renewable electricity (189-190). Microalgae exhibited a suitable pathway for the production of biohydrogen which aid in carbon neutrality and bioenergy viability (191-192). In another work by (193), a ternary mixture of electrochemical techniquesis used as a procedure for the treatment of canola oil refinery effluents. The efficiency of the processes is encouraging. However, regression modelling evaluation demonstrated that a binary mixture of electrocoagulation and electrooxidation exhibited superiority compared with electrochemical peroxidation in terms of soluble chemical oxygen demand (sCOD) and dissolved organic carbon (DOC) removal in canola oil refinery effluents. This shows that the efficiency removal of sCOD and DOC has been obtained at 98.6% and 95.28% under EC and EO methods. It should be noted that the degradation of sCOD lowered from 6403 mg/L to 72.40 mg/L concentrations within 13.66 mA/cm^{2}of current density after treatment (Fig. 8). A complex pollutant generated from textile industry effluents could be treated using binary electrocoagulation and organic coagulation mixture technology (194-195). The result showed that the application of an artificial neural network in the treatment of hybrid textile effluent is effective. However, the line dye concentration quantification in the reactor achievement flow may be a setback to the system.

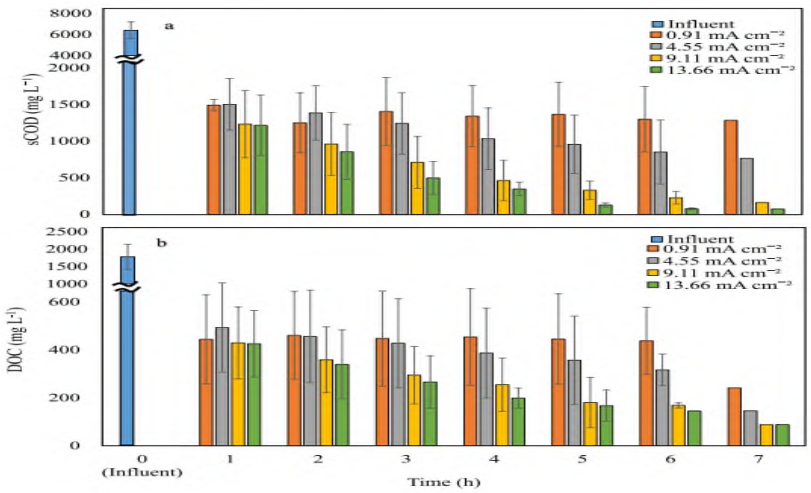

Figure 8: a) sCOD and b) DOC Removal from Canola Oil Refinery Wastewater using EC and EO Method [193]

k) Use of Bacillus Organismsin Effluent Treatment

Machines used for food processing harbour contaminated microorganisms on the machine surfaces before and after cleaning processes.The removal of such microorganisms from equipment surfaces is more tedious on stainless steel due to its rough surface nature (196). This tediousness occurs due to the exopolysaccharide's protective sheath against harsh conditions (197). Bacillus cereus variants exhibited efficient bioremediation possibilities during the degradation of fats, oils, greases, and odours reduction (198). But various probiotics strain of bacillus is beneficial to human health. Valuable substrates from agricultural effluentare used as a high efficient cellulase production (199). The authors concluded that bacterial strain is effective to degrade the coconut mesocarp which carries a high quantity of lignin and hemicelluloses without preliminary treatment. These features make it significant as an effective degrader for numerous other agricultural effluents. Similarly, normal antimicrobial lipopeptides discharged from bacillus spp acted as a food bio-preservative (200). This technique enhances the shelf life of numerous perishable foods like vegetables, fruits, drinks, and aquatic goods. This type of research is also conducted on a commercial scale in comparison with a laboratory setup (201). For example, commercial crop probiotic is examined using bacillus subtillis CW-S in closed vessel fermentation (202). The authors summarized that molasses and urea medium dished out an acceptable cell density of 7.19×10^8CFU/mL in comparison to the control of 1.51×10^7 CFU/mL with expensive media of $1.84 \times 10^7 - 1.37 \times 10^9$ CFU/mL. Metabolites produced from bacillus spp improve crop yieldby providing the plant with several micronutrients, volatile compounds, and antimicrobial earmarking pathogens (203). Other species of the bacillus display opposition to pathogens by generating growth hormones such as cytokinins, gibberellin, and spermidines leading to root and shoot growth. The presence of bacillus in the soil shows great protection against harsh environmental stimuli like droughts, heavy metals, and salinity in the plants. It can decontaminate metal-contaminated soil and enhance the carbon segregation procedure when used in a controlled concentration (204). It can act efficiently as a denitrifying agent in an agricultural environment and ensure soil health balance by green remediating automation. A strain of bacillus velezensis CE 100 is used to inhibit plant phytopathogenic fungi and its gain improves strawberry production (205). Also, the production of indole-3-acetic acid from the above bacillus enhances crop nutrient uptake while promoting cell division and distinctness. This particular strain is helpful in the organic matter removal and impedes the development of harmful bacteria from slaughterhouse effluent (206). The benefit of this method is that it acts as an antioxidant and angiotensin-converting enzyme that performs barrier occupation (207).

l) Eichhorniacrassipes (Water Hyacinth) and Panicum Maximum Treatment Method

Effluents from various food processing factories consist of high levels of chemical oxygen demand, suspended solids, biochemical oxygen demand, nitrate, and phosphate. Their value in the wastewater composition is above the standard recommended by World Health Organization (WHO). These effluents if discharged into fresh water without treatment can lead to public health catastrophes. By so doing, the removal of these parameters by Eichhorniacrassipes and Panicum maximum displayed high performance (41). The authors concluded that both Eichhorniacrassipes and Panicum maximum decrease pollutant loads of effluent undergoing fermentation. Another study by (208) investigated the best conditions for organic matter removal using Eichhornia crassipes. A factorial design denoted by X1, X2, and X3 is used to ascertain the impact of residence time, plant density, and COD concentration while process efficiency is evaluated with Y1 for COD, Y2 for NH^{4+} and Y3 for PO_4^{3-}, respectively. In summary, the optimal removal rate for COD is 81%, NH^{4+} is 95% and PO_4^{3-} is 99.35%. Phytoremediation drive in vetiver grass is utilized to decontaminate polluted water and industrial effluent due to its physiological and morphological attributes (209). Some other plants which performa similar function as Eichhornia crassipes include Seaweed (210) and macrophytes (211).

m) Antibiotic Resistance Treatment of Food Processing Effluents

The issue of antibiotic resistance is fast growing into a global health calamity. The overuse or misuse of this antibiotic is a major factor in the exposure of bacterial resistance to antimicrobial organisms. This problem is not eradicable but can be managed through the treatment of infections. Improving the use of antibiotics in food processing factories should be a prime concern to avoid the spread and disclosure of resistance across the food chain (212). Most of these treatment methods can cause selective elimination and alter the proportion of phenotypes or genotypesunder bacterial growth in the effluent. The ineffective elimination of antibiotic-resistant bacteria (ARB) and antibiotic-resistant genes (ARGs) from wastewater treatment plants and effluent lead to the active rollout of resistance genes to native microorganisms (213). The ecology of enterococci and associated bacteria in treated and untreated wastewater is examined on the widespread presence of antibiotic resistance phenotypes within the bacteria group (214). The result showed that the principal species of enterococcus are found in untreated wastewater while the associated quantities of enterococcus faecalis continue to exist in

treated and untreated wastewater. Furthermore, the antibiotic-resistant strains of enterococci are not removed through wastewater treatment. The use of reclaimed wastewater to irrigate farms with edible crops constitutes a big risk linked to the composition of antibiotic bacteria, antibiotic-resistant bacteria, and antibiotic-resistant genes (215).

A study of different effluent samples from two seafood processing industries are investigated between 2021 and 2022 (216). The result showed that from the samples, different bacterial species are identified with different bacterial loads. Because of a high level of recurrence of this antimicrobial resistant, urgent measures should be adopted across other industrial sectors to inhibit the increase and spread of this antimicrobial resistance. The use of nanoparticles also played a vital role in this regard (217). A novel use of mild heat and sonication is profitably developed to sanitize bacteria in fresh foods (218). The result showed that the integrated methods improved deactivation, leading to 5.58-log depletion in E. coli at 4 min. Furthermore, an increment in treatment time from 4 to 8 min ensued in absolute antibiotic resistance genes degeneration and constrained the horizontal gene transfer of ARGs. This study summarized that the synergistic impact of mild heat and sonication is opposed to ARB and ARGs. An attempt to obtain high efficient anaerobic digestion of swine wastewater through CH_4 production and ARG attenuation is carried out (219). The authors summarized that the dewatered swine manure-derived biochar-300 (DSMB-300) displayed the best performance. Besides, DSMB adapted from DSM and DSMB-assisted anaerobic digestion displayed a high possibility of resistance gene attenuation.The effluent discharged from fish processing plant help to spread antibiotic-resistant bacteria into our natural environments (220). Proper management practices and legislation can protect the environment and regulate seafood processing plants' hygiene.

n) Anaerobic/Aerobic Treatment in Food Processing Industries

Anaerobic wastewater treatment started full-scale operation in 1958 and its efficiency is highly encouraging (221). Inexpensive approaches are designed for food processing wastewater management. A study by (222) examined the impact of the anaerobic-aerobic treatment system of a potato processing factory. The result showed that the integrated anaerobic-aerobic system removal efficiency for TSS is 93%, for BOD is 90% and for COD is 80%, respectively. The average effluent concentrations of TSS, BOD, and COD increased in volume, and the wastewater treatment plant pleased National Environmental Quality Standard (NEQS) for TSS (200 mg/L), NEQS for BOD (80 mg/L) and NEQS for COD (150 mg/L). Assessment and maximization of textile wastewater using a hybrid anaerobic-aerobic system are carried out in two phases (223). The result shows that a single treatment of anaerobic exhibited low performance in the removal of COD, Total Nitrogen (TN), and dyes. Meanwhile, an integrated system of anaerobic-aerobic offers a better removal efficiency of 99.5% for COD, 99.3% for TN, and 78.4% for dyes. Combined anaerobic-aerobic sequencing batch reactor treated high-strength effluent (wastewater from poultry slaughterhouse) and displayed percentage removal of total COD (TCOD) at 97% ± 2%, soluble COD (SCOD) at 95% ± 3%, NH3-N at 98% ± 1.3%, fat, oil and grease (FOG) at 90% ± 11% and total suspended solids (TSS) at 96% ± 3% (224). Value-added products are increasingly gotten from dairy, slaughterhouses, and brewery influents as vital resources. Then, extensive anaerobic treatment automation of this can yield average methane of 487 Nm^3/day (225-226). Another study by (227) integrated an anaerobic-aerobic fixed bed reactor for the treatment of waste water, and the removal efficiency of organic matter content got to 83 ± 5%, and Nitrogen got to 73 ± 3% without the incorporation of electron donor.

The performance of aerobic and anaerobic membrane bioreactors is used as an alternative for water, energy, and fertilizer retrieval (228). The result showed that for organic matter treatment, anaerobic membrane displayed a better removal efficiency of 97% while aerobic membrane treatment showed better nitrogen removal efficiency of 80%. Recovery of 527 m3/h of permeate could be used in the cane-washing process or as feedstock for fertilizer procurement. Soybean molasses is a viscous liquid with high volumes of soluble carbohydrates, lipids, and proteins. Anaerobic-aerobic baffled reactor is used in organic matter degradation from soybean molasses for possible biogas generation (229). From the result, COD_{total} removal is efficient with average values between 88 and 98% while final effluent concentration is between 34 and 764 mgO_2/L. This shows that an anaerobic-aerobic baffled reactor possesses a great possibility for the biological degradation of soybean molasses. It further shows that the method produces an estimated 180000m^3/year with a concentration of methane high at 86%. An integrated anaerobic-anoxic-aerobic rector technique is utilized for nitrogen removal from poultry slaughterhouse effluent (230). The outcome indicated that the best-performed reactor is witnessed in step III with a recirculation rate of 2 and hydraulic retention time of 11 hr. On this particular performance, the NH_4^+ and TN removal efficiencies are 84% and 65%, respectively. Without much opposition, the 65% removal efficiency of TN is pronounced adequate because the conceptual denitrification efficiency anticipated for this situation is a recirculation rate of 2 67%, which occurred under no external carbon source. Slaughterhouse effluent

treatment undergoes a two-stage procedure with integrated anaerobic digestion and electrocoagulation to determine its efficiency (231). Both anaerobic digester and electrocoagulation serve as primary and secondary treatments, respectively. The result of the study showed that the integration of anaerobic digestion and electrocoagulation simultaneously enhances untreated slaughterhouse wastewater treatment. This indicated that the combined process exhibited removal efficiencies greater than 79% for COD, 95% for nitrate, and 90% for turbidity, respectively. A similar study is carried out by (232) but this time, an anaerobic filter and constructed wetland is used for the same poultry slaughterhouse effluent. The result showed that this system has efficient removal of organic matter of BOD_5 at 88.9%, COD at 92.9%, TSS at 93.4%, and FOG at 87.3%, respectively.

o) Microbial Electrolysis Cells Treatment of Food Processing Effluents

Microbial electrolysis cells(MECs) are one of the most favorable contraptions amid bio-electrochemical systems for the production of biohydrogen. A large collection of wastewater and organic wastes can be used as substrates in microbial electrolysis cells as they allow for the production of valuable chemicals like hydrogen gas. MECs can obtain clean and viable hydrogen production from a large collection of renewable biomass to displace fossil fuel (233). Cross-feeding is a possible design for treating industrial food processing wastewater samples (234). The study shows that reactor inoculated with domestic wastewater attained identical removal at a remarkably lesser time than MECs which is accustomed only to industrial wastewater, then possessing a lower wastewater treatment. Microbial electrolysis cell is used for the treatment of methanol-rich and food-processing industrial wastewaters under inexpensive cathode catalysts (235). The outcome indicated that molybdenum disulfide catalyst exhibited a better result than stainless cathode for the dual wastewater, while platinum catalyst usage displayed the best result during biogas production. This shows that molybdenum disulfide is in the best position to undergo cathode catalyst in MECs utilized for effluent treatment. Similar research showed that nickel-foam exhibited the best result (Table 5) for inexpensive electrodes during hydrogen production in the MEC system together with the treatment of food processing industrial effluents (236). Microbial electrolysis cell is simultaneously used to treat sugar factory wastewater and produce bio-hydrogen with electrodeposited cathodes (40). The result indicated that constructed cathodes exhibited better efficiency and Ni-co-p co-deposit displays the best cathode in both situations. This method generallytransforms organic waste into hydrogen gas and further degrades microorganisms(237-233).

Table 5: Rundown of Results from Mecs at the Applied Voltage 1.0 V for the 3 Cathodes in the 2 Sugar Industrial Effluents [236]

Substrate	Cathode	COD removal (%)	CE (%)	CHR (%)	OHR (%)	HPR (%)	η_ε (%)
CSW	SS mesh	40.59	45.11	13. 86	6.25	0.817	121.26
	Ni plate	48.11	54.52	15.73	8.57	1.329	124.49
	Ni foam	49.56	59.18	16.88	9.99	1.594	126.76
RSW	SS mesh	30.43	44.09	8.95	3.95	0.613	113.54
	Ni plate	38.99	54.67	9.39	5.13	1.022	114.54
	Ni foam	40.06	56.64	12.35	6.99	1.431	119.20

Note: COD=chemical oxygen demand, CE=coulombic efficiency, CHR=cathode hydrogen recovery, OHR=overall hydrogen recovery, HPR=hydrogen production rate, and η_ε = energy recovery

As part of this study to contribute to the 2030 United Nations sustainable development goals (SDGs), primarily to SDG 6 (ensure availability and sustainable management of water and sanitation for all) and SDG 7 (ensure access to affordable, reliable, sustainable and modern energy for all), efficient management of wastewater and generation of green energy from this effluent can ensure the target of these two goals. Utilizing untreated wastewater to irrigate farms with edible crops constitutes a risk to the agricultural production system and humans. By so doing, SDG 2 (end hunger, achieve food security, improve nutrition and promote sustainable agriculture) is under threat. Also, generating wealth (value-added byproducts) from the waste dump contributes immensely to SDG 2. In Nigeria, most of these SDGs are hard to achieve due to the government's attitude towards ameliorating the poverty level of its citizens. For instance, the government has not adopted any known engineering bio-treatment technologies to solve the problem of effluent disposal treatment from food processing industries. All effluents from food processing industries are channelled into fresh waters and sometimes into dumpsites, and the destruction is unprecedented in both environmental and groundwater pollution (SDG 7 not achievable in the near future). Utilizing untreated wastewater to irrigate farms with edible crops constitutes a risk to the agricultural production system and humans. By so doing, SDG 2 (end hunger, achieve food security, improve nutrition and promote sustainable agriculture) is under threat.

Also, generating wealth (value-added byproducts) from the waste dump contributes immensely to SDG 2. In Nigeria, most of these SDGs are hard to achieve due to the government's attitude towards ameliorating the poverty level of its citizens. For instance, the government has not adopted any known engineering bio-treatment technologies to solve the problem of effluent disposal treatment from food processing industries. All effluents from food processing industries are channelled into fresh waters and sometimes into dumpsites, and the destruction is unprecedented in both environmental and groundwater pollution (SDG 7 not achievable in the near future).

V. Conclusions and Future Prospectives

Effluents from food processing industries contain a high level of microorganisms and many of these organisms are recalcitrant pollutants. Agro-industrial wastes are a major threat to the soil and water resources, though contribute to greenhouse gas generation. The use of engineering bio-treatment methods to remove these microorganisms from food processing effluent is receiving a major boost. Effluents from various food processing industries are a major contributor to these environmental threats. The performance of each treatment method concerningthe removal efficiency of the microorganism is discussed. No individual method is generally efficient for the removal of these microorganisms from agro-industrial effluents. Integrating different technological methods can help to achieve greater efficiency in terms of organic load removal. This may provide an opportunity to carryout inter-governmental, cross-border microorganism eradication and monitoring while controlling anthropogenic pollution sources. Efficient and commercially workablescale-up microorganism treatment methods will produce huge benefits to public and environmental health, while economic benefits are not left out.

In this review, we have outlined the importance of various technological treatments of food processing effluents for their organic pollutant removal and biodegradability. Various treatment methods of food effluents are noticed to be very efficient in reducing the biological oxygen demand, chemical oxygen demand, total nitrogen, total phosphorus, total suspended solids, etc. Some of these treatment technologies act as a preservative to our food and it is capable of sanitizing bacteria from fresh foods. The drawback to this treatment method is: (a) Most of the processes do not undergo large-scale commercialization. (b) Much cost and energy consumption during the treatment processes scare many stakeholders from effectively adopting the novelty(c) Recalcitrant from microorganisms also limits the effort of these technologies. Optimum treatment conditions should be adopted to limit the cost and energy consumption during the treatment processes. Urgent measures should be created across other industrial sectors to inhibit the increase and spread of this antimicrobial resistance. An aggressive awareness campaign should be carried out to discourage the direct dumping of agro-industrial effluent into fresh waters and other ecosystem spaces.

Viable waste management is a panacea for achieving multiple Sustainable Development Goals created by the United Nations for the year 2030. This means that waste management can decrease the degradation of surface water sources and donate to the objective of these goals through the efficient use of resources. However, many countries limit the reuse of wastewater due to the legal framework, public health, and safety of its citizens.

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Exergetic Analysis in the Educational Field

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Abstract- The systematic review of the bibliographic heritage and other productions related to exergetic analysis highlights the growing use of this concept in the scientific community. We find this thermodynamic tool associated with other dimensions: the analysis of costs as an exergo-economy, the environment as an exergo-ecology or as an emergy, the search for indicators that establish a universal metric on human activity and its relationship with the environment. environment, to the dispersion of mineral resources, to the production of renewable energies, also to the social dimension as social exergy. However, it remains ignored by society and even worse by those who have the responsibility to make decisions. This article humbly proposes to contribute to its dissemination in the educational field, inquiring about some strategies that allow its teaching in different realities.

Keywords: *exergy; environment; education.*

GJSFR-H Classification: *DDC Code: 636.0852 LCC Code: SF95*

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Exergetic Analysis in the Educational Field

Análisis Exergético en el Ámbito Educativo

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Resumen- La revisión sistemática del acervo bibliográfico y otras producciones relacionadas al análisis exergético pone en evidencia la creciente utilización de este concepto en la comunidad científica. A esta herramienta termodinámica, la encontramos asociada a otras dimensiones: al análisis de costos como exergo-economía, al ambiente como exergo-ecología o como emergia, a la búsqueda de indicadores que establezcan una métrica universal sobre la actividad humana y su relación con el ambiente, a la dispersión de los recursos minerales, a la producción de energías renovables, también a la dimensión social como exergía social. Sin embargo, permanece ignorada por la sociedad y peor aún por quienes tienen la responsabilidad de tomar decisiones. Este artículo se propone humildemente a contribuir con su difusión en el ámbito educativo, indagando sobre algunas estrategias que permitan su enseñanza en distintas realidades.

Palabras clave: *exergía; ambiente; educación.*

Abstract- The systematic review of the bibliographic heritage and other productions related to exergetic analysis highlights the growing use of this concept in the scientific community. We find this thermodynamic tool associated with other dimensions: the analysis of costs as an exergo-economy, the environment as an exergo-ecology or as an emergy, the search for indicators that establish a universal metric on human activity and its relationship with the environment. environment, to the dispersion of mineral resources, to the production of renewable energies, also to the social dimension as social exergy. However, it remains ignored by society and even worse by those who have the responsibility to make decisions. This article humbly proposes to contribute to its dissemination in the educational field, inquiring about some strategies that allow its teaching in different realities.

Keywords: *exergy; environment; education.*

I. Introducción

El análisis exergético es una herramienta basada en la primera y en segunda ley de la Termodinámica, que resulta adecuada para la evaluación de irreversibilidades, y es particularmente útil en el estudiode sistemas que integran varios componentes, ya que los mismos pueden ser tratados independientemente, como si fuera cada uno un sistema abierto (Bejan, 1994). Con este método es posible evaluar las pérdidas de energía disponible de cada componente o parte de la instalación del sistema por separado mediante el concepto de destrucción de exergía. La exergía es la propiedad usada para determinar trabajo útil potencial máximo de una dada cantidad de energía de un sistema respecto a un estado denominado "estado muerto", hacia el cual iría dicho sistema realizando evoluciones teóricamente reversibles, de modo tal que alcanzadas las propiedades del estado muerto, el sistema queda imposibilitado de entregar exergía. Integrando al sistema y su entorno como un todo denominado universo, la Termodinámica nos enseña que la exergía siempre debe disminuir o a lo sumo permanecer contante en procesos idealizados. Es importante comprender que la exergía no representa la cantidad de trabajo que puede producir un sistema en las actuales condiciones, más bien representa el límite superior de la cantidad de trabajo que un dispositivo podría producir sin violar ninguna de las leyes de la termodinámica (Çengel y Boles, 2012). El análisis exergético usa los principios de conservación de masa y energía, junto con la segunda ley de la termodinámica para el diseño y análisis de sistemas térmicos. Los procedimientos usados en este método permiten identificar el lugar, tipo y magnitud real de las pérdidas que se producen (Moran y Shapiro, 1995). Es posible también realizar una comparación de la obtención de una cierta cantidad de energía en función de la realmente disponible para las condiciones del entorno en que se encuentra inmerso dicho proceso, lo cual nos conduce al concepto de eficiencia exergética. Surge además la idea de que la exergía "se destruye", es decir, lo que no se aprovecha de lo disponible, se pierde.

> *Este concepto es mucho más conveniente que la "conservación" de la energía, que a veces puede tenerse pero no darse las condiciones para aprovecharla, y el de la "generación" de entropía que permite decir cuán irreversible es un proceso pero no da pistas acerca de qué variables deben mejorarse para su disminución. Una de las grandes ventajas del método exergético es que es aplicable a cada componente de un sistema por separado y permite así averiguar la eficiencia del mismo independientemente de los otros componentes.* (Lucchini, Stoll, Garnica y Barral, 2013, p.1)

Desde el punto de vista de la exergía de una cierta energía, como estado muerto se considera el estado del sistema coincidente con las condiciones de

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presión y temperatura de la atmósfera ya que cesado el desequilibrio con la misma se pierde la posibilidad de producir trabajo. Pero también podemos encontrar otros estados de referencia, como el que plantea Valero (2022) al considerar la exergía correspondiente a la dispersión de los minerales disponibles en el planeta con un planeta imaginario llamado Thanatia, en el cual todos los minerales han resultado dispersados.

Cuando se piensa en energía, usualmente se la considera en términos de cantidad. Sin embargo, en un mundo con recursos limitados, la energía también debe ser valorada desde el punto de vista de la calidad, que es esencialmente una medida de su utilidad o su capacidad para realizar un trabajo. Y para dar cuenta de la calidad y no solo la cantidad de energía, se necesita pensar en términos de exergía.

Exergía es un concepto que ha logrado un extenso campo de aplicación. Más allá de las objeciones que se puedan encontrar en publicaciones y reuniones científicas y profesionales, como:

- *Ese tema no…, no es importante, (docente de cátedra, 1983)*
- *Ambigüedad en la nomenclatura, (Mora Casal, 2015)*
- *Redundancia respecto a otras propiedades, (Mora Casal, 2015)*
- *Porqué complicar con exergía si con disponibilidad (Keenan, 1951) ya está bien… (asistente a Sief 8°, 2006)*
- *Otros.*

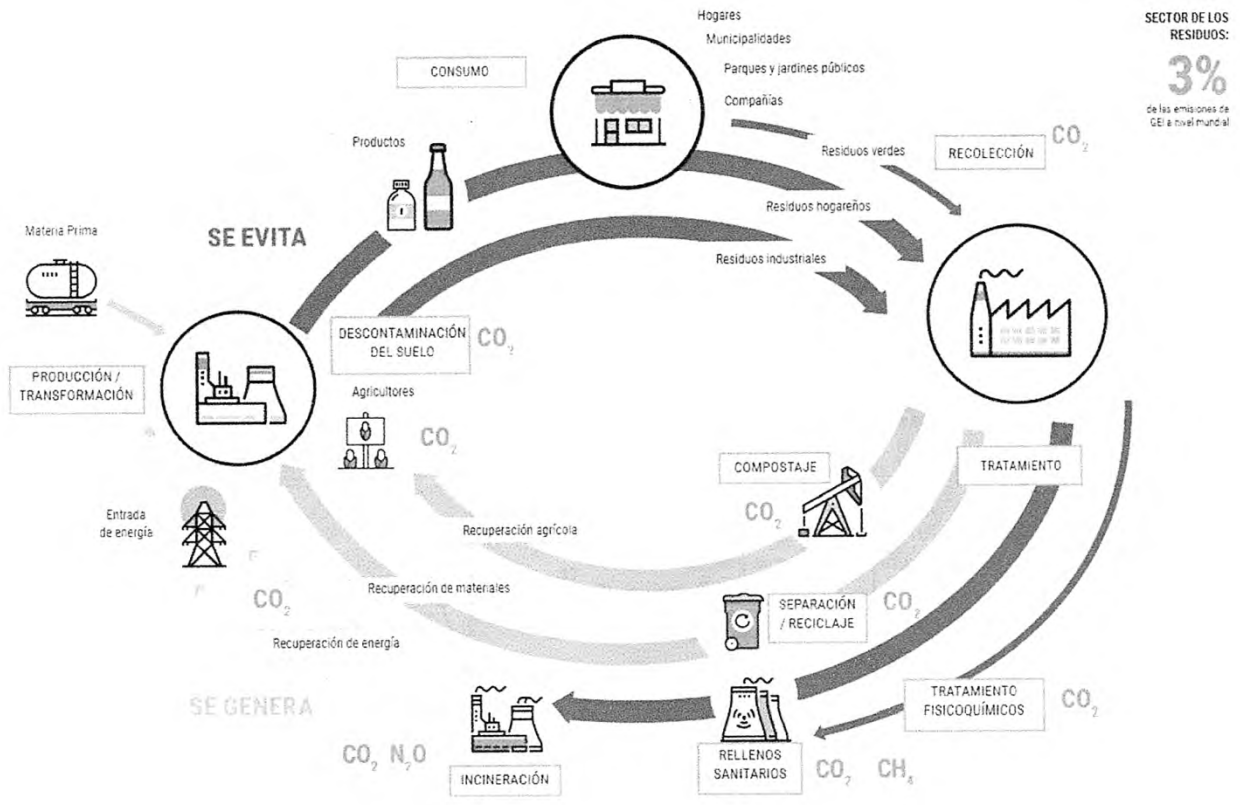
Este concepto recuperado por Rant Z. en 1953 (García, 1984), lejos de caer en desuso ha logrado continuar su construcción y ser muy utilizado en esta última década. Realizada una revisión sistemática, nos sorprende la distribución mundial de investigadores, profesionales, estudiantes, que utilizan esta herramienta de análisis. También la diversidad de áreas en que se aplica. A este concepto que inicialmente aparece asociado a la energía térmica y sus posibilidades de producir trabajo se lo encuentra en el presente relacionado a distintas manifestaciones de la energía: encontramos relaciones con la energía química, cinética, potencial, eléctrica, lumínica. Y a múltiples procesos industriales. Ante el crecimiento de su campo de aplicación, podemos encontrar investigaciones que lo relacionan también a la generación de energías renovables, aplicando el análisis de exergía en procesos y dispositivos de captación solar, eólica, de biomasa, biocombustibles. También lo podemos encontrar asociado a la economía, como análisis exergo-económico (Cidade Cavalcanti, 2018), al cuidado del ambiente, como análisis exergo-ambiental o ecológico o de sustentabilidad (Cidade Cavalcanti, 2018), a la biología (Alvarez Hincapiey Velásquez Arredondo, 2013). Nos sorprende además hallarlo asociado a ramas del conocimiento impensadas desde nuestra formación tecnológica, como el área psico social de la comunicación, presentado como exergía social, con paralelos con funciones y propiedades Termodinámicas (entalpía: actividad asociada, entropía: densidad de información, temperatura absoluta: velocidad con que se intercambia la información,…) e incorporando a expresiones específicas como disergía (Starkermann, 1988)

La necesidad de establecer algún tipo de actuación sobre aquellas actividades humanas que conducen a la progresiva destrucción del ambiente, a la dispersión de los recursos minerales, al cambio climático, ha propiciado la búsqueda de indicadores adecuados. Así como la huella de emisiones de carbono y otros gases de efecto invernadero (Science Europe, 2016)., el eco-indicador 99 (Goedkoop, 1999) (método para evaluar el impacto ambiental del ciclo de vida) (Fernández, 2015), emergia (Torres-Verzagas, 2019), desde el conocimiento termodinámico se ha propuesto la utilización de una métrica común internacional de eficiencia energética denominada Huella de Destrucción de Exergía, también la Rareza Exergética como indicador para un uso óptimo de nuestros limitados recursos naturales (Science Europe, 2016).

El establecimiento de indicadores adecuados permite conocer la calidad de los procesos y la conveniencia o no de los mismos. Por ejemplo: lentamente la sociedad va asumiendo la conveniencia de reciclar, pero ¿conocemos algún indicador que demuestre hasta dónde resulta conveniente hacerlo?

Ante este panorama que permite asomarnos al conocimiento exergético se debe trabajar en procura de que se comience a pensar en exergía más que en energía (Science Europe, 2016).

Es esta toma de conciencia la que está permitiendo, además, comenzar a mudar desde una economía lineal basada en “tomar-hacer-desechar” responsable en gran medida del cambio climático y el agotamiento de los recursos, hacia una economía circular con ejes en la eliminación de residuos y contaminación, el mantener productos y materiales en uso, la regeneración de sistemas naturales (Albaladejo M, Mirazo P y Franco Henao L., 2021).



Fuente: ONU Medio Ambiente

Figura 1: El Gráfico Muestra Cómo Lograr la Transición a la Economía Circular

Desde el rol que nos ocupe: educadores, investigadores, estudiantes, debemos instar a divulgadores, políticos, ciudadanos en general a comenzar a considerar la energía y los limitados recursos naturales sobre la base de la exergía, *entendiendo que:*

- mide la calidad de la energía y los recursos,
- a través de la huella de destrucción de exergía promueve mejoras en la eficiencia industrial,
- ofrece una métrica común internacional de eficiencia energética,
- la aplicación de la rareza exergética promueve un uso óptimo de nuestros limitados recursos minerales,
- debe ser integrada a la política, la ley, la educación y la práctica cotidiana.

Como exergía no es un concepto innato a nuestro conocimiento, se lo debe construir con gradualidad, y es en el sistema educativo donde se deben sentar las bases para la apropiación del concepto. Si se analizan las escasas comunicaciones sobre energía que aparecen en los medios de masivos de difusión, es posible observar que se trata a la energía como una rareza o apenas un asunto tarifario y poca o ninguna referencia aparece respecto a su calidad.

Es por eso que consideramos al ámbito educativo el sitio adecuado donde sentar las bases para la apropiación del concepto. Aunque algunos especialistas lo propongan como un concepto de postgrado, en este trabajo se propone que el concepto de exergía debe comenzar a ser construido desde la escuela. De otra manera, seguirán transitando por el sistema educativo promociones de estudiantes que no han adquirido una adecuada dimensión de la problemática energética y la realidad ambiental. ¿Exergía en la escuela? se preguntan Kranjc y Razpet (2017), sí en coincidencia con ellos, planteamos exergía en la escuela (tal es su conclusión).

II. Estrategias y Recomendaciones

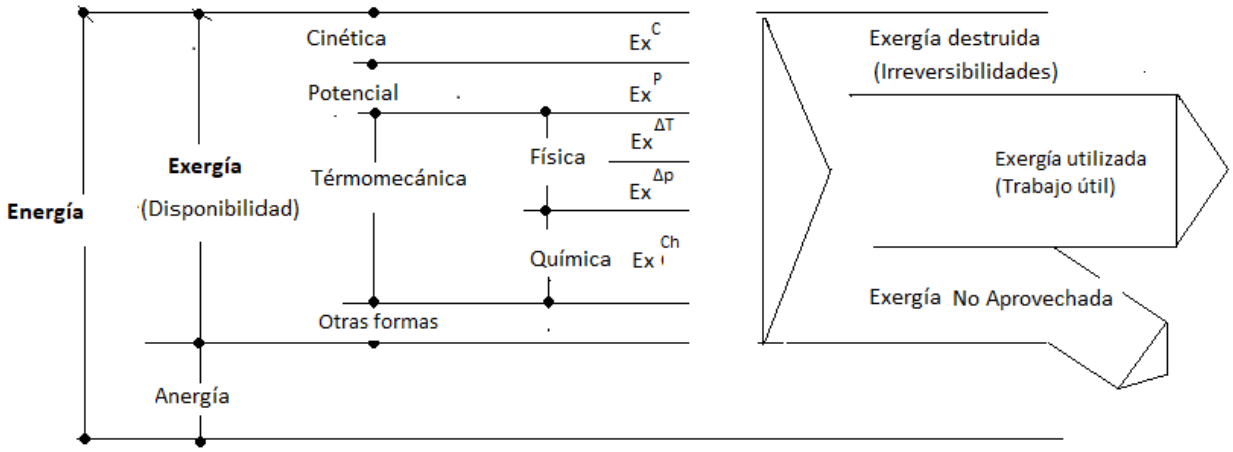
Aunque los materiales curriculares no hagan referencia expresa, consideramos que en la escuela secundaria se lo puede comenzar a trabajar, quizás desde la Física de 4° y 5° año cuando ya es esperable que los estudiantes dispongan de conocimientos previos sobre materia y energía, al menos por haber transitado espacios como Físico-Química. Para este fin, no hace falta recurrir a la complejidad de las fórmulas y funciones Termodinámicas. En cualquier caso, un acercamiento conceptual cualitativo sería suficiente. En igual sentido, se podría incursionar en la descripción de recursos como diagramas de flujo de exergía estilo

Sankey o Grassman, en el concepto de eficiencia y en indicadores de destrucción de exergía y dispersión de recursos minerales. En las escuelas de formación técnica: mecánica, electromecánica, construcciones, etc., sí se podría aspirar a un mayor acercamiento dado que disponen de Termodinámica como espacio curricular, donde se hace expresa referencia a los balances de masa, de energía, calor, trabajo, energía interna, entalpía, y se introduce someramente la idea de entropía, segundo principio y máquina térmica. (Ministerio de Educación La Pampa, 2022)

Desde nuestra experiencia, al comenzar con las tareas destinadas a explorar los saberes previos con que los estudiantes inician un curso de Termodinámica de 3° año en el nivel universitario, comprobamos inmediatamente la existencia de nociones de conservación de la masa y la energía, pero un desconocimiento generalizado sobre el concepto de calidad y disponibilidad de la energía (exergía).

Para tal fin, seleccionamos algunas propuestas de implementación para:

a) El Nivel Universitario



Fuente: Adaptado de Cidade Cavalcanti, (2018)

Figura 2: Parcelas de Exergía

Básicamente, en un curso de Termodinámica técnica, la determinación de la exergía física se realiza recurriendo a las funciones que aportaran Gouy y Darrieus a finales del siglo XIX (García, 1984). Para procesos de otra naturaleza se han desarrollado otras expresiones que no mostramos aquí.

La exergía de flujo por unidad de masa para un volumen de control (Çengel y Boles, 2006) es:

$$\dot{e_x} = (h - h_0) - T_0.(s - s_0) + \frac{v^2}{2} + g.z$$

Donde h es la entalpía, h_0 es la entalpía en el estado muerto, T_0 es la temperatura absoluta en el estado muerto, s es la entropía, s_0 es la entropía en estado muerto, v es la velocidad del fluido, g es la aceleración de la gravedad, z es la altura del punto donde se está aplicando la ecuación medida desde el nivel de referencia más bajo.

Para un sistema cerrado, la exergía por unidad de masa se calcula mediante:

$$e_x = (u - u_0) + P.(V - V_0) - T_0.(s - s_0) + \frac{v^2}{2} + g.z$$

Donde u es la energía interna, u_0 es la energía interna referida al estado muerto, P es la presión, V es el volumen del sistema y V_0 es el volumen en condiciones del estado muerto.

Pudiendo adicionarse en ambos casos otras manifestaciones: como exergía química en caso de ocurrir reacciones.

La Eficiencia Exergética de los distintos procesos o dispositivos, sin especificar criterios: *Gaggiloli, Rieckert, etc. se puede determinar mediante la siguiente relación:*

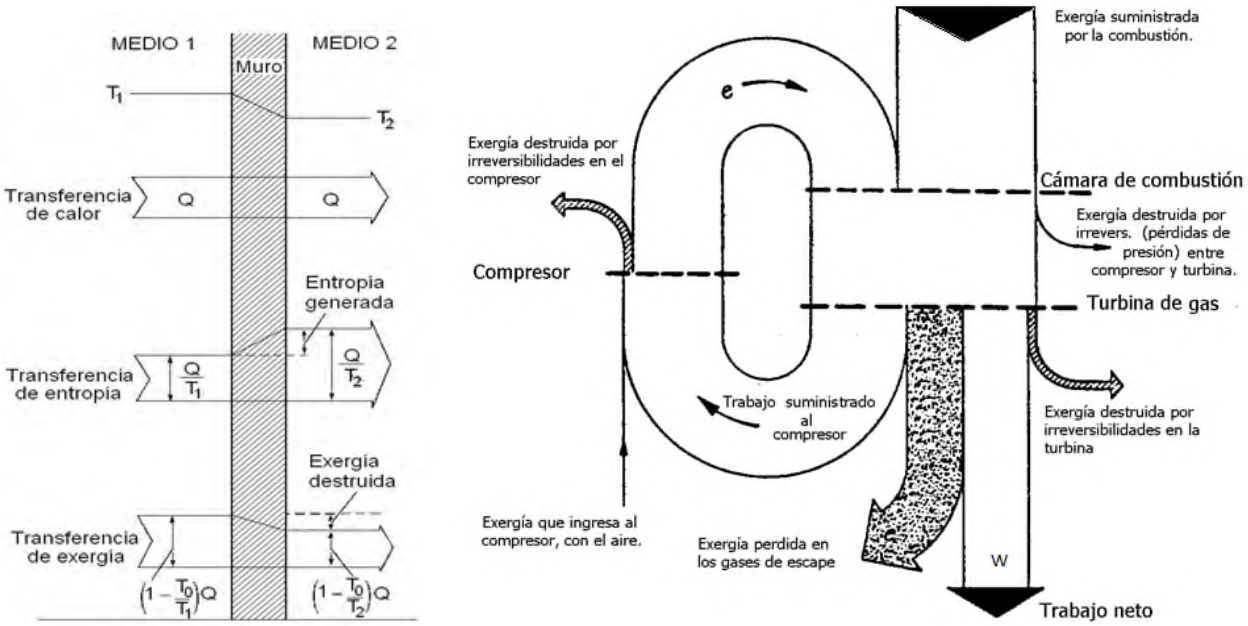
$$\eta_{Ex} = \frac{Exergíaaprovechada}{Exergíaqueingresaalsistemaenestudio}$$

Si se la relaciona con el diagrama anterior, es el cociente entre la salida (derecha) y la entrada de exergía (izquierda).

Un texto directivo puede contribuir al planteo de las cuestiones de carácter teórico, y al acercamiento de situaciones problemáticas resueltas y a resolver, junto a propuestas de carácter abierto, de reflexión y de investigación. Y en la medida de lo posible el acceso a la práctica de laboratorio, según la oferta posible dentro del ámbito de la institución.

Una práctica que resulta particularmente esclarecedora es la introducción de diagramas de flujo estilo Sankey o de Grassman. Construidos manteniendo

una escala apropiada los distintos grosores de línea representarán la magnitud de cada flujo de exergía. Mientras el estudiante no domine su técnica, hemos observado que aún no ha logrado una adecuada apropiación del concepto.



Fuente: Diagramas con adaptaciones propias. a) (Cengel y Boles, 2006) b)(Baehr, 1965)

Figura 3: a) Grassman Correspondiente a la Transferencia y Destrucción de Exergía Durante un Proceso de Transferencia de Calor Debida a una Diferencia Finita de Temperatura B) Sankey de un Ciclo Joule Brayton Irreversible

Nuestra experiencia desarrollando cursos de Termodinámica en carreras de Ingeniería Electromecánica, Electromecánica con orientación en automatización industrial, Industrial nos da evidencia de que aquellos estudiantes que demuestran un cierto manejo de las cuestiones relacionadas a exergía y eficiencia han tenido mayores logros en la comprensión del potencial de trabajo real de la energía, de la calidad de la energía , de cómo la energía y la entropía están conectadas entre sí, de cuestiones asociadas a la generación de entropía e irreversibilidades, antecedentes necesarios para referirnos a la destrucción de exergía y la eficiencia. La propia devolución que hacen algunos estudiantes en diálogos informales o cuando se los indagó mediante técnicas de Investigación Acción (Gago, 2000) indica queles confiere una mirada más crítica a la hora de realizar el estudio de sistemas más complejos, como ciclos termodinámicos, procesos de climatización, criogenia; y al aplicarlos en trabajos basados en proyectos.

Por otra parte, si las características de grupo y los tiempos lo permiten, hay muchos ejemplos disponibles en la literatura donde el análisis de exergía se combina con métodos de optimización en Matlab, EES, Aspen HYSYS/One u otros softwares, que se pueden usar como motivación. Una práctica adecuada en el laboratorio también puede motivar a los estudiantes a poner en práctica esos conocimientos. Por ejemplo: determinar la curva de rendimiento exergéticoo la destrucción de exergía de un ventilador centrífugo operando en diferentes estados de carga, hallar la eficiencia exergética de una bomba de calor disponible y otras.

b) El Nivel Secundario técnico

Se pueden aplicar estrategias similares recurriendo a resoluciones conceptuales y de baja complejidad en el cálculo, donde no aparezcan combinaciones de dispositivos. Por ejemplo, analizar los flujos presentados en el muro ilustrado anteriormente, una máquina térmica de Carnot y una real, una turbina de gas ideal reversible (ideal) frente a otra irreversible, un intercambiador de calor, entre otros.

c) El Nivel Secundario No Especializado

El abordaje en este caso se podría realizar lateralmente mediante situaciones como las planteadas por situaciones de la vida cotidiana que aunque no plantean directamente el concepto como exergía, si introducen la idea de calidad o de disponibilidad. Seleccionamos los siguientes ejemplos adaptados de Farshid Zabihian, (2015):

Ejemplo 1:

Imagine que hay dos profesores, el Sr. X y la Sra. Y, impartiendo el mismo curso, p e.

Termodinámica. Al final del período, ambas clases terminan con la calificación promedio B en el curso. ¿Qué profesor hizo un mejor trabajo?

Si nos limitamos a mirar los resultados finales y los consideramos como el parámetro para evaluar el desempeño de los profesores, entonces ambos profesores están haciendo un trabajo igualmente bueno (¡o malo!). Este enfoque se asemeja a la primera ley del análisis de la termodinámica o el análisis de la energía.

Pero como puede notar, esta comparación no es realmente justa porque los antecedentes de los estudiantes al comienzo de la clase no se tienen en cuenta. Si sabemos que el grado medio de aprobación de la clase que enseña el Sr. X en los últimos dos años ha sido By elgrado medio de aprobación de la clase que enseña la Sra. Y en el mismo período ha sido C, entonces la comparación será totalmente diferente. Si tenemos en cuenta los antecedentes de los estudiantes en cada clase, nos damos cuenta de que la profesora Y ha sido capaz de mejorar las calificaciones de los estudiantes en su clase de promedio C a B, mientras que el profesor X solo mantuvo las calificaciones de los estudiantes en B. Por lo tanto, en esta evaluación, donde tomamos en cuenta la calidad de los estudiantes asignados a cada profesor, así como las calificaciones finales, la Sra. Y está haciendo mucho mejor trabajo. Este enfoque es la segunda ley de la termodinámica, la exergía o el análisis de disponibilidad.

Después de este ejemplo preliminar, se pueden formular algunas preguntas más técnicas que serán bases para los otros ejemplos. Estas preguntas están relacionadas con algunas de las aplicaciones del análisis de exergía y están diseñadas para dar una apariencia tangible a la idea abstracta del análisis de exergía.

Ejemplo 2:

Estás construyendo tu nueva casa y estás tratando de decidir la fuente de calefacción para tu casa. Tus opciones son: a) Electricidad, b) Gas natural (o cualquier otro combustible fósil), c) Vapor a 500°C, d) Vapor a 50°C.

¿Cuál es tu elección? ¿Basado en consideraciones puramente económicas? ¿Basado en consideraciones económicas y ambientales?

Por otra parte, si se buscan recursos en la Web, es posible acceder a publicaciones con adaptaciones adecuadas para el nivel. Ejemplo de ello puede ser“Energía, Exergía y Emergía ¿Qué son y en qué se diferencian?” una amena descripción presentada enun canal de YouTube de Ingeniería y Química fácil (2021).

III. Conclusiones

No toda la energía posee la misma calidad, los recursos minerales se dispersan cada vez más. Se debe tomar conciencia de su finitud. Integramos una sociedad cada vez más urgida de concientizar a sus semejantes sobre los efectos que la acción humana produce sobre su hábitat y sus gravísimas consecuencias. Nuestra investigación nos permite concluir queel concepto de exergía, tienen el potencial para hacerlo. Así lo prueba el uso creciente en las últimas décadas. Pero debemos “arrancarlo” del campo netamente profesional y divulgarlo masivamente en procura de que cada vez haya más personas que lo hagan propio. Y para eso coincidimos en quese debe aprovechar mejoral sistema educativo dado el potencial multiplicador que posee. Hemos propuesto aquí algunas estrategias de implementación, a la espera de que otras se sigan comunicando. Observamos que la incorporación del concepto de exergía posibilita una visión más amplia y una mayor comprensión del significado dela energía, de la primera y segunda ley de la termodinámica y su interrelación. Pero el dominio de esta herramienta de análisis también deberá ser competencia de políticos, legisladores, divulgadores y población en general.

Nomenclatura

e_x = Exergía por unidad de masa. [J]
s = Entropía.[J/(kg °K)]
T = Temperatura. [°K]
v = Velocidad. [m/s]
$\dot{E}x$ = Flujo exergético. [W]
g = Gravedad. [m/s^2]
u = Energía interna. [J/kg]
h = Entalpía. [J/kg]
$\dot{e}_x$ = Flujo exergético por unidad de masa. [W]
m = Masa. [kg]
V = Volumen. [m^3] $\dot{m}$ = Flujo másico. [kg/s]
P = Presión. [N/m^2]

Subíndice

0 = referencia al estado muerto

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Wood Density Variations of Tropical Trees Differing in Shade-Tolerance and Leaf Phenology of the Congo Basin

By Yves Achille Amougou Ndi, François Borgia Amougou Amougou, Ndongo Din, Hans Beeckman & Marie Marguerite Mbolo

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Keywords: wood density, radial variation, tropical forest, shade tolerance, leaf phenology, congo basin.

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Wood Density Variations of Tropical Trees Differing in Shade-Tolerance and Leaf Phenology of the Congo Basin

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Abstract- Wood density (WD) is not only a key element in tropical forest ecology to estimate tree biomass but also an indicator of timber quality, and it integrates many aspects of tree mechanical properties and functioning. Notably, contrasting patterns of radial variation of WD have been demonstrated and are related to regeneration guilds (light-demanding vs. shade-bearing) but haven't been demonstrated to be related to leaf phenology (deciduous vs. evergreen). With the destructive method and the "archimed" principle, we investigated the WD radial variation of nine timber tree species harvested in the eastern region of Cameroon. The result showed that WD differed significantly among these nine species (P > 0.05). Their average WD was 0.70 ± 0.05; 0.79 ± 0. 14; 0. 69 ± 0.05; 0.55 ± 0.03; 0.81 ± 0.03; 0.63 ± 0.08; 0.65 ± 0.08; 0.64 ± 0.05; 0.44 ± 0.07 g.cm3 for *Afzelia bipendensis*; *Cylicodiscus gabunensis*; *Entandrophragma cylindricum*; *Entandrophragma utile*; *Erythrophleum suaveolens*; *Mansonia altissima*; *Milicia excelsa*; *Pterocarpus soyauxii* and *Triplochiton scleroxylon*. Variation in WD from bark-to-pith enabled three distinct patterns: type 1 in which WD increases (*A. bipendensis*); type 2 in which WD decreases (*C. gabunensis*; *E. cylindricum*; *E. utile*; *E. suaveolens*; *M. excelsa* and *P. soyauxii*); and type 3 in which WD values are substantially equal (*M. altissima* and *T. scleroxylon*). All nine timber tree species were deciduous. At the level of light requirement succession, the pioneer species were *E. suaveolens*, *M. excelsa*, *T. scleroxylon* and the other one was non-pioneer light demander species: *C. gabunensis*, *A. bipendensis*, *E. cylindricum*, *P. soyauxii, M. altissima* and *E. utile*. In addition, we found that WD in this study compared to the DRYAD global repository may strongly differ depending on the species (up to 133% for *T. scleroxylon* and less than 96% for *A. bipendensis*). Therefore, when estimating forest biomass in specific sites, we recommend that future studies on WD include the analysis of the effect of vertical variation with long-term phenological data and anatomical analysis in the same species and use a large sampling size, including individuals of both the same and different species.

Keywords: wood density, radial variation, tropical forest, shade tolerance, leaf phenology, congo basin.

I. Introduction

Reduction of tropical forest areas has a great impact on the amount of carbon dioxide stored in the atmosphere (Houghton 1985) because the forest is a great essential source of the world producing oxygen (O_2) and storing carbon dioxide (CO_2). Importantly, CO_2 is an influential gas leading to climate change. Estimating the aboveground biomass (AGB) content is necessary for considering the total carbon content stored in the forest ecosystem (Ketterings et al. 2001; Chave et al., 2004). This AGB is generally estimated by using allometric equations, the variables involved in such equations are the diameter at breast height, total height, and wood density (WD) or more conventionally the wood-specific gravity (WSG). Chave et al. (2005; 2014) showed that this calculation is used in the majority of studies involving allometric models. WD is one of the most important variables in forest and wood science as it is crucial for understanding tree structures and functions, and is relevant for timber properties and the energy content of the material. WD is calculated by dividing the oven-dry mass of a sample by the mass of a volume of water equal to the volume of the sample at a particular moisture content (ASTM 2011). According to Panshin & de Zeeuw 1980; Chave et al. 2009, it is a major predictor of wood's mechanical properties and is also a trait distinguished by chemical and anatomical traits (Lachenbruch & Mcculloh 2014). A key source of information on tree adaptation is the variety in wood anatomy (Beeckman 2016; Tarelkin et al. 2016).

The anatomical structure of wood, which includes the features of the vessels and fibres, can be used to describe the density fluctuations inside a tree (Roque & Filho 2007). In hardwood species, the ratio or

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quantity of various cell types and their spatial patterns determine this WD variation. These cell types include axial parenchyma, vessels, fibres, and rays (Panshin & de Zeeuw 1970). De Mil et al. (2018) shown that whereas vessels and parenchyma are adversely connected to the WD of the tree growth rate during ontogeny, fibres with thicker walls and flattened lumina increase WD. DRYAD is a global repository from which the average WD values at the species or genus level have been derived (Zanne et al. 2009). Using these repositories (Zanne et al. 2009; Chave et al. 2009) could result in an overestimation of WD for the species community of roughly 16 %. (Ramananantoandro et al. 2015). Also according to these archives, tropical WD (for light- to heavy-wood) range from 0.1 to 1.5 g.cm-3 (Zanne et al. 2009; Chave et al. 2009). In the tropical regions of the planet, this variety has been well preserved (Détienne & Chanson, 1996; Turner, 2001). Nonetheless, the majority of species have values that are quite near to the mean (Détienne & Chanson 1996). It was demonstrated by Chave et al. (2006) and Maniatis et al. (2011) that species differences in WD were bigger than those between them. With differences between shade-tolerant and light-demanding species (Chave et al. 2009; King et al. 2005). Light-demanding species are thought to require investment in denser wood to survive in a mature forest when there is greater competition for light since they are so sensitive to light exposure (Nock et al. 2009; Wiemann & Williamson 1988). In general, the fast growth of light-demanding species in the early stages is often associated with the production of softwood with low density (Woodcock & Shier 2002; Nock et al. 2009), in contrast with shade-tolerant species produced denser wood and grow very slowly (Woodcock & Shier 2002). Thought to offer a competitive edge, this relationship between density and growth can actually shorten a tree's lifespan (Wiemann & Williamson 1988). Greater resistance to physical harm and dangerous infections is induced by high values of WD (Putz et al. 1983; King et al. 2006; Chao et al. 2008). Together with a tree's vertical profile (Henry et al. 2010; Wassenberg et al. 2014) and radial profile, WD can also reveal changes inside the tree (Henry et al. 2010; Plourde et al. 2015; Osazuwa-Peters et al. 2014; Lehnebach et al.2018). Within specific trees, WD can also vary radially from pith to bark (Wiemann & Williamson 1988; 1989; Henry et al. 2010; Hietz et al. 2013).These density variations across a pith-to-bark profile are thus a good indicator of the variations of the fibres' anatomy and the abruptness of the change in wood anatomical structure.

The three goals of this study were to: (1) compare wood density (WD) between and within nine harvested tropical tree species; (2) find out how leaf phenology and shade tolerance may affect potential changes in WD; and (3) assess the discrepancy between estimated WD and database values.

II. Materials and Methods

a) Study Site

The study was conducted around the city of Gari-Gombo in the eastern region of Cameroon. Stem discs were collected inside the 2013 cutting block in the Forest Management Unit (FMU) 10 025 of the "Société Forestière Industrielle de la Lokoundjié (SFIL)" of the Decolvenaere Group Cameroon (DC). This FMU has been partially or fully exploited previously (1990–1997); its approximate boundaries are 3° 30' N and 3° 55' N latitudes and 14° 45' E and 15° 00' E longitudes. Its area is 49 595 ha, and the area of the 2013 cutting block (3-3) is 1586 ha (SFIL 2009). Soils are mainly ferralitic type, reddish-brown to yellow (Jones et al. 2013), and rest on a geological base consisting of metamorphic rocks with a high content of clay oxides iron and aluminum, formed from materials such as mica schists and chlorous schists (Martin & Segalen 1966). The climate of the site is equatorial rainforest, fully humid (Köppen 1936), with a unimodal rainfall distribution and a dry season from December to February: monthly rainfall less than 60mm (Worbes 1995). Rainfall amounts vary between nearby weather stations. The Yokadouma (85 km to the southeast of the study area) has four seasons, including a long dry season (mid-November to mid-March). The average annual rainfall is 1471.78 mm, and the annual average temperature is about 24 °C (21.94–24.56 °C). The annual average air humidity is 80 percent, with ranges of elevation between 600 and 680 meters above sea level. (Fig. 1.)

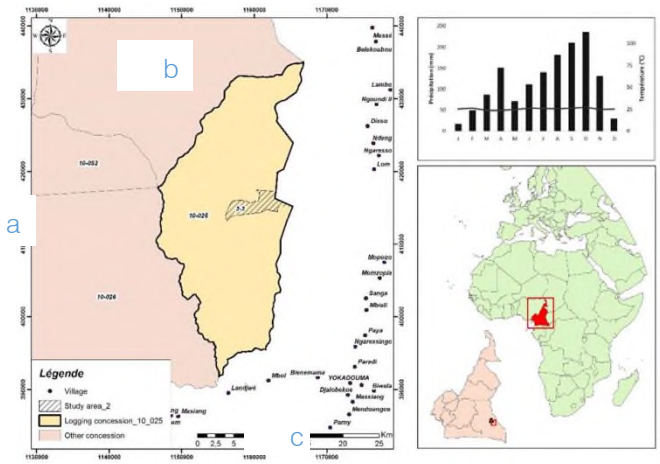


Fig. 1: a. Map of Study Site: 2013 cutting block (hatched) of Forest Management Unit 10 025 (wheat), the neighboring Forest Management Unit (pink), and the major village are also shown, *b.* the climate diagram for the meteorological station in Yokadouma town (1961-2013), *c.* the inlay shows the location of the study site in Cameroon

The vegetation of the region is the Guineo-Congolese dense forest (White 1983). For Letouzey (1968), FMU 10 025 is in the transition zone between dense, moist evergreen forest and semi-evergreen forest. This FMU was certified by the Forest Stewardship Council (FSC) until 2014, and now it only has a traceability and legality certificate. This study concerned nine legally harvested tree species. In 2013 cutting block of Forest Management Unit 10 025 of SFIL-GDC logging company (SFIL 2009). The selection of these species was based on their commercial potential, the availability of the resource, and the visibility of growth rings among the eighteen species harvested

b) Study Species

The following species were examined: *Afzelia bipendensis* Harms, *Cylicodiscus gabunensis* Harms, *Erythrophleum suaveolens* A. Chev. and *Pterocarpus soyauxii* Taub. (Fabaceae); *Entandrophragma cylindricum* Sprague and *Entandrophragma utile* (Dawe & Sprague) Sprague (Meliaceae); *Milicia exselsa* (Welw.) C. C. Berg (Moraceae); *Mansonia altissima* (A. Chev.) A. Chev. and *Triplochiton scleroxylon* K.Schum (Malvaceae) (Amougou et al. 2022). The specific wood density was extracted from the Global Wood Density Database (Chave et al. 2009; Zanne et al. 2009). Leaf phenology at the adult stage, regeneration guilds (Hawthrone 1995; Bénédet et al. 2019), and dispersal mode (Hawthrone 1995) at the species level.

c) Tree Logging and Sample Collection

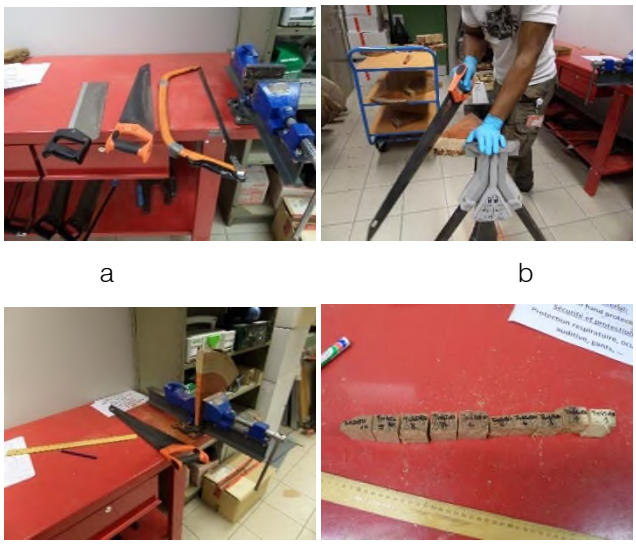
Tree DBH was measured before trees were felled by a diameter tape. One stem disc was collected at the base of the trunk of each tree (around 0.5 m from the ground or more if buttresses were observed). All stem discs were collected with a chainsaw and immediately they were divided into two halves and each half was divided into three fragments by ensuring that all parts of the stem discs were taken (pith-to-bark). Randomly, a total of 20 fragments of stem discs were collected: 3 fragments of stem discs for *M. excelsa*, *P. soyauxii, and T. scleroxylon*; 2 for *A. bipendensis*, *C. gabunensis*, *E. cylindricum*, *E. ivorensis,* and 1 for *E. utile*. The samples were transported by plane to the Royal Museum of Central Africa in Tervuren, Belgium, where they received unique Tervuren wood (Tw) identification numbers and were stored in the Xylarium. (Table 1).

Table 1: List of the 9 Studied Species with Their Botanical Family, Commercial Name, and Local Name, Tervuren Wood Identification Number (Tw); Diameter at Breast Height (DBH) of the Sampled Tree; Wood Density at the Species Level (Zanne et al. 2009), Dispersal Mode (Meunier et al. 2015), for the Regeneration Guild, P: Pioneer, NPLD: Non-Pioneer Light Demander, and SB: Shade Bearer, and for the Leaf Phenology, Dec.: Deciduous, Brevi.: Brevideciduous, and ev.: Evergreen (Bénédet et al. 2019)

Species	Family	Commercial/Local name	Tw number	DBH (cm)	Specific wood density (g.cm^3)	Dispersal mode	Regeneration guild	Phenology
Afzelia bipendensis	Fabaceae	Doussié/ M'banga	Tw65080, Tw69081	85	0.73 ± 0.05	Animal	NPLD	Dec.
Cylicodiscus gabunensis	Fabaceae	Okan/Adoum	Tw65078, Tw69079	65	0.79 ± 0.07	Wind	NPLD	Brevi.
Entandrophragma cylindricum	Meliaceae	Sapele/Assié	Tw65076, Tw69077	115	0.57 ± 0.04	Wind	NPLD	Dec.
Entandrophragma utile	Meliaceae	Sipo/Asseng-Assié	Tw65086	84	0.54 ± 0.04	Wind	NPLD	Dec.
Erythropleum suaveolens	Fabaceae	Tali/Elon	Tw65082, Tw65083	52	0.77 ± 0.06	Unassisted	P	Dec.
Mansonia altissima	Malvaceae	Bété/Koul	Tw65084, Tw69085	64	0.56 ± 0.03	Wind	NPLD	Dec.
Milicia excelsa	Moraceae	Iroko/Abang	Tw65067, Tw67068, Tw67069	102	0.58 ± 0.06	Animal	P	Dec.
Pterocarpus soyauxii	Fabaceae	Padouk/Mbel	Tw65073,Tw65074, Tw65075	62	0.66 ± 0.07	Wind	NPLD	Brevi.
Triplochiton scleroxylon	Malvaceae	Ayous/Ayus	Tw65070, Tw69071, Tw69072	92.1	0.33 ± 0.03	Wind	P	Dec.

d) Assignment of radial position

On the longest radius section of the fixed fragment of the stem disc (i.e., bark to pith), a piece of 1 cm wide wood was extracted from each stem disc using different hand saws (basic, flat, Japanese, splitter, hack, coping, and square) and two clamps (fixed and mobile) (Fig. 2.a, b, c). This piece of 1 cm was immobilized in a fixed clamp and cut using the same saws into ten (10) small pieces of roughly the same size, reporting the Tw number of the stem disc followed by the numbers 1 (at the bark piece) to 10 (at the pith piece) from the bark-to-the-pith for the ten small pieces (Fig. 2.d). Finally, using chisels and a wooden mallet, these small pieces were finely carved on the sides to have uniform pieces (Fig. 2.d.).



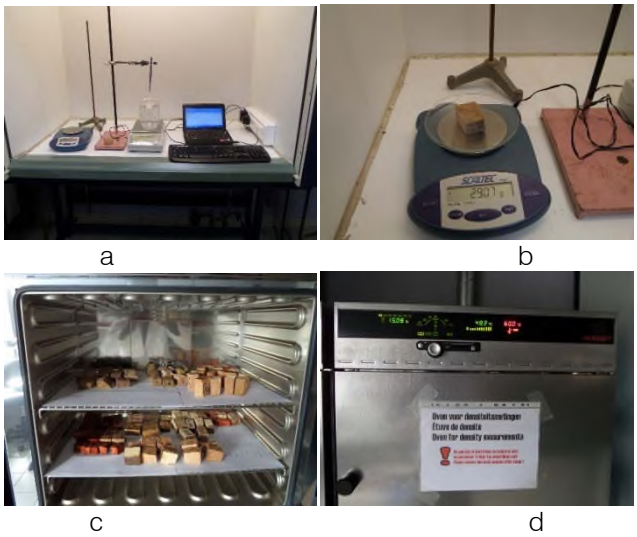
a b c d

Fig. 2: Preparation of Wood Fragments for Density Testing, a. Various Saws and a Fixed Clamp, b. Removal using a Saw of a 1 cm Fragment Lamella on the Longest Section Held Fixed on a Mobile Clamp, C. Removal Using a Saw of a 1 cm Fragment Lamella on the Longest Section of a Fragment of Stem Disc Held Fixed on an Immobile Clamp, and d. 1 cm Fragment Slice Taken, Subdivided, and Numbered from 1 to 10 in Direction (Bark-to-Pith)

e) Density Determination

Density tests were performed on these smaller fragments (pieces). The methodology used for these tests was water displacement, and it was based on the Archimedes principle by displacement water: the volume of a sample is estimated by the mass of the volume that is moved while the sample is immersed in deionized water, according to (Olesen 1971; Williamson & Wiemann 2010). This method is also called the hydrostatic method.

To regain its green condition, the small piece of wood (that had naturally dried) was immersed or soaked in a container filled with demineralized water for a few minutes to the point of saturation of the fibers. This container was under a digital balance, SCLATECSPB53 (max. 610; 0.01 g precision), and was calibrated and tared before and after measurement in the digital balance (Fig.3. a, b.). And those samples were immediately weighed. Then the dry weight or mass was obtained by introducing the samples to a Memmert UN75 oven for 48 h (2 h at 60° C, 4 h at 80°C, and 42 h at 103°C) (Fig.3.b,c.). To achieve constant mass, the oven temperature is gradually increased. To avoid the risks of burst or cracked samples, the dry weights were immediately taken out of the oven. At ambient moisture within the wood laboratory in the RMCA-Tervuren, it was 8 percent. To avoid a constant dry weight, samples were measured on a digital balance $KERN_{572}$ (up to 2,100 g; 0.1 g) three times successively (Fig. 3.a.).



a b c d

Fig. 3: Process of Density Tests a. Experimental Apparatus; b. Weighing Of Sub-Fragments To Obtain Fresh Mass; c. Removal of Fragments Dried in an Oven for Weighing of Dry Mass; and d. Drying of Wood Fragments in an Oven for 48 Hours

Using the formula, wood-specific gravity was computed as the ratio of each wood's dry mass to its corrected dry volume (Williamson & Wiemann 2010a).

$$WSG\ (8\%) = (Md)/\ (Vcd)$$

$$[\![W_{SG}]\!]_{(8\%)} = (M_d)/\ (V_{cd})$$

Where Wsd is the wood-specific gravity in g/cm3, Md is the anhydrous weight in g, and Vcd is the corrected dry volume in cm3.

III. Results

a) Wood Density Intra and Inter-Radial Variation

ANOVA test results ($P > 0.05$) showed that there was radial variation in wood density (WD) for each tree species and between tree species. These inter- and intra-specific radial variations in WD were as follows: *A. bipendensis* range, 0.65-0.75 g.cm3; and the average were 0.70 ± 0.05 g.cm3; *C. gabunensis* range, 0.65-0.93 g.cm3; and the average were 0.79 ± 0. 14 g.cm3; *E. cylindricum* range, 0.64-0.74 and the average were 0. 69 ± 0.05 $g.cm^3$; *E. utile* range, 0.51-0.58 and the average were 0.55 ± 0.03 $g.cm^3$; *E. suaveolens* range, 0.78-0.84 $g.cm^3$ and the average were 0.81 ± 0.03 $g.cm^3$; *M. altissima* range, 0.61-0.65 $g.cm^3$ and the average were 0.63 ± 0.08 $g.cm^3$; *M. excelsa* range, 0.45-0.73 $g.cm^3$ and the average were 0.65 ± 0.08 $g.cm^3$; *P. soyauxii* range, 0.59-0.69 $g.cm^3$ and the average were 0.64 ± 0.05 $g.cm^3$ and finally for *T. scleroxylon* range, 0.37 - 0.63 $g.cm^3$ and the average were 0.44 ± 0.07 $g.cm^3$ (Fig.2).

The observation of variations in WD from bark-to-pith enabled three qualitative types of radial patterns to be distinguished (Fig. 2.). Type 1 was represented by a tree species in which WD increased from bark to pith: *A. bipendensis*. Type 2 corresponded to tree species in which WD decreased from the bark to the pith: *C. gabunensis*; *E. cylindricum*; *E. utile*; *E.suaveolens*; *M. excelsa;* and *P. soyauxii*. And type 3 was represented by tree species in which WD values were substantially equal from bark-to-pith: *M. altissima and T. scleroxylon* (Figure 3, Table 2).

At the family species level, there was a significant difference between the WD of Fabaceae: *E. suaveolens,* with a WD of 0.81 ± 0.03 g.cm3, was less similar to the WD of *C. gabunensis* (0.79 ± 0.14 g.cm^3), and those two timber tree species were not similar with WD of *A. bipendensis* (0.70 ± 0.05 g.cm^3) and with WD of *P. soyauxii* (0.64 ± 0.05 g.cm), who is less dense wood species in this family. There was also a significant difference in the WD of Meliaceae: *E. cylindricum* with a WD of (0.69 ± 0.05 g.cm^3) which was not similar to the WD of *E. utile* (0.55 ± 0.03 g.cm^3). The WD of Moraceae was only for *M. excelsa* (0.65 ± 0.08 g.cm^3). And finally, there was also a significant difference between WD Malvaceae (*M. altissima* with a WSG of 0.63 ± 0.02 g.cm^3) and WD *T. scleroxylon* (0.44 ± 0.07 g.cm^3) (Figure 3).

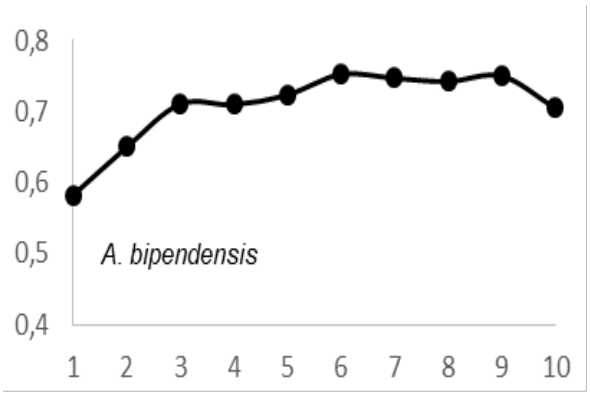
b) Wood Density Shade Tolerance and Phenology

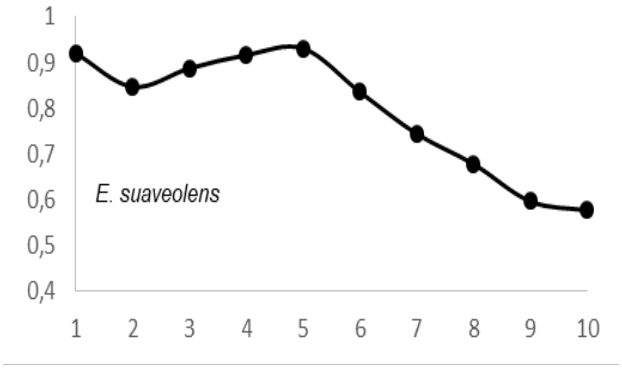
These timber tree species were classified into three leaf phenological types: brevideciduous, deciduous, and evergreen for drought tolerance (Bénédet et al. 2019). All these nine timber tree species were deciduous and were classified as heavy for the lower WSG: *E. suaveolens* (0.81 ± 0.03 g.cm^3); *C. gabunensis* (0.79 ± 0.14 g.cm^3); *A. bipendensis* (0.70 ± 0.05 g.cm^3); *E. cylindricum* (0.69 ± 0.05); *P. soyauxii* (0.64 ± 0.05 g.cm^3); *M. altissima* (0.63 ± 0.02); *M. exselsa* (0.58 ± 0.06 g.cm^3); E. *utile* (0.55 ± 0.03 g.cm^3); and *T. scleroxylon* (0.44 ± 0.07 g.cm^3). Particularly *A. bipendensis*, *C. gabunensis*, *E. cylindricum*, *E. utile*, *and E. suaveolens* were all deciduous; meanwhile, *C. gabunensis* and *P. soyauxii* were brevideciduous (Table 1; Table 2).

At the level of light requirement succession, these timber tree species were classified into three regeneration guilds: pioneer, non-pioneer light demander, and shade bearer (Hawthrone 1995; Bénédet et al. 2019). The pioneer species were: *E. suaveolens,* with its highest wood density (0.81 ± 0.03 g.cm^3); *M. excelsa,* with its medium wood density (0.65 ± 0.08 g/cm3); and *T. scleroxylon,* with its weakest wood density (0.44 ± 0.07 g.cm^3). And non-pioneer light demander species were: *C. gabunensis,* with its very highest wood density (0.79 ± 0.14 g.cm^3); *A. bipendensis,* with its highest wood density (0.70 ± 0.05 g.cm^3); *E. cylindricum,* with its highest wood density (0.69 ± 0.05 g.cm^3); *P. soyauxii*, with its medium wood density (0. 64 ± 0. 05 g.cm^3); *M. altissima,* with its medium wood density (0.63 ± 0.02 g.cm^3) and *E. utile,* with its lowest wood density (0.55 ± 0.03 g.cm^3) (Table 1; Table 2)

c) Comparison between Estimated Wood Density and Database Values

The difference was not significant between the calculated and measured WD and those of the Global Wood Density Database (Zane et al. 2009), particularly for tree species who's calculated WD were lower than the WD of the GWDD base: *A. bipendensis,* 0. 70 ± 0. 05 / 0. 73 ± 0. 05 g.cm^3; *P. soyauxii,* 0. 64 ± 0. 05 / 0. 66 ± 0. 07 g.cm^3. The calculated WD were greater than the WD value of the GWDD: *E.* utile, 0.55 ± 0. 03 / 0. 54 ± 0. 04 g.cm^3. And the calculated WSG were equal to the WD of the GWDD: *C. gabunensis,* 0.79 ± 0. 14 / 0. 79 ± 0. 07 g.cm^3. In contrast, the difference was very significant for the following species: *E. cylindricum* 0. 69 ± 0. 05 / 0. 57 ± 0. 04 g.cm^3; *E. suaveolens* 0. 81 ± 0. 03 / 0. 77 ± 0. 06 g.cm^3; *M. altissima* 0. 63 ± 0. 02 / 0. 56 ± 0. 03 g.cm^3; *M. excelsa* 0. 65 ± 0. 08 / 0. 58 ± 0. 06 g.cm^{3}and *T.scleroxylon* 0.44 ± 0.o7 / 0.33 ± 0.03 g.cm^3 (Table 2).





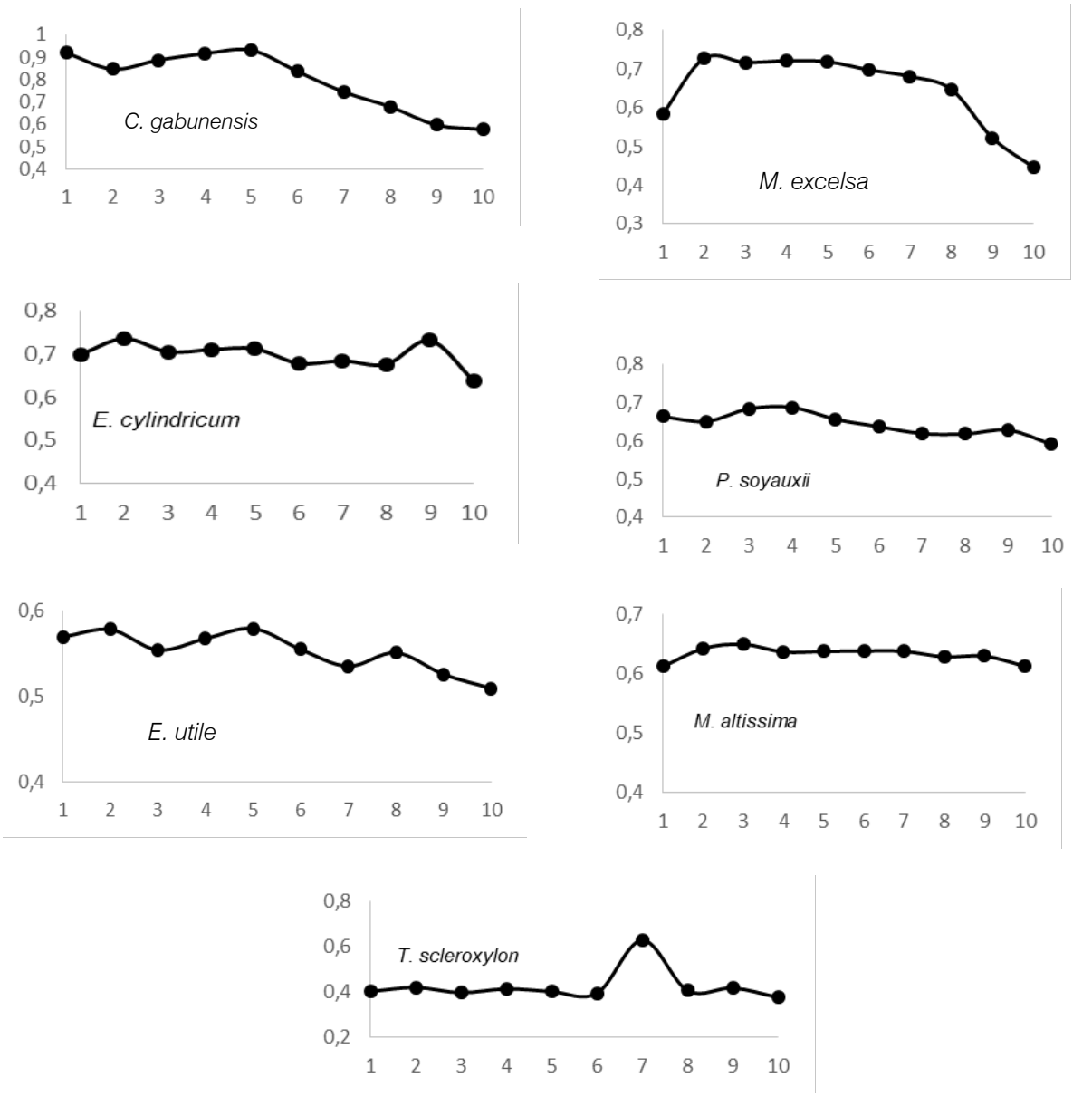


Fig. 4: Variation in Wood Density Measured (G.Cm- ³) at 8 Percent Moisture Content Along the Distance from Bark (1) to Pith (10) for the 09 Species Investigated in SFIL, Cameroon

d) Comparison between Estimated Wood Density and Database Values

The difference was not significant between the calculated/measured WD and those of the Global Wood Density Database (Zane et al. 2009), particularly for tree species who's calculated WD were lower than the WD of the GWDD base: *A. bipendensis* 0. 70 (± 0. 05) / 0. 73 ± 0. 05 g.cm^3; *P. soyauxii* 0. 64 (± 0. 05) / 0. 66 ± 0. 07 g.cm^3; the calculated WD were greater than the WD of the GWDD and *E.utile* 0. 55 (± 0. 03) / 0. 54 ± 0. 04 g.cm^3 and the calculated WSG were equal to the WD of the GWDD *C. gabunensis* 0.79 (± 0. 14) / 0. 79 ± 0. 07 g.cm^3. And in contrast, the difference was very significant for the following species: *E. cylindricum* 0. 69 (± 0. 05) / 0. 57 ± 0. 04; *E. suaveolens* 0. 81 (± 0. 03) / 0. 77 ± 0. 06 g.cm^3; *M. altissima* 0. 63 (± 0. 02) / 0. 56 ± 0. 03 g.cm^3; *M. excelsa* 0. 65 (± 0. 08) / 0. 58 ± 0. 06 g.cm^3 and *T. sclexylon* 0. 44 (± 0. 07) / 0. 33 ± 0. 03 g.cm^3 (Table 2).

Table 2: WD of the Measured Samples Per Species Compared to the WD Values in the GWDD. WD Values from the GWDD Were Taken for Species Occurring in Africa, as the Measured Species all Originate From Central Africa. an Asterisk (*) Next to a Species Name Indicates a Significant Difference ($P < 0.05$) Between the Mean of the Measured Values and the Mean of That Species in the GWDD

Species	No. Samples/Stem discs measured	Average WD ± STD ($g.cm^{-3}$) at humidity 8 %	Range WD ($g.cm^{-3}$) [Min-Max]	No. values are given in GWDD	WD value GWDD ± STD ($g.cm^{-3}$)	WD value GWDD range ($g.cm^{-3}$)
Afzelia bipendensis (Fabaceae)	01/02	0.70 (±0,05)	[0.65 – 0.75]	11	0.73 ± 0.05	0.66 – 0.82
Cylicodiscus gabunensis (Fabaceae)	01/02	0.79 (±0.14)	[0.65 – 0.93]	18	0.79 ± 0.07	0.62 – 0.97
Entandrophragma cylindricum (Meliaceae)*	01/02	0.69 (±0.05)	[0.64 – 0.74]	16	0.57 ± 0.04	0.50 – 0.63
Entandrophragma utile (Meliaceae)	01/01	0.55 (±0.03)	[0.51 – 0.58]	18	0.54 ± 0.04	0.44 – 0.58
Erythropheum suaveolens (Fabaceae)*	01/02	0.81 (±0.03)	[0.78 – 0.84]	20	0.77 ± 0.06	0.69 – 0.87
Mansonia altissima (Malvaceae)*	01/03	0.63 (±0.02)	[0.61 – 0.65]	23	0.56 ± 0.03	0.47 – 0.63
Milicia excelsa (Moraceae)*	01/03	0.65 (±0.08)	[0.45 – 0.73]	24	0.58 ± 0.06	0.44 – 0.67
Pterocarpus soyauxii (Fabaceae)	01/03	0.64 (±0.05)	[0.59 – 0.69]	14	0.66 ± 0.07	0.57 – 0.81
Triplochiton scleroxylon (Malvaceae)*	01/03	0.44 (±0.07)	[0.37 – 0.63]	24	0.33 ± 0.03	0.28 -0.41

IV. Discussion

a) Wood Density Intra and Inter-Radial Variation

The first aim of our study was to compare the variation in WD among and within nine harvested tropical tree species, including radial variation within individuals. At the light of this analysis conducted on stem discs. This results show that specie's explained most wood density radial variance whereas individuals explained only a minor part from pith-to-bark. These results were consistent with previous observations in different part of world (Parolin 2002 Woodcock & Sheir 2002; Nock et al. 2009; Onada et al. 2010; Hietz et al. 2013; Osazuwa-Peters et al. 2014; Bastin et al. 2015; Plourde et al. 2015; Lehnebach et al. 2019). And globally among tropical tree species (Zanne et al. 2009). Importantly, the WD values between 0.44 and 0.81 $g.cm^{-3}$ from this present study were within the range (0.11 to 1.39 $g.cm^{-3}$) reported for 2,456 tropical forest tree species (Chave et al. 2006). The differences in WD between our study and other studies may be due to aspects of the growing environment (biotic and abiotic) factors.

Particularly, the observation of variations in WD from bark to pith enabled three qualitative types of radial patterns to be distinguished. Type 1 was represented by a tree species in which WD increased from bark to pith: *A. bipendensis*. Type 2 corresponded to tree species in which WD decreased from the bark to the pith: *C. gabunensis*; *E. cylindricum*; *E. utile*; *E.suaveolens*; *M. excelsa;* and *P. soyauxii*. And type 3 was represented by tree species in which WD values were substantially equal from bark-to-pith: *M. altissima* and *T. scleroxylon*. These results confirms the effect of heartwood on WD radial variations already suspected (Parolin 2002; Hietz et al. 2013).

These findings contrast with the bulk of studies on WD radial variations (Parolin 2002; Woodcock & Sheir 2002; Nock et al. 2009; Hietz et al. 2013; Osazuwa-Peters et al. 2014; Plourde et al. 2015), which reported both negative and positive gradients. We presume that this difference is mainly due to the failure to take into account the presence of heartwood that was previously hypothesized by several authors (Parolin 2002; Hietz et al. 2013).

b) Wood Density Shade Tolerance and Phenology

Wood density profiles with a decreasing trend from bark to pith and a low wood density were not systematic for pioneer and non-pioneer light-demanding species, but our results demonstrated that the pioneer species *E. suaveolens* showed the very highest wood density value, the second highest wood density value was for *C. gabunensis,* and the lowest wood density value was found for the pioneer species *T. sceroxylon*. For the nine tree species studied, this assertion was true

For the nine tree species studied, this assertion was true for Type 2: *C. gabunensis*; *E. cylindricum*; *E. utile*; *E. suaveolens*; *M. excelsa* and *P.soyauxii*. The opposite shade-tolerant species systematically showed high wood density values. In our study, shade-tolerant species were not available. But Chao et al. (2008) and King et al. (2006) formulated the hypothesis that slow-growing species that invest in dense wood were shade-tolerant, in particular during the early stages of their lives. Other studies also reported that shade tolerant species tend to have a much higher WD than do pioneer species (King et al. 2006; Ramananantoandro et al. 2016). One explanation were that pioneer species produce a low WD to grow taller than their neighbors, thereby acquiring more resources (i.e., light) quickly (Woodcock & Shier 2002).The observations of these six listed tree species were unlikely to persist in old-growth forests, supporting the assumption that strictly light-demanding species present decreasing trends in wood density from bark to pith (Nock et al. 2009; Wiemann & Williamson 1988). Type 1: *A. bipendensis* presents an increasing trend in wood density from bark-to-pith. This observation was confirmed by Woodcock & Shier (2002), who corroborated that the increase in wood density from bark-to-pith is often attributed to increased light exposure and improved growth conditions in the later stages. With possible access to the canopy for some trees during ontogeny (Brienen & Zuidema 2006). All of this supports the idea that a species' regeneration guild may differ between places (Hawthorne 1985) and should only be assigned with care. This finding emphasises the significant correlation between wood density and regeneration guild and backs up the notion of a comprehensive wood economic spectrum (Chave et al. 009).

It's clear that the evergreen species invest in denser wood, the production of this denser wood induct the difficulty of detection of tree ring boundaries in wood samples of this species. And the evergreen species growth in entire year and during the drought periods. All these nine studied timber tree specie's, were deciduous, and there were no a significant difference between them (brevidecidious and deciduous). Only two: *C. gabunensis* and *P. soyauxii* were brevidecidious with a second highest density for *C. gabunensis:* 0.79 ± 0.14 g.cm^3. The other seven timber tree species were deciduous with highest density for *E. suaveolens* 0.81 ± 0.03 g.cm^3; and lowest density for *T. scleroxylon* 0.44 ± 0.07 g.cm^3. At the light of this exception and results, it's appeared clear that brevidecidious present more heavy wood than deciduous species.

c) Comparison between Different Wood Densities

The specific wood density of *A. bipendensis* in this study is 83 percent lower than the value obtained by (Sallenave 1964; 1971), 96 percent lower than that obtained by Zanne et al. (2009), and 106 percent higher than that obtained by Fayolle et al. (2013). For *C. gabunensis,* these values were 94 percent lower than those of Sallenave (1955) and were equal to the value obtained by Zanne et al. (2009). In *E. cylindricum,* they were equal to the value obtained by Sallenave (1955), 113 percent higher than those of Fayolle et al. (2013), and 121 percent higher than those of Zanne et al. (2009). For *E. utile,* the value obtained was 80 percent lower than that of Sallenave (1955), 91 percent lower than that of Sallenave (1964), and 101 percent higher than that of Zanne et al. (2009). The WD value of *E. suaveolens* was 102 percent higher than Sallenave (1971), 82 percent lower than the value of Fayolle et al. (2013), and 105 percent higher than the value of Zanne et al. (2009). In *M. altissima,* the WD values obtained in this study were 106 percent higher than those of Sallenave (1964), 85 percent lower than those of Fayolle et al. (2013), and 112 percent higher than the value of Zanne et al. (2009). In *M. excelsa,* they were 103 percent higher than those of Sallenave (1964) and 112 percent higher than those of Zanne et al. (2009). The WD value in *P. soyauxii* was 95 percent lower than that of Sallenave (1964) and 97 percent lower than that of Zanne et al. (2009). Finally, the WD values obtained in *T. scleroxylon* were 118 percent higher than those of Sallenave (1955), 125 percent higher, and 133 percent higher, respectively, than those of Fayolle et al. (2013) and Zanne et al. (2009).

V. Conclusion

In this study, we characterised detailed bark-to-pith WD profiles between and within nine harvested tropical tree species. Our study on WD radial gradients in Congo Basin tropical tree species showed an exclusively significant positive, neutral, and negative pith-to-bark WD gradient. These unique, site-specific details are not included in the global databases that are currently in use, which could result in assessments of species' functional attributes and estimates of tree biomass that are inadequate and erroneous.

We advise extreme caution when performing meta-analyses based on global functional trait databases to prevent mistakes brought on by insufficient data collection and storage. Regional biomass estimates will be improved, and our understanding of the functional strategies and successional behaviour of tropical tree species will be increased by future studies documenting trends in WD variance in new locations and forest types.

Particularly, this study recommends that future studies of wood density include the analysis of the effect of vertical variation with long-term phenological data and anatomical analysis in the same species and use a large sampling size including individuals of both the same

and different species to facilitate the analysis of the radial and vertical structure.

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Assessment of Water Quality of the Nalerigu Dam in the East Mamprusi Municipality of the North East Region of Ghana

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Abstract- The study investigated the water quality of the Nale-rigu dam and compared to the WHO recommended levels for both physicochemical and bacteriological parameters. There was also a survey of 99 out of 135 household heads who were within 50 meters around the dam to assess their usage of the dam water. The sampled dam water was analysed at the Water Research Institute laboratory in Tamale. The water pH was found to range from 6.30 to 6.50 with a mean temperature range of 30.3 to 30.50C. The turbidity of the water exceeded the WHO limits. Other physicochemical parameters monitored including total suspended solids, total dissolved solids, total hardness, total alkalinity values were within the WHO recommended levels for surface water quality. Results of the bacteriological analysis including faecal coliforms and total coliforms were high. It was concluded that the Nalerigu dam was contaminated and unsafe for human consumption if not treated. The study recommends a further study into metallic concentration of the dam to ensure the quality besides physicochemical and bacteriological parameters of the dam.

GJSFR-H Classification: DDC Code: 363.3497 LCC Code: TC556

ASSESSMENTOFWATERQUALITYOFTHENALERIGUDAMINTHEEASTMAMPRUSIMUNICIPALITYOFTHENORTHEASTREGIONOFGHANA

Strictly as per the compliance and regulations of:

Assessment of Water Quality of the Nalerigu Dam in the East Mamprusi Municipality of the North East Region of Ghana

Abdul-Rahaman Issahaku

Abstract- The study investigated the water quality of the Nalerigu dam and compared to the WHO recommended levels for both physicochemical and bacteriological parameters. There was also a survey of 99 out of 135 household heads who were within 50 meters around the dam to assess their usage of the dam water. The sampled dam water was analysed at the Water Research Institute laboratory in Tamale. The water pH was found to range from 6.30 to 6.50 with a mean temperature range of 30.3 to 30.5^{0}C. The turbidity of the water exceeded the WHO limits. Other physicochemical parameters monitored including total suspended solids, total dissolved solids, total hardness, total alkalinity values were within the WHO recommended levels for surface water quality. Results of the bacteriological analysis including faecal coliforms and total coliforms were high. It was concluded that the Nalerigu dam was contaminated and unsafe for human consumption if not treated. The study recommends a further study into metallic concentration of the dam to ensure the quality besides physicochemical and bacteriological parameters of the dam.

I. Introduction

The quality of water for both domestic and economic activities is threatened as human populations grow and affects the existence of all living organisms [1]. The quality of any water source is thus a function of both natural influences and human activities [2]. Aqautic environments are complex and require judicious and careful use to ensure sustainability into the future [1].

Water quality is a challenge to many communities and societies which are depended on rain or surface water such as dam, springs and rivers. This threatens human health, limit food production, reduced ecosystem functions, and hinders economic growth [3]. Waterquality degradation directly affects environmental, social and economic problems [4]. Globally, fresh water availability is limited due to worsening anthropogenic activities and competition from animals leading to pollution and degradation [5]. Potable water availability, access and affordability is still a major challenge in many developing countries as nearly 10% of the global population uses drinking water from unimproved and unsafe sources [6]. This is more conspicuous in rural areas and small towns in developing countries where nearly 38% of the population are still without access to potable water [7].

The [8] has estimated that 80% of the population has access to improved water sources but with a high risks of contamination due to improper maintenance and poor sanitation. In urban communities, accessibility of safe drinking water varies with their socio-economic status. In some settlements in rural areas and peri-urban area, springs, rivers, lakes, and wells are the traditional sources of water for drinking and for personal hygiene.

Surface water quality testing is rarely undertaken indeveloping countries, as more attention is usually paid to water availability and quantity than quality of water [9, 10]. The quality of fresh water is usually affected by natural and anthropogenic activities and must be treated before use especially in the case of surfacewater which is infamously known to be polluted [11, 12].

The quality of surface water in rural communities affected by excreta from both human and domestic animals, run-off fromagricultural fields and detergents from washing of chlothing [13, 14]. Therefore, many parameters of water in terms of its chemical, physical, and biological constituents must be analysed before use. In developing countries water quality standards are based on the World Health Organisation's (WHO's) guidelines for drinking water. The Ghana Water Company Limited (GWCL) is the institution responsible for water supply in urban areas while the Community Water and Sanitation Agency (CWSA) is in charge of water supply in small towns and villages. Drinking water quality monitoring is awide-range assessment of the quality of water in a distribution system as supplied to theconsumer [15] but this is rarely done in raw water from dams and rivers [16, 17].

A good environmental sanitation is required to maintain a clean, safe and good physical and natural aquatic environment in all human settlement, to enhance the socio-cultural, economic, and physical well-being of all aspects of the population [Republic of Ghana, 2010]. Open defecation in which individuals or households dispose of faeces in fields,forests, bushes, open bodies of water, beaches or other open spaces, or with solid waste pollute or degrade water quality. This result in the spread of diarrhoea as well as parasitic infections such

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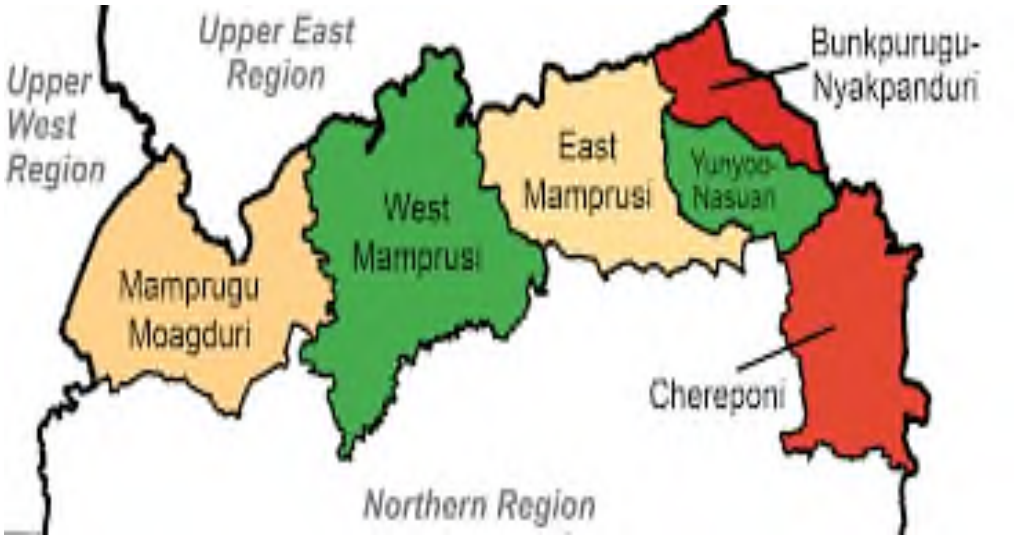
as soil-transmitted helminths (worms) [18]. Bacteria, viruses, protozoa and parasites such as worms can transmit typhoid fever, cholera, dysentery, infectious hepatitis and other forms of diseases to human. These pathogens enter water primarily through the faeces and urine of infected people and other animals.

The [19] have observed that 91% of the world's population used drinking water from improved sources leaving 663million people lacking access to an improved source of water. Unimproved water sources threatens people's lives with cholera, hepatitis A, diarrhoea, dysentery, and other sanitation-related diseases, increasing the mortality rate of people particularly children. Households that have no toilet facilities in the Gambaga and Nalerigu townships defecate in the bushes or fields [20]. The beauty of Nalerigu is marred by the practice of open defecation leading to poor sanitation. For instance, the proportion of households in Gambaga and Nalerigu Townships that have no toilet facilities is 70.5 percent and resort to open defecation. As a result, runoff easily washes the excreta into available surface waters such as rivers or dams. Water sampling and monitoring are required on an ongoing basis to back up hydrogeological studies and to more accurately assess water quality and propose sustainable management strategies [21, 22, 23, 24]. This study, therefore assesses water quality of the Nalerigu dam with the objective of unearthing and contributing to evidences required for sound decision-making on managing surface water quality in Ghana.

II. Study Area and Methodology

The study was conducted in Nalerigu which is the capital of the East Mamprusi Municipality (Figure 1) and also, the capital of the the North-East Region of Ghana. It has geographical coordinates of 0°32'N and 0°22'W [25]. It is the seat of the Mamprusi paramountcy. The inhabitants of the town are mostly farmers and grow crops such as maize, millet, groundnuts, cotton, soya bean, etc. They also rear domestic animals including sheep, goats, cattle and poultry (guinea fowls, ducks, turkeys and fowls)



Nalerigu experiences a single maxima rainfall regime from April to October. The annual average temperature of the District is 27.4℃ and varies from about 35℃ in March to about 27℃ in August. The high temperature is ideal for drying and preservation of groundnuts and other cereals produced in large quantities in the District. The climate is good for the rearing of animals like cattle, donkeys, small ruminants and poultry[25].

According to the provisional figures for 2010 Population and Housing Census, the East Mamprusi Municipality has a population of 188,006. The distribution shows that females account for 96,887 with 91,119 males, representing 51.5% and 48.5% respectively. The average population density is 105.9 persons per km^2. There are 142 communities. Nalerigu has a population of about 658,903persons [26].

Agriculture and its related activities is the main economic activity of Nalerigu in the East Mamprusi Municipality. Generally, agricultural production activities in the town are labour intensive carried out by both males and females. According to the [25] agricultural population by gender is 2:1 (male: female). Most often farmers. basically engaged in planting and harvesting as well as post-harvest activities. Most crop farmers (82%) are small-scale holder while only 3% of farmers have large scale holdings. Agriculture employs the largest proportion of the population aged 15 years and above as their main job [25].

a) Sampling Site

This research was conducted within the Nalerigu dam in the East Mamprusi District of Ghana. Three points of the dam named point A (upstream close to the

banks where there is little or no anthropogenic activity), B (midstream where usually people fetch water, bath and do washing) and C (lower stream where the water enters into the dam) were selected for sampling and over which samples were taken once every month for three consecutive months within the period of 4th December, 2023 to 4th February, 2023.

The samples were analyzed at the Water Research Institute laboratory in Tamale to determine some physic-chemical and biological parameters. The following water quality parameters were analyzed: temperature, colour, pH, hardness, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), turbidity, electrical conductivity, total alkalinity, iron (II), using standard methods. Presumptive test using lactose broth was performed for water samples to detect the presence of bacteria.

b) Sample Collection

Water samples were collected using 1.5 L Voltic plastic bottles. The containers were cleaned thoroughly with water and soap, sterilized with ethanol and rinsed with distilled water. The glass containers were washed by soaking in aqua regia (3 parts conc. HCl and 1 part HNO3) and rinsed with tap water and finally with distilled water. Samples were collected between the hours of 9 am and 10 pm. This was to ensure that the water. Sampling protocols were strictly adhered to during sample collection. The sample containers were rinsed with some of the dam water and then completely filled to capacity leaving no air space and immediately covered. For bacteriological analysis, Sampling bottles and culture tubes were immediately corked and neatly labeled. The environmental sanitation conditions around the dam were taken into consideration by careful observation of surrounding at least 50 m away. The human activity around the dam as well as the underlying topography was noted.Water samples were transported to the laboratory in an ice chest and stored in a refrigerator at 4℃ upon arrival. The dam water quality analysis was focused on bacteriological (Total coliforms and faecal coliforms) and physicochemical (temperature, pH, turbidity, total dissolved solids (TDS) dissolved oxygen (DO), total hardness and alkalinity) parameters [27].

c) Laboratory Analysis

The work bench was sterilized with about 70% alcohol to kill any bacteria. Glasses were also sterilized in hot air oven for about two hours 160℃ while media other rubber materials were autoclaved at 120℃ for 15 minutes, cups of plastic samples were slightly loosened to prevent distortion.

d) Physicochemical Analysis

The temperature was simply determined using the CO150 conductivity/TDS portable meter while measuring other parameters like conductivity and TDS. The procedure was repeated for the other samples two more times and the average temperature value of each sample was recorded.

The pH values of the various samples were determined using the pH colour Comparator. The colour comparator had two special test tubes of which one was filled with about 50mL deionized water while the other filled with about 50mL aliquot of the sample. The appropriate indicator (either Bromothymol blue or Thymol blue) was then used in two drops added to the sample depending on the pH range. These were then inserted into the comparator and the disc rotated until a standard colour corresponding to the pH of the sample was read on the disc by comparing the colour match with the blank. The readings were recorded for the sample. The procedure was repeated for the other samples and their pH values recorded.

10mL of each sample was measured into 250 mL conical flask and 2.0 mL of ammonium chloride buffer solution (pH=10) added to each followed by the addition of a few drops of Eriochrome Black-T indicator solution. The resulting solution was titrated with 0.01M EDTA solution with continuous stirring/swirling until the endpoint was reached. The endpoint is when the last reddish tinge disappears. The colour change obtained was blue black. The procedure was repeated three times for each sample and the average titre value was calculated. The appropriate calculations were made to obtain the actual value for total hardness mg/L as $CaCO_3$. This procedure was repeated for all the samples collected [28].

III. Calculations

Total hardness in mg/L $CaCO_3$ = A×B×1000 /Sample volume used (mL)

Where A= mL of titrant and B= mg $CaCO_3$ equivalent to 1 mL EDTA titrant

Similarly, 10mL of each sample was measured into 250 mL conical flask and 2.0 mL of NaOH buffer solution added to each followed by the addition of about 30mg of Murexide (Ammonium perpurate) indicator crystals. The resulting solution was titrated with 0.01m EDTA solution with continuous stirring/swirling until the endpoint was reached. The colour change obtained was from pink to purple. The procedure was repeated three times for each sample and the average titre value was calculated. The appropriate calculations were made to obtain the actual value for calcium hardness mg/L as $CaCO_3$. This procedure was repeated for all the samples collected.

Calculations:

Total hardness in mg/L $CaCO_3$ = A×B×1000/Sample volume used (mL)

Where A= mL of titrant and

B= mg $CaCO_3$ equivalent to 1 mL EDTA titrant

Magnesium hardness was determined simply by subtracting the calcium hardness from the total hardness. The determinations were made after refrigerated samples had been allowed to attain room temperature. The CO150 conductivity/TDS portable meter was used. The sample was poured into a 100mL beaker. The conductivity meter was calibrated by dipping the probe in distilled water. It was then transferred into the sample and the value recorded. The procedure was repeated for all the other samples.

a) Total dissolved solids (TDS) determination

A 50mL well-mixed sample was measured into beaker. The CO150 conductivity/TDS portable meter probe was immersed in the sample and its total dissolved solids recorded [28].

The stored program number for colour was entered into HACH DR/2000 spectrophotometer with the wavelength set to display 'PtCo Colour' units. A sample cell was filled with 10 mL of filtered deionized water (the blank). A second sample cell was filled with 10 mL of filtered sample (prepared sample). The blank was placed into the cell holder to zero the spectrophotometer followed by the prepared sample. The result in Platinum-Cobalt Units was displayed and value recorded. The procedure was repeated for the other collected samples.

The stored program number for turbidity was entered into HACH DR/2000 spectrophotometer with the wavelength set to display 'NTU Turbidity Units'. Two sample cells were obtained. One was filled with 10mL of filtered deionized water (the blank) and the other was filled with 10mL of the prepared sample. The blank was placed into the cell holder to zero the spectrophotometer followed by the prepared sample. The results in Nephelometric Turbidity Units was displayed and value recorded. The procedure was repeated for the other collected samples and the mean value taken.

An aliquot of 10mL of sample was measured into a conical flask. The pH was then adjusted to a range of 7-10 with H_2SO_4 for high pH samples and with NaOH for low pH samples. Two drops of K_2CrO_4 indicator was added. The colour change obtained was yellow to reddish brown. The procedure was repeated two more times and the average titre value calculated. This procedure was repeated for all the samples collected.

Chloride (mg $C1^-$/L) = $X \times N \times 1000 \times 35.5$/1mL of sample

X=end point volume
N=Normality of $AgNO_3$

b) Alkalinity Determination (Methyl Orange Alkalinity)

The total alkalinity as expressed in terms of calcium carbonate present was determined by titration using standard 0.02N H_2SO_4 with methyl orange as indicator to the first permanent pink colour for pH<8.3. For pH>8.3, phenolphthalein is used. Since all the pH values were less than 8.3, only methyl orange was used hence methyl orange alkalinity was determined. There was no phenolphthalein alkalinity for any of the samples. 10mL of the sample was measured into a conical flask and two drops of 5% methyl orange indicator was added and swirled to mix. It was titrated against standard 0.02N H_2SO_4 with continuous swirling. A colour change of yellow to orange was obtained when the endpoint was reached. The titre value was then recorded. The procedure was repeated for each sample and the average titre value was calculated. The procedure was repeated for all the collected samples. The alkalinity concentration was calculated as; Alkalinity mg ($CaCO_3$)/L = $A \times N \times 50{,}000$/1mL sample [28].

Where A=mL of acid used and
N= Normality of standard acid used

The stored program number for iron, FerroVer method was entered into spectrophotometer with the wavelength set appropriately. A clean cell sample was filled with 25mL of sample and the content of one FerroVer Iron reagent was emptied into the sample cell (the prepared sample). An orange colour was an indication of the presence of iron. The shift timer button was pressed and allowed for about five minutes to allow for a reaction to take place. 25mL of blank solution in cell was place in the cell holder and the light shield was closed to zero the spectrophotometer. The blank was then removed and the prepared sample was put into the cell holder and the result was displayed in mg/L Fe FV. The procedure was repeated for the rest of the collected samples.

c) Bacteriological Analysis

Total coliforms and faecal coliforms were enumerated by multiple tube fermentation tests as described by [28]. In the multiple-tube method, a series of 5 tubes with Durham tubes containing a suitable selective broth culture medium (lactose-containing broth, such as MacConkey broth) were inoculated with test portions of water sample from each of the boreholes. After an incubation time of 24-48 hours at a temperature of 37℃, each tube showing gas formation in the Durham tubes and a colour change was regarded as "presumptive positive" since the gas indicates the possible presence of coliforms. However, gas may also be produced by other organisms, and so a subsequent confirmatory test is essential. The two tests are known respectively as the presumptive test and the confirmatory test [28].

For the confirmatory test, a more selective culture medium (brilliant green bile broth) was inoculated with material taken from the positive tubes. After an appropriate incubation time of 24-48 hours and temperature of 44.5℃, the tubes were examined for gas formation as before. The most probable number (MPN) of bacteria present can then be estimated from the number of tubes inoculated and the number of positive tubes obtained in

the confirmatory test, using specially devised statistical tables. This technique is known as the MPN method.

A questionnaire was administered to 100 residents of Nalerigu who were within 50m from the damand uses the water for domestic purses from a population of 135 residents [29]to ascertain the perception of residents about the quality, usefulness or otherwise of the dam.

$$S = {X^2\ NP\ (1 - P)}\Big/{d^2(N-1) + X^2P(1 - P)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eqn\ (1)$$

Variables:

The respective variables have been given their explanations below.

$S = required\ sample\ size$

$X^2 = table\ value\ of\ Chi - square\ for\ 1\ degree\ of\ freedom\ (df)\ at\ desired\ confidence\ level\ (3.841)$

$N = The\ population\ size$ =135

$P = The\ population\ proportion\ (Assumed\ to\ be\ 0.5\ since\ this\ would\ provide\ the\ maximum\ sample\ size)$

$d = the\ degree\ of\ accuracy\ expressed\ as\ proportion\ (0.05)$

From the information above;

$$S = {3.841(135)(0.5)(1-0.5)}\Big/{(0.05)^2(135-1) + (3.841)(0.5)(1 - 0.5)} = {129.63375}\Big/{1.31025}$$

$= 98.9382$

$=$ 99 (Approximately)

The data obtained was analyzed using SPSS 16.0 for the physicochemical parameters, Microsoft Word and Minitab 16.0 for the public perceptions. Tables were used to present the findings.

IV. Results and Discussion

a) Physicochemical Parameters for the Dam Water Within the Sampled Period

A total of 3 samples were investigated for this work. The water samples from the dam were analyzed in order to compare their levels to WHO water standard for drinking water. The average physical and chemical properties and nutrient content of the dam water samples including pH, electrical conductivity, turbidity, alkalinity, hardness, total dissolved solids (TDS), total suspended solids (TSS), colour, chloride, iron content from these sample points are shown in Tables 1, 2 and 3.

i. *Temperature*

The mean temperature for all the sampling sites ranged from 30.3 and 30.5℃with the highest temperature of 30.5℃ recorded at sample A and the lowest temperature of 30.3℃recorded at sample B (Table 1). The little variation in temperatures in the dam water shows some uniformity of the dam water temperature in the study area.

ii. *Hardness*

Average total hardness for the dam water samples ranged from 5.0 to 6.0 mg/L (Table 1). The highest value was recorded at sample points A and B and the lowest at sample point C. The least Calcium hardness value of 2.00 mg/L was recorded for sample points A and B and the highest value of 3.00 mg/L. Calcium hardness was recorded for sample point C. also magnesium hardness was determined for all three samples with average values ranging from 2.00 mg/L for sample point C to 4.00 mg/L for sample points A and B. The hardness values were low which indicates that the water samples were all soft and within the WHO permissible limit of 500 mg/L. Hardness of water may not have any health implications but may affect the taste of water as well as influence its lathering ability by forming scum with soap when used for washing.

Table 1: Mean Values of Physico-Chemical Parameters and Nutrients at Nalerigu Dam

Sample Point	Temp ℃	pH	T Hardness mg/L	Ca Hardness mg/L	Mg Hardness mg/L
WHO Limit		6.5-8.5	500.00		
Sample Point A	30.5	6.40	6.00	2.00	4.00
Sample Point B	30.3	6.50	6.00	2.00	4.00
Sample Point C	30.4	6.30	5.00	3.00	2.00

pH-The mean pH ranged from 6.30 to 6.50 with the highest pH of 6.50 occurring at sample B and the lowest pH of 6.30 at sample C (Table 1). The pH values for all the three samples analyzed, two samples (A and C) fell

outside and only sample (B) fell within the WHO guidance limit of 6.5 – 8.5. Though the pH of drinking water has no direct health effects, levels outside the WHO range of 6.5 – 8.5 could indirectly affect the quality of drinking water by either resulting in acidic water for pH less than 6.5 or bitter taste for pH values greater than 8.5. The differences in the pH of the various samples may be due to the characteristics of the source waters influenced by both natural and anthropogenic factors such as washing of clothes back into the dam, agriculture, waste disposal and acid precipitations.

iii. *Turbidity*

Turbidity of the dam water samples for all the sample points varied from 7.0 to a very high turbidity value of 10.0 NTU. The lowest turbidity value of 7.0 NTU was recorded for two samples (B and C) and the highest value of 10.0 NTU was recorded for sample A (**Table 2**)

Table 2: Mean Values of Physico-Chemical Parameters and Nutrients Analyzed at the Dam

Sample Point	Total Dissolved Solids (TDS) mg/L	Apparent Colour HU (PtCo)	Turbidity NTU	Fe^{2+} mg/L
WHO Limit	1000.00	0.00 – 15.00	0.00 – 5.00	1.0
Sample Point A	35.20	6.10	10.00	0.63
Sample Point B	34.00	3.30	7.00	0.44
Sample Point C	34.40	3.50	7.00	0.53

From the results, turbidity of all the samples exceeded the WHO recommended acceptable limits of 0.00-5.0 NTU. Turbidity directly influences the colour of water and there is a general increase in colour with increasing turbidity values. The excessive turbidity in water correlates with the very high apparent colour. This makes water purification processes such as flocculation and filtration difficult making treatment expensive [30]. High turbidity can inhibit the effects of disinfection against microorganisms and enable bacterial growth. Ideally disinfection is effective at turbidity below 0.1 NTU. Turbidity is an important parameter which gives an indication of the effectiveness of the treatment processes especially with the coagulation or sedimentation and the filtration.

iv. *Total Dissolved Solids (TDS)*

Mean total dissolved solids concentrations ranged from 34.0 to 35.2 mg/L for all three samples with the highest value recorded at sample **A** and the lowest at sample **B (Table 2)**. These amounts of TDS measured in the monitored samples were within acceptable levels recommended by WHO. [31] stated that the palatability of water with TDS level less than 600 mg/L is generally considered to be good whereas water with TDS greater than 1200 mg/L becomes increasingly unpalatable. This indicates that all water samples that were taken were suitable for drinking in terms of palatability because all are within the recommended standards.

v. *Colour*

Colour is an important physical property of water because of its implications for water supply, and the need to reduce it to acceptable levels by water treatment is highly recommended. Increase in the colour of water in reservoirs results in increase in treatment cost. Colour in natural water usually results from the leaching of organic materials and is primarily the result of dissolved and colloidal humic substances, primarily humic and fulvic acids. Colour is also strongly influenced by the presence of iron and other metals, either as natural impurities or as corrosion products. Highly coloured water may be due to decaying vegetation. Apparent colour ranged from 3.30 to 6.10 Hazen units for all sample points with the highest at sample point **A** and the lowest at sample point B. All three samples were within the WHO limit of 15 HU (**Table 2)**

vi. *Electrical Conductivity*

Electrical conductivity gives an account of all, the dissolved ions in solution. The mean conductivity of all water samples ranged from a least value if 68.70µS/cm at sample point **C** to a considerably high mean value of 70.50µS/cm at sample point **A** (Table 2). The acceptable WHO limit of conductivity is 0 – 1000.00µS/cm. Generally, conductivity of clean water is lower but as it moves down the earth it leaches and dissolves ions from the soil and also picks up organic from biota and detritus [32]. Generally, the conductivity values recorded for the samples from the dam does not pose any potential health risk for consumers. They were all within the acceptable limit prescribed by WHO limits.

vii. *Alkalinity*

Total alkalinity ranged from 20.0-23.0 mg $CaC0_3$/L for all three sample points within sample period with the highest value recorded at sample point B and the lowest at sample point **C**. These values were within the WHO limit of 0-500.00 mg/L (Table 3). There was however no Phenolphthalein alkalinity for all three points sampled. This is because all the pH values were below 8.3 (pH<8.3) hence all alkalinity values were Methyl Orange alkalinity (Table 3). Alkalinity values provide guidance in applying the right amount of chemicals to the treatment of drinking and waste water. High alkalinity means the drinking water will have the ability to neutralize acidic pollution and hence keeps the water's pH constant. Water with very high alkalinity is not detrimen-

tal to humans but is generally associated with high pH values, hardness and excess dissolved solids. High alkalinity waters may also have a distinctly unpleasant taste. This is because such waters may excessively hard or may contain high amounts of sodium chlorides [33]. Alkalinity has no health standards, however, concentrations between 30-400 mg CaCO3/L is preferred for domestic drinking water supply.

Table 3: Mean Values of Physico-Chemical Parameters and Nutrients Analyzed for Dam Water in Nalerigu February, 2023

Sample Point	Total Alkalinity mg/L	Phenolphthale in Alkalinity mg/L	Methyl Orange Alkalinity mg/L	Conductivity µS/cm
WHO LIMIT	0-500.00		0-500.00	1000
Sample Point A	22.00	0	22.00	70.50
Sample Point B	23.00	0	23.00	68.80
Sample Point C	20.00	0	20.00	68.70

viii. *Total Iron*

The total iron (II) concentration ranged from 0.44-0.63 mg/L with the highest value occurring at sample point A which is within the WHO recommended limit of 0.01-1.00 mg/L. The lowest value of 0.44 mg/L occurred at sample point B.

Drinking water 0.1 – 1.00 mg/L of iron concentration has very slight effects on taste and other aesthetic effects such as deposits in plumbing materials and associated problems occurring. Iron concentration ranging from 0.3-1.0 mg/L has adverse aesthetic effects (taste) and a gradual increase in the possibility of problems with plumbing. There are however no health effects associated with it.

b) Microbiological quality of the dam water analyzed

The result obtained for the microbial analysis indicated that the water samples from sample points A, B and C were not free from faecal coliforms (faecal contamination). These samples show that the dam water without processing is not fit for drinking and domestic purposes because the sample points A, B and C had faecal coliform counts of 23, 43 and 20cfu/1mL respectively which is not in conformity with the set standards by [32] which says no water sample should contain faecal coliform in any 100 ml of water sample. However, the presence of faecal coliform count (Table 4) in the samples may be attributed to either proximity of open defecation to the dam at a distance less than 30 m as recommended by WHO or the general unhygienic environment surrounding the dam. The contamination even though may be small could also be attributed to increased infiltration during the wet season. Therefore, there is the need to boil and filter this water for clarity before drinking. The results however suggest that the general sanitary conditions around the dam were not very good.

Table 4: Showing Test for Microbiological Properties of Dam Water Samples

Sample Point	Total Coliforms cfu/1ml		Faecal Coliforms cfu/1ml	
WHO Limit		0.00		0.00
Sample Point A	Positive	69.00	Positive	23
Sample Point B	Positive	106.00	Positive	43
Sample Point C	Positive	70.00	Positive	20

c) Sociodemographic Results from the Study

The number questionnaire administered was 99 and indicates the percentages of males (44%) and females (56%) who responded to the questionnaires. The response from the respondents was 100% for the access to water to all the households interviewed, indicating that every household interviewed had access to water.The responses from the administration of the questionnaires showed that close to half of the interviewed households (48%) representing the largest number depend on the dam as their main source of water, 36% depend on boreholes as their source of water and 8% each depend on hand dug well and pipe borne water respectively.The response from the questionnaires showed that the various households employ various ways to treat their water to make it safe for consumption. The responses from the questionnaire revealed that a larger number of the interviewed households representing 76.0% had no toilet facilities at their homes and only 24% had toilet facilities at home. Those without toilet facilities at home either use public toilets or do open defecation.

Responses from how the various households disposed off their rubbish indicated that 78% of the households dispose their waste through burning whiles 22% disposed theirs through dumping the waste at dump sites. The multiple use of the dam by the various households interviewed is shown in the table 5.

Table 5: Showing the Various uses of the Dam by the Households Interviewed

Uses of dam water	Frequency	Percentage
Cooking	60	60.6
Washing	73	73.8
Bathing	81	81.8
Drinking	46	46.5
Irrigation	38	38.4

NB: The frequency and percentages for the uses of dam exceeded 99 respondents and 100.0% respectively because some of the respondents choose more than one answer.

V. Conclusions and Recommendations

All the physicochemical parameters analyzed except turbidity were within the WHO limits and Ghana Drinking Water Standards. The level of turbidity for all sampled points exceeded the WHO limits. The microbial load of the dam water was very high and exceeded the WHO limits and this can be attributed to the fact that the surroundings of the dam is used for open defection.The study concludes that raw dam water was not safe for consumption and other domestic uses unless it is treated. It is recommended that future researchers who are interested in the quality of water in the study area should broaden the scope to include the determination of the heavy metals, and other parameters which were not determined as a result of lack chemicals and the requisite equipment.Regular monitoring is necessary to ensure conformity to WHO standards. The inhabitants and users of the dam in Nalerigu should be educated on the need to keep the surroundings of the dam clean. Farming done close to dam should be done at a reasonable distance to avoid the washing of agrochemicals into the dam through runoff

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Techniques for writing a good quality Science Frontier Research paper:

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.

4. Use of computer is recommended: As you are doing research in the field of science frontier then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

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.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

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.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

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.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

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 though 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.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

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

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- 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.

Title page:

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.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- 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.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

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:

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

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- 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.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- 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.
- 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?
- 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.

The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

Criterion for Grading a Research Paper (Compilation) by Global Journals

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	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
Methods and Procedures	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
Result	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
Discussion	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
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

Index

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