



Article

Dissemination of a “Fake Miracle Cure” against COVID-19 on Twitter: The Case of Chlorine Dioxide

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Abstract: The COVID-19 pandemic has given rise to all types of beliefs, theories, and explanations, whether scientific, religious, or conspiratorial. At the beginning of the pandemic, science did not yet have a medicinal product for this new disease, and alternative medicines offering “miracle cures” were acclaimed by some citizens looking for an effective treatment for COVID-19. This article aims to study a specific “miracle cure”, namely, chlorine dioxide, a bleaching agent for textiles or paper that also has disinfectant properties (water, surfaces). The dissemination of information about chlorine dioxide to French-speaking people on the social network Twitter from 1 December 2019 to 30 November 2021 is analyzed using a graph network. The results show that messages promoting misinformation, even if they are likely to be quantitatively less numerous, spread more widely than those based on more reliable information. In addition, this article shows that chlorine dioxide was promoted as an effective cure by medical doctors and peer-reviewed articles, which consequently increased the dissemination of this belief in the social space. Consequently, the process of misinformation entered the sphere of scientific controversy. The boundary between science and misinformation is becoming blurred to the point that it is no longer possible until proven otherwise to call chlorine dioxide a “false miracle cure” but a controversial treatment against COVID-19.

Keywords: diffusion; beliefs; chlorine dioxide; pseudoscience; science; complementary and alternative medicine; rationality; social network analysis; Twitter; misinformation; controversy

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1. Introduction: Changing Beliefs: From Infodemic to “Miracle Cures”

Some beliefs persist and spread from century to century, while others fall into oblivion. The last two decades have revealed a growing increase in misinformation on the internet following the 1990s (Barkun 2015) and then on social media (Zhou et al. 2021). Misinformation can be considered a virus that spreads out of control. According to the journalist John Zarocostas (2020), while the “infodemic” increases following each pandemic, that of COVID-19, which appeared in December 2019, has the particularity of being based on the preponderant influence of social networks. The COVID-19 pandemic then contributed to the dissemination of new beliefs and adherence to new cults, particularly in the field of health (MIVILUDES 2021). The content of these beliefs then evolves with our societies to include additional current aspects, such as distrust of authorities, conspiracy, or antivaccinism. Adherence to conspiratorial beliefs, alternative medicine, and rejection of political or medical authorities have affected the way citizens accept recommendations concerning COVID-19 (barrier gestures, physical distancing, etc.) and vaccination (Soveri et al. 2021). The misinformation widely disseminated via social networks amplified vaccine hesitancy (Kanozia and Arya 2021), which limited vaccine adherence (believing in the safety of vaccines) and acceptance (receiving vaccines).

At the same time, the craze for “miracle cures” grew during the COVID-19 pandemic. A “miracle cure” is defined in the present study as a type of complementary and alternative medicine (CAM) that offers unfailing effectiveness against a fatal disease with safety and without side effects, but the claimed efficiency is not proven by the science community. Beliefs and promotion are then linked. Some people promote a remedy as a “miracle cure,” and some may believe in its “miracle” effectiveness.

In French-speaking countries, where the study takes place, the number of French newspaper articles extracted from *Europresse*, the requests by French internet users on Google extracted from Google Trends, and the French messages posted on Twitter extracted using the Twitter application programming interface (API) V2 peaked during the COVID-19 pandemic (Figure 1). Indeed, *Europresse* counted 9787 articles published between 2006 and 2021, mainly concentrated in 2020 (2319 articles) concomitant with the COVID-19 pandemic. The same evolution can be seen on Twitter: 87,564 tweets mentioning the terms “miracle cure” or “miracle cures” were posted between 2006 and 2021, and 52% were posted in 2020 and 2021 (i.e., 45,603 tweets).

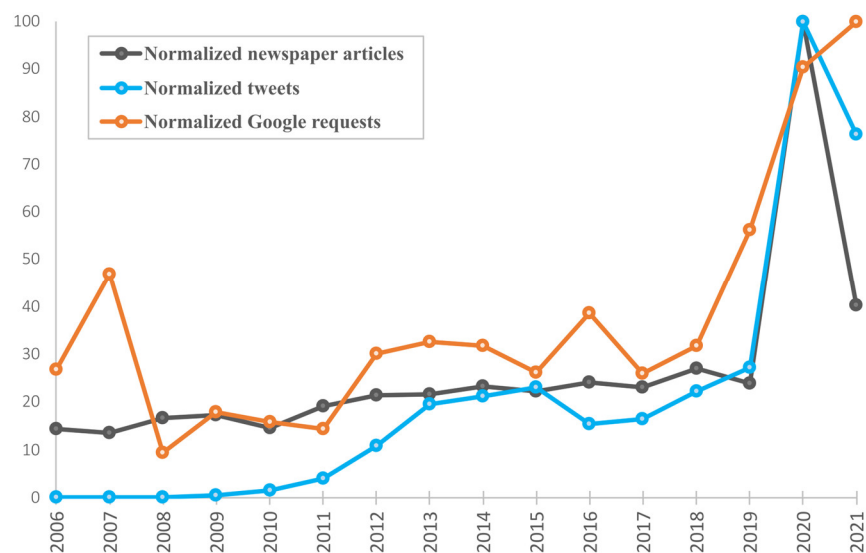


Figure 1. Comparison of the normalized number of French newspaper articles, Google requests by French users, and French messages posted on Twitter between 2006 and 2021. Sources: *Europresse*, Twitter API V2, and Google Trends.

During the COVID-19 pandemic, promises of healing through “miracle cures” have multiplied and spread. As revealed by Google Fact Check Explorer (Fact Check Tools n.d.) on 14 December 2021, there are three types of “miracle cures.” The first are based on medicinal substances, such as molnupiravir, budesonide, bromhexine, ivermectin, and hydroxychloroquine (Baker and Maddox 2022). The second type of “cures” is chemical substances promoted long before the pandemic, such as hydrogen peroxide promoted by Dr. William Campbell Douglass II (2003) or chlorine dioxide promoted by Jim V. Humble. The third type of “cure” is natural, proposing the ingestion of red onions, condensed milk, honey, pepper, ginger, vegetable soup, tea, hot water with lemon, and many other foods. These natural “cures” also invite the inhalation of salt water, clove, or orange vapor.

It might seem surprising to see rational individuals adhering to these types of cure not proven by science. However, this tendency to consider alternative promises of healing is found among a majority of French people. Indeed, in 2019, 68% of French people believed in the benefits of CAM, such as osteopathy, acupuncture, homeopathy, hypnosis, phytotherapy, sophrology, and meditation (Odoxa 2019). Almost half of the French (44%) even consider them to be more effective than conventional medicine. This leads some to replace conventional medicine with alternative medicine. Parallel to this trend observed

among citizens, researchers are increasingly interested in the beneficial effects of CAM. A systematic review (Badakhsh et al. 2021) published in September 2021 showed that CAM improved the physical and psychological symptoms of patients with COVID-19. How then can these “miracle cures” be considered as beliefs when science demonstrates the effectiveness of some of them?

2. Objective

The objective of this study is to explore the boundary between science and belief based on the case of chlorine dioxide, a toxic bleaching agent for textiles or paper that also has disinfectant properties (water, surfaces) presented as a “miracle cure” particularly effective against COVID-19. The aim is to measure the spread of misinformation and fact-checking of a “miracle cure” presented as scientifically proven to the French-speaking people using Twitter.

First, the two primary forms of chlorine dioxide promoted will be described: the Miracle Mineral Solution (MMS) and Chlorine Dioxide Solution (CDS). Second, the content of messages posted in French on Twitter about chlorine dioxide and the links between users (tweeters) will be analyzed.

Using these data and academic articles published on chlorine dioxide, this study aims to explore how a belief perceived as irrational (ingesting a bleach derivative to treat COVID-19) can be legitimized by a scientific discourse and what consequences this has in the dissemination of “miracle cures” on a social network such as Twitter.

While the dissemination of fake miracle cures on social media can generate public health problems, to the best of our knowledge, there is a lack of studies on this issue. While health misinformation has been explored (Waszak et al. 2018; Rovetta and Bhagavathula 2020; Suarez-Lledo and Alvarez-Galvez 2021), the dissemination of fake miracle cure information has yet to be investigated. Thus, this study will reduce the research gap on this topic and provide insight into the mechanisms of the spread of medical beliefs and its interaction with science and misinformation.

3. Two Types of Chlorine Dioxide Miracle Cures

3.1. *The Miracle Mineral Solution*

The first type of “miracle cure” based on chlorine dioxide was “discovered” by Jim V. Humble, the founder of the Genesis II Church of Health and Healing (Genesis II Church of Health and Healing n.d.). Founded in 2010, this nonreligious church is located in Florida (United States v. Genesis II Church of Health and Healing 2020). “Bishop” Humble presented himself as a former aerospace “research engineer” (Humble and Loyd 2016) converted to “gold mining” (Humble and Loyd 2016). He promoted a miracle cure derived from bleach, which he called the Miracle Mineral Supplement (MMS), comprising chlorine dioxide (MMS1) or calcium hypochlorite (MMS2) (Humble and Loyd 2016).

Humble said he discovered, as early as 1996, that chlorine dioxide quickly eradicated malaria during an expedition to South America. This product has, according to him, proven its effectiveness on “a wide range of diseases, including cancer, diabetes, hepatitis A, B, C, Lyme disease, MRSA, multiple sclerosis, Parkinson’s, Alzheimer’s, HIV/AIDS, malaria, autism, infections of all kinds, arthritis, acid reflux, kidney or liver disease, aches and pains, allergies, urinary tract infections, digestive problems, high blood pressure, obesity, parasites, tumors and cysts, depression, sinus problems, eye disease, ear infections, dengue fever, skin problems, dental issues, problems with prostate (high PSA), erectile dysfunction, and many others” (Humble and Loyd 2016).

The Humble website also contains many testimonials classified by type of illness or condition. The most filled category is that of cancer with 111 testimonials (What Is MMS n.d.). That of the coronavirus contains 23 testimonials posted between March and November 2020. One attests to the effectiveness of the MMS treatment on COVID-19 in four doses of 24 drops (Coronavirus n.d.).

To convince his followers, as shown in the following quotation, Humble uses pseudoscientific arguments based on valid scientific knowledge but grants the MMS a broader scope of application than what science has demonstrated:

“A great deal of evidence given by the FDA, EPA and various industrial corporations prove scientifically that MMS1 (chlorine dioxide) kills and or oxidizes pathogens and poisons in food, public water systems, hospitals, and even slaughter houses. It is our belief that the same thing can and does happen in the human body” (Humble and Loyd 2016).

In short, according to this fallacious reasoning, if chlorine dioxide purifies and disinfects water and surfaces, that it is used in sectors of activity (hospitals, laboratories, treatment of drinking water), then it can also disinfect the water contained in the body of anyone who ingests it.

However, as early as 2010, the French Agency for the Safety of Medicines and Health Products (ANSM) warned against the ingestion of chlorine dioxide, stating that “no medical efficacy of this product has been proven” (ANSM 2010). The Food and Drug Administration (FDA) did the same in 2019 (FDA 2019), specifying the risks of ingesting MMS that the agency had identified in consumers: “severe vomiting, severe diarrhea, life-threatening low blood pressure caused by dehydration, and acute liver failure after drinking these products” (FDA 2019). In 2020, the FDA fined Humble, Mark Grenon, and his sons (Joseph and Jordan) for the unauthorized sale of products for treating COVID-19 (Center for Drug Evaluation and Research 2020). The Grenons were responsible for selling and promoting MMS within the Genesis II Church before being arrested and charged on the basis of the FDA report (The United States Attorney’s Office, Southern District of Florida 2021). Finally, a study published in March 2022 demonstrated the toxicity of this product (Peltzer et al. 2022).

3.2. The Chlorine Dioxide Solution

The second type of “miracle cure” based on chlorine dioxide is the Chlorine Dioxide Solution (CDS) “invented” by Andreas L. Kalcker. Kalcker presents himself as a “biophysicist” (Kalcker 2021) who has been studying chlorine dioxide for over a decade (Kalcker 2021).

Kalcker tried to scientificize the promotion of this “miracle cure” by removing the spiritual dimensions brought by Humble and his church to give it medical and scientific probity. Indeed, in 2021, Kalcker published the book *Bye Bye Covid* (Kalcker 2021), as he said, which will change the “perspective on medicine” of readers. Chlorine dioxide is presented as a cure for COVID-19. Moreover, Kalcker claimed that the “CDS has brought healing in countless well-documented cases, and its effectiveness is now, despite what anyone might say, irrefutable” (Kalcker 2021). Kalcker compares the CDS and MMS. He claims that, unlike the MMS, the CDS does not cause adverse effects and that laboratory experiments with mice show that it “prolonged their lifespans up to 30%” (Kalcker 2021).

To reinforce this scientific “face” (Goffman 1955), he founded the *Coalición Mundial Salud y Vida* (COMUSAV, “World Health and Life Coalition” in English) (Accueil n.d.), bringing together several thousand doctors using CDS (Insignares-Carrione Eduardo et al. 2020). The COMUSAV has more than 46,000 subscribers to encrypted Telegram messaging. Members of the COMUSAV publish scientific articles and reports and give lectures alongside Kalcker and with members of the *Liechtenstein Association for Science and Health* (LVWG) (Home n.d.) based in Switzerland. The LVWG presents itself as an association aiming to bring together researchers, physicians, and funders. Its website provides numerous documents and publications oriented toward a single subject: demonstrating the effectiveness of chlorine dioxide for COVID-19. The scientific articles highlighted on the LVWG website and through speeches on the internet are signed by COMUSAV members attached to the LVWG or to the Jurica Medical Center (*Centro Médico Jurica*) located

in Mexico. Dr. Aparicio-Alonso practices at this medical center. He specializes in traumatology and orthopedics (Conoce al Dr. Manuel Aparicio Alonso n.d.), and has published three peer-reviewed articles demonstrating the effectiveness of CDS for COVID-19 (Aparicio-Alonso et al. 2021a, 2021b, 2021c). However, the evidence for the effectiveness of chlorine dioxide is contested in other scientific works (Baracaldo-Santamaría et al. 2022; de los Milagros Farfán-Castillo et al. 2022).

4. Materials and Methods

To measure the diffusion of chlorine dioxide as a “miracle cure” against COVID-19, the terms “chlorine dioxide” and “COVID” were searched in French-speaking messages posted on Twitter between 1 December 2019 and 30 November 2021 and extracted using the Twitter API V2 Academic Research with a Python script request (“dioxide de chlore” AND COVID lang: fr). The following data were downloaded: tweet content, tweet ID, author ID, and creation date. A total of 1,252 messages were collected containing 596 unique tweets. An analysis of tweets per user was conducted to identify bot accounts, and fake users were removed from the collected data.

As “retweeting rapidly disseminates messages across user networks, creating a wider sphere of influence” (Harrigan et al. 2021), several data were collected and aggregated to create a new indicator, a “diffusion metric,” to measure the dissemination of messages. The larger the “diffusion metric” is, the more the message is spread on social media, and the more influential it is likely to be. To obtain a diffusion metric for each tweet, the number of retweets, mentions, likes, and replies was summed. This new metric was then used to select the 100 most influential tweets (excluding duplicates and tweets posted by robots), i.e., the 100 most retweeted, liked, mentioned, and replied-to tweets. Indeed, as many messages are relayed, focusing on influential tweets is more informative for the study of information dissemination.

Following this step, the influential tweets were labeled in two categories: (1) a sentiment analysis category (pro, against, or neutral) and (2) an abductive categorization according to the recurrence of the content and the main arguments presented (effectiveness of the treatment, scientific evidence, fight against misinformation, etc.). The abductive approach, inspired by the philosopher Charles S. Peirce (Peirce 1931), consists of grouping the content of messages as faithfully as possible by abstraction. This approach then makes it possible to avoid defining categories a priori and thus avoid being far from the observable. Finally, this has the advantage of limiting the biases likely to influence the classification process.

The categories of these 100 influential tweets were then applied to the retweets to build a file of edges and nodes to visualize the links between tweeters using Gephi 0.9.2 software. The most relevant indicator for this study is the eigenvector centrality (Bonacich and Lloyd 2001) because it makes it possible to highlight the links in a graph between the most influential tweeters and thus better visualize the dissemination of information in the social network.

5. Results

The 100 most influential tweets posted by 70 tweeters include 6287 “diffusion metrics” (likes, retweets, quotes, or replies). They are followed by a total of 1,620,808 people (followers). It should be noted that only 3 tweeters have an identity verified by Twitter and practice journalism. They alone have 1,306,259 followers. These influential tweets were posted between 24 April 2020 and 28 November 2021, with the highest activity in August, September, and November 2021 (Figure 2). Note that, in this influential sample of tweets, the higher the number of followers, following, participation in a discussion, the higher the diffusion metrics as Spearman’s correlation analysis shows (respectively, $r_s = 0.488$, $p < 0.001$; $r_s = 0.271$ $p < 0.05$; $r_s = 0.502$ $p < 0.001$).

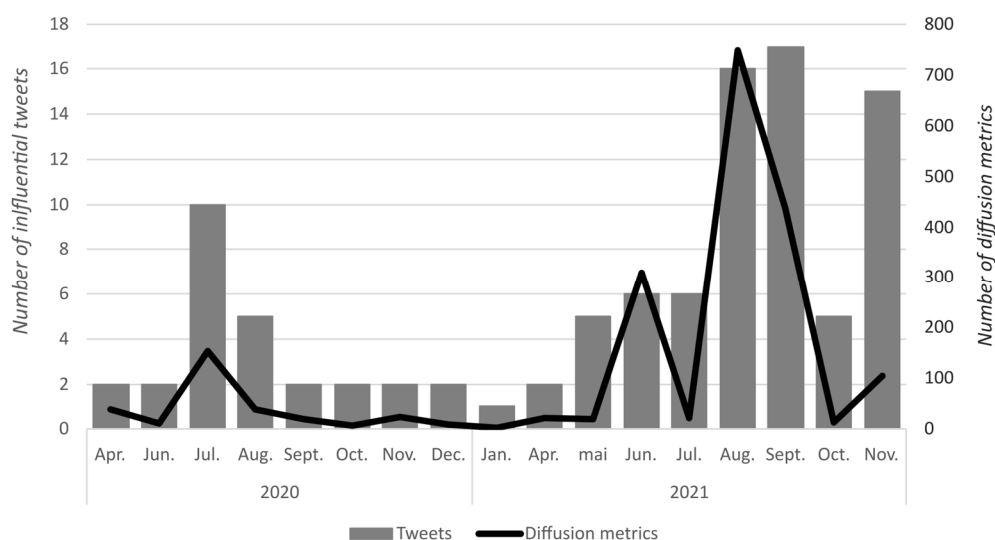


Figure 2. A total of 100 most influential tweets mentioning “chlorine dioxide” and “COVID” in French messages posted on Twitter as a function of the date and “diffusion metric.”

As Table 1 shows, while the majority of tweets (77%) do not mention anyone in particular, almost a quarter of tweets (23%) mention people belonging to the COMUSAV promoting CDS (including Manuel Aparicio-Alonso and Andreas Kalcker). Mark Grenon, one of the promoters of the MMS, was also found.

Table 1. Names mentioned in the most influential tweets.

Name	Number of Mentions	%
Manuel Aparicio-Alonso	9	36%
Andreas Kalcker	7	28%
Chinda Brandolino	3	12%
Astrid Stuckelberger	2	8%
Carlos Alvarado	1	4%
Denis Agret	1	4%
Mark Grenon	1	4%
Patricia Callisperis	1	4%

A sentiment analysis (Figure 3) shows that these influential tweets mainly relay content favorable to chlorine dioxide (“pro chlorine dioxide”) and, more rarely, comments coming in opposition to this product (“con chlorine dioxide”). The “pro chlorine dioxide” messages not only are more numerous but also include 3.2 times as many “diffusion metrics” than “con chlorine dioxide.” In addition, the “pro” tweets have 9.2 times fewer followers than the “con” tweets but were nevertheless more widely relayed.

As shown in Table 2, influential tweets mostly promote the effectiveness of chlorine dioxide against COVID-19 (50%) or argue that scientific evidence demonstrates its effectiveness (15%). A total of 69% of tweets present chlorine dioxide as an effective treatment, administered by doctors or having been scientifically proven. A third type of tweet attempts to deny or contest the effectiveness of this treatment. These debunking tweets are the most numerous in the full data but are poorly represented (14%) among the most influential tweets.

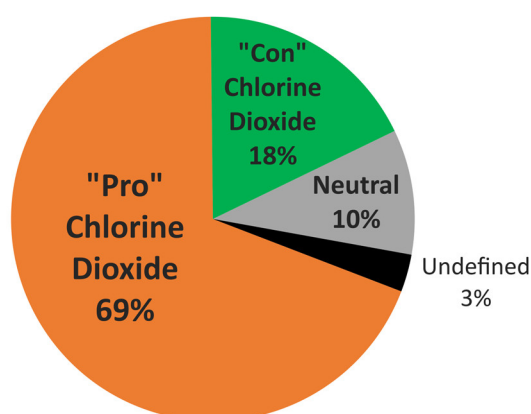


Figure 3. Sentiments (pro, con, neutral) of the 100 most influential tweets mentioning the terms “chlorine dioxide” and COVID on Twitter.

Table 2. Content of the 100 most influential tweets mentioning the terms “chlorine dioxide” and “COVID” on Twitter.

Tweet Content	Number of Tweets	%
Effective treatment	50	50%
Scientific evidence	15	15%
Fact-check	14	14%
Other	7	7%
Political or judicial information	6	6%
Product feedback	4	4%
Product danger	3	3%
Genesis II Church of Health and Healing	1	1%

Considering these data, fact-checking or any message aimed at reducing the spread of misinformation has a limited scope in the process of disseminating information on Twitter.

This is confirmed by a network analysis of all the tweets and retweets collected. Indeed, the influence of tweets disseminated by a French media dedicated to fact-checking (“Fact and Furious,” which disappeared at the end of 2022 (La Rédaction 2022)) had a limited and circumscribed scope (see green group in Figure 4). In contrast, the “pro chlorine dioxide” network has more links and more people relaying tweets with arguments in favor of chlorine dioxide (in purple in Figure 4). Arguments based on scientific evidence (claiming that a study demonstrates the effectiveness of the product) and doctors claiming the effectiveness of chlorine dioxide have a wider reach on this social network. The pro chlorine dioxide group, formed by relaying the same types of tweets, is carried by three main influencers. Few discussions take place with the fact-checking group of tweeters “con chlorine dioxide” (in green in Figure 4).

Therefore, the “pro chlorine dioxide” constitute a homogeneous group in terms of beliefs that relay more what they present as excellent news, namely, to have scientific proof of the effectiveness of the treatment, which also allows them to oppose anti-COVID vaccination. In addition, their followers are invited to click on the links pointing to the Odysee website dedicated to hosting videos similar to YouTube (Odysee Help 2021; Pezet 2020). Created in September 2020, Odysee had more than one million subscribers at the end of 2021. It notably hosts the very controversial conspiratorial documentary *Hold-Up on COVID-19*. Links posted on Twitter lead tweeters to Odysee, where they can see videos promoting the CDS treatment against COVID-19 by Dr. Aparicio-Alonso introducing

himself as a doctor (13,000 views as of November 2021) and by Kalcker introducing himself as a researcher (49,000 views as of August 2021).

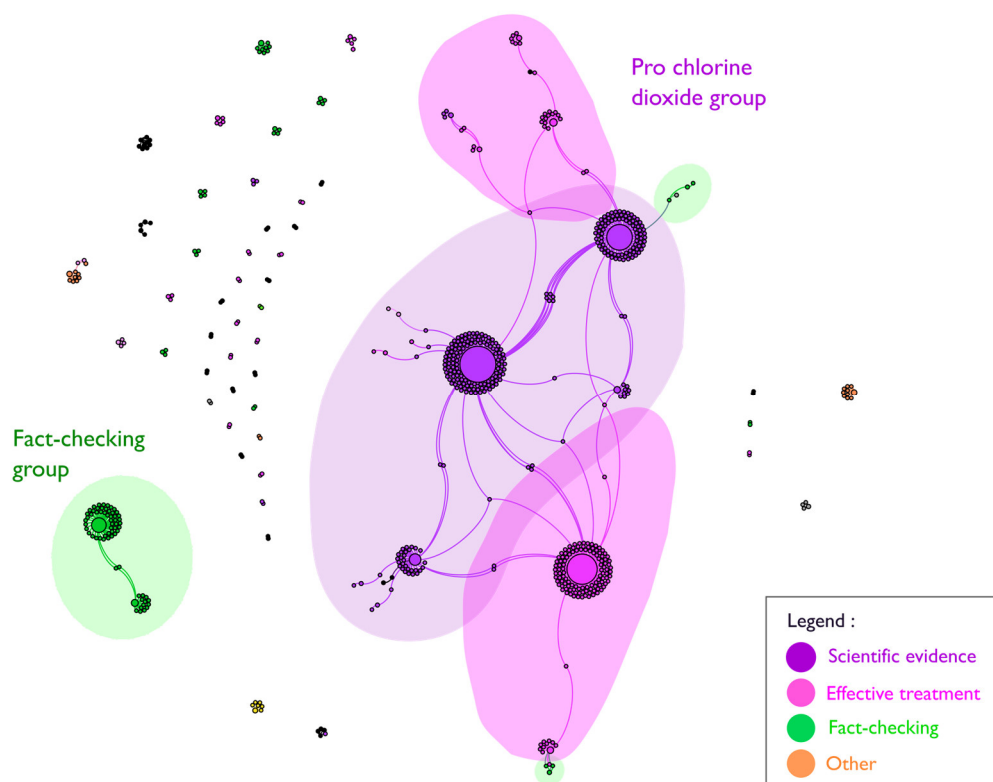


Figure 4. Network graph of tweets and retweets mentioning the terms “miracle cure” (N = 1252) as a function of content type (color group) and eigenvector centrality (size of nodes), using Gephi 0.9.2 and the Force Atlas algorithm.

6. Discussion

6.1. Dynamic of Misinformation Dissemination

This study aimed to explore the dissemination of false health information and, in particular, the promotion on Twitter of a “miracle cure” for COVID-19 during the pandemic. The number of tweets mentioning chlorine dioxide and COVID-19 had several peaks: a first peak in July 2020 and then three peaks in August, September, and November 2021. By comparison, a study looking at the evolution of Google queries about chlorine dioxide among the people of Mexico also showed peaks in July 2020 but differed at the level of the January 2021 peak (Chejfec-Ciociano et al. 2022).

Furthermore, this study has shown by means of a network graph that messages promoting misinformation, even if they are likely to be quantitatively less numerous, spread more widely than those based on more reliable information. This finding aligns with previous results showing that social media promotes the widespread and rapid dissemination of conspiracy theories (Cinelli et al. 2020) and false news (Vosoughi et al. 2018) by their supporters (Featherstone et al. 2019) and that misinformation about COVID-19 spreads more on social media if the content is presented positively (Zhou et al. 2021). This phenomenon is also found in the dissemination of antivaccinism on the internet (Kata 2010). Finally, this observation was established on social networks during the pandemic: even if the antivaccine network is quantitatively smaller than the provaccine network, it extends more widely and thus tends to spread to a growing number of people, especially undecided people (Johnson et al. 2020). In addition, the fact-checkers had few interactions with misinformation spreaders in the network; consequently, they had little influence on

the COVID-19 misinformation spreading, consistent with previous findings (Shahi et al. 2021).

6.2. *The Dynamic of Adherence to Misinformation*

How can we explain the adherence to and diffusion of “fake miracle cures”? The ethics of belief consists, as expressed by the philosopher William K. Clifford (Clifford 1877), of giving up believing without sufficient proof to do so. However, people adhering to or relaying pro chlorine dioxide messages can justify their adherence by means of assertions by experts (doctors, researchers) and academic journals. Consequently, they have factual elements whose epistemic value increases with the status of the people promoting this treatment (doctor or researcher) and the process by which the administration of the proof was carried out (scientific method with publication of conclusive results in an academic journal). The justification of their beliefs is therefore both rational (2003) and deontological.

In the case of chlorine dioxide dissemination, three elements justify the belief adherence of the followers. First, physicians such as Dr. Aparicio-Alonso present an unambiguous discourse on the efficacy of the product against COVID-19, as when he was interviewed by Stew Peters on his podcast *The Stew Peters Show* (2021).

Second, in the most retweeted chlorine dioxide video since the start of the pandemic dated 20 August 2021 (Astrid Stuckelberger-Andreas Kalcker-dioxyde de chlore 2021), Kalcker presents himself as a biophysicist who has been researching this product for 14 years. He claims to have found “the best oxygen provider in the blood that eliminates pathogens, especially viruses.” He also claims that nearly 5,000 physicians practicing in more than 25 countries are using the CDS with great success. He then recalls that they have proven the effects of this product without any toxicity or side effects by publishing, in particular, three peer-reviewed articles. One of these articles is based on a study conducted on a very large corpus of patients (100,000) in collaboration with many doctors practicing at hospitals. Kalcker said that the CDS had a preventive effect on 90,000 patients and their families, who then did not contract COVID-19. Like Aparicio-Alonso, he claims a recovery rate of 99.3%. Finally, he claims to have been his first human research subject since he saved his own “life more than once with this solution.”

Third, internet users have “scientific evidence” published in peer-reviewed articles. They can be found on the Kalcker site but also on other journals’ websites. Aparicio-Alonso is a coauthor of these three articles published in August and September 2021 in the journals *Journal of Infectious Diseases* and *Therapy and International Journal of Multidisciplinary Research and Analysis*. These journals, like thousands of others, are referenced neither by the Journal Citation Reports (JCR) based on the Web of Science (WoS) nor in the Scimago Journal & Country Rank (SJR) based on Scopus. Therefore, these journals do not benefit from a reputation in the scientific field. However, they are also not listed among the predatory journals ((New) List of Predatory Journals-2023 2020; Potential Predatory Scholarly Open-Access Journals 2021), which would fully disqualify their contribution.

6.3. *Fake Miracle Cure or Scientific Discovery of an Effective Treatment?*

During the COVID-19 pandemic, there have been numerous potential treatments (remdesivir, lopinavir, interferon, dexamethasone, tocilizumab, etc.), which have led to several randomized clinical trials (Solidarity, Discovery, Recovery, and others), which are the most esteemed method in the medical field. In 2020, Professor Didier Raoult’s team published a study on hydroxychloroquine (Gautret et al. 2020), which led many scientists to believe that it was an effective remedy for COVID-19 and then to conduct clinical studies to test this hypothesis. In “normal science” (Kuhn 1970), sometimes a study transforms knowledge, and then a process of verification and controversy ensues to confirm or dispute the results obtained. In the case of hydroxychloroquine, posterity and replication studies have not confirmed the substance’s effectiveness against COVID-19.

The only clinical trial on chlorine dioxide to our knowledge was registered on the National Institutes of Health (NIH) website in April 2020 (Insignares-Carrione and Bolano 2020) and led to the publication of an article in March 2021 in the unclassified *Journal of Molecular and Genetic Medicine* (Insignares-Carrione et al. 2021). The article demonstrates, based on a sample of 40 patients, the effectiveness of the substance against COVID-19. However, several indicators call for caution: the time between submission and publication of the article was only 7 days, whereas the process requiring evaluation by experts is generally much longer (several months); the journal is not classified; and the authors are not affiliated with universities or research institutes.

On 17 November 2021, another article appeared in the esteemed journal *BMC Public Health* demonstrating the effectiveness of chlorine dioxide in the prevention and treatment of COVID-19 in a sample of 3,630 Peruvians. Articles in favor of the effectiveness of chlorine dioxide subsequently accumulated. On 16 July 2022, an article published in the journal *Oral Diseases* (Soriano-Moreno et al. 2021), classified by the JCR and SJR, concluded that chlorine dioxide can be effective against SARS-CoV-2. On 9 December 2022, the JCR- and SJR-ranked journal *BioScience Trends* published an editorial (Asakawa 2022) and correspondence (Cao et al. 2022) citing nasal chlorine dioxide as a possible treatment for COVID-19. The authors cite two of the three articles by Dr. Aparicio. The correspondence (Cao et al. 2022) concludes that chlorine dioxide may be an effective remedy but that further research is needed.

In the case of chlorine dioxide, the research conducted offers contradictory results, and some researchers speak of controversy (Liester 2021). Then, chlorine dioxide could no longer be presented as a “fake miracle cure” but as a potentially therapeutic substance analyzed, discussed, and published as any other substance studied during the pandemic for treatment purposes. This raises important questions about the boundary between science and misinformation. Indeed, science makes it possible to draw this border. However, when scientists have unverified beliefs and try to publish them, the beliefs become potential knowledge until the process of replication allows the scientific community to decide. Until then, it has been difficult to say that this is misinformation. This leads unverified knowledge to spread widely on social networks, as this study shows.

7. Conclusions

The COVID-19 pandemic and the uncertainties regarding the disease have generated high expectations in terms of care. Researchers around the world have worked hard and published more than 50,000 articles on COVID-19 in 2020 and 2021 according to the WoS. Along with this effort by scientists, pseudoscience has offered “miracle cures” against COVID-19.

This study focuses on the examination of the dissemination a “miracle cure” on Twitter, namely, chlorine dioxide, a bleach derivative considered toxic by the FDA (FDA 2019) and in academic articles (Peltzer et al. 2022). Chlorine dioxide has been promoted by a nonreligious movement since 1996 as a cure for all fatal diseases and recently by physicians as a cure for COVID-19 despite insufficient evidence of its efficacy against this disease (Baracaldo-Santamaría et al. 2022).

The results show that messages promoting misinformation, even if they are likely to be quantitatively less numerous, spread more widely than those based on more reliable information. This result aligns with those found in previous studies conducted on misinformation spreading. In addition, the analysis of messages posted on Twitter has shown that the dissemination of this “miracle cure” accelerated following the publication of peer-reviewed articles, proving the effectiveness of chlorine dioxide on COVID-19 and the promotion on Odysee of very high success rates for patients treated by physicians. This shows that physicians, as well as famous or influential people, may generate a “super influencer effect” in medical misinformation that potentiates to the infodemic problem.

This study also shows that the process of misinformation entered the sphere of scientific controversy. When scientists have unverified beliefs and try to publish them, the

beliefs become potential knowledge until the process of replication allows the scientific community to decide. This allows unverified knowledge to spread widely on social networks. The boundary between science and misinformation is becoming blurred to the point that it is no longer possible until proven otherwise to call chlorine dioxide a “false miracle cure” but a controversial treatment against COVID-19.

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General Data Protection Regulation: The study is registered with the French National Centre for Scientific Research (CNRS) data protection officer under the following number: 2-22120.

Data Availability Statement: Data are available by contacting the corresponding author upon reasonable request. Note that, in accordance with Twitter’s terms of use under the European General Data Protection Regulation, tweets cannot be shared (Twitter Controller-to-Controller Data Protection Addendum n.d.).

Conflicts of Interest: The author declares no conflict of interest.

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