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Review

The Quantification of Non-Action Costs as an Incentive to Address Water Pollution Problems

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Abstract: Diffuse pollution is one type of pollution generated by agricultural, livestock, and urban runoff that is responsible for surface and groundwater pollution. As a result, the exposed population develops different diseases that affect their short, medium, and long-term quality of life. Researchers need to be able to assess the loss of quality of life in monetary terms to include this social impact in decision-making processes. Specifically, if no measure is implemented to correct the situation, these costs can be considered as the non-action costs of the social impact of water pollution. This study assesses the importance of measuring healthcare costs as a proxy for non-action costs for the economic assessment of water pollution consequences. Thanks to this analysis, it is possible to identify the health costs produced by the current environmental situation, making it possible to obtain an economic baseline scenario prior to the implementation of any project or measure. This approach is a novelty in the literature since, to date, healthcare costs have not been related to non-action costs. Including these costs in economic feasibility studies allow us to assess in detail both the social impact of pollution and the social benefits of develop water-quality improvement projects.

Keywords: non-action cost; healthcare; social impact; water pollutant; runoff

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1. Introduction

The impact of human actions on a territory entails changes in the natural ecosystem balance. In the case of the water cycle, agricultural practises such as the use of pesticides, liquid manure, and slurry, as well as substances from urban areas (including wastewater discharges not collected by the sewage system) cause the pollution of water bodies through surface runoff and soil leaching [1]. The population is exposed to this pollution through drinking water consumption, which causes different types of health problems that need to be addressed to ensure the safety of the drinking water supply. In addition, water stress caused by weather and overexploitation hampers the management of this situation due to the need to invest in new facilities and treatment technologies. The combination of these two factors requires new management approaches and measures to reduce pollution and obtain water with better quality that can be used for different purposes.

Global data reveal that water stress currently affects more than two billion people in more than 200 river basins [2]. In detail, 32 countries have a water stress level between 25% and 70%, which limits their economic and social development [3]. In the last 100 years, 54–57% of natural wetlands have been lost, and one third of rivers in developing countries face severe faecal and organic pollution from inadequate wastewater management, treatment, and runoff. As a result, there are places where people are being displaced by water and environmental conditions and experiencing the consequences through economic and productive systems [4].

Management of the water cycle and, specifically, the water flows directly and indirectly related to water supply, is a complex task. At the same time, it is fundamentally important to adapt uses and demands to each territory's needs. Diffuse pollution and the productive sector have strong impacts on water management, generating environmental and social costs with subsequent sustainability and health problems in the medium- and long-term. If these discharges are not identified, problems such as eutrophication, increased pathogens, and emerging pollutants can arise. The environmental and social costs related to this situation are described as non-action costs since authorities and decision-makers are not implementing concrete actions to change this situation [5].

The impact of non-action costs on the environment and water management are significant and are usually related to the baseline scenarios prior to the implementation of any management measure or project (Table 1). Non-action costs consider that any action is being implemented to correct pollution, provoking environmental and social imbalance. Obtaining the non-action costs in monetary terms allows one to identify the baseline scenario to compare whether future actions and measures will have an improvement on environmental and social conditions. These improvements are described as environmental and social benefits, which act as indicators of the improvement capacity of implemented actions, which are also calculated in monetary terms.

Table 1. Impact of the non-action costs on health, environment, and productive activities. Adapted from Hernández-Sancho et al. [6].

Health	Environment	Productive Activities
Increased risk of diseases caused by loss of quality in drinking and bathing water and unsafe food (polluted water used to produce vegetables or fish). Increased financial costs of healthcare	Loss of biodiversity. Unsuitable quality of ecosystems. Greenhouse gas emissions. Loss of recreational value of ecosystems.	Loss of productivity in the agricultural and industrial sectors. Reduced market value of unsafe products. Loss of earnings from tourism activities.

Runoff water has strong polluting potential due to the presence of certain undesirable substances from agricultural and urban origins, specifically nitrates, phosphorus, plant-protection products, heavy metals, and oils [7]. Furthermore, insufficient wastewater treatment, or its absence, is responsible for increasing environmental and human risks due to the discharge of human substances through effluents, such as emerging pollutants [8]. Laboratory analysis has also identified the presence of viruses and bacteria responsible for diseases such as gastroenteritis, encephalitis, meningitis, hepatitis (hepatitis A and E viruses), cancer (polyomavirus), and myocarditis (enteroviruses), among others [9]. All of these pollutants cause health problems in the short-, medium-, and long-term, provoking a social non-action cost related to the direct and indirect medical costs of dealing with these diseases. Non-action costs act as baseline indicators of the social situation and, at the same time, will make it possible to estimate the social impact on the population.

Understanding the chemical properties of pollutants and how they act when the population is exposed is essential to monitoring and regulating their use and disposal. Data from the Centres for Disease Control and Prevention detected more than 200 chemicals in the human body from pollutants present in the environment [10]. The main pathways by which pollutants enter the human body are (i) oral ingestion and absorption by the intestines, (ii) nasal and pulmonary absorption, and (iii) dermal contact (Table 2).

Table 2. Information about different pathways of pollutant exposure in humans [11].

Oral Ingestion	Nasal Absorption	Dermal Contact
Bioaccumulation in food	Chemicals in gas phase (vapor)	Cosmetics
Drinking water	Chemicals in particulate phase (aerosols, suspended dust)	Personal care products

Despite these pathways, the specific chemical properties of each pollutant are determinants of its behaviour in the human body, establishing the risk level, symptoms, and diseases generated. Prenatal and early life exposure have negative impacts on the neurological development of babies, affecting their endocrine and non-endocrine systems [12]. Based on this factor, decision-makers can design different strategies in order to prioritise economic resources to manage polluted discharges and risky products [11]. Reducing the presence of pollutants in the water cycle necessitates monitoring the water quality and runoff collection to be treated, improving the plant-protection products used, and applying technological improvements in wastewater treatment plants. These are the best options to manage water pollutants from diffuse sources. If pollutants are not removed, the social non-action costs of diseases are generated, which can be described as the direct and indirect healthcare and productivity costs.

The aim of this study is to present the non-action costs of water pollution as a tool to assess the social benefits of reducing pollution since understanding the healthcare costs of diseases and symptoms related to water pollutant exposure would help decision-makers implement new measures to ensure the population's life quality. Non-action costs act as baseline indicators of the social situation, allowing one to identify potential savings in healthcare if pollution were reduced and removed. This approach is the first step of future assessments focusing on the inclusion of non-action costs in decision-making processes to assess the feasibility of new measures to manage pollution and ensure the population's life quality, as well as environmental sustainability.

2. Non-Action Costs Considered as a Proxy for the Social Impact of Water Pollution

The balance between economic and productive decisions and environmental conservation and sustainability is difficult to maintain, as both the linear production scheme and consumption patterns are not favourable to reduce pollution. The population is engaged in a model where products are easily accessible, the production level is high, and the waste generated is also high. However, resources are limited, and other sources have been used, producing high environmental impacts due to their difficult access. This pressure on natural resources affects environmental quality, modifying ecosystems' conditions to the detriment of their long-term sustainability. As a result, the population exposed to both pollution and poor environmental quality is affected by different diseases and symptoms that reduce their quality of life and life expectancy. Hence, the relationship between health, the environment, and production systems directly affects human development, causing economic problems in the short-, medium-, and long-term [13].

Water consumption is one of the resources affected by this situation. Non-action costs are gaining importance when the impact of water management projects is assessed. Specifically, non-action costs are focused on studying baseline scenario prior to the improvement of environmental and health conditions. All water-polluted flows caused by human actions generate environmental impacts that not only produce ecological damage but also affect the health of the population. Even though the impact degrees on health can differ, it is necessary to identify the consequences of exposure and consumption to implement specific measures, including changing the management actions in a territory or implementing new wastewater treatments. The final aim is to reduce the health risk of the exposed population represented as economic savings in healthcare costs (Figure 1).

Identifying the health problems derived from illness and assessing the healthcare costs of treating those illnesses are the foundations for the non-action-cost approach. Collecting data on healthcare costs is complex because it is difficult to establish the cause-and-effect relationship between pollution (the consumption of a specific pollutant in water) and illness [14]. This relationship needs to be established and proven before using the non-action-cost approach to ensure that results obtained represent the real situation.

Before presenting a literature review of healthcare cost studies in water sector, it is necessary to establish the steps for a non-action cost assessment. These steps help decision -makers successfully implement a non-action cost assessment. Simultaneously, these steps correspond to the structure presented in Section 2. A non-action cost assessment is composed of the three steps presented in Table 3.

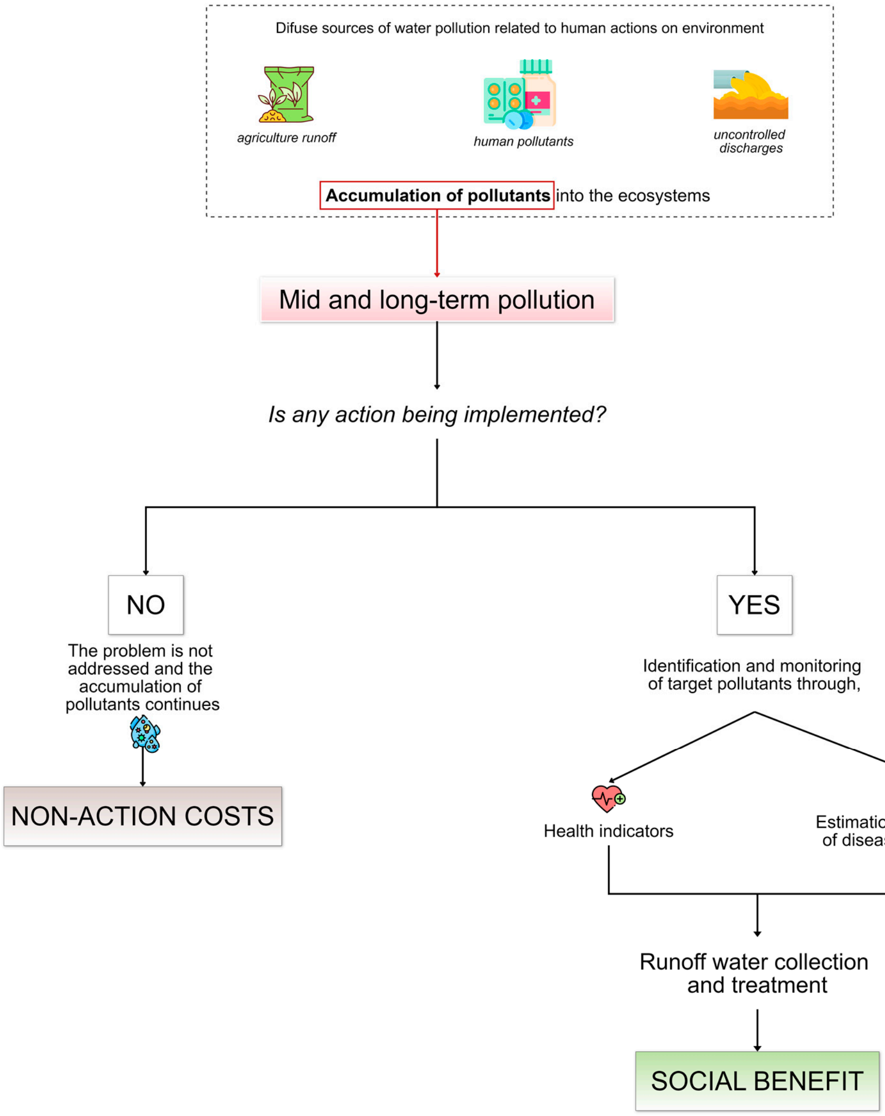

Figure 1. Non-action-cost approach. Source: own elaboration.

Table 3. Steps of non-action cost assessment. Source: own elaboration.

Step 1—Identification		**Step 2—Methodology Selection**		**Step 3—Valorization**	
Identifying goods and services (social and environmental) affected by pollution	Section 2.1.	Applying the appropriate methodology to assess short-, medium-, and long-term effects of pollution exposure	Section 2.2.	Assessing the results of the methodology applied to establish the baseline scenario	Section 2.3 and Section 2.4.

These steps act as a framework to implement non-action costs in decision-making processes, highlighting the importance of considering not only the environmental benefits of improving ecosystem quality, but also the social benefits related to better health conditions. As discussed in the following sections, the healthcare assessed showed high savings potential if concrete measures were implemented.

2.1. How Are Healthcare Costs Related to Non-Action Costs?

The influence of non-action costs on healthcare can be shown in different ways according to geographical location, types of pollutants, social groups, and income levels, among others. Risk exposure to urban wastewater discharges is not the same risk as exposure to industrial water flows or wastes. Depending on the origin of pollutants, the population develops different symptoms, including diarrhoea, fever, stomach and intestinal disorders, and certain types of cancer due to exposure to harmful substances [6]. According to information provided by Lanrewaju et al. [9], diarrhoea is the main consequence of water-polluted consumption caused by bacteria and viruses presents in domestic wastewater discharges. Both pathogens are the main causes of clinical cases of stomach and intestinal disorders.

Measuring non-action costs is complex because it involves different disciplines not directly related to classical economics. In addition, some of the diseases caused by exposure are difficult to monitor because symptoms must be observed over the long-term after early exposure [15]. To address this situation, it is necessary to apply a holistic approach to combine all these variables within economic assessments. As a result, decision-makers and managers can implement new actions in an area considering all the variables and impacts related to pollution and its management. This quantification represents a step forward in water cycle management, enabling the promotion of reuse and the circular economy in safe conditions.

To assess the non-action costs related to health issues, direct and indirect costs need to be considered. On the one hand, direct costs refer to the treatment of the illness itself: medicines, hospital admission, staff, and follow-up, among others. On the other hand, indirect costs result from the consequences that the illness causes for the exposed population, such as the temporary cessation of employment, loss of quality of life, and a reduction in life expectancy or premature death [16,17]. Indirect costs are more difficult to assess because they occur throughout the patient's life and affect different life domains (Figure 2). However, obtaining these costs allows for a more detailed assessment of the health impacts of polluted-water exposure and consumption.

Overall, an economic assessment of the costs of healthcare treatments is obtained through the human capital approach. This assessment is based on both the indirect costs related to the loss of productivity due to illness and the direct costs related to medical treatment. The human capital approach also considers the subclinical dysfunctions arising from pollutant consumption and exposure. Economical losses caused by dysfunctions affect human productivity (e.g., due to cognitive deficits) and are generally assessed from the perspective of projected life-time earnings converted to present-day values. Using information about intelligent quotient (IQ) and the economic losses related to losing an IQ point, as well as integration into the labour market and schooling, represent other approaches available to obtain the loss of economic productivity during one's lifetime. It should be noted that there is an intangible cost related to disease development, such as the value of avoiding pain. To assess this value, the Disability-Adjusted Life Year (DALY) method can be implemented. DALY combines the duration and quality of life with the impact that the illness has on the population, thereby obtaining an estimation about the years of life lost due to illness, disability, or early death [16]. However, the impact of exposure to and consumption of polluted water cannot be fully obtained because of both the difficulty in quantifying the effects of exposition time on subsequent development of disease and the incomplete understanding of the relationship between pollutants and environmental-related diseases [14].

2.2. Methodologies for Monetary Valuation of Social Externalities and Healthcare Costs

Once the affected goods and services (social and environmental) have been identified, monetary valuation methodologies are necessary to assess the short-, medium-, and long-term effects of pollution exposure. As previously discussed, non-action costs become an effective tool for understanding the healthcare and indirect costs of the current situation and the consequences for the population. At the same time, obtaining a monetary value allows one to develop a socio-economic scenario to justify the implementation of both new technologies and management frameworks to improve water quality for human consumption and ecosystem balance.

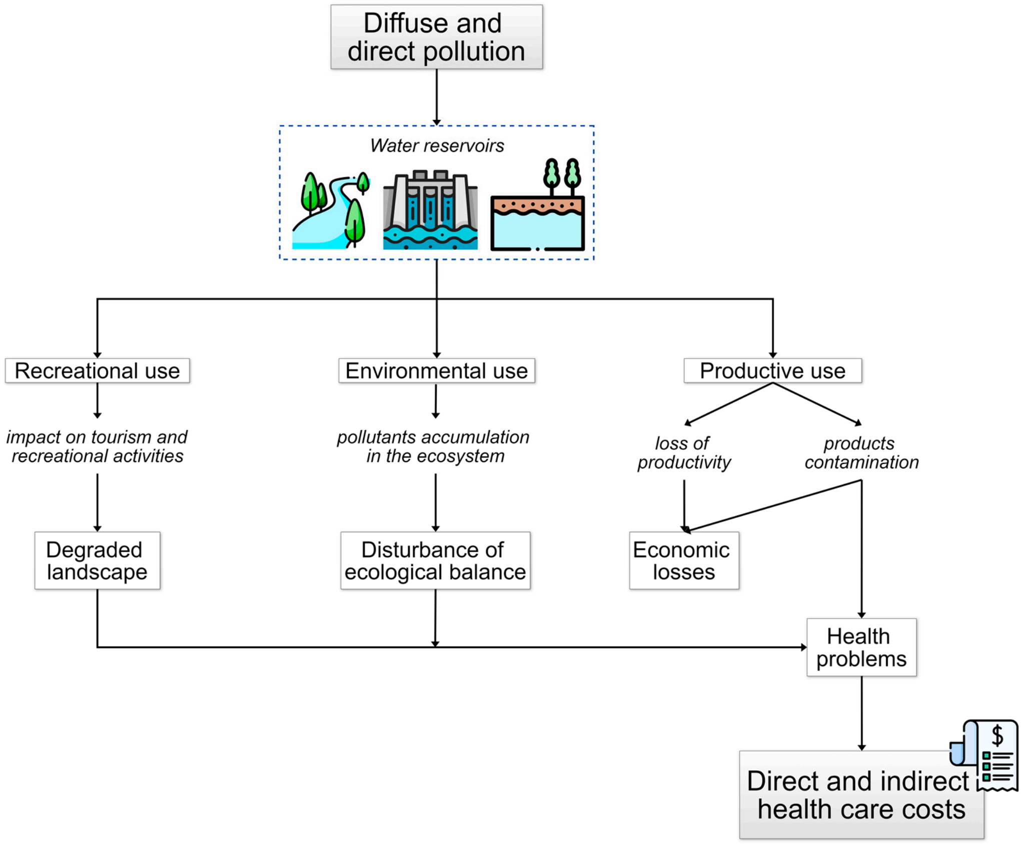

Figure 2. Relationship between impacts on water bodies with direct and indirect costs. Source: own elaboration.

To assess the consequences of not implementing measures to manage water scarcity and pollution, monetary valuation methodologies have been developed [18,19]. Monetary valuation methodologies aim to obtain the economic value of ecosystem damage, acting as a proxy for the environmental benefits of implementing the measures proposed. In this way, non-action costs can be obtained and used in economic and social assessments [20]. These methodologies can provide more complete information for decision-makers to design actions and measures focused on water reuse. Then, the different methodologies available to obtain the monetary value of social and environmental externalities are presented.

2.2.1. Shadow Prices

Shadow prices represent one type of methodology that quantifies the monetary value of externalities lacking reference market value, such as wastewater pollutants (emerging pollutants, for instance). These approaches highlight the positive effects that water-quality improvements have on both the environment and society [21]. This methodology is based on an econometric analysis developed by Färe et al. [22], which applied distance functions to represent the technology used in the production process. Through this, shadow prices can identify the difference between the efficiency of a wastewater treatment plant and its efficiency frontier of reference, which refers to the wastewater treatment plants with the highest efficiency at a specific input level [23,24]. Considering these assumptions, Färe et al. [22] proposed a shadow price formula:

$$r'_m = r^0_m \frac{\frac{\partial D_0(x,u)}{\partial u'_m}}{\frac{\partial D_0(x,u)}{\partial u_m}}$$

where m is the desired output with a market price of r_{m}, and D_0 is the distance function.

One specific implementation of the shadow price methodology within the water cycle consists of considering the water quality. Many water polluting substances are anthropogenic and reach aquatic ecosystems through effluents from wastewater treatment plants. These pollutants are negative externalities of the wastewater treatment process that are not quantified under traditional economic approaches. Through the shadow price approach, the marginal value of reducing the pollutants in effluent is considered to obtain a monetary value of environmental externalities [25]. Table 4 shows the different shadow prices obtained for wastewater treatment plant effluents. Given that shadow prices estimate the marginal cost of pollutants, the shadow price serves as a proxy for the environmental benefit associated with removing these pollutants from the WWTP effluent and improving water quality. The shadow price methodology for effluent pollutants allows environmental externalities to be internalized within the decision-making process.

Table 4. Shadow price values for different wastewater pollutants obtained from the literature.

Pollutant	Shadow Price	Units	Source
Nitrogen	66	EUR /kg	[19]
Phosphorus	264		
Salts (conductivity)	62		[18]
Trimethoprim	0.4	EUR /mg	[8]
Acetaminophen	128.2		
Ibuprofen	11		
Naproxen	3.4		
Carbamazepine	0.6		
Salicylic acid	33.5	EUR /µg	[26]
Methylparaben	24.6		
THCOOH	30.8		

This improvement will achieve economic savings in the short-, medium-, and long-term for all stakeholders by improving their living conditions (increased life expectancy) and ensuring their productivity. Using healthcare costs as a proxy for non-action costs is a novel approach that allows the development and implementation of ambitious measures to improve the population's quality of life through the improvement of water quality.

2.2.2. Contingent Valuation

Contingent valuation is used to identify the preferences of the population towards an environmental or social issue that needs to be changed. Through a survey, researchers create a fictitious market where respondents express their willingness to pay or willingness to accept/to be compensated for different situations. This methodology is suitable to easily obtain a monetary approximation of the importance of the goods and services assessed since it seeks to determine what amount of money would be paid or accepted by the respondent [27]. From an environmental point of view, specifically in the water sector, there are some studies that implement contingent valuation for different purposes [28–33]. From a social point of view, contingent valuation was previously used to identify preferences about health treatments or services [34].

Literature about healthcare issues has used contingent valuation to assess social behaviour in different situations. The consequence of pollution is a real worldwide issue, and some diseases and symptoms are related to pollutant exposure. Mussio et al. [35] assessed the willingness of parents to pay to reduce their child's asthma symptoms. The results highlighted that parents concerned about frequent asthma episodes are often willing to pay more than parents whose children only have a few days per year with symptoms. Wang et al. [36] determined the willingness of farmers in China to pay to implement health risk reductions related to pesticide use. The results demonstrated that educational and training programs are necessary to increase farmers' knowledge about the use of pesticides and risk perception. Contingent valuation has also been used to assess the willingness to pay for environmental and healthcare improvements in territories with pollution problems [37–41]. Regarding the water sector, Deh-Haghi et al. [42] assessed the public willingness to pay and accept water reuse for agricultural uses in Iran. The results highlighted that both the willingness to pay and accept reclaimed water for irrigation were higher when farmers were aware of water reuse processes and quality. As noted previously, educational programs are necessary to inform the population about sustainable alternatives for environmental management.

2.2.3. Choice Experiment

The choice experiment methodology is based on using a survey to assess different hypothetical scenarios involving at least two alternatives with different attributes. Respondents choose their preferred alternative, which represents the alternative with the highest utility. Using choice experiments, researchers can obtain information about the probability of selecting an alternative based on its attributes and the characteristics of the respondents selected [43]. Choice experiments have been used in the environmental literature to assess the impacts of pollution on exposed populations and to explore the importance of environmental conservation from a social point of view. Regarding the impacts of pollution, Rolfe et al. [44] assessed the social perception of meat production by asking about greenhouse emissions. Considering that the attributes of the goods and services analysed are the main advantages of a choice experiment, the authors assessed the interest of the respondents toward the environmental impact of meat production according to greenhouse emissions and animal welfare. The results highlighted that, even though the population had some information about meat production impacts, only changes in prices were able to modify consumers' decisions. Similar to Rolfe et al. [44], Mazzocchi et al. [45] assessed a hypothetical market where the conditions of swine farms and production were modified. The results highlighted that consumers have a preference and willingness to pay for products without antibiotics and for less air pollution with the use of different technologies to remove air pollutants.

The forest is a core area of concern from an environmental conservation point of view. Bruzzese et al. [46] investigated the social perception of forests and the services they provide considering the behavioural patterns of respondents. The results obtained showed a lack of interest regarding the provisioning of forest services but high interest in biodiversity, landscape, and social health related to the presence of such services. Castillo-Eguskitza et al. [47] assessed the social perception regarding the quality of water bodies, agricultural production, forest protection, biodiversity, and recreation at the Urdaibai Biosphere Reserve (Biscay, Spain) under different management scenarios. The results highlighted strong population awareness about supporting new management actions focused on improving and ensuring ecosystem sustainability and improving landscape conservation.

Choice experiments have also been used in studies focused on the water sector. The influence of urban areas on water bodies is a common issue that needs to be addressed. Badura et al. [48] assessed the influence of climate change (heatwaves and floods) in Prague using nature-based solutions to buffer temperature changes. The results showed that respondents were aware of nature-based solutions and their potential to act as natural barriers in case of weather extremes. L'Ecuyer-Sauvageau et al. [49] used the choice experiment method to study the influence of algal blooms in human well-being in Quebec. The excessive use of phosphorus in agriculture is responsible for cyanobacterial blooms along the territory. The results proved that respondents valued recreational activities along the water bodies and were willing to pay to limit the use of phosphorus and reduce algal blooms.

2.2.4. Benefit Transfer

The benefit transfer methodology is based on adapting an economic value obtained for one territory or context to a new territory or context with similar characteristics. This method needs a previous monetary valuation (such as contingent valuation, e.g., shadow prices) to identify both the monetary value of resources and the characteristics of the resources analysed. Through the characteristics of the resource, researchers and decision-makers can determine if the value obtained can be used in the study area [50].

Benefit transfer is used not only to quantify the monetary value of environmental goods and services but also to assess different healthcare scenarios. Herrera-Araujo et al. [51] assessed the impact of reducing the health risk of zoonoses in humans by improving policy measures for livestock management. Zoonosis causes problems in livestock and humans, thereby reducing the incidence in animals by increasing the economic benefits of production. The authors analysed the consequences of zoonosis specifically from a health point of view. If zoonotic disease is reduced, the quality of life of the population will increase. As previously noted, the benefit transfer methodology needs a previous monetary assessment of the target issue to transfer the value to the study area. In the case of Herrera-Araujo et al. [51], the willingness to pay to avoid zoonosis disease was obtained from the United States Department of Health and Human Services. Once obtained, the benefit transfer methodology was implemented in Burkina Faso, Egypt, Ethiopia, Kenya, and Uganda. These findings are important from a policy point of view since they allow decision-makers to design concrete measures to prevent, detect, and control zoonotic diseases, thereby improving the quality of life and life expectancy of the population.

2.3. Quantification of Healthcare Costs Caused by Polluted-Water Exposure and Consumption: Literature Studies

Once the methodology was selected, the results have been assessed to establish the baseline scenario. Considering the data limitations and difficulty of obtaining long-term healthcare costs data, this work presents a literature review of different studies that quantify the healthcare costs of different water pollutants to highlight the importance of health as a vector of human and economic development.

2.3.1. Nitrates

Nitrates are a worldwide pollutant that affect freshwater and groundwater bodies and have increased significantly due to intensive agriculture. Water-polluted consumption has a direct effect on blood oxygen transport, reducing oxygen's presence and increasing the risk of asphyxia (also called methaemoglobinaemia). In addition, long-term exposure to concentrations above 5 mg/L increases the risk of developing certain types of cancer (stomach and colorectal), as well as fertility problems [52,53]. These diseases have associated health costs for governments in affected countries. The data provided by the US National Cancer Institute quantifies the direct cost of cancer treatment related to water-polluted consumption as between 250 million and 1.5 billion dollars. These data indicate that more than 5 million people in the United States were exposed to nitrates in drinking water [52].

The treatment costs of water pollution illness are not the only costs to be considered. A study by Temkin et al. [54] estimated the annual economic losses from the decreased productivity caused by the consumption of polluted drinking water. The results showed that annual economic losses range from $1.3 to 6.5 billion (Table 5), considering that 12,000 cases of colorectal cancer are detected annually in the United States. It should be noted that the United States has a high level of groundwater consumption from private wells (about 12–24%) where there is no control over nitrate levels. Considering both the exposed population and water consumed from private wells, the healthcare costs to address colorectal cancer in the United States are between $157 million and $1.3 billion per year. The authors highlighted that population ageing and medical treatment improvements will increase the annual costs for colorectal cancer treatment by 27–39% in subsequent years.

Table 5. Cancer cases, costs from the loss of productive activities, and medical costs related to water-polluted consumption with nitrates in 2014 [54].

Cancer Type	Cancer Cases Attributable to Consumption of Water with Nitrates	Economic Losses Due to Loss of Productive Activity (Billions of Dollars)	Medical Costs of Healthcare Treatment (Billions of Dollars)
Colorectal	24,479	11.56	3.13
Ovaries	690	0.56	0.13
Thyroid	1416	1.15	N/A
Kidney	454	0.25	0.06
Bladder	134	0.03	0.01

The results obtained by Temkin et al. [54] are significant because they reveal the economic impact on the population that the consumption of nitrate-polluted water has within a territory. These results highlight the need to monitor the levels of nitrates in aquifers while ensuring the availability of data to keep the population informed. High levels of nitrate mean that the aquifer cannot be used, and the administration should ensure alternative water sources to meet demands. Investments to monitor nitrate levels and implement new technologies for reducing nitrates in drinking water were justified by the healthcare costs obtained. Healthcare costs provide a strong argument to implement sustainable solutions in order to preserve the integrity of freshwater bodies, such as the management of agricultural runoff and the modification of fertiliser types, as well as the promotion of different water sources to meet demands [55].

2.3.2. Pesticides

Pesticides are substances used worldwide to ensure agricultural productivity. However, their high toxicity jeopardises the water ecosystem's balance and use for human purposes. Although these substances are regulated by current legislation, their widespread use and chemical persistence are responsible for population exposure, both directly (i.e., farmers or industrial workers) and indirectly (i.e., the overall population that consumes food and water polluted by agricultural runoff). This exposure generates effects within the population, including acute toxicity, carcinogenicity, reproductive and neurodevelopmental disorders, and endocrine disruption [56].

The work of Bourguet and Guillemaud [57] highlights the need to consider both the direct and indirect costs of pesticide-related illness. This quantification depends on the social context in which the illness develops. For instance, in the case of a farmer, the indirect costs correspond to the worktime lost during and after the accidental poisoning. Indirect costs also involve the recovery time after diagnosis, when the patient cannot engage in any working activities. Hence, recovery time represents a loss of economic productivity, which is the main consequence of pollution exposure. To this cost, we must add the loss of productivity associated with family members who are responsible for the care and recovery of the patient. This study shows that assessments of the health and economic effects of pesticide exposure have mostly focused on acute poisoning episodes. This scenario is important as it causes severe short-term health problems with a correspondingly high economic cost to the population. However, the long-term effects of pesticide exposure (such as cancer, diabetes, depression, and blindness) are not considered because of the complexity of both long-term effects monitoring and the nexus between the pollutant and the disease. This situation hampers the non-action cost assessments and feasibility studies of new measures and technologies.

Ngowi et al. [58] analysed the use of pesticide and their influence on farmers' health and costs in Tanzania. This study revealed that 61% of farmers surveyed did not spend money on consultations related to the physical consequences of pesticide use, although they were aware about the dangers of such substances. This situation highlights the need to implement campaigns at a local level to inform the population about the risks of pesticide use and exposure. At the country level, the work of Pretty et al. [59] quantified the total annual social cost of pesticide exposure in agriculture in the UK at $134 million per year. In the case of the United States, annual health costs due to pesticide exposure have been quantified at $1.1 billion per year [56]. This value considers the exposure of both farmers and their families.

2.3.3. Metals

Worldwide intensive industrial and mining activities are responsible for a wide range of environmental impacts and health problems produced by metals. Environmental regulations consider metals (such as cadmium, chromium, and lead) as high-risk substances in ecosystems because they are absorbed and accumulate in bodies. As with other worldwide pollutants, metals are difficult to monitor because there are many activities that lead to their discharge in surface and groundwater [60,61].

Cadmium

Cadmium is a toxic metal typically detected in mining areas. If it is not properly managed, cadmium can enter rivers and poison the population, leading to the itai-itai disease. This disease, which was detected in Japan, causes softening of the bone, kidney failure, and renal dysfunction. The work of Maruzeni et al. [62] presented a 26 year follow-up survey targeting 7529 inhabitants of the Jinzu River basin polluted by cadmium and 2149 controls from non-polluted areas who participated in urinary examinations between 1979 and 1984. The results highlighted that the mortality risk ratios for all causes (including cancer) in men and women of the polluted areas were significantly higher than those of populations that lived in non-polluted areas. Considering these findings, the inhabitants of polluted areas have both poor life expectancy and poor quality of life.

Chromium

Tanneries use a high water volume to tan leather and metals such as chromium, which is toxic to the population and individual organisms. This high water volume needs to be treated before being discharged into ecosystems. However, this treatment is not always carried out, leading to serous environmental impacts with consequences for the exposed population [63]. Specifically, the work of Yoshinaga et al. [64] assessed the presence of Cr(VI) and Cr(III), the main forms of chromium, in the Buriganga river (Bangladesh). Buriganga is used as a water supply but receives wastewater from tanneries. The results highlighted that the presence of both forms increased the carcinogenic risk of water. Specifically, Cr(VI) is more dangerous than Cr(III); however, when both are present in water, a synergic relationship is created, and Cr(III) increases the carcinogenicity of Cr(VI). It is necessary to manage wastewater from tanneries to reduce the environmental impact of metal accumulation and guarantee drinking water safety.

Metal accumulation in humans is a worldwide problem that affects the quality of life of the entire population. The work of Tseng et al. [65] assessed the health costs of Cr(VI) detected in water in the Wu river watershed in Taiwan. Assessing a watershed is difficult due to the different environmental conditions along the area. Furthermore, not all territory is focused on the same activities. For this reason, the authors identified different levels of Cr(VI) in the watershed. Despite this result, this work approximated the healthcare costs of chromium exposition in the water supply. Considering that Cr(VI) has high carcinogenetic potential, the authors quantified the health costs in terms of life loss expectancy and medical expenditures. The results showed that the loss of life expectancy is quantified as 1162–1337 USD million/year, and the medical costs of treatment are 6.45 USD million/year.

Lead

The presence of lead in drinking water is due to the pipes and plumbing production themselves. Ancient water distribution systems were made with lead materials, without considering if lead would be stable over time. Depending on the corrosivity of the water (i.e., the chloride level), lead can be released from pipes. Drinking water with a high level of chloride has high corrosive potential and releases lead into the water. From a health point of view, lead is a potent neurotoxin that affects many developmental and biological processes in childhood [66]. In childhood, lead exposure from drinking water is dangerous since children can absorb between 40 and 50% of the oral dose intake [67]. Lead pollution in drinking water systems is an ongoing issue because not all plumbing and lead pipes have been changed. Between April 2014 and October 2015, around 100,000 inhabitants in the City of Flint (Michigan) were exposed to high amounts of lead in drinking water, leading to a state of emergency in December 2015 [68]. Health damage among children and adults was significant [69]. As a response to this situation, the US Government approved funding for water infrastructure improvements. However, the cost of the full replacement of water distribution infrastructure is high (between $100 and $120 million, according to [68]). Specifically, studies have quantified that the total cost to replace the US's drinking water system to remove lead pipes and plumbing, restore system failures, and expand the water network to ensure the drinking water supply would total around $1 trillion by 2035 [70]. Here, the monetary valuation of social and environmental externalities becomes relevant, such as healthcare costs as a proxy for non-action costs. Such values help decision-makers consider the high benefits that preventive and corrective measures have on the population and environment. The literature has shown that the healthcare costs of lead poisoning are between $11 and $53 billion [71], which is in line with the results obtained by Landrigan et al. [72], where the annual lead poisoning costs in the US were quantified as $48.8–$64.8 billion. These values reflect the importance of increasing investments in controlling and preventing lead pollution in water to preserve childhood health.

2.4. Other Pollutants to Consider

Calculating the direct and indirect costs of healthcare treatment and recovery time has not been widely addressed in the literature due to the difficulty of obtaining long-term data about healthcare costs. Table 6 summarizes the annual healthcare costs related to exposure to different pollutants in air, food, and water [16].

Table 6. Annual costs of population exposure to different types of pollutants, considering costs related to both healthcare and loss of quality of life. Adapted from [16].

Type	Pollutant	Disease	Economic Cost ($billion/Year)
Neurotoxicants	Lead exposure	Cognitive deficits	876.7–1373.5
	Methylmercury [a]		13.8–16.9
	Polybrominated diphenyl ethers [b]		135.08–396.4
Air pollutants	N/A	Asthma in European Union	0.568–1.98
		Cardiovascular problems	24.47–49.83
Endocrine disruptors	Aldrin [c], bisphenols [d], dichlorodiphenyltrichloroethane (DDE) [e], lindane [c], organic and inorganic mercury, organophosphates [f], polybrominated diphenyl ethers [b], and phthalates [d]	Childhood and adult obesity, testicular cancer, male infertility, and mortality associated with reduced testosterone, fibroids, and endometriosis	110–359

[a] Methylmercury reaches humans through food, specifically by eating large fish, which bioaccumulate large amounts of this metal in the aquatic environment. [b] Polybrominated diphenyl ethers are used as chemical flame retardants. [c] Insecticide. [d] Chemical substance mainly used in combination with other substances to manufacture plastics and resins—present in shampoos, lotions, and personal care products in general, as well as in plastics for food and other industrial plastics [73]. [e] Byproduct arising from the degradation of DDT (insecticide). [f] Insecticides, medications, and nerve agents.

2.4.1. Neurotoxicants Such as Lead, Methylmercury, and Polybrominated Diphenyl Ethers

Industrial pollution has caused several environmental and health issues since the Industrial Revolution. Currently, some territories of the USA and Europe are implementing different policies to control and prevent chemical pollution to ensure a suitable environment for the population and ecosystem. Most of the chemicals produced in industrial processes and products produce cognitive deficits in infants and children since they modify the normal development of the brain [74]. Previous studies reported the cost of illness related to neurotoxicant pollution in the exposed population [75–77]. Such chemicals are toxic substances present in the air, food, and water that are not easily controlled by the population itself. The work of Gaylord et al. [12] highlighted that methylmercury in the United States is not properly regulated since coal-fired electric power facilities are the main source of this pollutant, and corresponding environmental regulations stopped in 2011. Consequently, there are some plants still operating and maintaining population exposure along with the risk of neurodevelopment impairment and loss of intelligence quotient in young children. Accordingly, a policy framework is being developed to reinforce the necessity to remove substances created anthropogenically.

2.4.2. Air Pollution

Air pollution is a worldwide problem that produces several impacts on populations from healthcare, urban, and mobility perspectives. Air pollution is mainly produced by combustion processes such as traffic, coal-fired power plants, agricultural production, and forest fires, among others [78]. The scope of the problem is serious since the impacts of such pollution are long-term and chronic. According to WHO recommendations, exposure to only 10 $\mu g/m^3$ of PM2.5 would add 22 months to one's life expectancy, delaying around 19,000 deaths [79]. However, complying with the corresponding regulations is difficult, and populations are still exposed to high levels of air pollutants. The main consequences to the exposed population are respiratory (asthma) and cardiovascular diseases, mainly in the short-term, and premature death with long-term exposure [80–82]. There are also consequences for pregnancy [83,84] and prenatal issues such as preterm births and low birth weights [85]. Issues also emerge at school age [86]. Considering this information from an economic point of view, the literature highlights the importance of ensuring suitable air quality by identifying the healthcare benefits of increasing the quality standards of urban air [87–90]. These results reinforce the need for changes to urban mobility and air pollution control (such as eco-friendly transport and increasing green urban areas) to ensure population well-being and health.

2.4.3. Endocrine Disruptors

Endocrine disruptors are substances that contribute to certain forms of disease and disability, mainly focused on the hormonal functions of organisms and their progeny. Endocrine disruptors not only affect the reproductive stage of the population (infertility and endometriosis) but also produce cognitive disfunction, childhood and adult obesity, testicular cancer, and mortality related to testosterone reduction and fibroids [91]. Endocrine disruptors are substances used in a wide variety of products at different levels (agriculture, plastics, electronics, and food, among others), making it difficult to reduce exposure. The European Union has implemented measures to regulate endocrine disruptors through REACH legislation (Registration, Evaluation, Authorization, and Restriction of Chemicals) and specific regulations governing pesticide and biocide use. All these regulations have an impact on industry because chemical levels need to be monitored and reduced, entailing monetary investments. Nevertheless, a clear social benefit in terms of reducing disease risk is generated through such investments. For instance, healthcare savings in Canada if exposure to polybrominated diphenyl ethers were reduced would total $276.5 billion/per capita, which correspond to the costs of intelligence quotient loss and intellectual disabilities [92]. In the case of the United States, the results of polybrominated diphenyl ether regulation have been revealed through costs savings data related to intelligence quotient loss. Data from 2001 reported $190 billion in treatments, but in 2016, this value decreased to $38 billion. Reducing exposure to polybrominated diphenyl ethers has generated $153 billion in economic benefits, which represents a significant improvement to quality of life in childhood [12]. The healthcare costs of other endocrine disruptors have also been assessed in the literature [93–96].

The values included in Table 6 highlight that non-action costs entail a high social impact, which could be avoided through the implementation of specific management measures that would provide significant social benefits. These measures must be adjusted to (i) the specific needs of the territory, (ii) the matrix in which the pollutant is found (surface water, aquifer, air, or soil), and (iii) the risk level or exposure that is affecting the population. In the case of water pollutants, identification of the pollution sources is essential to develop new measures. However, diffuse pollution is difficult to identify and avoid. To reduce the risk level of water-polluted consumption, it is recommended to implement on-site measures that allow the population to be supplied at a lower cost. For instance, to avoid water-polluted consumption, filters could be installed to retain nitrates and lead at the outlets of wells [97]. Such measures, in addition avoiding the economic and the healthcare costs mentioned above, would yield a reduction in the cost per family, as it would no longer be necessary to buy bottled water for cooking and washing.

This reduction in household expenditures to access a safe water source has clear social and environmental benefits, not only in terms of healthcare, but also in terms of household costs. Misopoulos et al. [98] determined the environmental impacts of both water bottling and distribution through the assessment of greenhouse gas emissions during the entire process. The average emissions for a bottling plant that produces 8000 bottles/hour total 87,147 tonnes (data for the year 2019). Considering that the price of CO_2 emissions is quantified at EUR 61.13/tonne (October 2022), the environmental cost of CO_2 is quantified at 5.3 million euros. The population that consumes bottled water produces a carbon footprint that can be also quantified. According to Botto et al. [99], consuming a volume of 1.5 L of bottled water has a carbon footprint of 163.50 kg of CO_2 compared to 0.34 kg of CO_2 for tap water consumption.

These studies have been collected as a starting point for new research to establish both the non-action costs and social impacts of the current water pollution scenario and the positive impacts of implementing new measures on population health. Healthcare costs are useful from a policy point of view since diseases and symptoms caused by pollution produced through human actions could be avoided by designing new stringent measures and boosting new investments in the water sector. Future research should focus on assessing the healthcare costs of water pollution in specific areas where water scarcity and pollution problems threaten the drinking-water supply. Once these healthcare costs are identified, they will be included in economic feasibility studies to assess in detail the social benefits of water-quality improvement projects and water reuse implementation.

3. Conclusions

Diffuse pollution is a worldwide social and environmental problem due to the high variety of pollutants from agricultural, livestock, and urban runoff flows. From a social point of view, the healthcare costs caused by exposure to pollution need to be considered as part of feasibility studies and decision-making processes for new water management measures. Specifically, health problems have high treatment costs and economic losses due to the loss of productivity that must be quantified to identify the social impact of the current situation. Identifying non-action costs is a complex task, given the difficulty of understanding the nexus between pollutants and diseases in the short-, medium-, and long-term. This work assessed the current state of healthcare costs through different examples where healthcare costs have been assessed.

From a water management point of view, healthcare costs were proposed as a proxy for the non-action costs of water pollution in population. In this way, water managers can identify a baseline scenario where no measure is implemented to correct the situation.

Quantifying healthcare costs is a difficult task due to the long-term impacts of diffuse pollution on the population. However, considering healthcare costs as a baseline scenario of future savings in population health is a clear advantage in social policies. This baseline scenario is useful to assess the improvements of the new measures proposed. This framework is a novelty in the literature since, to date, healthcare costs have not been related to non-action costs. Through the results of the articles assessed in this work, the healthcare costs of water-polluted diseases and their nexus with water management and water reuse potential can act as an effective tool to understand and analyse the social impact of water pollution, highlighting that population health is an essential part of feasibility assessments and should not be ignored.

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