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Assessment of The Environmental and Human Health Impacts of Plastic Additives Used in Plastic Manufacturing in Vietnam

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Abstract: The plastics manufacturing industry in Vietnam has expanded rapidly, reaching nearly 11.13 million tons by 2025, leading to the widespread use of additives such as phthalates, bisphenols, flame retardants, heavy metal stabilizers, etc. Although these substances improve the properties of plastic products, they pose serious risks to the environment and human health. This study surveys the current status of plastic additive use in Vietnam, classifies the main types of additives, examines their emission mechanisms into the environment through production, use, and disposal stages, and assesses their impacts on air, soil, water, and human health. The results show that plastic additives can be emitted through industrial emissions, waste incineration emissions, leachate, microplastics, and indoor dust; leading to environmental pollution, bioaccumulation, and human exposure through inhalation, ingestion, and skin contact. The study also proposes several management solutions, alternative technologies, and policies, such as applying green chemistry, regulating the concentrations of toxic substances, ensuring transparency in the chemical composition of plastic products, and improving the collection and recycling of plastic waste. These measures aim to minimize the use of toxic additives, thereby limiting negative impacts on the environment and public health.

Keywords: Bisphenol A, environment, human health, phthalates, plastic additives.

1. INTRODUCTION

Currently, Vietnam's plastic market is projected to reach approximately 11.13 million tons in 2025, with more than 7,000 enterprises participating in the sector. The market is forecast to grow at a compound annual growth rate (CAGR) of 8.40% over 2026-2035, reaching an estimated 24.93 million tons by 2035 [1]. The plastics industry is increasingly consolidating its position as one of Vietnam's key industrial sectors.

Vietnam has strong production capacity across various plastic product segments, including packaging, consumer plastics, construction plastics, and high-performance engineering plastics, such as oil pipelines and plastic components used in automobiles and computers. The packaging segment accounts for the largest share, representing approximately 39% of total plastic output, followed by consumer plastics (32%), construction materials (14%), technical plastics (9%), and other sectors (6%) [2].

However, most plastic products require additives to improve their mechanical and chemical properties. According to international studies, more than 13,000 different chemicals can be present in plastics, including monomers, processing aids, and additives; of which more than 7,000 are considered hazardous, and 3,200 are harmful chemicals to health and the environment [3]. Common groups of these substances include phthalates, bisphenols, halogenated flame retardants, antioxidants, and heavy metal stabilizers (cadmium, lead, barium, etc.). Plastic additives are found in the air, wastewater, freshwater, seawater, soil, and in the human food chain, causing toxicity.

In Vietnam, as the plastics industry develops rapidly (production reaching nearly 11.13 million tons by 2025), the use of these additives is also increasing. The rapid expansion of the plastics industry in Vietnam has led to significant environmental and public health challenges, driven by the widespread use of toxic chemicals such as phthalates, bisphenols, and flame retardants throughout the plastics product lifecycle. Therefore, research and evaluation of additives used in plastics production in Vietnam are necessary to identify risks and propose mitigation measures.

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Research article

Table 1. Some typical plastic manufacturing companies in Vietnam by plastic product segment.

No.	Company	Design capacity	Products
I. Construction plastics			
1	Tien Phong Plastic Joint Stock Company	260,000 tons/year	Plastic pipes and pipe fittings PVC, PP, HDPE
2	Binh Minh Plastic Joint Stock Company	150,000 tons/year	PVC, PP, HDPE
II. Packaging			
3	An Phat Xanh Plastic Joint Stock Company	108,000 tons/year	PE plastic packaging, thin film
4	Bien Hoa Packaging Joint Stock Company	100.000 tons/year	Flexible plastic packaging, industrial packaging
III. Consumer plastics			
5	Duy Tan Plastic	116,000 tons/ year	PET bottles, plastic containers, household goods, packaging
6	Song Long Plastic	Large scale in the North	Household appliances, plastic containers, household items
IV. Technical plastics			
7	Dong Asia Plastic Group Joint Stock Company		Electronic plastic componen, technical packaging

Source: Vietnam Plastics Association.

2. RESEARCH METHODOLOGY

This study was conducted as a qualitative review combined with a pilot survey of the Vietnamese plastics industry. Specifically, we synthesized documents from various sources and collected data from businesses to describe the overall picture of plastic additive use and preliminarily assess the associated risks.

2.1. Selection of sources

We used scientific databases and Vietnamese libraries based on keywords. The search focused on the period 2010–2025. Selection criteria included scientific publications related to plastic additives, environmental and health impacts, and a preference for data collected in Vietnam or Southeast Asia. Official reports (Ministry of Agriculture and Environment, Institutes, etc.) were also considered.

2.2. Field survey

Survey sample: A convenience sampling method was applied. The representative plastic manufacturing companies (main products: PVC pipes, PE granules, PVC household items) were selected to cover a diverse range of sizes and technologies. Criteria: companies with large production volumes, representative of commonly used additives (plasticizers, flame retardants).

Data collection tools: A combination of self-completion questionnaires and interviews with technical leaders. The questionnaire included questions about the type of additives used (name, estimated content) and management and safety measures. Interviews clarified the production process, control standards (if any), and verified information from the questionnaire. The survey was conducted in January–March 2025.

Data processing: The collected data was compiled, qualitatively analyzed, and used to illustrate the results.

2.3. Simple quantitative risk assessment

To assess the risks associated with additives, we use basic quantitative indicators:

(i) Hazard Quotient (HQ) assesses the risk to humans:

$$HQ = EDI/RfD \quad (1)$$

where EDI (Estimated Daily Intake) is the estimated exposure dose (μg/kg-body weight/day), RfD is the reference dose (μg/kg-body weight/day) of each chemical (e.g., DEHP, DBP) obtained from an agency (EPA, WHO). For example, EDI through drinking water is calculated using the formula:

$$EDI = (C \times IR)/BW \quad (2)$$

with C being the concentration (μg/L), IR being the daily water consumption (L/day), and BW being body weight (kg) (adult BW=60 kg, IR=2 L/day).

(ii) Risk Quotient (RQ) for environmental ecological assessment:

$$RQ = PEC/PNEC \quad (3)$$

where PEC (Predicted Environmental Concentration) is the observed concentration (e.g., in water/sediment), PNEC is the ecologically safe limit concentration (refer to ecological literature or calculations).

HQ, RQ rating scale: <1: safe; = 1: threshold; >1: risk.

3. SURVEY OF THE CURRENT STATUS OF ADDITIVE USE IN PLASTIC PRODUCTION IN VIETNAM

3.1. Plastic additives and their role in the plastics industry

In most plastic products, the base polymer is formulated with a range of chemical additives to produce a plastic compound with enhanced performance. These additives improve processability during manufacturing (e.g., injection moulding, extrusion, blow moulding, vacuum forming) and the functionality and ageing resistance of the final material. Common additives used in polymeric packaging include plasticizers, flame retardants, antioxidants, acid scavengers, light and heat stabilizers, lubricants, pigments, antistatic agents, slip agents, and thermal stabilizers. Each additive serves a specific function in optimizing the final properties of the plastic product. Globally, an average plastic product contains around 20 different additives to achieve desired technical and functional requirements.

Overall, plastic additives are commonly classified into

Table 2. The main additives used vary depending on the range of plastic products.

Products	Polyme	Production technology	Main additives	Representative substance
Packaging	PE, PP, PET	Extrusion blow moulding Blown film extrusion	Plasticizers, antioxidants, UV stabilizers, antistatic agents, lubricants, pigments	Phthalates (DEHP, DBP), BHT, Irganox, benzophenone, HALS, erucamide
Construction	PVC, PE, PP, HDPE	Extrusion moulding	Heat stabilizers, plasticizers, flame retardants, fillers, foaming agents	Ca/Zn stabilizers, organotin, DINP, DIDP, brominated flame retardants (PBDEs), $CaCO_3$
Consumer	PP, PS, ABS, PVC	Injection moulding	Antioxidants, pigments, flame retardants, UV stabilizers, antimicrobials	BHT, pigments (TiO_2), PBDEs, benzotriazoles, triclosan
Technical	PP, PU, PVC PA, POM, ABS, PBT	Injection moulding	Flame retardants, reinforcing agents, thermal stabilizers, lubricants	BPA (trong PC), BFRs, phosphate flame retardants, glass fiber, PTFE lubricants

four main categories: (i) functional additives (e.g., stabilizers, plasticizers, flame retardants, lubricants, curing and foaming agents, biocides), (ii) colorants (pigments and soluble dyes), (iii) fillers (e.g., mica, talc, kaolin, calcium carbonate, barium sulfate), and (iv) reinforcements (e.g., glass and carbon fibers) [4].

The main problems related to additives stem from the fact that many are currently under review by environmental health agencies, such as the US EPA, Environment Canada, ECHA, etc. [5], and some additives are not regulated under current environmental regulations. Furthermore, it is difficult to obtain detailed information about additives, such as quality, content, type, etc., on the label of the final product. Therefore, manufacturers should provide more transparent information to facilitate a better understanding of additives and their release from the parent material. Although additive concentrations typically range from 0.001% to 50% by weight (w/w) of the final product [6], this data is not available in most cases.

These additive groups play a crucial role in expanding the use of plastics across many industries and, at the same time, can be a source of chemical releases throughout the product lifecycle if not properly controlled.

3.2. Current status of additive use in the Vietnamese plastics industry

Vietnam has a number of plastic resin factories with a capacity of hundreds of thousands of tons per year. However, domestic raw material supply only meets about 20% of the demand, the rest depends on imports. In the production and processing of plastics, additives are added in significant amounts. According to UNEP [3], plasticizers can account for up to 50–70% of the weight of input materials, the proportion of flame retardants used in the entire Vietnamese plastics industry can be in the range of 2–8%, and the proportion of heavy metal stabilizers (lead, cadmium) can reach 0.02–2% depending on the technology. These figures show that the use of additives is widespread, posing significant risks if not well controlled.

Some typical plastic manufacturing companies in Vietnam, categorized by plastic product segment, are shown in Table 1.

Different plastic product lines have distinct characteristics in terms of raw materials, manufacturing technology, and additives used. Table 2 shows the main additives used according to plastic product lines.

According to the research group's survey, plastic factories in Vietnam are currently also using plastic additives in quite large quantities, depending on the type of production.

SIK Vietnam Co., Ltd. specializes in the production of colored plastic granules, primarily using a mixing, heating, cutting, and sieving process. The company's factory uses virgin plastic granules (polycarbonate (PC), acrylic butadiene, styrene, ABS, PC/ABS, etc.) as raw materials, accounting for approximately 40-95%; additives and dispersants (glass fiber, metallized aluminum, etc.) accounting for approximately 5-59.9%; and colorants (Yellow 5950, brown 24, carbon black, etc.) accounting for approximately 0.1-5%. Based on the factory's 2024 production capacity of 34,292 tons per year, the amount of chemical additives used would be approximately 1,700-20,000 tons per year.

Tien Phong Plastic Joint Stock Company specializes in producing PVC, PEHD, and PPR plastic pipe products with a production capacity of 260,000 tons/year, using

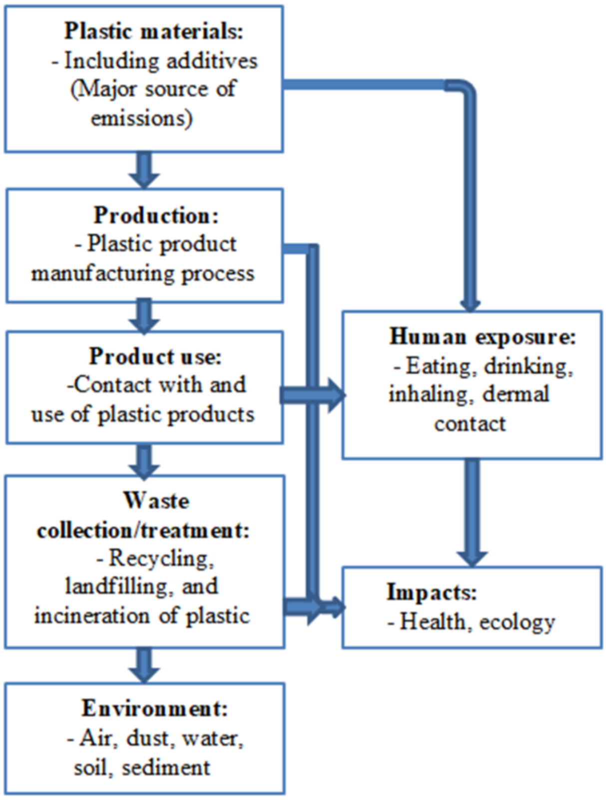

Fig. 1. Diagram of the emission pathways and impacts of plastic additives.

two technologies: injection molding and extrusion. The company uses raw materials such as PVC, PE, PP, PPR, ABS, and additives including heat stabilizers, processing aids, inner and outer lubricants, UV inhibitors, etc.

According to UNEP (2023) [3], additives such as phthalates, bisphenol A, flame retardants (brominated, chlorinated), and metal-containing stabilizers have been and are being widely used in plastic production in Vietnam. Domestic studies show that Vietnam currently lacks a comprehensive monitoring system for the levels of these substances in plastic products or the environment. For example, in the children's toy sector, surveys by authorities have shown that imported PVC toys contain very high levels of phthalates (measured levels have reached several thousand mg/kg). Currently, Vietnam has not issued specific limits on phthalates in plastic products related to children or food contact. In general, toxic additives are still widely used, but there has been no comprehensive assessment of their dosages or specific types in the Vietnamese plastics industry.

4. IMPACT ON THE ENVIRONMENT AND HUMAN HEALTH

4.1. Mechanism of additive release into the environment

Chemical additives can migrate within the polymer substrate, diffuse to the surface, and disperse into surrounding environments, such as water, soil, food, and other receiving environments [4]. The release of these additives raises significant concerns about potential impacts on organisms, including humans. Additives in plastics can be released into the environment through several stages:

During production: The synthesis and processing of plastics often release volatile organic compounds (VOCs) and toxic intermediates. During the production stage, many hazardous substances such as vinyl chloride (in PVC), styrene (in polystyrene), bisphenol (in polycarbonate),… can be released into the air and wastewater. These emissions include smoke, dust, and solvent vapors containing additives that can directly affect the surrounding ecosystem.

During product use: When plastic products are used, additives that are not covalently bonded to the polymer can slowly leach out. For example, phthalates and bisphenols can diffuse from plastic materials into the surrounding environment (house dust, contact surfaces, food, or drinking water) even under normal conditions. Products such as packaging, cosmetics, and household items can release additives like phthalates, which are linked to health hazards such as asthma, reduced sperm quality, and developmental toxicity in children. Additionally, damage, scratches, or exposure to heat and light accelerate the release of additives.

During disposal: At the end of its life cycle, plastic is released into the environment through various pathways. Uncontrolled burning of plastics, such as incineration of household waste, releases additives and combustion products into the air (including phthalates, dioxins, furans, bromides, etc.), polluting the atmosphere and causing respiratory consequences. Landfilling and settling of plastic waste, both household and industrial, generate leachate containing additives that, over time, can seep into the soil and groundwater, leading to widespread pollution. Microplastic particles generated from the decomposition of debris also contain additives and are distributed throughout the soil, water, and air environments.

Figure 1. illustrates the emission pathways and impacts of plastic additives. Additives from plastic materials move into the environment mainly through diffusion, influenced by factors such as the polymer's porosity and thickness, the molecular weight and hydrophobicity of the additive, the characteristics of the receptor, and weathering and aging of the material [7].

Studies have shown that weathering can significantly increase the rate of additive leaching from the polymer matrix [7]. During the aging phase of the polymer, the cleavage of polymer chains degrades the material's structural integrity, thereby promoting the release and leaching of additives into the surrounding environment [8]. The entire process of leaching additives from the polymer matrix is described and controlled by Fick's law, including mechanisms such as diffusion, desorption, adsorption, and adsorption/dispersion [7]. In general, the diffusion rate of chemical additives depends on the concentration gradient, with diffusion occurring from the high-concentration region to the low-concentration region, and the diffusion rate increases with the concentration gradient [6].

4.2. Environmental impact assessment

In the Vietnamese context, the "Source-to-Sea" pathway plays a critical role in transporting plastic additives from terrestrial sources to marine environments. Coastal industrial hubs such as Hai Phong, which host dense plastic manufacturing activities and port operations, represent significant emission hotspots. Additives released from production processes, industrial wastewater, urban runoff, and mismanaged plastic waste can enter river systems such as the Cam and Lach Tray rivers. These riverine systems act as major conduits, transporting contaminants into estuarine and coastal waters.

Along this pathway, plastic additives may undergo partitioning between dissolved phases, suspended particles, and sediments, or become associated with microplastics, enhancing their persistence and mobility. Once in the marine environment, these substances can accumulate in sediments and biota, posing risks to marine ecosystems through bioaccumulation and trophic transfer. This land–sea connectivity highlights the importance of integrated environmental management approaches that consider the full lifecycle and transport pathways of plastic additives from source to marine receptors.

Plastic additives negatively affect air, soil, and water quality.

Emissions from plastic production and incineration contain many toxic volatile organic compounds. VOCs and halogenated compounds produced from burning PVC or plastic production can cause cancer, endocrine disruption, and birth defects. In addition, research in Vietnam measuring phthalate concentrations in indoor air in northern cities showed that the average concentration of total phthalates ranged from 106 to 16,000 ng/m³ (average: 1040 ng/m³). Diethyl phthalate (DEP) was found at the highest concentration in indoor air, ranging from below the method's quantification limit (MQL) to 12,400 ng/m³ (average: 376) [9]. High concentrations of phthalates in the air lead to significant respiratory exposure. The average inhaled exposure dose for phthalates calculated for infants, toddlers, children, adolescents, and adults was 780, 485, 416, 292, and 213 ng/kg body weight/day, respectively [9]. Air pollution from phthalates and other additives contributes to increased respiratory problems and may pose long-term health risks.

Phthalates and many other soluble additives can enter the soil through leachate and microplastic particles. When plastics decompose or are burned, their additives can diffuse into agricultural soil and soil ecosystems. Studies show that phthalate residues have been detected in sediments and soil in many parts of the world, as predicted for Vietnam. High concentrations of additives in soil can affect soil microorganisms and plants, and they can be transmitted into the food chain.

Several phthalate isomers in plastic have been detected in soil and indoor dust, and their concentrations are much higher near e-waste recycling sites. PAE (phthalate ester) concentrations in soil at e-waste recycling sites and plastic waste dumps in India were 396 and 93 ng/g, respectively [10]. The release of different PAE isomers during e-waste recycling may be the main cause of such high concentrations. At an e-waste recycling site in China, concentrations of BDE209 (brominated diphenyl ether, or PBDE) were 30,446 and 718 μg/g in plastic debris and soil, respectively [11], clearly indicating the rapid release of plastic additives from the original plastic material into the environment.

Most of these chemical additives are persistent, meaning they are not easily degraded in the environment. The presence of these persistent additives can affect the biodegradability of plastics [12]. Therefore, the characteristics of plastic additives, such as quantity, composition, and concentration, are particularly important in determining the ecotoxicity of plastics. These additives pose a serious threat to organisms because their concentrations in the original plastic are higher than those of other environmental pollutants absorbed into the plastic [4]. However, the environmental risks associated with these additives remain poorly understood, largely due to insufficient information on plastic additives.

Phthalates, bisphenol A, and other chemicals from plastics are discharged into surface and groundwater. A recent study in Vietnam identified more than 60 organic micropollutants (OMPs) in northern groundwater, including chemical plastics and flame retardants that were frequently detected [13]. This demonstrates that Vietnam's water sources are currently at risk of pollution from plastic additives. These substances can accumulate in aquatic organisms, causing declines in biodiversity and the risk of re-entering the human food chain.

According to the research results of Thuy Minh Le et al. [14], ten typical phthalic acid esters (PAEs) were studied in different water samples collected from the urban area of Hanoi, Vietnam. The results showed that the PAE concentrations in lake water and wastewater were measured in the range of 19.6–127.0 μg/L (mean/median: 51.8/49.3 μg/L) and 20.7–405.0 μg/L (mean/median: 121.0/115.0 μg/L), respectively. Among the PAEs, di-(2-ethylhexyl) phthalate (DEHP) accounted for the largest proportion of the total concentration (45%) in wastewater, followed by diisobutyl phthalate (DiBP, 10.3%) and dibutyl phthalate (DBP, 9.53%).

The PNEC value of DEHP in lake water is (National technical regulation on Surface water 8 μg/L quality QCVN 08:2023/BTNMT); in wastewater it is 20 μg/L (National Technical Regulation on Industrial Effluent - QCVN 40:2025/BTNMT - column A).

Applying the formula RQ = PEC/PNEC shows that the RQ >1 indicates high risk.

Plastic additives have also been detected in freshwater sources, including rivers and lakes worldwide. Polybrominated diphenyl ethers (PBDEs) have been found in freshwater sources in the Han River in China at concentrations of 2.30–5.0 μg/L [15]; and the Zhujiang River Estuary in China, 26.10–156.90 μg/L [16]; and Shihwa Lake in Korea, 0.16–11 μg/L [17]. Phthalate esters have been detected in Lake Asan, Korea, with a maximum concentration of 2.29 μg/L in water [18].

DEHP concentrations in municipal wastewater samples collected in 10 different countries—Taiwan, Finland, Germany, Australia, China, Scotland, Denmark, Norway, the UK, and the Netherlands—ranging from 21 to 400 μg/L [19]. These values indicate high phthalate (especially DEHP) consumption in plastic products for various applications. More importantly, high-molecular-weight phthalates are strongly adsorbed by sludge due to their low water solubility. In addition, high-molecular-weight phthalates have low biodegradability, making their removal during treatment more difficult.

Plastic additives enter the marine environment through municipal and industrial wastewater, atmospheric deposition, runoff from agricultural land due to the use of agricultural sludge, and direct leakage from plastic particles. Phthalates have also been detected in seawater samples from various locations with concentrations ranging from 1 pg/L to μg/L. Among phthalate isomers, DEHP is the most prevalent additive in seawater. The DEHP concentration observed in the Italian Liguria Sea was 18.38 ± 44.39 μg/L [20]. Other plastic additives, such as bisphenol A, have also been detected in seawater, with concentrations ranging from ng/L to μg/L [21].

4.3. Assessing the impact on human health

The impact of plastic additives on human health is still limited in terms of research data.

In Hanoi, according to research by Thuy Minh Le et al., the total concentrations of 10 PAEs measured in 21 plastic bottled water samples ranged from 1.64 to 15.70 μg/L (mean/median: 6.40/5.82 μg/L). PAE concentrations in carbonated bottled water samples were 1.2–1.5 times higher than in non-carbonated bottled water samples. The estimated mean exposure dose (EDI) of the 10 PAEs through drinking water consumption for adults and children in Vietnam was 0.254 and 0.256 μg/kg-bw/day, respectively. The US Environmental Protection Agency (EPA) RfD (Reference Dosage) values for DBP and DEHP (the two most common of the 10 PAEs studied) are 100 and 20 μg/kg/day, respectively (US FDA, 2012) [14].

Applying the formula HQ= EDI/RfD shows that the HQ < 1. This reference result indicates that the risk to human health is negligible.

Plastic additives can be transported through the food chain in both aquatic and terrestrial ecosystems, primarily through predator-prey relationships. Many studies show that the accumulation of microplastics and additives in organisms (such as fish) occurs more strongly through the nutrient pathway than through direct contact. Experiments have recorded nutrient amplification for substances such as PBDEs, PAEs, and UV stabilizers, with bioaccumulation and nutrient amplification coefficients >1 at many trophic levels [22]. In terrestrial ecosystems, evidence of microplastic transport through soil-plant-animals is also becoming increasingly clear, suggesting potential human exposure through the food chain, although further in-depth studies are still needed.

Plastic additives have been identified as endocrine-disrupting chemicals (EDCs) and are associated with numerous human health problems, such as reproductive disorders, obesity, diabetes, breast and prostate cancer, thyroid disorders, cardiovascular disease, developmental impairment, and neurological function [23]. Notably, more than 50% of the chemicals used in plastics have not yet been fully evaluated for their toxicity to human health.

In vitro studies show that the toxicity of plasticizers varies considerably between compounds. Octylphenol (OP) and nonylphenol (NP) are the most cytotoxic to human placental JEG-3 cells (EC50: 36–40 μM), followed by BPA (EC50: 138–219 μM), while phthalates do not exhibit significant toxicity to this cell line [24]. BPA has also been shown to be cytotoxic and inhibit aromatase enzyme (CYP19), which is associated with recurrent miscarriage in women. Some phthalates, such as BBP, DBP, and DEHP, have the potential to impair estrogen activity and affect embryonic development due to their ability to cross the placenta [25].

In addition, brominated flame retardants (PBDEs) have been shown to cause cytotoxicity, neurotoxicity, lipid metabolism disorders, oxidative stress, and genotoxicity in in vitro and in vivo studies [26]. Overall, the available evidence suggests that plastic additives may have adverse effects on human health even at low concentrations.

The main routes of exposure to plastic additives include inhalation (respiration), consumption (ingestion), and skin contact. Humans inhale polluted air containing plastic additives and combustion products (phthalates, dioxins, heavy metal oxidizers, etc.) at levels that may affect health. These substances are linked to asthma, respiratory inflammation, and prolonged respiratory irritation. Plastic additives can enter the body through ingestion. For example, microplastics in drinking water and food contain plasticizers that can release phthalates, leading to long-term exposure. Although there are no direct studies in Vietnam, global evidence suggests that phthalates and bisphenol A in mineral water, bottled water, and packaged foods pose endocrine and reproductive risks to consumers. Direct contact with plastic products (toys, food containers, household items) also facilitates the absorption of additives through the skin. Phthalates and organic substances in sweat or skin oils can diffuse into the body through the skin. The level of risk depends on the concentration of chemicals in the product and the duration of exposure.

The health consequences of long-term exposure to these additives have been demonstrated in numerous studies: phthalates are linked to endocrine disruption, reduced fertility, birth defects, and developmental problems in children. For example, phthalates such as DEHP and DBP are recognized as reproductive toxins and hormone disruptors. Media reports in Vietnam also note that high levels of phthalate exposure can cause fatigue, headaches, and endocrine disorders in children. These effects are particularly serious for vulnerable groups such as young children, pregnant women, and workers who are frequently exposed to plastics.

5. PROPOSE MANAGEMENT SOLUTIONS, ALTERNATIVE TECHNOLOGIES, AND POLICIES

5.1. Gaps in management and research gaps

Currently, Vietnam only has a few regulations on additives in plastics in contact with food, such as the National Technical Standard QCVN 12-1:2011/BYT on safety and hygiene for packaging and utensils made of synthetic plastics in direct contact with food; and the Vietnamese Standard TCVN 6514-8:1999 (AS 2070-8:1992) on Plastic materials in contact with food - Part 8: Additives. Vietnam does not have any specific standards or regulations on the composition of plastic additives in other plastic products. Finding information about plastic additives on plastic products is impossible because manufacturers do not disclose this information on their products.

Furthermore, Vietnam's national technical standards for air, soil, water, and sediment quality lack regulations on permissible limits for plastic additives in the environment. We only found regulations on DEHP parameters in QCVN 08:2023/BTNMT and QCVN 40:2025/BTNMT. This leads to limited and difficult control of plastic additives in the environment. Environmental monitoring systems and data are lacking, especially regarding the presence and distribution of plastic additives in water, sediment, air, and the food chain.

Research on human exposure and health risks is limited, with only preliminary studies on BPA and phthalates in children. The management of the plastic lifecycle is inadequate, including the sorting, collection, recycling, and treatment of plastic waste. There is a lack of research on the emission of additives during plastic recycling and processing, as well as the transformation of persistent organic compounds in these processes.

5.2. Propose management solutions, alternative technologies, and policies

To minimize the impact of plastic additives, a comprehensive approach is needed:

Firstly, regarding management and policy: The Law on Environmental Protection (No. 72/2020/QH14) stipulates expanded responsibilities for manufacturers and importers regarding recyclable or difficult-to-recycle products/packaging. Decree No.08/2022/ND-CP guiding the implementation of the Law clearly states that businesses must collect and recycle according to mandatory rates or contribute financially to the environmental protection fund if they fail to meet the targets, and impose heavy penalties for violations. The Law on Environmental Protection (2020) promotes a circular economy model, calling for emission reduction and resource reuse. The Law affirms that EPR not only saves resources but also promotes a circular economy.

The Global Plastics Treaty, aimed at ending plastic pollution, is still being negotiated by more than 175 countries by 2025. Plastic additives such as phthalates, bisphenol A (BPA), and PFAS are increasingly recognized as key components of the global plastics pollution crisis. These substances are currently being considered in the ongoing negotiations of the Global Plastics Treaty, which aims to address the entire plastic lifecycle, including chemical safety, transparency, and human health impacts [27, 28]. Besides these regulations, the Government needs to issue regulations restricting the use of toxic additives (e.g., limiting phthalate content in plastic products for children and food contact items) and publicly disclose the chemical composition of plastics. Stricter environmental safety standards are needed for emissions and wastewater from plastic industrial zones. Simultaneously, Vietnam needs to actively participate in international treaties on plastics and chemicals (such as the The Global Plastics Treaty) to update and apply modern safety standards. Training and raising awareness among businesses and the community about the risks of plastic additives is essential.

Secondly, regarding alternative technologies: Encourage the development and use of safer additives: for example, switching to natural solvents and plasticizers (citrate and adipate plastics instead of phthalates), using harmless colorants, and halogen-free flame retardants. Implement "green chemistry" manufacturing technologies to design plastic products with fewer toxic additives from the outset. In addition, advanced plastic waste recycling and treatment technologies (such as reuse, chemical recycling, and controlled incineration) help reduce the release of additives into the environment.

Thirdly, regarding waste management solutions: A comprehensive plastic collection and recycling system is needed to limit indiscriminate burning and disposal. Apply the Extended Producer Responsibility (EPR) principle to hold plastic companies accountable for the entire product lifecycle. For waste incineration facilities, enhance exhaust gas treatment (dust filtration, adsorption) to prevent chemical release.

Fourth, research and monitoring: Establish an environmental monitoring system for typical additives (phthalates, bromides, heavy metals) in plastic industrial zones and polluted areas. Promote additional research on the long-term health effects of additives in Vietnam to inform policy.

The implementation of these measures aligns with international recommendations encouraging the adoption of green chemistry principles, international cooperation, and stakeholder participation to transition to safer additives, thereby minimizing environmental and health harm. Simultaneously, the global trend is towards stricter regulations on toxic chemicals in plastics, and Vietnam can adopt this to develop a sustainable plastics industry.

6. CONCLUSION

The widespread use of plastic additives in Vietnam is creating significant risks to the environment and human health. Substances such as phthalates, bisphenols, and halogen compounds improve the performance of plastics but simultaneously pollute the air, soil, and water through various pathways. Humans can be exposed to these substances through inhalation, ingestion, and skin contact, leading to potential endocrine, reproductive, and other chronic diseases. To mitigate these harms, a comprehensive solution is needed, including stricter management of toxic chemicals, a shift to safer alternative additives, and improved plastic waste management. This requires coordination among the government, businesses, and the community towards green chemistry and sustainable development. This study underscores the critical importance of the Source-to-Sea continuum for understanding and effectively managing plastic additive pollution in coastal countries such as Vietnam.

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