Curr Probl Pediatr Adolesc Health Care 55 (2025) 101821

Contents lists available at ScienceDirect

Current Problems in Pediatric and Adolescent Health Care

journal homepage: www.elsevier.com/locate/cppeds

Full Length Article

Integrating environmental risk factors into pediatric cancer care: Laying the groundwork for improved outcomes and primary prevention

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ARTICLE INFO

Keywords:
Childhood cancer
pediatric oncology
environmental exposures
environmental health
preventive medicine
cancer prevention
survivorship care

ABSTRACT

Childhood cancer incidence has steadily risen both in the United States and worldwide, yet its environmental contributors remain underrecognized in clinical care. Children and cancer survivors are particularly susceptible to environmental exposures due to their unique physiology and the long-term health vulnerabilities that follow cancer treatment. Although exposures to substances such as pesticides, air pollution, and household chemicals are linked to increased cancer risk, limited clinical frameworks and clinician training leave oncologists underprepared to address growing environmental health concerns from families.

A holistic pediatric oncology environmental health program in Murcia, Spain offers a scalable vision for embedding the environment into longitudinal cancer care. In the United States, survey data from two large academic pediatric cancer centers revealed strong clinician interest in addressing environmental health in pediatric oncology, leading to the development of a consultative model. Workshops and a standardized environmental health history tool, adapted for clinical use and integration into the medical record, have laid the groundwork for implementation of an environmental consult service across 3 care settings: cancer predisposition clinics, survivorship programs, and as requested. These efforts aim to reduce family anxiety, offer actionable risk-reduction strategies, and empower primary teams with the knowledge to engage in meaningful conversations.

The patient-centered tools, interdisciplinary training, and structured integration into clinical workflows are designed to strengthen environmental health knowledge and practice of pediatric oncologists in the United States.

Rising trends in childhood cancer

Childhood cancer incidence in the United States (U.S.) is rising, with recent data from the National Childhood Cancer Registry (NCCR) showing a steady upward trend over the last several decades. Among individuals under age 20, the age-adjusted incidence rate for all cancer sites increased by 5.3% from 2001 to 2021, from 174.5 to 183.7 per 1,000,000 (3.7% in males and 7.2% in females). These data reflect findings from 28 cancer registries that cover approximately 75% of the U.S. pediatric, adolescent, and young adult populations[1]. While mortality rates have declined, incidence has steadily increased, a 0.7% annual percent change (APC) in delay-adjusted, age-adjusted incidence rates has been observed in long-term U.S. trends from 1975 to 2023 in individuals under age 20. This indicates a significant and consistent increase in childhood cancer diagnoses over time, even after accounting for reporting delays and late case ascertainment (Fig. 1) (2). To put this

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https://doi.org/10.1016/j.cppeds.2025.101821

Available online 1 December 2025

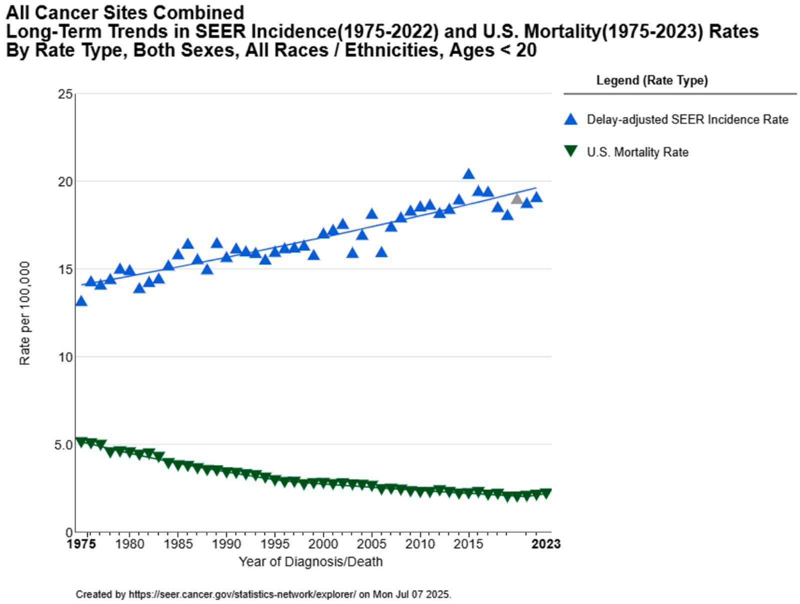

Fig. 1. SEER Data Explorer. There was a 0.7% annual upward percentage trend in delay-adjusted all cancer site incidence rates from 1975-2023. All Races. Ages <20[2].

into perspective, a 0.7% annual increase means that for every decade, roughly 7 more children per million are diagnosed with cancer, an upward trend that cannot be explained by improved diagnosis.

Leukemia is the most common cancer diagnosed in children and adolescents, accounting for approximately one-third of all childhood cancer cases and is the leading contributor to the overall rising trend in childhood cancer incidence[3]. As such, leukemia serves as a cornerstone for much of the environmental health-related epidemiologic research into pediatric cancer etiology. Leukemia incidence varies across racial and ethnic groups, with notable recent increases in rates in some groups. Most striking, among Hispanic children, the age-adjusted incidence rate rose from 54.7 per 1,000,000 in 2001 to 60.1 in 2021, a 9.9% increase. In non-Hispanic Black children, the rate increased from 27.5 to 31.7 per 1,000,000, a 15.3% rise (Fig. 2) (1). These differences are critical not only for understanding disease burden but also for informing research into sociodemographic factors that may underlie these trends. This is not a concern unique to the U.S.— global patterns show similar increases in childhood cancer incidence across diverse geographic and economic settings, underscoring the need to better understand environmental and social determinants of childhood cancer[4-7].

> Among individuals under age 20, the age-adjusted incidence rate for all cancer sites increased by 5.3% from 2001 to 2021, from 174.5 to 183.7 per 1,000,000 (3.7% in males and 7.2% in females) (1).

More than 10% of all cancers in children are caused by an inherited pathogenic variant but for most children the underlying etiology of their cancer remains largely unknown[8-10]. This suggests that exogenous factors, such as environmental exposures, are contributing to an increasing

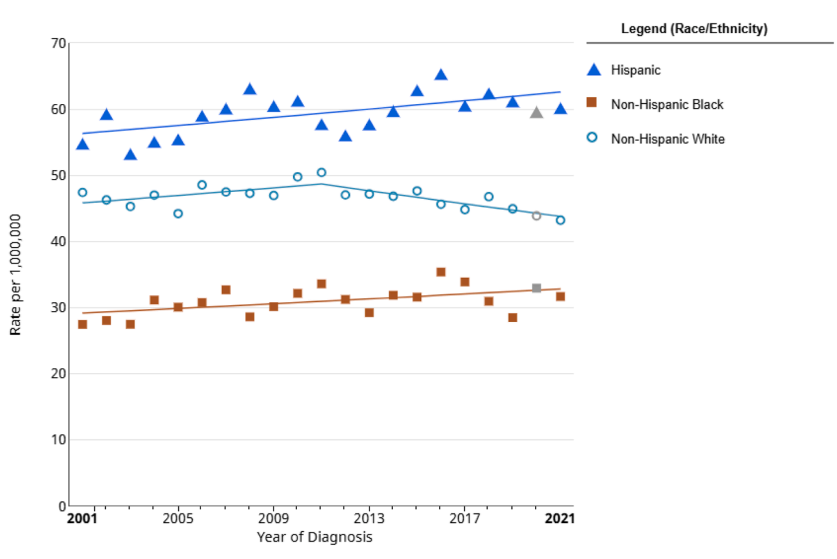

Fig. 2. NCI's NCCR Data Explorer. Upward trend in age-adjusted cancer incidence rates in leukemia from 2001-2021. By Race/Ethnicity (Hispanic, Non-Hispanic Black, Non-Hispanic White), Both Sexes. Ages <20[1].

proportion of cancer cases. Environmental exposure to substances including tobacco smoke, air pollution, pesticides, industrial chemicals, and chemicals in common consumer products is associated with childhood cancers[11]. Notably, some of these risk factors are not just associated with incidence but also are associated with morbidity and mortality of childhood cancer survivors[12, 13].

Vulnerability of children and childhood cancer survivors

Pregnancy, childhood, and adolescence are uniquely vulnerable periods due to rapid growth and development, making children especially susceptible to the harmful effects of environmental exposures. Their unique anatomy and physiology—such as higher respiratory rates, lower breathing zones, and frequent hand-to-mouth behaviors—result in increased contact with air pollutants, dust, and chemical residues found indoors and outdoors[14]. These early-life exposures can have lasting consequences, including increased risk of developing cancer in childhood or later in life[11, 15-27].

Monozygotic twin studies have helped clarify the timing of leukemia-initiating mutations. In one case, genetically identical twins developed leukemia years apart but shared the same leukemic translocation at birth, indicating that the initiating somatic mutation occurred in utero. This supports the “two-hit” hypothesis model, in which a prenatal “first-hit” creates a pre-leukemic clone, followed by postnatal “second-hits” that lead to disease.[28]. Population-based studies reinforce this model: studies have detected the *ETV6-RUNX1* fusion, arising early in development, in approximately 1-5% of cord blood samples from healthy newborns. Yet, the vast majority of these children never develop leukemia[29, 30]. These findings confirm that a prenatal genetic alteration alone is not sufficient for disease and suggest that an additional “hit”, somatic mutations, or environmental exposures, is necessary for leukemogenesis. Together, these insights underscore the importance of developmental timing and early-life vulnerability in the pathogenesis of childhood leukemia.

For children diagnosed with cancer, the opportunity for primary prevention has passed by the time they reach an oncologist. However, this does not diminish the clinical relevance of environmental exposures. Survival and long-term health outcomes among children, adolescents, and young adults with cancer are influenced by social determinants of health, including the environment to which they and their families are exposed[31]. Siblings, both current and future, often share the same environment and may face elevated risk. Children remain vulnerable not only during treatment but throughout their lives. By age 50, nearly all childhood cancer survivors experience at least one chronic health condition (32), particularly affecting the cardiovascular and respiratory systems, making them more susceptible to the adverse effects of environmental exposures[12]. Recognizing the role of environmental and social factors is essential for understanding and improving long-term survivorship outcomes. Even after diagnosis, there are meaningful opportunities to implement personalized risk reduction and mitigation strategies that can help protect survivors and their families moving forward[13, 33].

Environmental Exposures and Risk of Childhood Cancer

Harmful modifiable exposures that may influence the development of childhood cancer include exposure to ubiquitous substances such as ambient and indoor air pollution, tobacco smoke (including paternal smoking and secondhand smoke exposure), pesticides, and industrial or household chemicals. Emerging evidence also points to the influence of changing climate conditions such as extreme weather events and their indirect effects on childhood cancer[34-36]. Examples of the risk factors for the development of childhood cancers include:

Pesticides

Positive associations between pesticide exposures and childhood cancer were found in 80% of 49 studies conducted between 2013 and 2023 examined in a scoping review by Navarette-Menes[11]. Pesticides have been identified as a contributing risk factor in childhood leukemia[19], childhood brain tumors[37], and Wilms tumor[38-40]. Although these cancers are most studied, smaller numbers of studies have found risks with neuroblastomas, retinoblastomas, and lymphomas[11]. Critical windows of susceptibility have identified elevated risks related to exposure during the periconceptional, prenatal, and post-natal periods[41]. Additional studies examining exposures related to parental occupation, household and garden use, and agricultural uses also have identified increased risk[11, 37, 41-44].

Air Pollution

Many individual studies and meta-analyses have found an increased risk of childhood leukemia associated with traffic-related air pollution[11, 16, 17, 20, 23, 45-52]. These findings are not surprising given that a component of traffic-related air pollution is benzene, a known human leukemogen[22, 53]. A meta-analysis of traffic-related air pollution identified benzene as a main component contributing without an apparent threshold to childhood cancer risk, particularly acute myeloid leukemia (AML)[20]. Air pollution also has been associated with increased risk of rarer childhood cancers including retinoblastoma, brain tumors, and Wilms tumor[21, 25, 26, 39, 54].

Paint/Solvents

A pooled analysis of the impact of household painting based on 8 case control studies identified an increased risk for childhood acute lymphocytic leukemia (ALL)[15]. This was found whether the painting (a source of solvent exposures) occurred in the home during the immediate preconception period, prenatal period, or after birth. Painting the home in the 1-3 months preconception was associated with more than a 50% increase in risk. Risks were accentuated if painting was done by professionals (likely representing higher dose exposures) or oil-based paints, which contain more hazardous volatile organic compounds, were used[15, 22].

Conversely, certain exposures may play a protective role. For example, early-life exposures to infections, birth order, and delivery mode have been proposed to influence immune development in ways that may reduce leukemia risk[55]. Nutritional factors—including folate intake during pregnancy and healthy dietary patterns in early childhood—also have been associated with a lower risk of some pediatric cancers[56-58]. Adequate folate intake, whether from diet or supplementation during the peri-conception and prenatal periods is associated with reductions in leukemia, Wilms tumor, and childhood brain tumors[56, 57, 59-64]. Pooled and meta-analyses of breastfeeding have found it to be associated with significant reductions in risk for ALL, AML, and rhabdomyosarcoma[65]. Breastfeeding exclusively for at least 4 months reduced ALL risk by approximately 30%[66].

While epidemiologic evidence on environmental influences continues to accumulate, questions from patients and families about potential environmental causes of cancer remain deeply personal and pressing. In the absence of clear guidance, parents are often left to seek answers on their own, at times delaying routine treatment for an unstudied alternative. This highlights a disconnect between emerging science and clinical care. As one parent reflected:

“Could there be an environmental link? Our oncologist’s work is to cure, not to sleuth. As an environmental health journalist, it didn’t sit well with me that no one at our top cancer hospital asked about home environment or gave specific environmental advice during or after treatment. I was left to do my own research. Exhausted patients and caregivers rely on our medical team to guide us through this unique hell. I would have vastly preferred to collaborate

on her care rather than arrive at my own environmental health conclusions." -Alexandra Zissu

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A Holistic Model from Murcia, Spain

Growing worldwide recognition of environmental influences on childhood cancer catalyzed a clinical program in the Pediatric Environmental Health Specialty Unit in Murcia, Spain, where a pediatric environmental history has been embedded into routine pediatric oncology care since 2004[67, 68]. Recognized as a national "Good Practice" in 2006, the pediatric environmental history now anchors a long-term follow-up program that integrates environmental assessments, prevention tools, and, more recently, biomarkers of chronic exposure across the survivorship continuum[68, 69]. Practical components of the Murcia model include the "Green Page" (initial exposure screen) and "Green Passport" (ongoing risk-reduction checklist), which enable clinicians to identify modifiable exposures, anticipate late effects, and personalize follow-up[70]. Early outcomes include lower indoor toxicant levels, reduced smoking prevalence among survivors, improved metabolic profiles, and improved coordination with primary care[68, 71-74].

The anticipatory, "ambiomic" approach of the work in Murcia—merging exposomic, genomic, and socio-environmental data from diagnosis onward—illustrates how environmental medicine can be woven into oncology to deliver primary, secondary, and tertiary prevention in real time[75, 76]. The model is now being implemented through collaborations with centers in Barcelona and Berlin. It aligns with the Horizon Europe Mission Cancer call to elucidate how air, water, and soil pollutants affect cancer in children, adolescents, and young adults[77].

Assessing the Needs for a Consultative Service in the U.S

A 2014 study by Zachek et al. highlighted early gaps in clinician preparedness to address environmental health in pediatric oncology. Clinicians at 18 pediatric cancer centers around the U.S. were surveyed, with most acknowledging the potential role of environmental exposures in childhood cancer but reporting limited knowledge, training, and comfort discussing these issues with families[67]. To assess current clinician interest and potential usage of an environmental health consultative service at their institution, REDCap surveys were distributed via electronic mail to members of the pediatric oncology divisions at two major pediatric cancer centers — Texas Children's Hospital (Houston, Texas) in 2024 and Children's Mercy Kansas City (Kansas City, MO) in 2025. Surveys were distributed within four weeks following each institution's in-person environmental health workshop that are discussed further in a later section. While most survey respondents had not attended the workshops, the close timing provides useful context for interpreting overall division attitudes and needs. The target audience included physicians, advanced practice providers, staff nurses, and social workers. Participation was optional. The survey assessed clinician knowledge of environmental risk factors, the frequency of patient--initiated questions, clinician comfort in addressing these issues, and interest in using a consult service. Additional questions allowed respondents to elaborate on potential concerns or share open-ended comments. Texas Children's Hospital distributed the survey to 154 individuals and received 49 responses (32% response rate), while Children's Mercy Kansas City distributed the survey to 166 individuals and received 41 responses (25% response rate).

Survey responses were largely consistent between the two institutions, with minimal variation in overall trends. Most respondents demonstrated awareness of environmental exposures as a risk factor for childhood cancer and acknowledged receiving related questions from families. Despite this, most clinicians at both centers expressed discomfort addressing these questions directly. Physicians and advanced practice providers demonstrated the highest awareness that environmental exposures can increase the risk of childhood cancers. Physicians were also most likely to report receiving related questions from families. However, comfort discussing these exposures varied, with fewer than half of respondents across all roles indicating comfort with these conversations. Reported concerns about offering a consult service were low across all clinician types, suggesting general openness to implementing such support mechanisms (Fig. 3). When asked about the potential utility of a consult service, more than 90% of respondents indicated it would be helpful. Notably, 57% stated they would use such a service in addition to answering questions themselves, while 37% preferred to use it instead of engaging in those conversations directly; only 6% indicated they would not use the service (Fig. 4). These findings, consistent across institutions and clinician roles, underscore the need for structured clinical resources and support to oncology clinicians in addressing environmental health concerns.

There is an unmet need for reliable information on how to reduce exposures to improve the health of cancer patients. Having a trustworthy resource within the clinical team may reduce the anxiety that

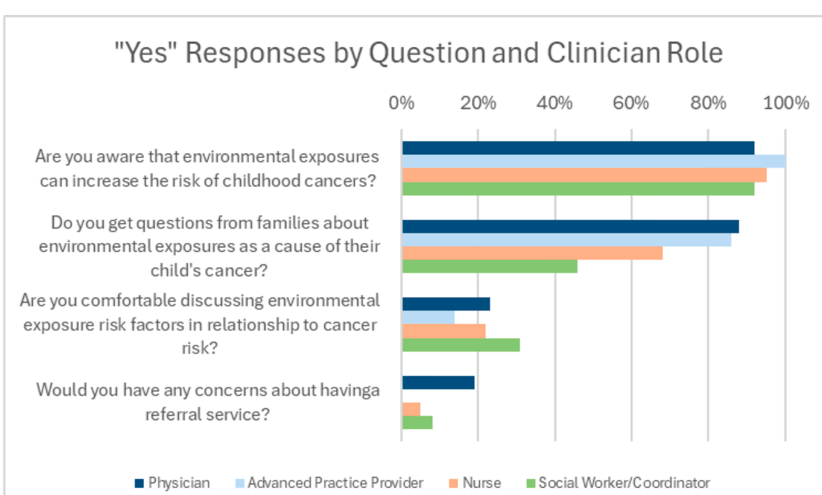

Fig. 3. Clinician Attitudes and Preferences. This horizontal bar chart illustrates the percentage of "Yes" responses to four key questions assessing clinician awareness, clinical experience, and comfort regarding environmental exposures and cancer risk, stratified by clinician role.

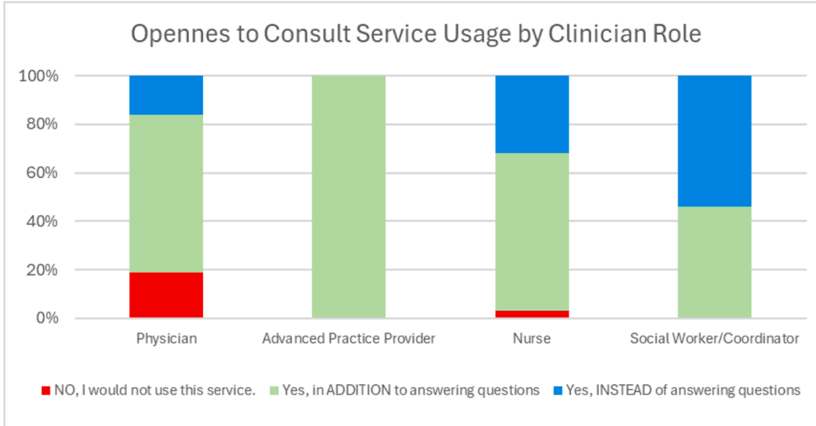

Fig. 4. Potential Use of a Consult Service. This bar chart displays the percentage of respondents by clinician role and how they responded to the question, "would you use this consult service?" Most respondents across all roles reported they would use the service, either in addition to or instead of direct engagement. Social workers and nurses showed greater interest in using the service instead of direct engagement. Few physicians and nurses reported they would not use the service.

many families experience during their cancer journeys. Many participants requested additional training and emphasized the importance of having access to reliable, up-to-date evidence-based information to guide patient and family discussions. One clinician shared, "It would be great to have some more educational sessions for all of us in oncology… to learn more about environmental effects and pediatric cancers. So much information on social media for parents and the general population is not accurate." Another commented, "I don't feel comfortable addressing this information," highlighting the need for a specialized team to help bridge this gap. While some respondents raised concerns about timing— "Overwhelming families and patients if scheduled during acute and intense phases of treatment"—or the potential for parental guilt, the overarching sentiment was one of support for having accessible, expert guidance in this area. These findings suggest widespread interest among pediatric oncology clinicians at these institutions to learn more about environmental health. There is a clear need for dedicated infrastructure to support both clinicians and families in navigating this complex and evolving domain.

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Expanding Environmental Health Literacy in Pediatric Oncology in the U.S

In 2022, the Childhood Cancer and the Environment Program (CCEP) was initiated through the Pediatric Environmental Health Specialty Unit program in the U.S., with support from the U.S. Centers for Disease Control and Prevention and the Agency for Toxic Substances and Disease Registry, in response to the growing recognition of environmental contributions to childhood cancer and the lack of standard clinician training in this area. The Childhood Cancer and the Environment Program began by training 10 clinical champions—one at each of the ten regional Pediatric Environmental Health Specialty Unit sites. In the spring of 2023, the program expanded its educational outreach by hosting two in-person workshops spanning over several days aimed at building capacity among oncology clinicians to better understand and communicate the role of environmental exposures on pediatric cancer. There was a total of 42 participants across both workshops, including pediatric oncology fellows and nurse practitioners. Content included key evidence on environmental contributors to childhood cancers; risk communication strategies; and guidance on identifying, contextualizing, and working with community members and public health authorities when unusual patterns of childhood cancers occur[78].

In addition to the workshops, members of the Childhood Cancer and the Environment Program have delivered educational presentations across a variety of settings. These have included grand rounds and other educational presentations at pediatric cancer centers, academic conferences, institutional teaching sessions, and public health forums nationwide to disseminate knowledge and resources. The program has also developed—and continues to expand—practical educational tools, including fact sheets, quick-reference resources, and a revised "A Story of Health" eBook chapter, all designed to support clinician counseling and medical education[79]. These educational efforts laid the groundwork for clinical implementation, including the development of a consult service and a standardized environmental health history intake.

Preparing for Clinical Implementation in the U.S.: Clinician Workshops and Tool Development

Institutional Workshops and Evaluations

In collaboration with the Childhood Cancer and the Environment Program and the Pediatric Environmental Health Specialty Units, two in-person clinician workshops were held to prepare two U.S. institutions to launch environmental consult services in pediatric oncology. The first occurred in February 2024 at Texas Children's Hospital, drawing 36 attendees. A similar workshop followed in March 2025 at Children's Mercy Kansas City, attended by 20 participants. Post-workshop surveys demonstrated strong participant satisfaction and increased confidence. Across both sites, 93-100% of respondents agreed the sessions were scientifically sound, enhanced their professional capacity, and improved their understanding of environmental contributors to pediatric cancer. Notably, 62-73% of participants felt that traditional clinical education does not adequately prepare clinicians to address environmental exposures.

Participants described the workshops as providing "great information and communication tools", and many left inspired to act—reporting plans to share content with their teams, educate families more confidently, and pursue further training. One participant noted, "I have better language to answer hard questions", while another commented, "My goal is to continue to pursue education in order to be a clinician who can impact health during and after cancer care". These findings highlight the value of dedicated training and the growing momentum to integrate environmental health into pediatric oncology care.

Families want answers—often before clinicians have them. A structured, compassionate, and evidence-based approach gives clinicians the tools to respond and researchers the data to learn more. To ensure the service aligned with family needs, a parent advisory group was convened at Texas Children's Hospital following the clinician workshops. During this session, parents of children undergoing or having completed cancer treatment were asked about the potential value of an environmental consult service. Many felt that access to such a resource during treatment could have eased anxiety and uncertainty. Representative comments–composites drawn from panel members, parents, and advocates–include: "This was the first question we had after diagnosis: how did our child get this, what did we do?" Families consistently preferred to "discuss this up front" and were relieved to know that "knowledgeable resources" would be available. Concerns about cancer clusters arose, with families wondering whether "something in the home or community might be contributing". Many were encouraged to hear that the hospital was "taking initiative on this topic". These perspectives highlight the importance of early engagement and underscore the value of a trusted, informed team to support families navigating environmental concerns.

Environmental Health History: Design, Adaptation, and Integration

To operationalize this work and provide a structured approach to environmental exposure identification, the first version of a standardized environmental health history intake was created in the U.S. in early 2024. The intake was curated in collaboration with national experts, pediatric epidemiologist, and with guidance from published tools developed by leading academic organizations, the Pediatric Environmental Health Specialty Units, and the pediatric environmental history used in Murcia[70, 80-82]. The intake was designed for families of children with cancer and has been adapted for readability at an eighth-grade level, translated into Spanish, and formatted in REDCap for electronic distribution and collection. For use in non-oncology populations—such as those in cancer predisposition clinics—certain items that presume a prior cancer diagnosis will be reworded. Responses will be confidential and integrated into the electronic health record as part of the patient's social history, providing consult teams with a structured foundation to tailor educational materials and evidence-based recommendations. The environmental health histroy includes assessment of key domains such as residential location at birth and diagnosis, tobacco smoke exposure, parental occupational exposures to chemicals, exposure to pesticides, air pollution, and UV radiation (See Supplemental Material). Standardizing the environmental health history intake and integrating it into the medical record not only facilitates personalized counseling and clinical decision-making but also lays the groundwork for future research. Structured data collection enables secondary analyses that could strengthen epidemiologic evidence, inform environmental risk assessments, and ultimately guide public health interventions.

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Designing an Environmental Health Consultative Service in Pediatric Oncology in the U.S

Growing recognition of both clinician uncertainty and family desire for trusted information has shaped efforts to integrate an environmental consult service into pediatric oncology clinical care in the U.S. The following sections outline how such a service can align with existing workflows, address common clinical scenarios, and provide families with personalized, evidence-based guidance. Early implementation strategies are currently being developed and refined at two pediatric oncology institutions, Texas Children's Hospital and Children's Mercy Kansas City, in collaboration with the Childhood Cancer and the Environment Program and the Pediatric Environmental Health Specialty Units. The long-term vision is to formalize these efforts into a replicable framework that can be adapted and implemented across diverse clinical settings in the U.S.

Goals of a Consult Service

The goals of a pediatric environmental health consult service are:

1. **Advance understanding of environmental risk factors for childhood cancer** both to inform primary prevention efforts that may reduce incidence and to support survivors by minimizing exposure-related morbidity and mortality.
2. **Reduce family anxiety** by directly addressing questions about potential environmental causes of their child's cancer.
3. **Provide current, evidence-based information** on environmental risk factors for childhood cancer.
4. **Offer families practical, low-cost strategies** to reduce harmful exposures in the home and community.
5. **Support primary oncology teams** by equipping them with the knowledge and tools to engage in these discussions as part of routine care.

Patients may be helped at various points along the care continuum—from cancer predisposition clinics to active treatment and survivorship. The service plans to offer a flexible, multidisciplinary model tailored to individual family preferences and clinical context, acknowledging that some may raise concerns at diagnosis while others may prefer engagement later in care, and that cultural and ethnic backgrounds also may influence how and when families choose to engage[83-86]. The service will be structured to align with existing clinical documentation and billing processes; the use of CPT code 90882 ("environmental intervention for medical management purposes") supports appropriate documentation and reinforces the legitimacy of these conversations as part of comprehensive cancer care. The model is designed to remain adaptable, evolving in response to early feedback and implementation data.

Cancer Predisposition Clinic

In the cancer predisposition clinic, discussions around environmental exposures are tailored to reflect established vulnerabilities in the population of people with predisposition to develop cancer. Cancer predisposition clinics provide specialized care for individuals with inherited genetic syndromes that increase their risk of developing cancer. For instance, patients with Li-Fraumeni Syndrome undergo routine whole-body MRI surveillance due to their markedly elevated lifetime risk of developing a broad spectrum of malignancies, including—but not limited to—central nervous system tumors[87, 88]. MRI is intentionally used in place of radiation-based imaging (such as CT scans) to reduce cumulative radiation exposure, given the known sensitivity to Li-Fraumeni Syndrome patients to ionizing radiation. While much attention has been given to minimizing radiation from diagnostic imaging, conversations often overlook potentially modifiable household environmental factors. As an illustrative example, many families report routine use of professional pest control services, including indoor and outdoor pesticide spraying. This is particularly relevant given associations between pesticide exposure and increased risk of central nervous system tumors in children[18, 89]. In these scenarios, risk reduction counseling can be offered using evidence-based, practical strategies—such as switching to integrated pest management (IPM) practices, limiting indoor pesticide use, and focusing on dust control. Since pesticide residues and other chemical contaminants often accumulate in household dust, families are advised to regularly clean with damp microfiber cloths, use vacuums equipped with HEPA filters, and avoid dry dusting or sweeping which can resuspend particles[24, 27, 90, 91]. Resources from the Western States Pediatric Environmental Health Specialty Unit also provide tailored guidance for safer pest control and household maintenance practices.

Childhood Cancer Survivorship Clinic

In the childhood cancer survivorship clinic, the emphasis shifts to reducing future risk and supporting long-term health. These clinics provide specialized follow-up care for individuals who have completed cancer treatment, focusing on monitoring for late effects, managing ongoing health concerns, and promoting long-term wellness. Survivors of childhood cancer are at risk for chronic health conditions and subsequent malignancies because of late effects of therapy and environmental exposures may further exacerbate these risks[31, 32, 92, 93]. Based on information gathered through the environmental health history, the consult team can provide evidence-based recommendations for reducing chemical exposure concern— offering survivors and their families a sense of agency in managing their long-term health.

As an example, a family may have noted in the environmental health history that the survivor is exposed to secondhand tobacco smoke and indoor pesticide spray. There has been growing concern and emerging evidence regarding the impact of environmental exposures, such as pesticides, air pollution, and tobacco smoke on the outcomes and general health of pediatric cancer survivors. Childhood cancer survivors are more likely to have existing cardiovascular and respiratory health issues, making them more susceptible to treatment-related morbidities and early mortality from tobacco use and other air pollutants. A recently published study reported reduced survival among children with acute leukemia who were exposed to residential pesticides[94]. Living in areas of high air pollution has been associated with decreased survival and respiratory hospitalizations among childhood cancer survivors[39, 95]. Ways of reducing pesticide exposure could be discussed with families. Similarly, tobacco use and secondhand smoke exposure decreased survival and increased treatment related mortality in children with acute leukemia[73, 96]. As such, we recommend survivors avoiding smoking, vaping, chewing tobacco, and secondhand smoke exposure at every annual survivorship visit. Alteration in activities and use of indoor HEPA filters are suggested for days that the air quality index is unhealthy[97].

On Demand Situations

The environmental health consult service can be available on a PRN (as-needed) basis to support families with specific concerns. One such example involved a Hispanic family whose child had been newly diagnosed with leukemia. The father, a landscaper with regular pesticide exposure, expressed concern that his occupation may have contributed to his child's cancer. He questioned whether his other children also were at risk and asked whether he should quit his job altogether. His concerns were met with empathy and normalization—parents often voice similar questions. He was told that he did not cause his child's cancer. He was reassured that cancer is multifactorial, and while many people work with chemicals, only a subset face adverse health outcomes. Importantly, his question raised a well-documented exposure pathway; pesticide exposure among Hispanic populations has been associated in several studies with increased childhood cancer risk[98-100]. He was empowered with evidence-based, practical steps to reduce exposure—such as wearing proper protective equipment at work and removing shoes and clothing before entering the home. He requested more information and was provided with Spanish-language materials from the Childhood Cancer and the Environment Program, along with an open offer for follow-up consultation[79].

Another example includes a caregiver of a child receiving chemotherapy for non-Hodgkin lymphoma, who was concerned about her son's nutrition. She asked whether sugar could worsen his cancer and what she could do to help him nutritionally. Her concerns were acknowledged and reframed around building resilience through healthy, balanced eating[57, 101]. She was informed that while no strong evidence links sugar to cancer progression, reducing refined sugar intake and emphasizing whole foods, fruits, and vegetables is encouraged. There is evidence that shows a decreased risk of pediatric leukemia with higher intake of fruits and vegetables during pregnancy[57]. Additional guidance was offered on reducing pesticide exposure through diet, such as selecting organic produce when feasible and using tools like the Environmental Working Group's Dirty Dozen and Clean Fifteen lists to guide decisions[102]. As in the previous example, the consult emphasized empathy, cultural sensitivity, and actionable strategies aligned with each family's needs and concerns.

Across all settings—cancer predisposition clinic, active oncology treatment, and survivorship care—these early efforts aim to identify practical, scalable strategies for integrating environmental health into routine pediatric oncology care.

Discussion and Conclusions

The integration of environmental health into U.S. pediatric oncology care is still in its early stages, but momentum is growing. A 2024 policy statement from the American Academy of Pediatrics emphasized the urgent need to embed environmental health into pediatric training and clinical care, calling for "proactive, prevention-oriented approaches that account for environmental influences on child health[103]." The Murcia model offers valuable insight into what a more comprehensive and longitudinal approach can achieve and a proof-of-concept: a holistic, continuum-wide service that is clinically practical, research-enabling, and broadly relevant. Standardizing an environmental health history and recording it in the medical record not only supports individualized counseling but also builds a structured data resource for future epidemiologic analyses. Adapting a similar model in the U.S. through Pediatric Environmental Health Specialty Unit networks, dedicated consult teams, and interoperable data platforms, could accelerate risk-stratified prevention (i.e., in comprehensive cancer control plans), enhance survivorship care, and cultivate new professional roles (e.g., clinical environmental health specialists, digital exposome analysts)[104]. The work in Murcia, Spain demonstrates that integrating environmental health into pediatric oncology is both feasible and impactful, providing a roadmap for scaling similar services nationally and globally.

The implementation of environmental health consult services in U.S. pediatric oncology offers a unique opportunity to address unmet needs among families and close critical training gaps among clinicians. Trainees—particularly pediatric residents and oncology fellows—have played a meaningful role in shaping and participating in the consult service during its early stages. Many trainees report encountering core concepts such as environmental health exposures, risk reduction strategies, and family-centered communication tools for the first time. These experiences emphasize the absence of formal training on environmental contributions to childhood cancer within traditional clinical education pathways. Embedding environmental health into oncology practice thus offers dual benefits: improving patient care while preparing a more environmentally literate pediatric workforce for the future.

Despite its promise, the consult service also faces important limitations. Although most families express a strong interest in understanding how environmental factors may influence their child's cancer, these conversations may introduce emotional complexity, including guilt or anxiety. Clinicians must be equipped to navigate these discussions with empathy and balance. In general, we cannot make definitive causal connections between the environmental exposures of an individual and risks. We must extrapolate from childhood cancer data that are based on population statistics. The responses to environmental health histories collected by patients and families are subject to differential recall—particularly when exposures occurred years prior to diagnosis. While the intake tool attempts to capture exposure timelines and changes following diagnosis, this remains a methodological challenge. Nonetheless, families often appreciate the opportunity to reflect, ask questions, and act on exposures that have been identified as potential risk factors for cancer and other health problems, even in the face of scientific uncertainty.

The consult service offers a model for integration of environmental health into pediatric oncology care in the U.S. The work underway at two U.S. pediatric cancer centers represents an early step toward broader adoption. Earlier work in Murcia, Spain—where the Pediatric Environmental Health Specialty Unit has embedded environmental health guidance across the cancer continuum—demonstrates the feasibility and impact of a sustained, holistic approach. Continued collaboration, feedback from families and clinicians, and alignment with existing clinical workflows will be key to realizing the full potential of these innovative efforts.

Author Contributions

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Funding source

This work was supported by cooperative agreement FAIN: NU61TS000356 from the Centers for Disease Control and Prevention/ Agency for Toxic Substances and Disease Registry (CDC/ATSDR) totaling $3,673,450.00 with 73% funded by CDC/ATSDR. The U.S. Environmental Protection Agency (EPA) provided the remaining support through Inter-Agency Agreement 24TSS2400078 with CDC/ ATSDR. The Public Health Institute supports the Pediatric Environmental Health Specialty Units as the National Program Office. The contents are those of the author(s) and do not necessarily represent the official views of, nor an endorsement, by CDC/ATSDR, EPA, or the U.S. Government. Use of trade names that may be mentioned is for identification only and does not imply endorsement by the CDC/ATSDR or EPA.

Declaration of competing interest

The authors declare no conflicts of interest. The funders had no role in the writing of the manuscript or in the decision to publish the results.

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