

Perspective

Bioethical Analysis of the Socio-Environmental Conflicts of a Pig Industry on a Chilean Rural Community

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Abstract: Environmental conflicts, particularly within the pig industry in Chile, pose serious ecological, social, and economic challenges. This study focuses on analyzing the bioethical aspects of the ongoing environmental conflicts at an industrial pig farm in the Maule Region's rural localities. Employing heuristic and hermeneutic methodologies, the research analyzed over 790 documents, such as environment agency reports, legislation, and community testimonials. The findings underscore severe environmental harm, highlighted by air and water pollution caused by waste and emissions from pig farms. These environmental issues correlate with significant health problems in the community, including respiratory diseases and psychological stress. Furthermore, the study outlines the socio-economic repercussions, such as unsustainable water use and the detrimental impacts on local agriculture and livelihoods. The findings advocate for the enhanced management of natural resources, further scientific investigation, and the adoption of sustainable practices to ensure environmental justice and improve the well-being of impacted communities.

Keywords: environmental health; swine farming; environmental justice; community health; rural economy

1. Introduction

Environmental conflicts arise when interests, values, perceptions, or needs differ on issues linked to ecology. Such disagreements manifest when there are discrepancies among various groups, such as local communities, civil organizations, corporations, and government authorities, regarding the appropriate ways to use, protect, or manage natural resources, conservation areas, or different aspects of the environment [1,2]. These can encompass a wide range of issues, including the exploitation of natural resources, the location and operation of industrial projects, the management of protected areas, land use,

air and water pollution, among others. These disputes can emerge at the local, national, or even international level [1].

Common reasons include competition for scarce natural resources, the unequal distribution of environmental benefits and costs, a lack of both public participation and scientific evidence in decision-making, non-compliance with environmental regulations, and the perception of negative impacts on the health and quality of life of local communities [2].

The search for effective solutions typically requires an inclusive approach, involving the trust, participation, and collaboration of all stakeholders. The consideration of environmental, social, occupational, economic, and cultural aspects, as well as respect for human rights and sustainability, are essential elements for reaching agreements and decisions that promote responsible and equitable environmental development [3].

Globally, intensive pig farming has generated various environmental impacts [4]. According to the literature, large factories for pig farming, also known as industrial or concentrated pig farms, have been a concern due to the health issues they can generate for the workers, animals, and surrounding communities [4]. The high concentration of animals in confined spaces increases the risk of outbreaks and the spread of diseases such as swine flu (and other influenzas), bovine tuberculosis, salmonellosis, and other bacterial and viral infections [4,5], which may affect workers and animals. In some cases, pig industries use large amounts of antibiotics, among other compounds, to prevent and treat diseases in crowded animals, contributing to the development of antimicrobial resistance, which represents a serious threat to public health by complicating the treatment of bacterial infections in both animals and humans [5].

They also produce large quantities of waste and contribute to odorant inorganic substances and greenhouse gas emissions, such as ammonia, hydrogen sulfide, and methane. These gases can have negative effects on the air quality of nearby communities and cause respiratory problems and other health issues for exposed individuals [4]. On the other hand, the accumulation of manure and waste from pig factories can leach into the soil and contaminate nearby water sources, affecting water quality for human consumption and aquatic life, posing a risk to health and the environment [6].

The confinement conditions and intensive practices at pig factories can cause stress and suffering in pigs. Prolonged stress and inadequate conditions can increase the susceptibility of animals to diseases and affect the quality of the meat produced. At the same time, workers at pig factories may be exposed to harmful gases and dust, as well as to zoonotic diseases transmitted by pigs. The lack of adequate working conditions can increase the risk of health problems among the employees of these facilities [7].

Furthermore, in the pig industry, there is an intensification of pesticide use, mainly to control the insect populations (flies) generated by manure, which has significant implications for both individuals and the environment. Among the impacts on human health are the risks of acute and chronic poisoning and other possible long-term effects, due to the chronic occupational and environmental exposure to these pesticides faced by workers and the population living around pig farms [8]. Environmentally, pesticides can contaminate water sources and soils, affecting biodiversity and local ecosystems. Additionally, the continuous reliance on pesticides can lead to pests' resistance to these chemicals, reducing their effectiveness in the long term. This cycle of intensive pesticide use underscores the need for more sustainable and less harmful pest control approaches in the pig industry [8,9].

In Chile, this practice has also been the subject of controversy and has led to environmental conflicts in different regions of the country. The National Human Rights Institute of Chile [Instituto Nacional de Derechos Humanos (INDH)] has identified that the main environmental conflicts caused by the pig industry relate to pollution and the improper use of natural resources, especially water and air (emission of bad odors) [10]. Chilean pig production is mainly concentrated in the Metropolitana, O'Higgins, and Maule regions [11].

In the Maule Region, there is a significant socio-environmental conflict in the San Javier commune. Since 2015, more than 200 complaints have been filed by the community due to the pollution emitted by a nearby pig farm [10].

Therefore, this work aims to analyze, from a bioethical perspective, the situation of an active socio-environmental conflict of an industrial pig farm, and the repercussions on psychological, physical, economic, and social well-being reported in various rural localities of the Maule Region, such as El Arbolillo, Pillay, Santa Rosa de Purapel, Caliboro, La Puntilla, Santo Toribio, and Huerta del Maule, based on documented research.

The relevance of this review involves the critical reflection of the conflict and the environmental, social, and health consequences in the affected community due to exposure to polluting sources from the pig industry, as well as discussing the actions implemented from a bioethics and environmental justice approach, enabling the active participation of the community in conjunction with the scientific, political, and productive sectors to find a fairer and more sustainable solution.

2. Methods

A qualitative study, with a narrative review of documentary research. Using the terms “El Arbolillo San Javier”, “pig industry”, and “environmental conflict” (“El Arbolillo de San Javier”, “industria de cerdos”, and “conflicto ambiental” in Spanish), more than 790 documents were consulted in different information sources, such as electronic files from the Superintendence of the Environment [Super Intendencia de Medio Ambiente (SMA)], the National System of Environmental Enforcement Information [Sistema Nacional de Información de Fiscalización Ambiental], the website and environmental conflict map of the INDH, resolutions, environmental regulations and laws, environmental observatory websites, interviews, journalistic articles linked to the socio-environmental conflict of the pig farm in the area, and written documents of complaints and other reports provided by the communities of the El Arbolillo sector in San Javier of the Maule Region. Finally, 80 electronic documents published since the year 2008, coinciding with the approval of the pig plant project, and 160 digitized written documents, all linked to the socio-environmental conflict, were analyzed (Total = 240).

The documents were analyzed in two phases [12]: heuristic phase (searching, compiling, and organizing the existing information of the case); and a hermeneutic phase (reading and critical-reflective analysis of the collected information).

The contents of the documents were examined, and the information was categorized into three relevant themes: (a) description and legal components of the conflict; (b) impact on the environment and consequences on the physical and mental health of the community; (c) socio-economic consequences of the environmental conflict.

Finally, the discussion addresses the evidence from a proponent and constructive approach that guides the analysis from the theoretical–conceptual components of this kind of conflict and environmental justice, qualitatively comparing them with the experience of other national and international environmental conflicts, and generating projections and suggestions for communities, decision-makers, and future research in the area.

For ethical and privacy reasons, this document omits direct mention of the names of the individuals or companies involved in the events described, in order to protect their identity and confidentiality.

3. Results

1. Description and legal components of the conflict

The legal and environmental conflict surrounding the establishment of a pig farm or breeding site in the San Javier commune has been a matter of great concern and debate, involving several communities in the Maule Region.

The company proposed the construction of a massive pig breeding operation, with a monthly capacity of 144,288 pigs, in an area of agricultural and viticultural relevance, marked by a high risk of water scarcity [13]. This project has faced strong opposition from local communities, including El Arbolillo, Pillay, Santa Rosa de Purapel, Caliboro, La Puntilla, and Name, who have expressed environmental and public health concerns.

Below is a synthesis of the legal aspects and significant developments in the case:

- Lawsuit against the pig farm and the Environmental Assessment Service [Servicio de evaluación Ambiental (SEA)] [14]: Neighbors from the sector have filed a lawsuit against SEA and the company, requesting the revocation of the Environmental Qualification Resolution [Resolución de Calificación Ambiental—RCA], granted in 2008, and the execution of a new Environmental Impact Study [Estudio de Impacto Ambiental (EIA)]. Neighbors have denounced that the company began construction without adequately informing the community, creating a situation of misinformation and vulnerability.
- Irregularities in the EIA [15]: The lawsuit points out inconsistencies and omissions in the EIA, including the lack of an adequate evaluation of odor dispersion, impact on local health, and impact on the area's water balance.
- Actions by the municipality of San Javier [14,16]: In December 2015, the municipality has stopped the pig farm construction due to irregularities in land use change. However, in 2016, the pig farm obtained the necessary permits to continue construction.
- Actions by the SMA [17]: Since 2019, the SMA has formulated several charges against the project due to environmental non-compliances. The sanctioning processes include accusations of operating without adequate manure treatment, constructing and operating treatment systems without the mandatory qualification resolution, failing to comply with the required biological monitoring, and not implementing measures to mitigate odor impact. These non-compliances have been classified into different degrees of severity and have led the company to submit compliance programs and take corrective measures.
- Ruling by the INDH [10]: In 2019, the INDH filed a protection appeal, resulting in the Supreme Court confirming the violation of the right to live in an environment free of contamination.
- Supreme Court Resolution [18]: The Supreme Court, in August 2023, accepted a cassation appeal and ordered a new process of public participation, recognizing that the second environmental tribunal had made an error in dismissing the need for this process after significant modifications to the project. Following this, SEA complied with the sentence and arranged through its digital platform in 2023 the opening of a new process of public participation [19].

In 2023, the Chilean Supreme Court emphasized the importance of community inclusion in the environmental impact assessment, especially when significant modifications to projects are proposed. Temporarily maintaining environmental qualification resolution No. 225/19, the court demanded an expanded process of public participation [19], thus reinforcing the rights of involved communities to receive information and exercise their voice in decisions impacting their environment and quality of life. To date, there are still no results of the public consultation.

On May 16, 2024, the SMA [20] filed two serious charges against Agrícola Coexca S.A., the company responsible for the “Plantel porcino de 10 mil madres San Agustín del Arbolito” pig breeding facility, located in the San Javier commune, Maule Region. These new charges stem from around 300 citizen and municipal complaints about harmful odors and vector proliferation attributed to the facility's operations. The first charge relates to the inadequate operation of the anaerobic biodigestion system, which fails to produce biogas with a methane content sufficient for fuel management or controlled burning. The second charge involves non-compliance with the conditions set for digestate irrigation under the facility's environmental permit (RCA No. 225/2019). This non-compliance is evidenced by the use of digestate in irrigation at low pressure, causing it to fall directly onto the ground without atomization, and emitting offensive odors. These infractions could lead to a penalty of up to 10,000 annual tax units (UTA), equivalent to more than 9.7 million dollars (assuming an exchange rate of 800 Chilean pesos per dollar).

2. Environmental impact and consequences on the physical and mental health of the community

The complaints primarily focus on unpleasant odors, which intensify during the night and early morning due to the transportation of manure, and on the proliferation of insects, especially flies, that invade the sector [17]. Among the observed environmental consequences are the contamination of the Purapel river with liquid digestate, as well as environmental pollution by gases such as methane and ammonia [17]. Moreover, the company has used various pesticides since the SMA ordered provisional measures in 2021 due to the high number of flies attracted by the pig farm. According to the information provided by the community, organophosphates such as diazinon and pirimiphos-methyl, pyrethroids such as cypermethrin and beta-cypermethrin, and a neonicotinoid called thiamethoxam have been identified [21].

The operations of the breeding site have intensified the risk of contamination in water sources and soils [10,17,22]. This risk includes the leaching of nitrates and other contaminants into ground and surface water bodies, notably the Purapel river, located near the industrial area. The Purapel river, a tributary of the Perquilauquén river, and this in turn a tributary of the Loncomilla river, ultimately affects the Maule river basin. Considering the community complaints and hydrological studies of the Maule basin [23], these river interactions could alter aquatic ecosystems and decrease the water quality and quantity, impacting human consumption and irrigation in the agricultural area. Additionally, pesticide use for vector control and manure could change the composition of soil and water, adversely affecting local agriculture and the human population chronically exposed to these chemicals [21,24].

The proximity of the breeding site to ecologically sensitive areas, such as the Purapel, Perquilauquén rivers, and the Name Swamps (“Ciénaga del Name” in Spanish), poses a threat to local biodiversity. Habitat alteration and potential contamination can cause the displacement and/or extinction of species (especially the most vulnerable) and the alteration of trophic chains. This situation has generated controversy, as reflected in the resolution of the Environmental Tribunal of Santiago, which suggests the non-existence of a significant environmental risk, based on studies carried out by the company itself or involving methods that do not ensure a longitudinal and exhaustive evaluation of the company’s impacts on key environmental matrices, such as air, soil and their microorganisms, water, insects, and flora, in areas of aquifers and priority conservation [18,24].

In terms of human-health consequences, symptoms such as nausea, diarrhea, stomach pains, vomiting, loss of appetite, and headaches have been reported, as well as irritation of eyes, nose, and throat. The proliferation of disease vectors, such as mice and flies, has also been reported. Regarding psychological repercussions on the community, problems such as insomnia, anxiety, distress, depression, loss of appetite, feelings of isolation, and lack of social cohesion have been noted [10,17,24,25].

Various legal documents recognize that the emission of gases and unpleasant odors from the pig farm can have long-term effects, including diseases related to the toxicity of these compounds. Water and soil contamination can lead to gastrointestinal problems if contaminated water or food grown in affected soils are consumed. Additionally, contact with contaminated water can cause dermatological issues. The constant presence of bad odors, fear of contamination, and concern for health and economic future generate high levels of stress and anxiety in the community [17,24–28].

The alteration of the natural environment and quality of life in the community affects daily activities, significantly reducing outdoor recreational opportunities, and leading to a weakening of social cohesion, as the community is forced to adapt to an altered and potentially hostile environment. Forced migration due to unsanitary conditions and the devaluation of properties can result in psychological distress, financial losses, a lack of a sense of community belonging and cultural roots [10,17–19,28].

3. Socio-economic consequences of the environmental conflict

The pig farm project has been criticized for its excessive use of water, consuming approximately five million liters daily, which exceeds the water consumption of the city of San Javier [25–28]. This problem has led to questions regarding water allocation to polluting industries while local communities face scarcity [28]. Moreover, concerns about corruption and the lack of proper action by authorities have been reported, given that the involved company has operated despite irregularities and without necessary permits [17,24,25,28].

Neighbors have reported issues, such as an increase in vectors like flies and rats, the contamination of groundwater, water scarcity, bad odors, and health problems, such as bronchial asthma and allergic sensitization. These issues have affected the community's quality of life. Consequently, it has limited other economic activities, such as tourism and gastronomy [17,24,27,28], and impacted organic crops, honey production, and other aspects.

Currently, the environmental conflict remains active, with environmental impact studies associated with both the company and the INDH, as well as inspections carried out by the SMA [10]. However, scientific studies by research centers or universities addressing the environmental, rural economy, and health situation of the communities residing in the affected area have not yet been conducted.

4. Discussion

Rural communities near the pig farm, notably El Arbolillo, Pillay, Santa Rosa de Purapel, Caliboro, La Puntilla, Santo Toribio, and Huerta del Maule, experience an intense grievance regarding their quality of life due to bad odors and the presence of insects, directly impacting the physical, psychological, and social well-being of the community [10,28,29]. The pesticide used by the company as a mitigation measure against insects is concerning, including a pesticide classified as possibly carcinogenic by the IARC [30], namely diazinon.

These social conflicts highlight the need for the more responsible environmental management of pig farming, and effective regulation to protect both the environment and the rights and health of local communities.

Chile's environmental legislation comprehensively addresses all productive sectors, aiming to promote a genuinely sustainable economy. Industrial sectors such as mining, forestry, aquaculture, and pig production present socio-environmental challenges that require strict state regulation to ensure the least possible impact on ecosystems and local communities [31]. Specifically, in the case of pig farms, significant conflicts related to waste management and the emission of unpleasant odors have been identified in Chile and elsewhere, creating serious tensions with neighboring communities [29]. A prominent example is the case in Freirina, Atacama Region, a socio-environmental conflict where the pressure of citizen protests led to the definitive closure of the largest pig plant in Latin America (Agrosuper) in 2012 [32].

According to Law 19,300 on the general basis of the environment in Chile [33], it is mandatory for a pig breeding industry to meet certain conditions. Among these, the need to conduct an environmental impact study stands out, which must include the evaluation of odor emissions and potential environmental contamination. However, the pig breeding site located near the San Javier community began its operations only with an environmental impact declaration, without complying with all the required regulations [17,24]. Given the intrinsic characteristics of this industry, from the outset, the SEA should have demanded a more comprehensive environmental impact study. This case highlights a deficiency in monitoring and applying environmental regulations, as well as in the community's participation and consultation, a key aspect that was not duly considered and led to the irregular installation of the pig farm [24].

According to Law 21,600 [34], which governs the national system of protected areas in Chile, the installation of the pig farm near the "Name Swamp" acquires critical relevance in terms of bioethics and environmental conservation. The alteration of habitats and the potential contamination generated by the breeding site could displace species and significantly alter trophic chains. This situation underscores the need for more active and

rigorous intervention by the government authorities. It is not only necessary to ensure compliance with Law 19,300 regarding environmental impact studies, but also to guarantee that the breeding site's operations do not irreparably compromise the conservation of the protection areas, which have are invaluable for the region's ecological and water balance.

It is important to highlight that not all pig breeding operations face these problems, and some companies implement more sustainable and responsible practices to mitigate the negative impacts on the environment and nearby communities [11]. However, when practices are not adequately regulated and complied, regulations are violated, communities and ecosystems are harmed, or measures to address environmental issues are not adopted, significant conflicts arise. Environmental management and proper enforcement are key to addressing and preventing these environmental conflicts [35–37].

Additionally, it is relevant to emphasize the particularly poorly developed rural economy of the affected sectors. Often overlooked, rural activities and their economies are inherently sustainable, cyclical, and interconnected. They are also deeply intertwined with cultural expressions and traditions. When industrial practices disrupt these rural economies, they do not only affect financial transactions but also deteriorate the very fabric of community life that has been cultivated over generations [38–40]. This degradation not only undermines the economic stability of these areas but also leads to a loss of cultural heritage, which is vital for the identity and continuity of these communities [41–43].

On February 6, 2023, the first Chilean environmental standard regulating odor emissions from the pig sector in the country came into force. Supreme Decree N°9/2022, titled "Emission standard for pollutants in pig farms that, due to their odors cause annoyance and pose a risk to the quality of life of the population" [36], is the first regulation established within the framework of the odor control management strategy implemented by the Ministry of the Environment of Chile [Ministerio de Medio Ambiente] since 2014 [37]. The regulation promotes the use of novel techniques to prevent and control odors from their source, and the implementation of good operational practices. Among the highlighted measures is the online monitoring of odor through abatement equipment to avoid odor events and nuisance to the surrounding population [36]. As the first odor standard in Chile, it represents an important step towards environmental justice, especially in rural areas where most pig farms are located, aiming to improve communities' quality of life.

From Potter's environmental bioethics perspective, the environmental conflict involving the pig industry affects human health and ecological balance. It is necessary to emphasize the need to balance economic interests of the pig industry with environmental and human health. The legal action of the INDH and the Supreme Court's condemnation reflect a step towards environmental justice, aligning with ethical responsibility towards the environment and community [38]. Water and air pollution, as well as adverse effects on the health of the local community, are indicative of an imbalance in the relationship between industrial development and environmental sustainability [39]. In this respect, a holistic approach involving stricter regulations, sustainable technologies, and active community participation in decisions related to the pig industry is urgently needed.

From Leopold's perspective [40], the preservation of local ecosystems must be prioritized. Rivers' pollution and effects on biodiversity and organic crops are contrary to the principles of respect and the protection of nature [41]. Agricultural practices that maintain ecological balance and avoid deteriorating the quality of life of nearby communities, and biodiversity should be favored. A more inclusive and environmentally respectful approach is perceived as necessary, considering the short- and long-term health and well-being of the land and its inhabitants [42].

For Singer [43], the situation regarding animal welfare in intensive pig farms deserves critical review. The extreme confinement and widespread use of antibiotics illustrate a disregard for the suffering of animals. Priority should be given to the health and welfare of the animals, workers and people involved [43]. Additionally, the negative impacts on the health of pig plant workers, agricultural workers and nearby residents should not be overlooked, particularly given the ethical controversy surrounding pesticide use

against flies due to the pig waste. These factors affect human health and the environment, highlighting the urgency of implementing less harmful and more sustainable pest control methods [44].

The factory operations conflict with the bioethical principles of respect for life and the integrity of ecosystems, as well as with the current environmental legislation in Chile.

This critical analysis reflects the need for a multidimensional approach that considers human and animal welfare as well as ecosystem integrity. The approaches of Potter, Leopold, and Singer together suggest a management and regulation model that balances economic needs, animal rights, community health, and environmental sustainability.

Addressing this conflict from Bullard's environmental justice stance, it is concerning how the most disadvantaged and vulnerable communities and peasant agriculture are the most affected by pollution and health risks. Thus, it is necessary to analyze the unequal distribution of environmental costs and economic benefits, underlining the need to ensure that the voices of these communities are heard and considered in decision-making [45].

Moreover, Schlosberg [46] addresses environmental justice from a "capabilities" perspective, focusing on the links between equitable access to a healthy environment and the ability of individuals to thrive in their surroundings. Applying this approach to the Chilean pig farm case, the company's pollution and practices are limiting the capabilities of local communities to maintain their health, well-being, and livelihoods, as well as highlighting the need for the relocation or closure of the factory due to irregularities in its operation and the environmental pollution it generates. A solution should be sought that not only addresses environmental problems but also improves the capabilities and quality of life of those affected [47].

Furthermore, in the context of the pig farm conflict in Chile, according to Shiva [48], it is essential to examine how industrial practices negatively affect local agriculture and food sovereignty, and how this disproportionately impacts women and other marginalized populations. The community has reported that emissions of unpleasant odors and the presence of vectors are harming the development of their livelihoods. This affects not only the rural economy of the area but also the essential networks of communication and the exchange of goods and services, which have supported the localities even before the arrival of industry. It is imperative to advocate for more sustainable and ethical practices that protect the environment and the rights of local communities, with a particular emphasis on ensuring access to resources and healthy food.

It is therefore imperative to highlight the importance of equity, participation, and respect for the diverse needs and rights of the communities impacted by environmental conflicts. Adopting a multidimensional approach is crucial for a comprehensive understanding and an effective resolution of the challenges presented by the pig industry in Chile, with the aim of achieving solutions that are equitable in both social and environmental terms.

Moreover, it is imperative to recognize the importance of active and meaningful community participation in environmental assessment processes that were unjustly not considered at the beginning of the company's operations. The inclusion of affected communities not only promotes transparency and trust in regulatory processes but also ensures that their experiences and knowledge are considered in decision-making. This collaboration can lead to more innovative and suitable solutions that effectively address the specific concerns of the community [49].

However, it is urgent for Chile to conduct scientific studies from independent research centers or universities examining the effect of the pig industry on the health of nearby communities and the environment. These studies may provide valuable information to properly address community concerns and to make informed decisions to promote sustainable development that respects the environment and the health of people residing in these affected areas.

The need to conduct comprehensive studies evaluating the impact of the pig industry on the quality of life and health of the community is fundamental to building public policies.

These studies should be designed to capture data on the incidence of respiratory conditions, allergies, and other acute and chronic health conditions that may be correlated with proximity to pig farms and exposure to bad odors and pollutants. Special attention must also be paid to the risk associated with occupational and environmental exposure to pesticides and other chemicals. The presence of chemicals classified as probably carcinogenic by the IARC warrants a detailed analysis of their concentration in air, water, and soil, as well as the cumulative and long-term effects on human health [50].

The results of such studies are urgent, not only to inform existing policies and regulations, but also for the implementation of preventive and corrective measures. They could significantly contribute to creating a reference framework for the responsible and restricted use of pesticides, as well as for the promotion of sustainable and less harmful alternatives in pest management. The adoption of such practices would benefit not only public health, but also environmental quality and local biodiversity.

Therefore, integrating community participation and rigorous scientific research into environmental impact assessment is not just a matter of methodological rigor but also an expression of ethical commitment to environmental and social justice. It is an approach that responds to the demand for sustainable development that prioritizes human well-being and ecological preservation over short-term economic interests [47].

The resolution of environmental conflicts related to the pig industry has been a topic of global interest, and several countries have implemented strategies that have been relatively successful. For example, in the European Union [51], the Nitrates Directive (91/676/EEC) has established frameworks for the sustainable management of livestock waste, thus minimizing its impact on water and the quality of life of nearby communities. These regulations mandate the adoption of action plans that include the controlled application of manure and the creation of vulnerable zones, where its use is restricted [52].

In Denmark, innovation in waste management technologies, such as anaerobic digestion systems, has been promoted. These systems not only reduce odor emissions but also generate renewable energy. Furthermore, collaboration between pig farms and governmental entities has led to the implementation of vegetative barriers that act as biological filters to mitigate odors [53,54].

The Netherlands has launched relocation and modernization programs for pig farms, moving them towards more sustainable practices and away from residential areas. These initiatives include financial compensation and technical assistance, ensuring a transition towards more sustainable production systems [55].

In the United States, some states have established “Good Neighborhood?” guidelines, which include odor management agreements and the installation of odor mitigation technology. Moreover, there are examples of pig producer cooperatives working with environmental and community organizations to improve waste management practices and to reduce environmental impacts [56].

These international experiences suggest that an effective strategy for resolving environmental conflicts should include [57]:

- Clear and enforceable regulations: the implementation of laws regulating waste management and odor emissions, with penalties for non-compliance.
- Technology and innovation: investment in waste and odor mitigation technologies, including anaerobic digestion and vegetative barriers.
- Cooperation and compensation: programs that facilitate the modernization of pig farms and, if necessary, their relocation, with financial and technical support.
- Community participation: the development of “Good Neighborhood” agreements and dialogue platforms between pig producers and communities to ensure transparency and the consideration of local concerns.
- Education and environmental awareness: campaigns to educate producers and the community on sustainable practices and their positive impact on quality of life and the environment.

Finally, incorporating successful international models into environmental management involves a detailed critical analysis and careful adaptation to the specific context of Chile. This adaptation must consider local particularities and the disparate consequences of implementing these strategies in different regions. The transition towards sustainable practices may require significant effort in the short, medium, and long term. However, the urgent situation in the rural community studied indicates the need for the immediate closure of the pig factory. This extreme measure is widely justified by the company's blatant non-compliance with environmental regulations and ethical principles, and above all, by the imperative need to safeguard the health and well-being of the affected communities and the environment.

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