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FROM MISINFORMATION TO POLLUTION: HOW COVID-19 POLICIES AFFECT THE IGUAÇU RIVER AND THREATEN THE ATLANTIC FOREST IN SOUTHERN BRAZIL

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Abstract: A hidden threat emerged during the COVID-19 pandemic: pharmaceutical contamination in the Iguaçu River. Flowing through Curitiba and several Atlantic Forest fragments, the river became polluted due to a surge in medications, including antibiotics, psychiatric drugs, and controversial "COVID kit" drugs. Although only 15% of COVID-19 patients needed antibiotics, they were prescribed in 59% of hospitalizations and experienced a 683.9% sales increase. Sales of ivermectin and hydroxychloroquine increased by 857% and 126% in the first year of the pandemic, respectively, and antidepressant sales rose by 32% from 2020 to 2023. Poorly treated in wastewater, these pharmaceuticals accumulate in river sediments, posing long-term ecological risks. Misinformation and government promotion of unproven drugs contributed to this rise. The Iguaçu River now transmits the consequences of misguided policies and fake news, threatening the Atlantic Forest fragments adjacent to the Iguaçu River in Paraná biodiversity. Therefore, immediate action is needed to implement sustainable practices and educate the public on the impact of pharmaceutical pollution.

Keywords: Antimicrobials; Biodiversity; Ecotoxicology; Pandemic; Pharmaceutical contamination

During the COVID-19 pandemic, air quality temporarily improved due to reduced industrial activities and vehicular traffic (Nakada & Urban 2020, Rocha *et al.* 2022, de Souza *et al.* 2022, Rudke *et al.* 2022). This improvement was one of the few positive environmental changes observed during the pandemic. However, it was overshadowed by a growing issue: the significant and less visible threat of pharmaceutical contamination in water bodies like the Iguaçu River (Marques *et al.* 2024). Originating in the Serra do Mar in Paraná, Brazil, the Iguaçu River extends for approximately 1,320 km, passing through several municipalities, including Curitiba, which has about 3 million inhabitants (IBGE 2023). From Curitiba, the river flows through numerous fragments of the Atlantic Forest in Southern Brazil, becoming a conduit for pollutants and raising severe ecological concerns. The river's contamination with pharmaceuticals poses significant risks to these ecosystems, particularly in regions adjacent to its flow (Marques *et al.* 2024).

The pandemic saw a surge in the consumption of pharmaceuticals, including antibiotics, psychiatric drugs, and COVID-19-related drugs, such as ivermectin and hydroxychloroquine (João 2021, Balza 2021, Maguire *et al.* 2022, Tiger *et al.* 2023, 2024, Ying *et al.* 2023). These substances, often inadequately treated in wastewater facilities, contribute significantly to the contamination of rivers (Marques *et al.* 2024). Studies indicate

a significant increase in the presence and concentration of pharmaceuticals in the Iguaçu River during the COVID-19 pandemic (Gomes & Gomes 2024, Marques *et al*. 2024). Preliminary data suggest that concentrations of fluoxetine and sertraline increased by up to 246% and 180%, respectively, within six months of the pandemic's onset (September 2020) (Gomes & Gomes 2024). The increase was even more pronounced for antibiotics, with sulfamethoxazole concentration increasing by 535% by January 2022 (Marques *et al*. 2024). Additionally, the concentrations of ivermectin surged by 333% from September 2020 to March 2021 (Gomes & Gomes 2024). These increased concentrations, observed in the urban areas of Curitiba along the Iguaçu River, have severe implications for the ecology of the Atlantic Forest.

Although natural processes such as photolysis, chemical degradation, and biological degradation should reduce some pharmaceutical concentrations (Yan *et al*. 2023) as the river flows from Curitiba towards the preserved areas of the Atlantic Forest, these substances often settle in the sediment (Marques *et al*. 2024). This sediment is a repository and a "time bomb" for pharmaceuticals. Even residual concentrations reaching the preserved areas via the Iguaçu River can, over time, accumulate in sediments and persist there for an extended period. When environmental conditions change, such as during floods or shifts in pH, these substances can be re-released into the water column, resulting in these contaminants reaching toxic levels and posing a threat to benthic organisms and the broader aquatic ecosystem over time (Marques *et al*. 2024). Moreover, their bioaccumulative nature means they can still pose long-term risks. (Calisto & Esteves 2009).

The spread of pollutants from urban areas such as Curitiba into the Atlantic Forest can disrupt delicate ecological balances. The Paraná Atlantic Forest is characterized by a high level of biodiversity, including numerous endemic and threatened species (Marques *et al*. 2021), which makes it particularly vulnerable to environmental stressors such as pharmaceutical contamination. Increased levels of pharmaceuticals in the Iguaçu River affect microbial communities, which are crucial for nutrient cycling and overall ecosystem health. The bioaccumulation of these substances in aquatic organisms can have cascading effects throughout the food web, impacting species diversity and ecosystem functionality (Yan *et al*. 2023, Rubio-Vargas *et al*. 2024). Pharmaceuticals present in river water can also infiltrate the soil, especially in floodplains and through irrigation practices. Like sediments, soils are potential sources of pharmaceuticals through their sequestration by soil organic matter. Once bioavailable in the soil solution, pharmaceuticals can pose constraints for soil microbiota and can be taken up by plants (Gomes *et al*. 2020, Marques *et al*. 2023b). When absorbed into plant tissues, they can be toxic, leading to lower productivity, accumulation, and entry into the food chain (Rocha *et al*. 2021), with negative prospects for ecosystem health and biodiversity (Rocha *et al*. 2021). The increased use of drugs during the COVID pandemic probably affected the ecological dynamics in important conserved fragments of the Atlantic Forest. Given that the Atlantic Forest is a conservation hotspot (Scarano & Ceotto 2015), it is urgent to regulate the release of pharmaceuticals into urban rivers.

Between 2020 and 2023, Brazil saw a 32% increase in antidepressant sales (Gomes *et al*. 2023). This rise can be linked to the temporary relaxation of dispensation regulations during the pandemic and a growing trend toward medicalizing health, leading to the inappropriate use of these medications (Barros & Silva 2023, Del Fiol *et al*. 2023) . Additionally, research suggesting the potential benefits of some psychoactive drugs in preventing SARS-CoV-2 infection and improving disease outcomes may have also contributed to the increased consumption of psychiatric medications (Stingl 2022).

Moreover, the pandemic saw indiscriminate use of antibiotics, particularly azithromycin, which was part of the "COVID kit" (CRFSP 2023, Marques *et al*. 2024). This misuse of antibiotics contributed to the rise in antimicrobial concentrations in rivers and antimicrobial resistance (Marques *et al*. 2024). According to the World Health Organization, only 15% of COVID-19 patients require antibiotics. However, studies indicate that this class of pharmaceuticals was prescribed in approximately 59% of COVID-19 hospitalizations, even when bacterial infections were absent (Dos Santos *et al*. 2023). Moreover, sales of these drugs increased by up to 683.9% during the pandemic (Marques *et al*. 2024). The Brazilian federal government's promotion of unproven medications as part of the "COVID kit" significantly exacerbated this problem. Despite a

lack of scientific evidence supporting their efficacy, drugs like azithromycin, hydroxychloroquine, and chloroquine became widely promoted as treatments for COVID-19 (Santos-Pinto *et al.* 2021). This was reflected in online behavior; hydroxychloroquine and chloroquine were among the most searched terms on social media during the pandemic. The widespread belief in these unverified treatments was fueled by misinformation and a lack of clear public health communication, leading to a surge in their use (Bezerra *et al.* 2022)

Self-medication during the pandemic was primarily driven by information spread through social media, personal interactions, and television broadcasts, which often mirrored the views and recommendations of government officials and agencies, such as the Ministry of Health (Dos Santos *et al.* 2023). Ivermectin saw such a dramatic increase in demand that its sales had to be controlled to prevent shortages for patients who genuinely needed it (CRFSP 2023). A medical prescription became mandatory to purchase ivermectin, and its sale required compulsory reporting to the Brazilian National Health Surveillance Agency (ANVISA 2024). Sales of ivermectin and hydroxychloroquine increased by 857% and 126% in the first year of the pandemic (João 2021, Balza 2021). The promulgation of the use of the COVID kit by the Brazilian government and social media, combined with the increased use of antimicrobials (to treat COVID-positive patients) and psychiatric drugs (due to mental health degradation during the pandemic), likely resulted in increased concentrations of these drugs in environmental matrices of the Atlantic Forest fragments. This may have contributed to the degradation of these critical sources of biodiversity. Ivermectin, which was the most-sold drug in Brazil in 2022 (Matoso & Saraiva 2023), is one of the most toxic pharmaceuticals for several aquatic species (Marques *et al.* 2023a), and its toxicity increases when mixed with other COVID-kit drugs, especially azithromycin (Marques *et al.* 2023a). Unfortunately, their simultaneous occurrence in the Iguaçu River has been reported (Marques *et al.* 2023a). Therefore, the Iguaçu River has become a carrier, transmitting the consequences of misguided policies and fake news to the vital fragments of the Atlantic Forest.

The COVID-19 pandemic has highlighted the critical intersection of human health and environmental sustainability. As we navigate post-pandemic recovery, we must address the silent threat of water pollution and pharmaceutical contamination. Policymakers must prioritize sustainable practices and informed public health strategies to mitigate these impacts. The Iguaçu River's contamination is a stark reminder of the interconnectedness of urban activities and natural ecosystems, urging immediate action to protect the Atlantic Forest and its invaluable biodiversity.

Nature-based solutions through bioremediation have emerged to replace the costly and technologically required systems used in tertiary treatments in wastewater treatment plants (WWTPs) (Kochi *et al.* 2020, Salvi-Taga *et al.* 2024), which are mostly inaccessible to developing countries such as Brazil. Providing WWTPs with the capacity to remove pharmaceuticals from water will decrease the pharmaceutical discharges in rivers, avoiding their toxicological effects on ecosystems. Furthermore, enhancing public awareness about the environmental consequences of pharmaceutical pollution is crucial. Educational campaigns and policy interventions can help shift behaviors towards more sustainable practices. By fostering a greater understanding of the link between human health practices and environmental health, society can move towards a more integrated approach to managing human and ecological well-being.

In conclusion, the pandemic has underscored the importance of considering the environmental dimensions of public health crises. The Iguaçu River's pollution threatens local ecosystems and warns about the broader implications of unchecked pharmaceutical use. Protecting the Atlantic Forest requires a concerted effort to address these emerging threats through research, policy, and public engagement. Only by recognizing and acting on the interconnectedness of our health and the environment can we hope to preserve the rich biodiversity and ecological integrity of this critical region. More detailed studies are urgently needed to assess the impacts of pharmaceutical pollution on the Paraná Atlantic Forest, particularly its distinctive flora and fauna. Such research is crucial for developing targeted conservation strategies and mitigating long-term ecological risks.

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REFERENCES

ANVISA. 2024. Venda de Medicamentos Industrializados Sujeitos à Escrituração no SNGPC - Sistema Nacional de Gerenciamento de Produtos Controlados [WWW Document]. Portal Brasileiro de Dados Abertos. (Retrieved on from https://dados.gov.br/dataset/venda-de-medicamentos-controlados-e-antimicrobianos-medicamentos-industrializados).

Balza, G. 2021, May 6. Venda de remédios do "kit Covid" dispara até 857% na pandemia. Globonews.

Barros, J. C., & Silva, S. N. 2023. Use of Psychotropic Drugs during the COVID-19 pandemic in Minas Gerais, Brazil. Revista Brasileira de Epidemiologia, 26. DOI: 10.1590/1980-549720230059

Bezerra, M. M. A., Moraes, I. N. da S., Barboza, A. L. de O., Silva, E. S. da, Cardoso, E. C. de O., Oliveira, G. S. X. M. de, Coelho, I. M., Magalhaes, L. W., Gomes, L. C. C., Gomes, M. F., Lima, A. de M., Rodrigues, L. M. P., Pimentel, C. P., Silva, S. F. da, & Carvalho, D. C. de. 2022. Medicamentos na pandemia da COVID-19: Análise da comercialização de azitromicina, hidroxicloroquina, ivermectina e nitazoxanida no Brasil. Research, Society and Development, 11(6), e16711628726. DOI: 10.33448/rsd-v11i6.28726

Calisto, V., & Esteves, V. I. 2009. Psychiatric pharmaceuticals in the environment. Chemosphere, 77(10), 1257–1274. DOI: 10.1016/j.chemosphere.2009.09.021

CRFSP. 2023. Abastecimento de medicamento nas farmácias - Fase III (Conselho Regional de Farmácia do Estado de São Paulo). p. 6. (Retrieved on from https://www.crfsp.org.br/images/arquivos/Levantamento_medicamentos_fase_III.pdf).

de Souza, A., Abreu, M. C., de Oliveira-Júnior, J. F., Aviv-Sharon, E., Fernandes, W. A., & Aristone, F. 2022. Variations in the tropospheric concentration of NO2 in the central west of Brazil, MS, and their relationship with the COVID-19. Air Quality, Atmosphere & Health, 15(7), 1169–1182. DOI: 10.1007/s11869-021-01121-8

Del Fiol, F. de S., Bergamaschi, C. de C., Lopes, L. C., Silva, M. T., & Barberato-Filho, S. 2023. Sales trends of psychotropic drugs in the COVID-19 pandemic: A national database study in Brazil. Frontiers in Pharmacology, 14. DOI: 10.3389/fphar.2023.1131357

Dos Santos, M. L., Falcão, A. H. P. B. de M., De Jesus, M. M. R., Oliveira, A. P. da S., Baia, S. J. de A. A., & Brito, F. Í. de S. 2023. Aumento do consumo de antibióticos em ambiente hospitalar durante a pandemia de Covid-19. Brazilian Journal of Health Review, 6(1), 2341–2350. DOI: 10.34119/bjhrv6n1-183

Gomes, C. A., Pereira, J. S., & D, M. A. C. 2023. O aumento do uso de psicotrópicos por jovens brasileiros em períodos pandêmicos. Revista FT, 28. DOI: 10.5281/zenodo.10251221

Gomes, M. P., Marques, R. Z., Nascentes, C. C., & Scotti, M. R. 2020. Synergistic effects between arbuscular mycorrhizal fungi and rhizobium isolated from As-contaminated soils on the As-phytoremediation capacity of the tropical woody legume Anadenanthera peregrina. International Journal of Phytoremediation, 0(0), 1–10. DOI: 10.1080/15226514.2020.1775548

Gomes, M. P., & Gomes, L. P. 2024. Tracking the surge of psychiatric pharmaceuticals in urban rivers of Curitiba amidst and beyond the SARS-CoV-2 pandemic. Science of the Total Environment., 954, 176685. DOI:10.1016/j.scitotenv.2024.176685

IBGE. 2023. Curitiba, Cidades e Estados. (Retrieved on from https://www.ibge.gov.br/cidades-e-estados/pr/curitiba.html).

João, W. S. J. 2021. Palavra do Presidente. Pharmacia Brasileira, 10(92), 0.

Kochi, L. Y., Freitas, P. L., Maranho, L. T., Juneau, P., & Gomes, M. P. 2020. Aquatic macrophytes in constructed wetlands: A fight against water pollution. Sustainability (Switzerland), 12(21), 1–21. DOI: 10.3390/su12219202

Maguire, A., Kent, L., O'Neill, S., O'Hagan, D., & O'Reilly, D. 2022. Impact of the COVID-19 pandemic on psychotropic medication uptake:

time-series analysis of a population-wide cohort. The British Journal of Psychiatry, 221(6), 748–757. DOI: 10.1192/bjp.2022.112

Marques, M. C. M., Trindade, W., Bohn, A., & Grelle, C. E. V. 2021. The Atlantic Forest: An Introduction to the Megadiverse Forest of South America. In: The Atlantic Forest. pp. 3–23. Cham: Springer International Publishing.

Marques, R. Z., da Silva Nogueira, K., de Oliveira Tomaz, A. P., Juneau, P., Wang, S., & Gomes, M. P. 2024. Emerging threat: Antimicrobial resistance proliferation during epidemics — A case study of the SARS-CoV-2 pandemic in South Brazil. Journal of Hazardous Materials, 470, 134202. DOI: 10.1016/j.jhazmat.2024.134202

Marques, R. Z., Kochi, L. Y., Guzman-Tordecilla, M., Malage, L., Juneau, P., & Gomes, M. P. 2023a. COVID-19 pharmaceuticals in aquatic matrices: The threatening effects over cyanobacteria and microalgae. Science of The Total Environment, 892, 164309. DOI: 10.1016/j.scitotenv.2023.164309

Marques, R. Z., Rodrigues, L. P., Kaschuk, G., Moreira Brito, J. C., & Gomes, M. P. 2023b. Protecting soybean yields from enrofloxacin toxicity: The role of Bradyrhizobium japonicum inoculation. Rhizosphere, 28, 100813. DOI: 10.1016/j.rhisph.2023.100813

Matoso, L. M. L., & Saraiva, A. M. de M. 2023. Automedicação Durante Pandemia a COVID-19 e Sua Relação com as Redes Sociais. UNICIÊNCIAS, 27(1), 31–37. DOI: 10.17921/1415-5141.2023v27n1p31-37

Nakada, L. Y. K., & Urban, R. C. 2020. COVID-19 pandemic: Impacts on the air quality during the partial lockdown in São Paulo state, Brazil. Science of The Total Environment, 730, 139087. DOI: 10.1016/j.scitotenv.2020.139087

Rocha, C. A., Marques, E. V., dos Santos, R. P., de Santiago, Í. S., Cavalcante, C. L. A., Cassiano, D. R., Ribeiro, J. P., Bertoncini, B. V., Nobre, J. S., Freitas, J. V. B., Ferreira, A. G., & Cavalcante, R. M. 2022. A better understanding of air quality resulting from the effects of the 2020 pandemic in a city in the equatorial region (Fortaleza, Brazil). Environmental Science and Pollution Research, 29(14), 20921–20938. DOI: 10.1007/s11356-021-16697-y

Rocha, D. C., Rocha, C. S., Tavares, D. S., Calado, S. L. M., & Gomes, M. P. 2021. Veterinary antibiotics and plant physiology: An overview. Science of The Total Environment, 767, 144902. DOI: 10.1016/j.scitotenv.2020.144902

Rubio-Vargas, D. A., Morais, T. P. de, Randi, M. A. F., Filipak Neto, F., Martins, C. de C., Oliveira, A. P., Nazário, M. G., Ferreira, F. C. A. da S., Opuskevitch, I., Penner, D., Esquivel-Muelbert, J., Prodocimo, M. M., Choueri, R. B., & Oliveira Ribeiro, C. A. de. 2024. Pollutant bioaccumulation in sentinel fish chronically exposed in Iguaçu river reservoirs (Southern Brazil) and human health risk of fish consumption. Chemosphere, 349, 140812. DOI: 10.1016/j.chemosphere.2023.140812

Rudke, A. P., de Almeida, D. S., Alves, R. A., Beal, A., Martins, L. D., Martins, J. A., Hallak, R., & de Almeida Albuquerque, T. T. 2022. Impacts of Strategic Mobility Restrictions Policies during 2020 COVID-19 Outbreak on Brazil's Regional Air Quality. Aerosol and Air Quality Research, 22(4), 210351. DOI: 10.4209/aaqr.210351

Salvi-Taga, R. G., Meffe, R., Martínez-Hernández, V., De Miguel Garcia, A., & De Bustamante, I. 2024. Amended Vegetation Filters as Nature-Based Solutions for the Treatment of Pharmaceuticals: Infiltration Experiments Coupled to Reactive Transport Modelling. Toxics, 12(5), 334. DOI: 10.3390/toxics12050334

Santos-Pinto, C. D. B., Miranda, E. S., & Osorio-de-Castro, C. G. S. 2021. O "kit-covid" e o Programa Farmácia Popular do Brasil. Cadernos de Saúde Pública, 37(2). DOI: 10.1590/0102-311x00348020

Scarano, F. R., & Ceotto, P. 2015. Brazilian Atlantic forest: impact, vulnerability, and adaptation to climate change. Biodiversity and Conservation, 24(9), 2319–2331. DOI: 10.1007/s10531-015-0972-y

Stingl, J. C. 2022. Antidepressant drug treatment protecting from COVID-19: one more piece in the repurposing puzzle. BJPsych Open, 8(1), e20. DOI: 10.1192/bjo.2021.1075

Tiger, M., Castelpietra, G., Wesselhoeft, R., Lundberg, J., & Reutfors, J. 2024. Utilization of antidepressants, anxiolytics, and hypnotics during the COVID-19 pandemic. Translational Psychiatry, 14(1), 175. DOI: 10.1038/s41398-024-02894-z

Tiger, M., Wesselhoeft, R., Karlsson, P., Handal, M., Bliddal, M., Cesta, C. E., Skurtveit, S., & Reutfors, J. 2023. Utilization of antidepressants, anxiolytics, and hypnotics during the COVID-19 pandemic in Scandinavia. Journal of Affective Disorders, 323, 292–298. DOI: 10.1016/j.jad.2022.11.068

Yan, Z., Zhou, Y., Zhang, Y., & Zhang, X. 2023. Distribution, Bioaccumulation, and Risks of Pharmaceutical Metabolites and Their Parents: A Case Study in an Yunliang River, Nanjing City. International Journal of Environmental Research and Public Health, 20(4), 2967. DOI: 10.3390/ijerph20042967

Ying, L. T., Yarema, M. C., & Bousman, C. A. 2023. Dispensing patterns of mental health medications before and during the COVID-19 pandemic in Alberta, Canada: An interrupted time series analysis. The International Journal of Psychiatry in Medicine, 58(2), 172–184. DOI: 10.1177/00912174221084818

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