Review Article :

The Ripple Effect of Plastic Pollution: Environmental and Public Health Perspectives: A review

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Abstract:

Plastic pollution is a major issue of the current century. This waste is found in seas, freshwater, lakes, rivers, coastal areas, and soil. In this article, this article discusses the various sources of plastic pollution, including the manufacturing process of plastics and the addition of materials to improve their properties, as well as the use of single-use plastics that are not recyclable, in addition to burning and illegal waste disposal in the open. The impact on public health is through human exposure to toxins from plastics in the environment directly through inhaling dust and fumes, consuming contaminated food and drink, and skin contact. Indirectly, when marine creatures consume microplastics, they will find their way into our diet. Recycling plastic waste and using bioplastics is one solution to alleviate this problem, but consideration must be given to reducing overall plastic consumption.

Keywords: Plastic pollution, Plastic waste, Microplastic, Public health, Environment .

التأثير المضاعف للتلوث البلاستيكي على البيئة والصحة العامة :مراجعة

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الخلاصة:

يعد التلوث البلاستيكي مشكلة رئيسية في القرن الحالي. وتوجد هذه النفايات البلاستيكية في البحار والمياه العذبة والبحيرات والأنهار والمناطق الساحلية والتربة. نناقش في هذا المقال المصادر المختلفة للتلوث البلاستيكي، بما في ذلك عملية تصنيع البلاستيك وإضافة مواد لتحسين خواصه، وكذلك استخدام المواد البلاستيكية ذات الاستخدام الواحد غير القابلة لإعادة التدوير، بالإضافة إلى الحرق والتخلص غير القانوني من النفايات في العراء. ويتم التأثير على الصحة العامة من خلال تعرض الإنسان للسموم الناتجة عن المواد البلاستيكية في البيئة بشكل مباشر من خلال استنشاق الغبار والأبخرة واستهلاك الطعام والشراب الملوثين وملامسة الجلد. وبشكل غير مباشر، عندما تستهلك الكائنات البحرية المواد البلاستيكية الدقيقة، عندها ستجد طريقها إلى نظامنا الغذائي. إن إعادة تدوير النفايات البلاستيكية واستخدام البلاستيك الحيوي هو أحد الحلول للتخفيف من هذه المشكلة، ولكن يجب النظر في الحد من استهلاك البلاستيك بشكل عام.

الكلمات المفتاحية : التلوث البلاستيكي ، النفايات البلاستيكية ، البلاستيك الدقيق، الصحة العامة، البيئة .

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1. Introduction

The synthetic organic polymers that we refer to as "plastics" were developed by chemists throughout the 20th century. Leo Baekeland, a Belgian scientist, created the first one (Bakelite) in 1907. The term "plastic" alludes to the fact that certain materials may be molded during production. In the 1930s, the plastics business began to take off. Nylon and polyethylene were both created in 1935. Nylon fiber and polystyrene entered commercial production in 1936 and 1937, respectively. During World War II, several novel polymers were developed. However, the rapid rise and widespread use of plastics in common household items began in the 1950s [1]. Since then, polymer research has advanced with a deeper mechanistic knowledge of how polymer structure, morphology, physical and mechanical behavior are related. Due to this, a wide range of plastic materials with various properties have been produced [2].

Plastics, as the material of the moment, are convenient for molding, lightweight, durable, dust- and water-resistant, and available at low cost. These properties make plastics versatile products across many sectors, including construction, automotive, leisure, health, and consumer appliances. [3] At the same time, one of the greatest successes of this versatile and affordable material has led to an inevitable accumulation of plastics in a subsequent variety of consumer products. Inadequate waste management, negligence in maintaining clean spaces, and inappropriate disposal have contributed significantly to the accumulation of plastics in the environment. Predominantly, the last 70 years have seen approximately over 9 billion tons of virgin plastic produced globally. However, the global recycling rate of this versatile material remains low, with nearly 60% of these products ending up in landfill sites or leaking into the wider natural environment, causing significant environmental pollution. [4], [5] Although recovery and recycling systems have emerged in various segments of the economy, primarily enforced through social pressure, of concern is that recycling has not been able to keep pace with the growing demands for this versatile, multipurpose material. Plastics represent approximately 80% of the accumulation of marine debris, causing danger alongside terrestrial habitats. [6], [7].

Plastic pollution is undeniably expanding exponentially since its invention at the beginning of the 20th century [8]. Consequently, concern about the effects of plastic pollution on ecosystems and public health has also grown considerably and has therefore been added to the high-priority topics of the comprehensive sustainable development of future cities and societies. Plastic pollution occurs and may also disrupt the natural environment at a range of scales, ranging from the neighborhood and municipality to the biosphere. This becomes a holistic interconnection between environmental and public health issues in the time of the Anthropocene [9], [10].

In this review will discuss the sources of plastic pollution and affecting marine ecosystems, terrestrial ecosystems and then affect to public health.

2. Plastic Pollution

Plastic pollution can be conceptualized as a multi-faceted, complex issue. Firstly, plastic pollution can originate from both individual and retail settings such as grocery stores and restaurants, as well as from construction and industrial applications [11], [12].

Secondly, In terms of size, waste plastics are generally categorized as microplastics or macroplastics and nanoplastics [13].

Microplastics, further divided into primary and secondary categories, are less than 5 mm in diameter and can absorb chemicals and persistent organic pollutants [14]. Primary microplastics are directly produced at the microscale before being released into the environment, while secondary microplastics are formed when larger plastic particles break down into smaller fragments [15].Foundations of microplastic management must consider both inorganic and organic contaminants [16].

Macroplastic is commonly defined in distinction to microplastics as items with a diameter of 5 mm or more [17]. However, both size classifications are not internationally standardised.

Regarding macroplastic, other definitions are also published. For example, Barnes et al. (2009) [18] defined macro-debris with a diameter>20mm, the European Commission (2013) [19] defined it as items > 25 mm.

Nanoplastics are plastics with a size range of 1 nm–1 μm [20] that may have a greater ecological impact. This is due to their size and colloidal properties, which include a high specific surface area and the ability to absorb persistent organic pollutants toxic microorganisms and heavy metals .Therefore, consuming these concentrated contaminants is more detrimental to living organisms and human health, which raises scientific and public concerns [21].

While reducing waste and pollution seems like a daunting obstacle at present, it is essential to gain a deeper understanding of the issue so that society can address plastic pollution effectively.

2.1. Sources of Plastic Pollution

Plastic pollution arises from a variety of sources, significantly affecting ecosystems and human health **(Figure1)**. Understanding these sources is crucial for developing effective mitigation strategies. The most important sources of plastic pollution are explained below:

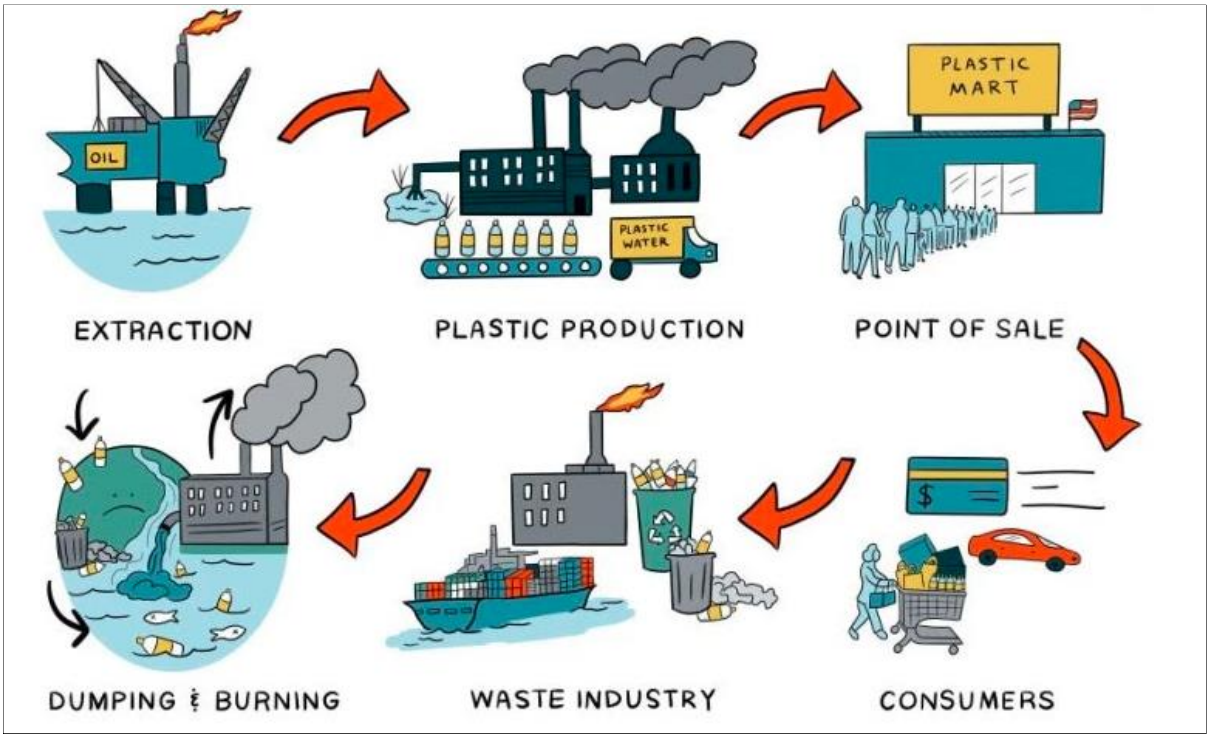

Figure (1) : The sources of plastic pollution .

2.1.1. Industrial-Based Activities There are various types of industrial activities that contribute to the generation of plastic waste. At the first stage in the production chain, the actual manufacturing of plastics generates waste, including the products of combining petroleum and gaseous monomers, which is the main feedstock for plastics. The transportation and logistics of feedstock and actual plastic goods result in waste indirectly. During production, it is the melting and forming processes, or the removal of excess plastic used in the cutting processes, that create postindustrial waste from the factory. Some industries generate postconsumer plastic waste, either through disposable food packaging or non-recyclable products in a business-to-business setting [22].

2.1.2. Consumer Habits Consumer habits play a significant role in the generation of postconsumer solid plastic waste. One of the main factors is the manufacturing of single-use plastic items made of non-recyclable or non-biodegradable plastics, meant to be disposed of after a single use, later needing replacement[23],[24]. Household goods and food products encased in plastic generate waste each time a new package is bought. Improper waste disposal, such as illegal dumping, poor recycling practices, or use of substandard or old waste bins that allow for refuse to be transported and scattered during waste collection, are major contributors to plastic waste pollution [25].

2.1.3. Agencies, Urban Development, and Population Growth As the global population spreads, urban and residential development is fueling the consumer-based industries that generate plastic waste, which all contribute to a compound plastic waste issue [26]. While some countries have strict waste management systems, others have laws that allow for plastic waste to be disposed of openly or with an open burning/controlled burning system [27], [28]. Many population-based areas are not able to provide adequately funded waste incineration, while others do not have the necessary space to bury or recycle waste. Standard laws and regulations for waste management procedures and impacts are often figured out at a state or country level, but many manufacturers have discovered that illegally shipping waste to other countries or underreporting waste is a low-enforcement, cost-effective practice[29].

2.1.4. Alternate and Unexpected Sources In addition to incineration and disposal, many unexpected sources of plastic waste contribute to the general plastic waste issue. Microplastics found in oceans, fish, and other sources have also extended their impact into our everyday wardrobe. Synthetic fibers from textiles such as polyester and spandex release microplastics into wash water, leading to a wastewater system source of plastic waste [30], [31]. Two hundred seventy-five million metric tons of dedicated microplastics enter oceans annually. Maintaining lush green lawns, golf courses, and sports fields come at a cost. Golf course turf and many artificial lawns are constructed of virgin and/or recycled polyethylene terephthalate or, for its cheaper alternative, a combination of polyethylene and plastics such as nylon or polypropylene [32].

3. Impact on the Environment

If the monetary cost of plastic waste in the oceans is of any consequence, the estimate is roughly 13 billion US dollars annually, while reducing greenhouse gas emissions, via the decreased production of new plastic, reduces that estimate to 4 billion US dollars. However, economic values do not encapsulate the importance of the severe ecological consequences of plastic pollution - perhaps of equal importance in a more just valuation of harm. The abundance and distribution of global plastic production have resulted in plastic pollution ubiquitously visible in virtually every environment around the world [33].

Plastic debris is found in marine[34], freshwater[35], and terrestrial ecosystems, across the coast and in the open ocean and sediments of rivers[36] and lakes[37], atop the tallest mountains[38] and the bottom of sea trenches, as well as on beaches[39], underground[40], and in urban gardens[41]. Countries with low waste management standards bear the burden of a higher input to the ocean. In the ocean, plastic pollution not only accumulates at the sea surface but also thousands of meters below in benthic communities [42].

Beyond looking unsightly, carelessly disposed of plastic waste has led to a cascade of harmful impacts on both wildlife and the ecosystems in which it occupies. For instance, plastic waste has been shown to enter the food web via ingestion by a wide variety of animals [43]. Microplastics have been found in seals, seabirds, cetaceans, fish, shellfish, waterbirds [44], and agricultural soils [45]. Marine organisms found with plastic in their gut include not only shellfish but species like the blue mussel, which is a major protein source for humans [46].

Cases of plastic through albatross chicks have demonstrated that plastic moves up trophic levels, thus impacting predator species [47].

3.1. Marine Ecosystems

Plastic pollution results in a range of impacts on marine ecosystems, where it accumulates as macro, micro, and nanoplastics. The primary inputs are through mismanaged waste and sewer outfalls into rivers and directly from some coastal areas. Rivers have been estimated to carry millions of metric tonnes of plastics into the ocean each year [48].

Thushari et al. (2017) [49] revealed that >60% of beach debris from selected beaches on the eastern coast of Thailand originates from tourism and recreation-related activities. Plastic debris in beaches carries into the ocean as microplastic fragments and secondary plastics [50]. In the urban beach of the northeast of Brazil, plastic pellets and fragments have been reported as contaminants. The main source of those fragments was the breaking down of larger size plastic debris accumulated on the beach, while the major sources of plastic pellets were from the operational activities of nearby port facilities [51]. Another potential cause of plastic

pollutants is persistent fishing fleet, based on the literature records [52].
Offshore activities such as commercial fishery, navigation actions, waste disposal, and shellfish/fish culture are key ocean-based sources that contribute to plastic debris accumulation into the marine and coastal zones. Offshore fishing and aquaculture-related operations have been identified as a significant source of plastic pollution into the ocean basins and coastal ecosystems by the number of literature records. Damaged fishing nets and abandoned, lost, or discarded fishing nets **(Figure 2)** can enter the offshore by fishers during fishing operations [53].

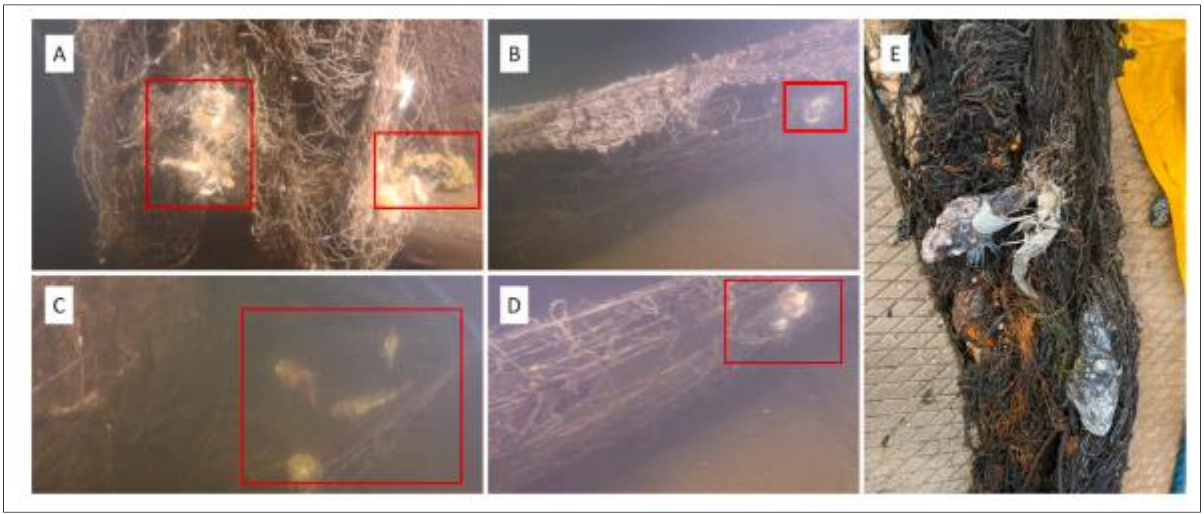

Figure (2) : Example of abandoned, lost or otherwise discarded fishing gear, Gulf of Riga along the coast of Engure, Latvia. (A–D) Underwater images of the derelict net at sea showing ghost fishing (marked in red) (E) Image of part of the retrieved ghost fishing net on land. Images: Riga Technical University.

3.2. Terrestrial Ecosystems

Land-based sources of plastic can suffocate and smother soils and contribute to soil erosion and soil degradation because plastic waste inhibits water infiltration and results in surface runoff even in dry conditions [54]. A soil pollution overview points to the contamination of plastic waste with persistent organic pollutants and polycyclic aromatic hydrocarbons (PAHs) [55]. PAHs present significant health risks due to their toxic, mutagenic, and carcinogenic properties [56].
Although the current evidence base regards the exposure of terrestrial wildlife to microplastics as inadequate, it is possible that the chemical leaching of persistent organic pollutants and additives from microplastics could similarly affect terrestrial fauna to the extent that sediment and oceanic fauna are affected. Furthermore, waste mismanagement and the overflow of urban landfills indicate that microplastics can be widespread in the terrestrial environment [57, [58].
De Souza Machado et al. (2018) [59] focused on the uptake of microplastics by plants. Their study revealed that microplastics can be absorbed by plant roots, potentially entering the food chain. This raises concerns about the bioaccumulation of toxic additives found in plastics, such as heavy metals and persistent organic pollutants, which could have serious implications for human health. The researchers emphasized the need for further studies to assess the long-term effects of plastic-laden crops on consumer health.
In a comprehensive review, Russo et al. (2023) [60] examined the broader implications of plastic pollution on soil quality and agricultural practices. They highlighted that the presence of plastics in soil not only impacts soil biota but can also lead to the leaching of hazardous substances into groundwater. This contamination poses risks not only to ecosystems but also to human populations reliant on groundwater for drinking and irrigation. The authors called for integrated waste management strategies to mitigate plastic pollution, particularly in agricultural contexts.

4. Impact on Public Health

Plastic pollution has consequences for both the broader environment and the health of human populations. Historically, public health discourse may have failed to account for what has been described as 'invisible' mechanisms of plastic pollution impacts on human bodies, due to the intangible, almost molecular-level effects of plastic toxins accumulation in body tissues [61].

There are direct and indirect pathways through which plastic pollution may impact the health of communities and individuals **(Figure 3)**. In terms of direct health effects, humans can be exposed to toxins from plastics in the environment through the inhalation of dust and fumes, ingestion of contaminated food and beverages, as well as skin contact [62],[63].

Figure (3) : Plastic impacts every facet of the One Health paradigm. One Health views animal, human, and environmental health as a single, interconnected entity, with impacts on one sphere affecting all others, both directly and indirectly. Plastic pollution has multiple potential effects on every aspect of global health [63].

There are many literatures focused on the effect of plastic pollution on Endocrine disruption[64], immunotoxicity[65], increased likelihood of cancer[66] and early onset diabetes[67], low birth weight[68], and impaired childhood mental development due to phthalate associations[69], respiratory diseases from bisphenol A[70].

Moreover, plastic may serve as a transport and storage medium, accumulating and concentrating viruses and secondary bacterial colonizers of aquatic systems. The absence of functioning waste management systems and environmental protection measures in many places increases the potential health impacts on these vulnerable populations. Repeated exposure to toxins may further increase a person's 'body burden,' or the amount of chemicals stored in their body. Patterns of lifetime exposure, dynamic human development, and individual predispositions could further personalize the risk of developing plastic pollution-related health effects [71].

4.1. Direct Health Effects

Primary direct health effects occur when humans or animals are physically exposed to plastics and their toxic constituents, when these play a role as vectors for contaminants or through transdermal absorption of contaminant chemicals. Overexposure will lead to acute health risks and may result in death. With long-term exposure to relatively low concentrations, the body can also suffer significant harm from plastics, but the effects or diseases will only become clear after a relatively long period of time [72], [73].

While plastics are known to leach various toxicologically relevant chemicals into the food chain, the most researched and most likely candidates for plastic leachate toxicity are bisphenol A and phthalates [74]. These endocrine disruptors have been associated with various health impacts on humans, including altered prenatal testosterone levels [75] and inversely related anogenital distance in offspring [76] and adverse neurodevelopmental outcomes [77], asthma[78], and respiratory infections in children[79]. Indeed, chemicals have been added intentionally to countless plastic items to lend special qualities, such as flexibility, rigidity, or the ability to withstand various environmental conditions, including heat, cold, and high UV exposure. And while chemicals leach out of many materials and products, it is plastics that have appeared as the highest-risk biohazards for humans in part because we ingest these minute leachates in our food, water, and air [80].

Many studies have indicated that workers in plastic manufacturing facilities face a higher risk compared to the general public because of the higher exposures associated with plastic product production[81].

Ruder et.al.(2016)[82] reported mortality through 2011 for 5203 boat-building workers potentially exposed to styrene and analyzed mortality among 1678 employed a year or more between 1959 and 1978. The priori hypotheses: excess leukaemia and lymphoma would be found.

4.2. Indirect Health Effects

A great proportion of plastic waste ultimately ends up in the oceans, and there are hopes that the issue can be rectified before permanent damage is done through ocean clean-up activity and local intervention strategies. While a large body of information regarding marine microplastics exists, less attention has been given to the pathways through which marine plastic contamination could affect human or environmental health. One of the main concerns is the potential impacts on the human diet when toxicants and microplastics are ingested by the fish or shellfish we eat after mistaking the resin pellets in formative life for prey [83].

If humans are consuming large amounts of these toxic fish and the microplastics that come with them, through larger and longer exposure over a lifetime of eating seafood, our internal microplastic concentration could become significantly high. Subsequently, when large fish and large marine mammals consume the smaller fish, even if the original plastic-resin contaminated fish are cut out by the fisher's catches, microplastics may still find their way into our diet [84].

Consumers of bottled water may have long-term exposure to microplastics through their diet. Because plastics are abundant in all consumer products and are present in materials used in food processing, plastic debris is also present in drinking water [85].

5. Mitigation and Solutions

On the international stage, several policies and regulations address plastic waste through bans, limits, or specific requirements. Though it is difficult to assess their effectiveness in combating some of the issues cited above, they are generally made to either reduce or displace plastic pollution. Quite often, however, these policies are implemented without extensive research or thought about the potential drawbacks or sizable benefits to pursuing biodegradable plastic alternatives. Bioplastics are but one touted ‘solution’. Overall, efforts should be focused on producing less plastic, developing advanced recycling techniques, combating alleged or perceived ecotoxicity, empowering clean-up campaigns, and educating the public[86],[87].

A variety of alternatives to plastic and petroleum-based products are being and have been developed, including biodegradable plastics as mentioned above and substitutes, much like what was used prior to Bakelite, when conservation of commodities was a matter of perceived necessity, and the value of reusability was instilled. Bioceramics are a type of material based on renewable resources which are characteristics of biodegradability, reusability, and recyclability for material applications [88].

Further discoveries will require the development of novel materials and manufacturing technologies. Public education, circular eco-design, and environmentalism among younger generations are the most important avenues to consider in the immediate future. Many community-based non-profits are currently involved in cleaning campaigns that can contribute to funding multiple campaigns or starting new ones. Individual involvement is highly recommended [89].

Although some companies pledged to reduce their environmental impact drastically, this promise is not likely to yield good results. Diplomacy will thus play a significant role in pushing for international collaboration on measures to combat this situation. Individuals, too, must make their own changes, recycling and keeping reusable items at hand. Even better, reducing overall consumption is advisable [90].

Conclusion

Many studies indicate that plastic waste is a serious environmental problem that must be dealt with and solved to preserve the environment and public health. Although plastic materials are very useful in our daily lives, it is necessary to reduce their use and enact laws by environmental organizations and government institutions to monitor the plastic production process and additives to improve its properties. Most studies have shown that these additives are toxic and may cause cancer and genetic mutations, such as bisphenol A and phthalates. Recycling plastic waste and using alternatives such as bioplastics and bioceramics is one of the solutions to reduce the aggravation of this problem.

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