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Pseudoscience in the Times of Crisis: How and Why Chlorine Dioxide Consumption Became Popular in Latin America During the COVID-19 Pandemic

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INTRODUCTION

The COVID-19 pandemic has affected the economic and political landscape of the world (Blofield et al., 2020; Greer et al., 2020). Low- and middle-income countries (LMICs) have been particularly vulnerable to the effects of the disease (Breevoort et al., 2020; Dahab et al., 2020; Elhadi et al., 2020; Loayza and Pennings, 2020). Yet, LMIC regions have different approaches to disease response, control and monitoring. For instance, while Africa centralizes these roles in the Africa Centers for Disease Control (Africa CDC) (Wadvalla, 2020), Latin American countries lack a common health administration, making them more susceptible to complications due to poverty, comorbidity and political dynamics (Pablos-Mendez et al., 2020).

Traditional and social media have been important to disseminate information related to disease containment and treatment (Basch et al., 2020; Hopman et al., 2020). Yet, these tools have also served to spread misinformation, conspiracy theories and "miracle cures" for COVID-19 (Malinverni and Brigagão, 2020; Moreno-Castro et al., 2020; Oliveira et al., 2020; Pereira et al., 2020). In Latin America, there are several instances in which media trends have shaped policy and resulted in dangerous interventions to fight the pandemic (Oliveira et al., 2020). These have included the administration of hydroxychloroquine and ivermectin (Mega, 2020), as well as the use of untested convalescent plasma as therapy for COVID-19 (Ferreira and Mostajo-Radji, 2020).

While the world was horrified by President Donald Trump's suggestion of drinking household disinfectants to prevent COVID-19 (Litman et al., 2020), less has been mentioned about the extensive use of chlorine dioxide as treatment in Latin America. Chlorine dioxide is a disinfectant commonly used to clean medical equipment and treat residual waters (Smith et al., 2001). At high concentrations and non-physiological pH, chlorine dioxide effectively inhibits microbial and viral activity (Hauchman et al., 1986; Zoffoli et al., 2005). Exposure to high doses of chlorine dioxide has been shown to cause thyroid suppression, DNA damage and neurotoxicity in several animal models (Bercz et al., 1982; Abdel-Rahman et al., 1984; Orme et al., 1985; Harrington et al., 1986; Toth et al., 1990). It is therefore understood that chlorine dioxide is not safe for human consumption.

At the global scale, the dissemination of pseudoscience and post-truth phenomena is often associated with income inequalities (Rijs and Fenter, 2020). Interestingly, however, while Latin American countries often have similar levels of inequality, the use of chlorine dioxide as COVID-19 treatment varied significantly across countries (**Table 1**). In this article, I use chlorine dioxide consumption to further dissect the contribution of additional variables to pseudoscience dissemination, including scientific literacy and the democratic state of internal politics.

TABLE 1 | Positions of Latin American countries in international rankings and their chlorine dioxide consumption.

Country	Global innovation index	Global innovation rank	Gini index	Freedom in the world index	COMUSAV chapter	Proposed and discussed in congress	Income	Chlorine dioxide consumption
Chile	33.86	54	44.40	90	Yes	Proposed but not discussed	High income	Low
Mexico	33.60	55	45.40	62	Yes	No	Upper-middle income	Medium
Costa Rica	33.51	56	48.00	91	Yes	No	Upper-middle income	Low
Brazil	31.94	62	53.90	75	Yes	No	Upper-middle income	Low
Colombia	30.84	68	50.40	66	Yes	No	Upper-middle income	Low
Uruguay	30.84	69	39.70	98	Yes	No	High income	Low
Panama	29.04	73	49.20	84	Yes	No	High income	Low
Peru	28.79	76	42.80	72	Yes	Discussed but not approved	Upper-middle income	High
Argentina	28.33	80	41.40	85	Yes	Proposed but not discussed	Upper-middle income	Medium
Dominican Republic	25.10	90	43.70	67	Yes	No	Upper-middle income	Medium
El Salvador	24.85	92	38.60	66	No	No	Lower-middle income	Medium
Paraguay	24.14	97	46.20	65	Yes	No	Upper-middle income	Low
Ecuador	24.11	99	45.40	65	Yes	Yes	Upper-middle income	High
Honduras	22.95	103	52.10	45	Yes	No	Lower-middle income	High
Bolivia	22.41	105	42.20	63	Yes	Discussed and approved	Lower-middle income	High
Guatemala	22.35	106	48.30	52	Yes	No	Upper-middle income	High

A list of all Latin American countries ranked by their position in the Global Innovation Index, as well as the Gini Index and the Freedom in the World Index. Additionally, information on whether COMUSAV has an active chapter in these countries, as well as whether there were discussions on approving chlorine dioxide in congress is included. Only countries considered in all 3 rankings are included. Of note, as COMUSAV is not formally registered in any country. The information of whether there is an active chapter in a country was obtained from its official website comusav.com. Importantly, no information is available on the degree of activity that individual chapters have.

BRIEF HISTORY OF CHLORINE DIOXIDE AND ITS USE IN MEDICINE

Chlorine dioxide is obtained by the chemical reaction of sodium chlorite with an acid (Burela et al., 2020; Galloso, 2020). In his book "Master Mineral Solution of the 3rd Millennium," Jim Humble claims that he stumbled upon chlorine dioxide as a miracle solution to malaria when four members of his camp came down with the disease in Guyana (Humble, 2011). He then refined his formula through trial-and-error testing in Latin America and Africa (Humble, 2011). Since then, the use of chlorine dioxide has been promoted as a cure for cancer, HIV, hepatitis, malaria, H1N1, Ebola, acne, autism and other disorders (Humble, 2011; Harrison and Zane, 2017). The major proponent of this compound as a medication is the "Genesis II Church of Health and Healing," of which Humble is one of the founders (Harrison and Zane, 2017). Self-defined as a "non-religious church," this organization considers chlorine dioxide to be a sacrament that is administered in exchange for donations (Braga, 2020).

There are several documented cases, both in the scientific literature and in the popular media, of strong side effects caused by chlorine dioxide intoxication (Montoya and Rocha, 2020). According to court documents, in the United States alone, poison control centers have handled over 16,000 cases of chlorine dioxide intoxication since 2014 (Braga, 2020; Orshan, 2020). Some of the common symptoms of intoxication include severe vomiting and diarrhea, anemia, severe liver failure, low blood pressure, arrythmia and methemoglobinemia (US Food and Drug Administration, 2020).

During the COVID-19 pandemic, proponents of chlorine dioxide resurfaced, claiming that this compound could prevent and treat SARS-CoV-2 infections (Karnik-Henry, 2020). While no evidence was presented to support those claims, one observational clinical trial was registered in clinicaltrials.gov which aimed to determine the effectiveness of oral chlorine dioxide administration to treat COVID-19 in 20 volunteers. This study, which was to take place in Colombia, was sponsored by the Genesis Foundation. Yet, to date, no results have been reported (US National Library of Medicine, 2020).

USE OF CHLORINE DIOXIDE FOR COVID-19 PREVENTION AND TREATMENT IN LATIN AMERICA

In Latin America, the biggest proponent of chlorine dioxide is the "Coalicion Mundial Salud y Vida" (translated to "Global Health and Life Coalition" - COMUSAV). Created in 2020, this coalition has over 3,500 members and chapters in 16 Latin American countries, although it is not formally registered in any country (Gonzalez, 2020). COMUSAV defines itself as a coalition

that encompasses "open-minded" physicians, researchers, health professionals and enthusiasts promoting integral health approaches and homeopathic practices (Lammoglia, 2020). The leaders of COMUSAV are practicing physicians who treat thousands of patients with chlorine dioxide (Gonzalez, 2020). Several of its members have been outspoken at promoting unproven therapies, such as the use of scorpion venom to treat cancer (Musacchio, 2020), as well as rejecting the application of vaccines against the SARS-CoV-2 virus (Molina, 2020). COMUSAV claims to have done chlorine dioxide toxicology studies in chicken embryos infected with avian coronavirus, although those results have not been published in a peer-reviewed journal (La Red, 2020). Moreover, COMUSAV falsely claimed that these results demonstrate chlorine dioxide is safe to administer to other animals, including humans and that the results are extrapolatable to other coronaviruses, such as SARS-CoV-2 (La Red, 2020).

Many Latin American countries debated the use of chlorine dioxide to treat COVID-19. For example, in Peru congressman and physician Posemoscrowte Chagua requested the congress to create a "neutral" special commission to evaluate the effects of chlorine dioxide in the treatment of COVID-19 (Redaccion Gestion, 2020). The health commission of the congress evaluated the proposal and proponents of chlorine dioxide were invited to present their viewpoints to lawmakers (Loayza, 2020). The commission eventually suspended the investigation and did not approve the use of chlorine dioxide in Peru (El Universo, 2020). In Argentina, congresswoman Monica Frade requested the central government to authorize the chlorine dioxide as a medication, although the request was unsuccessful and the topic was not further discussed in congress (El Intransigente, 2020). In Chile, congressman Florcita Alarcon presented a similar request (Dote, 2020), which was also rejected (Camara de Diputados de Chile, 2020). In Costa Rica, the main proponent was former presidential candidate Rolando Araya who claimed he "didn't need to be a doctor to know it works" (Roque, 2020). While these motions were particularly effective at promoting the public image of specific political figures, they failed to gain formal authorization to commercialize chlorine dioxide as a medication. However, this compound was extensively sold in illegal markets and promoted in social media (Oliveira et al., 2020).

Within Latin America, Bolivia represents a particularly interesting case, as it is the only country in which congress approved the use of chlorine dioxide in the prevention and treatment of COVID-19 (Porter and Moynihan, 2020; Trigo et al., 2020). Bolivia has a complicated political landscape. Until November 2019, President Evo Morales and his political party "Movimiento al Socialismo"(translates to "Movement toward socialism" —MAS) governed the country for almost 14 years. Yet, after the Organization for American States (OAS) found indictments of fraud in the October 2019 presidential elections, Morales and his closest allies resigned and fled the country amid massive protests and loss of support from the police and the armed forces (Escobari and Hoover, 2019). Through constitutional succession, Jeanine Añez assumed the interim presidency of Bolivia (Sohr, 2019). However, the members "Plurinational legislative assembly" (PLA), the majority of which were from MAS, did not resign. In the mist of the presidential elections, MAS-dominated PLA approved a bill to "exceptionally elaborate, commercialize and supply chlorine dioxide for COVID-19" (Porter and Moynihan, 2020; Trigo et al., 2020). While President Añez never signed the bill to legalize the use of chlorine dioxide as a drug (King, 2020), several governors, majors and political candidates, most of which were from MAS, distributed this compound in their respective regions (Associated Press, 2020).

THE REASONS BEHIND CHLORINE DIOXIDE CONSUMPTION IN LATIN AMERICA

When trying to pinpoint the reason behind the spread of pseudoscience and misinformation in the context of COVID-19, science advisors and epidemiologists have focused on income inequality as an important measurement (Rijs and Fenter, 2020). Indeed, one survey of over 20,000 scientists has shown a strong correlation between governmental acceptance of science advise and the Gini Index (GI), a standard measurement of a country's income inequality (Rijs and Fenter, 2020; Ward, 2020). Yet, on several occasions the GI has not been accurate at measuring phenomena between different Latin American countries, due to the large informal sector of the economy and the fact that most Latin American countries score similarly in this index (Dobson and Ramlogan-Dobson, 2010; Hartmann et al., 2016) (**Table 1**). Not surprisingly, when comparing the GI to the penetrance of chlorine dioxide consumption in the population (as measured by news and blog articles), there is no obvious correlation (**Figure 1A**).

Previously, the Global Innovation Index (GII) has been used to assess the degree of science literacy in a population (Filho and Heerdt, 2018; Ferreira et al., 2019). GI and GII are unrelated, as countries like the United States and China with a relatively unequal societies, rank high in GII, due to their strong science agencies and research facilities. Latin American countries, on the other hand, consistently rank among the worst performers in this index (Crespo and Crespo, 2016; Ferreira et al., 2019). Science literacy and education are anticorrelated to pseudoscientific beliefs in the population (Carosso et al., 2019). As result, when comparing chlorine dioxide consumption in individual Latin American countries to their performance in the GII it becomes evident that poorly GII performing countries had a high penetrance of chlorine dioxide consumption (**Figure 1B**).

Recently, the degree of freedom of speech and democracy, as measured by the Freedom in the World Index (FWI), has been used to better understand the COVID-19 response of individual governments, particularly in reporting case numbers and death tolls (Hussein et al., 2020). Unlike in the GI and GII, Latin American countries have very different degrees of FWI, with some countries considered "Free" such as Chile, while others considered "Not Free" like Cuba and Venezuela (Santiago et al., 2020). Of note, populist governments tend to score low in the FWI (Waisbord, 2018) and pseudoscientific beliefs are often seen in cultures

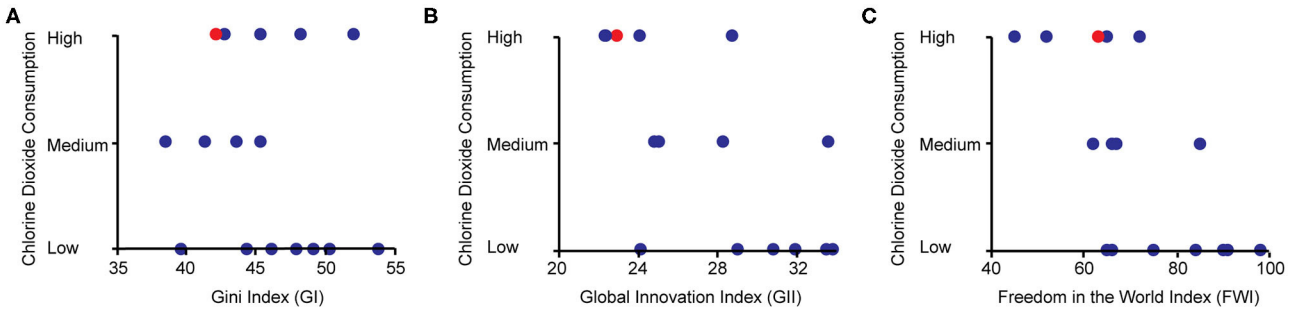

FIGURE 1 | Chlorine dioxide consumption in Latin America. Latin American countries had different degrees of chlorine dioxide consumption during the COVID-19 pandemic and are classified as "low," "medium," or "high" according to the number of media articles and blog posts related to this chemical as a potential COVID-19 treatment. Comparison to **(A)** Gini Index, **(B)** Global Innovation Index, and **(C)** Freedom in the World Index. Red dot represents Bolivia, as the only country in which chlorine dioxide was approved by congress as a COVID-19 treatment. For raw values, refer to **Table 1**.

and regions with low freedom of speech (Anthony, 1999). Interestingly, there was minimal chlorine dioxide consumption in countries that scored high in the FWI, while low scoring countries showed the highest consumption (**Figure 1C**). Together, one can only conclude low science literacy and low freedom of speech, and not income inequality, were determinant in the pseudoscientific belief that chlorine dioxide could be consumed for the prevention and treatment of COVID-19.

DISCUSSION

COVID-19 has often been described as the first post-truth pandemic (Parmet and Paul, 2020; Shelton, 2020). Several studies have identified sources of this phenomenon, including contradicting information in social media, failure of governmental officials to accurately predict the spread of the disease, mistrust in the WHO, and increased economic inequalities (Parmet and Paul, 2020; Puri et al., 2020).

In the times of crises, scientists are key figures to serve as advisors to governments and common citizens (Awandare et al., 2020). Unlike popular media, which depicts messages based in emotions, evidence-based science communication is factual, therefore reducing fear and uncertainty (Szczuka et al., 2020). In Latin America, the communication strategy of chlorine dioxide proponents followed an approach in which pseudoscientists were presented as experts in the media, whose messages were considered equal to those of epidemiologists, public health officials and science diplomats (Associated Press, 2020; Awandare et al., 2020; Barber and Mostajo-Radji, 2020). This strategy became most effective in countries with low scientific literacy (**Figure 1**).

Anxiety and desperation have been extensively observed throughout the world during the COVID-19 pandemic (Ornell et al., 2020). These feelings have been accompanied with an increase in the search of homeopathic solutions to overcome the disease, particularly in regions with weak and saturated healthcare systems that have undergone strict lockdowns (Escola-Gascon et al., 2020; Espin, 2020; Vega-Dienstmaier, 2020). Several governmental global leaders have taken advantage of this phenomenon in order to promoter their personal image (Parmet and Paul, 2020), specially during elections periods.

As we approach a time period in which massive vaccinations against the SARS-CoV-2 virus will be needed, understanding the roots, as well as the causes of dissemination, and politicization of scientific misinformation will be key to overcome this pandemic.

AUTHOR CONTRIBUTIONS

MM-R did the research and wrote this manuscript.

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Conflict of Interest: MM-R is the former Bolivian science, technology and innovation ambassador.