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Review

Atmospheric Pollution Depicted in Impressionists' Paintings

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Abstract: Art is perhaps the most important means of expressing creativity and imagination. It can serve as a form of communication, allowing artists to convey messages and comment on various topics. Environmental art is a dynamic and multifaceted form of artistic expression that highlights the causes and consequences of environmental problems, such as atmospheric pollution, and facilitate the environmental awareness of societies along with the need to find sustainable solutions to address environmental degradation. The aim of this study was to present paintings created by impressionists that depict atmospheric pollution. A total of 43 paintings were listed after searching the websites of 26 museums worldwide and 10 of them were indicatively selected by applying specific criteria and commented on in this paper. Four of the selected paintings were created by Claude Monet, two by Jean-Baptiste Armand Guillaumin, and the rest of them by James McNeill Whistler, Charles-François Daubigny, Camille Pissarro, and Vincent Van Gogh. These 10 paintings depict, among other things, the emission of pollutants into the atmosphere, due to fossil fuel combustion, mainly coal, which contributes to smog development. This study could be exploited by authorities, associations, educational centres, and other interested parties when planning educational activities for the causes, consequences, and solutions of atmospheric pollution over time, while promoting the use of art in environmental and sustainability education.

Keywords: atmospheric pollution; painting; impressionist; museum; environmental and sustainability education

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1. Introduction

Art can serve as a form of communication, allowing artists to convey messages, comment on social issues or express their cultural or personal identity. It can be a powerful medium that allows artists to tell stories and communicate the messages they wish to convey [1]. From the time of the industrial revolution, many artists aimed to present through their works the cosmogenic changes that were taking place and the consequences they had in people's everyday lives [2,3]. Environmental art, a dynamic and multifaceted genre of artistic expression, stands at the intersection of creativity, ecology, and activism, commenting on humanity's relationship with the natural environment mainly through visual documentation of changes in landscapes and climates over time. One research study [4] found through quantitative surveys and qualitative interviews that environmental art can be an effective tool for raising awareness about environmental pollution, advocating for conservation efforts, while enhancing students' creativity and supporting a deeper appreciation for environmental management. Other scientists [5] performed a questionnaire study and reported that environmental art can be useful for environmental communication, emphasizing the potential benefits of art that encourage personal responsibility. Nevertheless, art can also support scientific research in many other fields and in different aspects, such as various medical specialties [6–10]. This collaboration between art and science enriches public discourse and inspires innovative solutions to environmental challenges, making art a powerful tool for education while supporting sustainability actions.

The Impressionist art movement, which celebrated its 150th anniversary in 2024, emerged at a time when industrialization was in progress [1,11] and was the first to depict

environmental pollution. Impressionists aimed to convey the fleeting, sensory impressions of a moment rather than precise details, often painting en plein air to observe natural light directly, challenging in that way traditional techniques and perspectives, and laying the groundwork for modern art [11]. Through their paintings, many impressionists in an indirect but obvious way depicted the drastic changes brought about by industrialization and environmental pollution, as well as physical phenomena [12–16]. Key figures of Impressionism include Claude Monet, whose work "Impression, Sunrise" that is presented later in this paper inspired the movement's name [17], along with Edgar Degas, Pierre-Auguste Renoir, Camille Pissarro, Eduard Manet, Alfred Sisley, Frederic Bazille, and Berthe Morisot. Artists such as Charles-François Daubigny, Jean-Baptiste Armand Guillaumin, Gustave Caillebotte, and others were also involved with the movement [11].

Atmospheric pollution is a critical environmental issue caused by the release of harmful pollutants into the atmosphere, primarily from human activities such as industrial processes, transportation, and the use of fossil fuels, especially coal. The main types of primary pollutants include particulate matter (PM), nitrogen oxides (NO_x), sulphur dioxide (SO_2), carbon monoxide (CO), and volatile organic compounds (VOCs), while secondary pollutants like ozone (O_3) are also produced in photochemical reactions in the atmosphere involving primary pollutants [18]. Emissions from coal combustion are particularly significant, releasing large amounts of SO_2, NO_x, and PM, which contribute to the formation of smog, a complex mixture of air pollutants [19]. There are two types of smog: industrial and photochemical. Industrial smog, or simply smog, is the result of industrialization. It is therefore often depicted as huge grey clouds coming out of factory chimneys [20]. This is an obvious way of depicting it, given that the main source of industrial smog is coal combustion for heating and energy production [21]. Consequently, the main pollutants in industrial smog are SO_2 and PM [22,23]. The formation of industrial smog is favoured when air temperature and relative humidity are relatively low and high, respectively. Photochemical smog arises mainly from the exhaust gases of internal combustion engines that power most vehicles. The main components of photochemical smog are CO, NO_x, and VOCs. These primary pollutants in the presence of sunlight react with each other, while also producing secondary pollutants such as O_3 [24,25].

This paper presents paintings created by impressionists, exhibited in many museums worldwide, which depict atmospheric pollution. Focusing on the works of some of the most important impressionists, it aims to sheds light on the historical context of environmental degradation and also demonstrates the power of art as a means for raising awareness and fostering a deeper understanding of environmental issues. Additionally, it aims to highlight certain regularities that indicate atmospheric pollution based on current knowledge that were unconsciously captured by the artist. This fact provides the opportunity to recognize certain features and situations of the atmospheric pollution of that era. Its main objectives consist of supporting the links between environmental art and science, promoting the integration of art into environmental and sustainability education, encouraging a holistic approach to sustainability, and providing a creative platform for engaging the public in discussions about the ongoing challenges of atmospheric pollution. This research can thus be a valuable tool in designing programs that connect the historical impacts of pollution with contemporary efforts to address environmental sustainability.

2. Materials and Methods

For the purpose of this study, 43 paintings created by impressionists that depict atmospheric pollution were selected after searching the websites of 26 museums worldwide. Information about each is given in Table 1. It is worth mentioning that one of the authors of this paper examined various works of impressionists and other famous artists, focusing on various forms of environmental pollution (air pollution, pesticide pollution, waste and overconsumption, and climate change) [26]. While this paper presents paintings that depict air pollution, the above mentioned study [26] included a broader examination, referring to 37 museums and analysing 106 paintings created by 37 prominent artists.

Table 1. Information for the 43 paintings selected for the purpose of this paper in chronological order.

No	Title	Date	Artist	Museum (Name and Official Link)
1	Grey and Silver: Old Battersea Reach	1863	James McNeill Whistler	The Art Institute Chicago (https://www.artic.edu/)
2	St Paul's from the Surrey Side	1870–1873	Charles-François Daubigny	The National Gallery, London (https://www.nationalgallery.org.uk/)
3	The Thames below Westminster	1871	Claude Monet	The National Gallery, London (https://www.nationalgallery.org.uk/)
4	Impression, Sunrise	1872	Claude Monet	Musée Marmottan Monet, Paris (https://www.marmottan.fr/en/)
5	Sunset at Ivry	1873	Jean-Baptiste Armand Guillaumin	Musée d'Orsay, Paris (https://www.musee-orsay.fr/fr)
6	Factory on the Oise at Pontoise	1873	Camille Pissarro	National Gallery of Art, Washington, DC (https://www.nga.gov/)
7	The Factory at Pontoise	1873	Camille Pissarro	The Israel Museum, Jerusalem (https://www.imj.org.il/en)
8	The River Oise Near Pontoise	1873	Camille Pissarro	The Clark Art Institute, Massachusetts (https://www.clarkart.edu/)
9	The Seine at Charenton (formerly Daybreak)	1874	Jean-Baptiste Armand Guillaumin	Norton Simon Museum, California (https://www.nortonsimon.org/)
10	The Train in the Snow, the Locomotive	1875	Claude Monet	Musée Marmottan Monet, Paris (https://www.marmottan.fr/en/)
11	The Station St-Lazare	1877	Claude Monet	The National Gallery, London (https://www.nationalgallery.org.uk/)
12	The Station Saint-Lazare: Arrival of a Train	1877	Claude Monet	Harvard Art Museums, Massachusetts, USA (https://harvardartmuseums.org/)
13	The Bridge of Europe. Station Saint-Lazare	1877	Claude Monet	Musée Marmottan Monet, Paris (https://www.marmottan.fr/en/)
14	The Station Saint-Lazare	1877	Claude Monet	Musée d'Orsay, Paris (https://www.musee-orsay.fr/fr)
15	Arrival of the Normandy Train, Station Saint-Lazare	1877	Claude Monet	The Art Institute Chicago (https://www.artic.edu/)
16	Coke Factory in the Borinage	1879	Vincent van Gogh	Van Gogh Museum, Amsterdam (https://www.vangoghmuseum.nl/en)
17	Factories at Clichy	1887	Vincent van Gogh	Saint Louis Art Museum, Missouri (https://www.slam.org/)
18	Paris in Snow	1887	Albert Edelfelt	Ateneum Art Museum, Helsinki, Finland (https://ateneum.fi/en/)
19	The Mine Crachet-Picquery in Frameries, Borinage	1888–1890	Eugène Boch	Van Gogh Museum, Amsterdam (https://www.vangoghmuseum.nl/en)
20	The Great Bridge, Rouen	1896	Camille Pissarro	Carnegie Museum of Art, Pittsburgh, Pennsylvania (https://carnegieart.org/)
21	Morning, An Overcast Day, Rouen	1896	Camille Pissarro	The Metropolitan Museum of Art, New York (https://www.metmuseum.org/)
22	The Pont Boieldieu at Sunset	1896	Camille Pissarro	Birmingham Museums Trust (https://www.birminghammuseums.org.uk/)
23	Misty Morning, Rouen	1896	Camille Pissarro	The Hunterian, University of Glasgow (https://www.gla.ac.uk/hunterian/)
24	The Saint-Sever Bridge, Rouen: Mist	1896	Camille Pissarro	North Carolina Museum of Arts (https://ncartmuseum.org/)
25	French Theatre Square: Fog Effect	1897	Camille Pissarro	Dallas Museum of Art (https://dma.org/)
26	Rouen, Saint-Sever, Morning	1898	Camille Pissarro	Honolulu Museum of Art (https://honolulumuseum.org/)
27	Waterloo Bridge, Overcast Weather	1899–1903	Claude Monet	Hugh Lane Municipal Gallery of Modern Art, Dublin (https://hughlane.ie/)

Table 1. *Cont.*

No	Title	Date	Artist	Museum (Name and Official Link)
28	Charing Cross Bridge (overcast day)	1900	Claude Monet	Museum of Fine Arts, Boston (https://www.mfa.org/)
29	Waterloo Bridge, Gray Weather	1900	Claude Monet	The Art Institute Chicago (https://www.artic.edu/)
30	Houses of Parliament, London	1900–1901	Claude Monet	The Art Institute Chicago (https://www.artic.edu/)
31	Charing Cross Bridge, London	1901	Claude Monet	The Art Institute Chicago (https://www.artic.edu/)
32	Charing Cross Bridge	1903	Claude Monet	Saint Louis Art Museum, Missouri (https://www.slam.org/)
33	Charing Cross Bridge: Fog on the Thames	1903	Claude Monet	Harvard Art Museums, Massachusetts, USA (https://harvardartmuseums.org/)
34	Charing Cross Bridge, the Thames	1903	Claude Monet	Musée des Beaux Arts de Lyon (https://www.mba-lyon.fr/fr)
35	Waterloo Bridge, London	1903	Claude Monet	Carnegie Museum of Art, Pittsburgh, Pennsylvania (https://carnegieart.org/)
36	Waterloo Bridge, Sunlight Effect	1903	Claude Monet	The Art Institute Chicago (https://www.artic.edu/)
37	The Houses of Parliament, Sunset	1903	Claude Monet	National Gallery of Art, Washington, DC (https://www.nga.gov/)
38	The Houses of Parliament, Seagulls	1903	Claude Monet	Princeton University Art Museum, USA (https://artmuseum.princeton.edu/)
39	Houses of Parliament, Sunlight Effect	1903	Claude Monet	Brooklyn Museum, New York (https://www.brooklynmuseum.org/)
40	The Houses of Parliament (Effect of Fog)	1903–1904	Claude Monet	The Metropolitan Museum of Art, New York (https://www.metmuseum.org/)
41	London, the Houses of Parliament. Effect of sunshine in the fog	1904	Claude Monet	Musée d'Orsay, Paris (https://www.musee-orsay.fr/fr)
42	Houses Of Parliament: Effect Fog, London	1904	Claude Monet	Museum of fine Arts St. Petersburg, Florida, USA (https://mfastpete.org/)
43	The Port of Hamburg	1909	Ulrich Hübner	Staatliche Museen zu Berlin (https://www.smb.museum/en/home/)

This paper focuses on 10 of the paintings listed in Table 1 that were indicatively selected and commented. Claude Monet created four of them (No. 4, No. 11, No. 27, No. 41), Jean-Baptiste Armand Guillaumin created two of them (No. 5, No. 9) and the rest of them were created by James McNeill Whistler (No. 1), Charles-François Daubigny (No. 2), Camille Pissarro (No. 7), and Vincent Van Gogh (No. 17). Their selection was based on specific criteria: all of them offer a unique portrayal of industrial air pollution in urban and suburban landscapes. These works capture the pervasive atmospheric haze and reduced visibility caused by the emission of pollutants into the atmosphere, due to fossil fuel combustion, mainly coal, which contributes to smog development. They are characterized by their muted palettes, blurred forms, and emphasis on light diffusion. Each one of them serves as an artistic documentation of 19th-century air pollution, providing insight into the era's environmental conditions as well as the visual impact of urban and industrial development on the landscape. These 10 paintings and the corresponding official web links are presented in Figure 1.



(**a**)



(**b**)



(**c**)



(**d**)



(**e**)

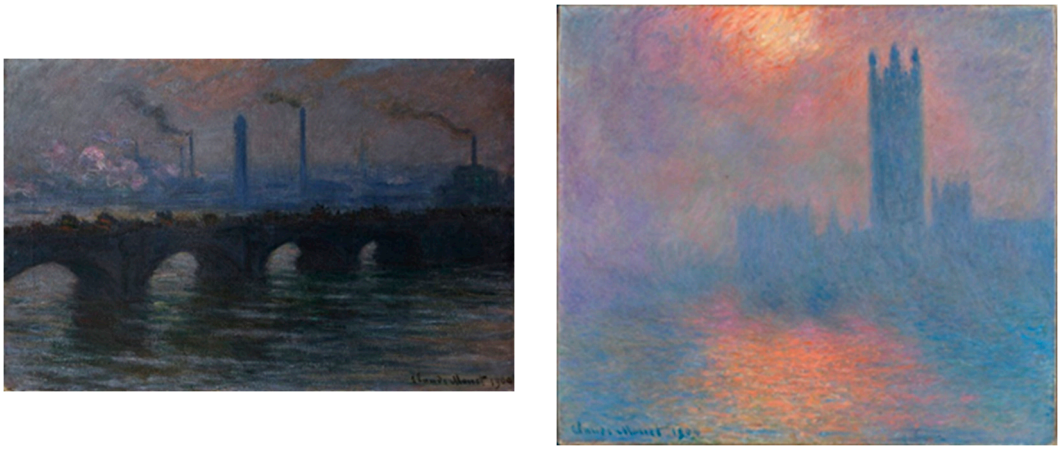


(**f**)

Figure 1. *Cont.*



(**g**) (**h**)



(**i**) (**j**)

Figure 1. Representative paintings chosen from Table 1 that were commented on in this paper, accompanied by their official web links. Original dimensions (D), height × width, are expressed in cm. Paintings' dimension ratios are not altered. (**a**) No.1, Grey and Silver: Old Battersea Reach (James McNeill Whistler) (D: 50.8 × 68.6) [27]. (**b**) No. 2, St Paul's from the Surrey Side (Charles-François Daubigny) (D: 44.5 × 81.0) [28]. (**c**) No. 4, Impression, Sunrise (Claude Monet) (D: 50.0 × 65.0) [29]. (**d**) No. 5, Sunset at Ivry (Jean-Baptiste Armand Guillaumin) (D: 65.0 × 81.0) [30]. (**e**) No. 7, The Factory at Pontoise (Camille Pissarro) (D: 38.0 × 55.0) [31]. (**f**) No. 9, The Seine at Charenton (formerly Day-break) (Jean-Baptiste Armand Guillaumin) (D: 53.3 × 63.5) [32]. (**g**) No. 11, The Station St-Lazare (Claude Monet) (D: 54.3 × 73.6) [33]. (**h**) No. 17, Factories at Clichy (Vincent van Gogh) (D: 53.7 × 72.7) [34]. (**i**) No. 27, Waterloo Bridge, Overcast Weather (Claude Monet) (D: 65.0 × 100.0) [35]. (**j**) No. 41, London, the Houses of Parliament. Effect of sunshine in the fog (Claude Monet) (D: 81.5 × 92.5) [36].

3. Results and Discussion

3.1. Presentation of the Selected Paintings

The 10 paintings presented in Figure 1 are commented upon in this section. A short description of each painting extracted from the corresponding official museum's website and other sources, the environmental issue depicted, as well as other information, are provided.

3.1.1. Painting No. 1: Grey and Silver: Old Battersea Reach (James McNeill Whistler)

James McNeill Whistler uses soft greys and silvers to depict London's industrial riverside, subtly hinting at air pollution. His use of blurred lines and muted colours evokes the heavy, smog-laden atmosphere caused by coal-burning, making the Thames River and sky appear hazy and indistinct. The painting reflects the visual impact of pollution on London's landscape during the industrial revolution. In the foreground, boats, barges, and workers can be seen, while in the background, the smoky chimneys of the factories rise.

3.1.2. Painting No. 2: St Paul's from the Surrey Side (Charles-François Daubigny)

In this painting, Daubigny captures the view of St. Paul's Cathedral from the south bank of the Thames and the surrounding London skyline. Daubigny paints with a softened palette, blending greys and browns to create an impression of smoke and fog merging together, a common sight in industrial London due to coal-burning factories and homes. The dome of the St. Paul's Cathedral, the factory chimneys and the train crossing the bridge in front of the Cathedral appear distant and somewhat blurred, emphasizing the pervasive smog that conceals details and casts a thick, atmospheric veil over the scene. In addition, the boats and steamers that cross the river are barely visible. This subdued representation of London not only conveys a sense of calm but also subtly reflects the impact of urban pollution on visibility and the natural landscape during the 19th century.

3.1.3. Painting No. 4: Impression, Sunrise (Claude Monet)

Over the harbour of Le Havre, this painting shows a misty scene where the sun's orange glow is partially veiled, hinting at the presence of industrial smoke and fog that blend seamlessly with the natural steam over the water. On the first level, the rowers of the ferries can be seen. The blurred forms of ships and smokestacks in the background emit faint plumes, which mix with the fog to obscure sharp details and soften the landscape. Monet's use of cool greys and blues, contrasted with the fiery sun, emphasizes the way pollution affects light and visibility, capturing the ethereal quality of an industrial port shrouded in morning haze. This impressionistic style evokes the air's thickness and subtly reflects the impact of pollution on the atmosphere.

3.1.4. Painting No. 5: Sunset at Ivry (Jean-Baptiste Armand Guillaumin)

In "Sunset at Ivry", Jean-Baptiste Armand Guillaumin portrays air pollution through the vibrant, smoky hues of the setting sun that merge with industrial smoke rising from the factories along the riverbank. The painting's sky is filled with intense reds, oranges, and purples, blending together in a way that suggests both natural sunset colours and the heightened effect of smoke in the atmosphere. The thick, layered clouds and diffused light indicate the presence of pollution, with factory smokestacks releasing plumes that obscure parts of the horizon. Guillaumin's dynamic brushstrokes and use of warm tones amplify the sense of a densely polluted industrial landscape, capturing the visual impact of air pollution on the evening sky in Ivry [37].

3.1.5. Painting No. 7: The Factory at Pontoise (Camille Pissarro)

In this painting, Pissarro depicts a factory within a rural setting, with smoke drifting up from its chimneys and blending into the sky. He uses delicate colours and light brushstrokes to render the smoke as it disperses, creating a blurry, overcast atmosphere that suggests the impact of industrial activity on the natural landscape in the Pontoise area. The smoke contrasts with the surrounding countryside, highlighting the intrusion of industry into a rural scene. This blend of nature with industrial elements reflects the gradual spread of pollution beyond urban areas, capturing the environmental changes brought on by the industrial expansion.

3.1.6. Painting No. 9: The Seine at Charenton (Formerly Daybreak) (Jean-Baptiste Armand Guillaumin)

In this view of a Parisian suburb, large plumes of dark smoke rise from factory chimneys along the water, creating a stark contrast with the blue sky. The billowing smoke spreads outward, drifting across the sky and partially obscuring the clouds, a clear indicator of air pollution from the factories. The setting along the riverbank, with pedestrians walking beside the industrial area, highlights a unique perspective on modern Paris, depicting not its glamorous centre but its rough industrial suburbs.

3.1.7. Painting No. 11: The Station St-Lazare (Claude Monet)

This painting is one of a dozen views of the Gare Saint-Lazare that Monet painted in early 1877 [38]. Monet unintentionally captures air pollution by focusing on the thick clouds of steam and smoke filling the bustling train station. While the Station is surrounded by passengers, probably waiting to board, the smoky atmosphere blurs the architectural details and almost merges with the ceiling, creating a foggy effect that obscures clarity. Monet's use of swirling whites, greys, and blues conveys the dense, churning exhaust from the steam engines, filling the station with a fog-like effect. This depiction reflects the air quality issues in industrial Paris, showing how transportation advances, like trains, contributed to pollution and altered the environment's visual and sensory experience.

3.1.8. Painting No. 17: Factories at Clichy (Vincent Van Gogh)

In the industrial suburb of Clichy, northwest of Paris, Vincent van Gogh depicts a row of factories with tall smokestacks releasing dark plumes into the sky. The smoke drifts across the landscape, blending with the blue and green tones of the sky and giving it a polluted appearance. Van Gogh contrasts the industrial skyline, in which two piles of coal match the height of the buildings, with a foreground of green fields, highlighting the encroachment of pollution on the natural environment. The grey and black smudges of smoke above the factories dominate the scene, emphasizing the presence of industrial pollution as a defining characteristic of the landscape [39].

3.1.9. Painting No. 27: Waterloo Bridge, Overcast Weather (Claude Monet)

Monet painted forty-one versions of Waterloo Bridge in London, which linked the west end of the city to the more industrial south bank. The early morning traffic on the bridge, both vehicular and pedestrian, and vertical smoking chimneys are shown in the foreground and the background, respectively, of this painting. Monet uses greys, blues, and purples to create a thick, atmospheric cloud that envelops the scene, which was typical of London's air quality due to industrial smoke and coal-burning. The diffuse light and fog-like appearance result from a combination of natural mist and pollution, blending the forms of the bridge and buildings into the background [40].

3.1.10. Painting No. 41: London, the Houses of Parliament. Effect of Sunshine in the Fog (Claude Monet)

This painting shows the London Houses of Parliament in the light and atmosphere due to the famous London fog. Monet uses a golden palette to depict sunlight filtering through the dense smog, which both obscures and diffuses the light, creating an almost ethereal, dreamlike quality. The building's details are blurred and blending into the fog, giving a sense of the heavy, industrial atmosphere that was common during that period of time in London, due to coal smoke and pollution. This painting captures how air pollution altered natural light and visibility, with the sunlight appearing diffused and dimmed rather than clear, highlighting the way smog transformed London's atmosphere into a thick, fuzzy shroud.

3.2. On the Relation of the Selected Paintings with Atmospheric Pollution

Anthropogenic aerosol and sulphur dioxide emissions increased to unprecedented levels during the 19th century as a consequence of the industrial revolution, particularly in western European cities, leading to an optical environment with less contrast and more intensity. All the above mentioned paintings, except No. 11, address the environmental issue of industrial smog, capturing the thick, hazy atmosphere that results from the emission of pollutants due to industrial activities, particularly the burning of fossil fuels like coal [41]. Changes in these local emissions could explain trends in the contrast and intensity of Turner, Monet, and others' works [15]. The depiction of smog in a painting not only conveys the visual impact of this pollution but also serves as a poignant reminder of the detrimental effects of industrialization on air quality and public health [42]. It is well

documented that long-term exposure to fine particulate matter (PM 2.5) is associated with an increased risk of chronic obstructive pulmonary disease [43]. Scientists exploited a large UK cohort and found that people who were exposed to the London smog in December 1952 had substantially lower fluid intelligence and worse respiratory health [44]. Additionally, industrial pollution substantially increased mortality in 1851–1860, while these effects grew as coal use intensity rose from 1851 to 1900 [45].

A study [16] provided information about the sources and impacts of London smog, which was probably the most famous global air pollution phenomenon of the 19th and 20th centuries, being observed in the city mainly during the cold period of the year. According to this study. Monet's London Series, i.e., more than 100 canvases of Charing Cross Bridge, Waterloo Bridge (painting No. 27), and the Houses of Parliament (painting No. 41), provide a fascinating representation of London's climate and atmosphere that represents a mixture of pollution and nature. London smog is also depicted in painting No. 2 by Daubigny.

Another region of London which many painters dealt with was Battersea Fields. According to George Grove's memoires, this area, at least until 1820, was not air polluted at all [46]. This serene image comes to contradiction with painting No. 1, where Whistler depicted the polluted air during the industrialization produced by the factories settled there. The reason for this dramatic change was mostly the installation of two companies in the area. Due to their industrial activity, which commenced with the production of candles and gradually evolved into the production of motor oil and petroleum by-products, both of these companies caused intense air pollution. These environmental consequences were envisaged many years later with the Clean Air Act in 1956. After that, it took fourteen years to redevelop the site [47].

During the same chronological era, the economies of some Parisian suburbs were also dominated by industrial activities, like chemical and textile factories. When commenting on painting No. 17 [39], many environmental and health problems that were caused by the operation of these factories in Clichy, like sulphurous discharges, emissions of repulsive odours, and other chemicals and lead colic were listed. The radical changes in the Parisian suburbs and other French cities brought about by new industrial complexes and the building of workers' estates are often reflected in paintings, like in painting No. 4 created by Monet and in paintings No. 5 and No. 9 created by Guillaumin [11,37]. Landscape painting also provided to artists an opportunity to depict the reality of the change in French nature resulting from industrialization, as Pissarro did in painting No. 7.

The railway was a key driver of the development of mass industrialization as it offered the possibility of faster transport of goods and people. It was precisely this image of a crowded railway station that Monet wanted to describe in his twelve paintings of St. Lazare railway station. Thus, beneath the brushstrokes of Monet's painting No. 11 lies a subtle commentary on the environmental issues of the time, depicted through the rising fumes and their diffusion into the Parisian sky. This image leads to the conclusion, which is scientifically confirmed, that railways contribute to air pollution. Specifically, the air quality within enclosed railway stations, affected by both diesel engines and electric trains, does not meet European air quality standards for nitrogen dioxide and particulate pollution [48,49].

3.3. Scientific Considerations

Paintings can be used as a means to confirm past environmental pollution. In particular, this study reveals that paintings from the industrial era can be used to confirm that smog is consistent with time. It is difficult to make accurate quantifications of pollution levels, as the degree of atmospheric pollution can vary depending on the colouring method of the painting and the painter's style. However, an analysis of (a) measurable elements of atmospheric pollution depicted in each painting, such as smoke colour and density, (b) the prevailing meteorological conditions, and (c) the differences between these elements and conditions among paintings can provide the opportunity to develop scientific indicators to gather information about the atmospheric pollution at the time. Nevertheless, the approach of an interpreter of art and an artist is different from that of a scientist. The artist—and by

extension the interpreter of art—approaches the world and artistic creation based on his subjective preferences and his own value system. On the other hand, scientists attempt to explain the world, with the ultimate goal of finding objective truth, using scientific methods that are neutral and not tied to subjective choices, preferences, and values [50]. The analysis in this paper attempted to combine the different approaches adopted by artists and scientists. Other studies have also performed similar analysis and confirmed that Impressionists achieved accurate rendering of physical changes in their creations. Successful attempts were made to estimate the aerosol optical depth following major volcanic eruptions by analysing the coloration of sunsets in famous art paintings [13,14]. Trends in the contrast and intensity of Impressionist paintings could be attributed to changes in sulphur dioxide emissions [15].

Interesting information can be revealed when analysing smoke colour in the selected paintings. Black smoke, like in paintings No. 5 (Figure 1d), No. 9 (Figure 1f), and No. 17 (Figure 1h), generally indicates incomplete combustion of fossil fuels, often coal, but with a small coefficient of excess air. Such large chimney losses were a common problem associated with primary combustion processes in not fully adapted furnaces or boilers. The black colour suggests that the smoke is rich in particulates and possibly other pollutants like unburned hydrocarbons, a typical indicator of high pollution levels. Grey smoke, like in paintings No. 1 (Figure 1a), No. 2 (Figure 1b), and No. 7 (Figure 1e), consists of a mixture of steam and pollutants, probably mainly particulate matter and sulphur compounds. Grey smoke often suggests that combustion of wet biomass or chemical synthesis (e.g., distillery processes) is occurring. These processes were common in industrial areas during the time period these paintings depict. White smoke, like in painting No. 11 (Figure 1g), indicates that it primarily consists of water vapour released from steam engines. White smoke may also contain some trace combustion products, but in much lower concentrations than black air does.

Smog is thick in some paintings, like in paintings No. 4 (Figure 1c), No. 27 (Figure 1i) and No. 41 (Figure 1j). This fact indicates high concentration of particles in the air that scatter and diffuse light, creating a hazy effect that blurs the details of buildings and structures in the background. Moreover, smog formation is enhanced when humidity levels are high. Secondary particles could be formed by gas to particle conversion processes, which increase along with air's relative humidity [51]. Painting No. 41 (Figure 1j) was created by Monet in February or in March 1900 [52], i.e., late winter, when temperature and humidity are generally low and high, respectively. Therefore, part of the particulate matter in the air of London is likely composed of secondary particles.

4. Conclusions

Works of art made during the industrial revolution, and in particular those of Impressionist artists, may unwittingly serve as a magnifying glass illuminating the environmental pollution that marked that era. The artists, while they were depicting the evolving natural and urban landscapes, were most likely unaware of the long-term effects of industrialization on the environment. However, this obvious change that was taking place in their daily lives was most palpably captured in their creations. The smog-filled skies and industrial landscapes depicted in the artworks serve as visual evidence of the environmental challenges faced during this particular era. The development of scientific indicators like smoke colour and density along with the prevailing meteorological conditions provided the opportunity to analyse measurable elements of atmospheric pollution depicted in selected paintings and thus obtain information about the atmospheric pollution of the time. These paintings are therefore invaluable historical documents, providing tangible evidence of the early stages of environmental pollution. This fact also supports the conclusion drawn by other studies that impressionistic representations accurately rendered physical changes like atmospheric pollution in their local optical environment. Moreover, science, by examining the consequences of environmental pollution on the basis of the artists' works, has initiated a two-way dialogue between art and science. By analysing and explaining in a

scientific way the impact of pollution on ecosystems and human health, the credibility of the images rendered by the artists is established. Promoting such an artistic approach in environmental and sustainability education could provide a creative yet impactful avenue for engaging diverse audiences. Ultimately, this research supports the idea that art can play a central role in shaping a more holistic understanding of sustainability and drive meaningful discussions on the urgent issue of atmospheric pollution.

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