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Exposure of lead from electronic waste with the incidence of attention-deficit/ hyperactivity disorder, can it be prevented? : a literature review

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Abstract

Due to the significant and long-term effects of exposure to these chemicals on the neurological system, kidneys, bones, reproductive and endocrine systems, lead from electronic waste (E-Waste) has emerged as a key global environmental health issue. Women who became pregnant when they were growing up in a recycling facility would have an even longer exposure history, a larger body burden in physiologic deposits, and can trigger new problems when pregnant, one of the problems that can arise is Attention-Deficit/Hyperactivity Disorder (ADHD). The prevalence of ADHD in the world ranges from 2% to 7%, and an average of about 5% among children and 60% of them can continue into adulthood. The diagnosis of ADHD is more of a phenomenological diagnosis than an etiologic one, because many factors are involved and suspected to be the etiology, but manifest as the same symptoms. Article searches were carried out through PubMed, Scopus, ProQuest, Science Direct, Portal Garuda Indonesia, Sinta, and Google Scholar. The articles were selected with the following criteria: the dependent variable was lead and ADHD, the independent variable was the exposure to dust, open access to full text, and the articles selected with a publication date around 2011-2021. Based on 173 relevant articles, 18 main articles fulfil the criteria. Many studies have concluded that ADHD is the result of impaired neurological function by an imbalance of neurotransmitters belonging to the category of executive function of the brain. This study discovered that recycling of e-waste contaminates the environment with lead, which affects children's neurobehavioral development.

Keywords: E-Waste; Lead; Children; ADHD

Introduction

Ewaste is the acronym used to designate out dated or abandoned electronics and appliances, such as keyboards, computer mouse, printers, copier, desktop and laptop computers, liquid crystal display (LCD) monitors, and CRT televisions and computer monitors (Agawa et al., 2020).

E-waste includes valuable components that can be recovered during recycling, such as precious metals, However, it also contains significant amounts of persistent organic pollutants (POPs) and heavy metals, which when released through ineffective recycling processes can be hazardous to the environment and human health. (Munoz et al.,

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2020).

Since the pollutants in e-waste are produced in combination, it is impossible to determine the effects of exposure to a single molecule or element. But a deeper understanding of how the chemical components of e-waste interact is necessary. The process of being exposed to e-waste is complex, involving a number of channels and sources of exposure, a range of exposure times, and the possibility of additive, synergistic, or inhibitory effects of several chemical exposures. Since exposure to e-waste is a unique variable in and of itself, the exposures involved should be considered as a whole. The three kinds of sources of e-waste exposure are exposure to hazardous e-waste compounds still present in the environment, official recycling, and informal recycling. (ie, environmental exposure) (Master et al., 1998).

Informal electronic waste recycling practices include the disassembly of outdated electronics to recover valuable components using ad hoc methods, with little to no technology to minimize exposure and enabling the release of hazardous substances (Wong et al., 2011; Wong et al., 2012). Formal electronic trash recycling facilities use technology that is specially designed to properly retrieve salvageable components from outdated devices while safeguarding workers' health. These facilities are uncommon in less developed nations since they are expensive to establish and maintain. Workers at formal or semi-formal recycling centers may still be in danger of exposure to low dosages of contaminants due to varying national safety requirements (Nicolescu et al., 2012). Residents who live a certain distance from e-waste recycling areas are also in danger of environmental exposure due to the high levels of environmental, food, and water pollution, though at lesser levels than through occupational contact. (Wong et al., 2011).

E-waste is linked to certain chemical elements and compounds, either as equipment parts or as substances discharged during recycling. A category of lipophilic, bioaccumulative compounds known as persistent organic pollutants have extended half-lives and are extremely resistant to decomposition. (Frazzoli et al., 2012).

540,000 people have died as a result of lead exposure, and 13.9 million years have been lost to disability and death as a result of long-term consequences on health. When it comes to the weight of this disease, developing areas bear the greatest financial cost (Hong et al., 2015).

Lead is a well-known neurotoxin that can harm several organs and obstruct the growth of the brain (Agency for Toxic Substances & Disease Registry, 2020; Carfield et al., 2003). Children are particularly vulnerable to lead toxicity because lead may quickly pass the blood-brain barrier and is absorbed at a higher rate in children than in adults. In addition, even at levels lower than 10 g/dL, it has been reported that lead exposure is associated with reduced intelligence, impaired academic achievement, and executive functioning (Costa et al., 2004; Surkan et al., 2007).

Lead is a poison that can harm a variety of organ systems in the human body (Agency for Toxic Substances & Disease Registry, 2020). Lead exposure is toxic at any age, but it is most detrimental during the crucial years of brain development in childhood and early adolescence because it interferes with the development of the central nervous system (Carfield et al., 2003). Lead exposure can cause serious side effects like coma, death, and neurological damage such as cerebral palsy, mental retardation, and seizures (Hubbs-Tait et al., 2005). Lead exposure has been linked to a number of negative effects, including (a) lowered intellect and academic impairments, (b) impaired executive functioning, and (c) behavioral issues, antisocial behavior, and criminality, even at low exposure levels. (Munoz et al., 2020). The negative effects of lead exposure on a child's ability to learn have been the subject of extensive investigation. However, concentration issues, hyperactivity, and impulsivity—the three main signs of attention-deficit/hyperactivity disorder—have also been linked to lead exposure (ADHD) (Franke et al., 2017).

A child's exposure to lead can have a number of negative health impacts. It may result in deficiencies in cognitive, behavioral, or motor skills, as well as issues with hand-eye coordination and reaction speed, as well as poorer scores on IQ tests (Surkan et al., 2017). Adults who are exposed to lead over an extended period of time risk having high blood pressure, renal, and nervous system problems (Nigg et al., 2008).

Lead is thought to cause methylation disorders in DNA, thereby changing gene expression patterns (Nigg et al., 2008). DNA methylation suggests one possible mechanism for how environmental influences may influence genetic expression over time. DNA methylation disorders have been associated with ADHD symptoms in childhood (Mitra & Ahua, 2012).

Attention Deficit Hyperactivity Disorder (ADHD) is a developmental disorder in increasing children's motor activity, causing children's activities to be unusual and tend to be excessive. This disorder is characterized by difficulty focusing attention accompanied by feelings of restlessness, can't stay still, can't sit still and always leaves a steady state such as sitting or standing. Some other symptoms that are often seen are like to explode, excessive activity and like to make a fuss (Choi et al., 2020). Three main symptoms that are often seen in children with ADHD are difficulty paying attention, hyperactivity and impulsivity. At least in 2 different settings, for example at home and at school (Andres et al., 2018).

The prevalence of ADHD in the world ranges from 2% to 7%, and an average of about 5% among children and 60% of them can continue into adulthood (Hubbs-Tait et al., 2005). The diagnosis of ADHD is more of a phenomenological diagnosis than an etiologic one, because many factors are involved and suspected to be the etiology, but manifest as the same symptoms (Nicolescu et al., 2012).

Blood lead levels were much greater in the hyperactive youngsters than in the non-hyperactive children. The blood lead levels reported by David et al., by today's standards were startlingly high, with many members in the hyperactive group having blood lead levels that were almost poisonous (Zhang et al., 2015). Even the control group's blood lead levels, which were on average 22.5 g/dL, were more than four times the current level of concern indicated by the Centers for Disease Control and Prevention, which is 5 g/dL. (Department of Health and Human Services, Public Health Services, 2022). In the following decades, systematic research on the relationship between lead exposure and symptoms of ADHD has gradually grown.

Methods

This research is based on a review with the type of narrative review. This review aims to synthesize past research findings on the variables linked with Attention-Deficit/Hyperactivity Disorder from lead sourced from electronic waste. The journal search conducted for this study used the keywords 'paparan limbah elektronik terhadap kejadian ADHD' and 'dampak limbah elektronik dengan ADHD' for journals published in the Indonesian language, and the keywords ‘electronic waste and ADHD’ and 'lead from electronic waste with the incidence of ADHD' for journals published with the English language. Journals are located using a database such as PubMed, Scopus, ProQuest, Science Direct, Portal Garuda Indonesia, Sinta, and Google Scholar. The publications were chosen based on the observational research design utilized.

Selecting an article starts with a quick scan of the title, followed by a study of the abstract for parallels to the research issue, specifically a link between exposure of lead with the incidence of ADHD. 18 articles matched out of 173 that were discovered. The papers were then chosen for a full-text evaluation based on the inclusion criteria that had been established. The study's inclusion criteria were as follows:

1. Articles published in 2011-2021
2. Articles with the type of observational research
3. The dependent variable in the article is Attention-Deficit/Hyperactivity Disorder

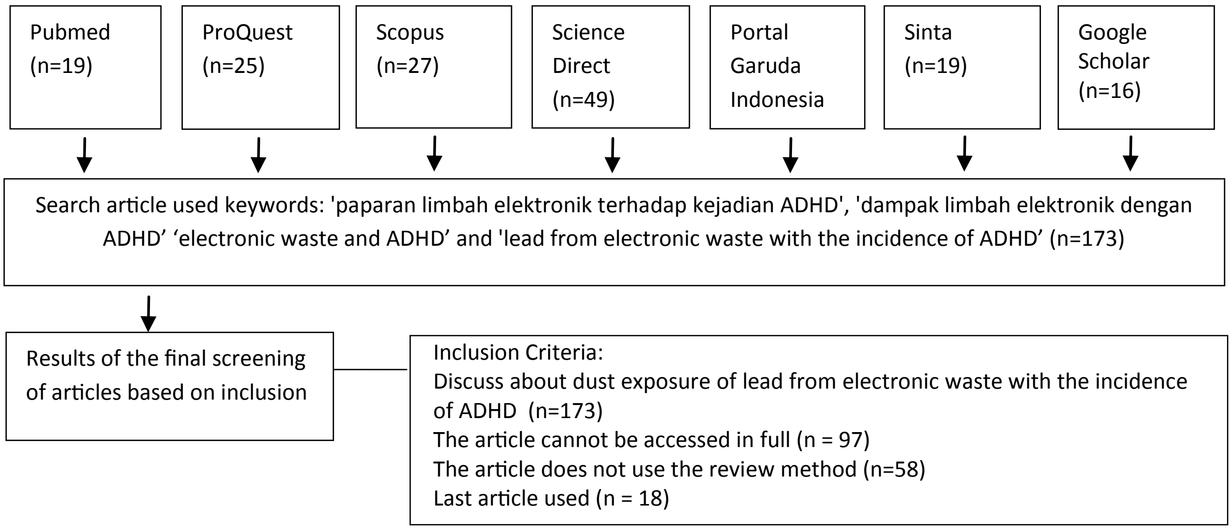

Figure 1. Flow chart screening article

Result

The According to the findings of a review of ten selected articles, all articles stated that lead exposure from electronic waste have an association with incidence of Attention-Deficiency/Hyperactivity Disorder (Table 1).

Based on the findings in the synthesized article, Attention-Deficiency/Hyperactivity Disorder (ADHD) can occur due to lead exposure from electronic waste. Based on the findings of the article synthesis, ADHD can occur due to lead exposure to young children or pregnant women.

Discussion

Electronic Waste (E-Waste)

Due to the vast and growing volume of electronic garbage (E-Waste) discovered in the market and the lack of adequate management policies in many countries, E-Waste has emerged as a serious global environmental health concern.

Ewaste is the acronym used to designate o utdated or abandoned electronics and appliances, s uch as keyboards, computer mouse, printers, copier s, desktop and laptop computers, liquid crystal displ ay (LCD) monitors, and CRT televisions and compute r monitors (Zhang et al., 2015).

But heavy metals and persistent organic pollutants (POPs), which can be hazardous to both human health and the environment when discharged through improper recycling methods, are also present in high concentrations in e-waste. E-Waste contains valuable components that can be recovered through recycling, such as precious metals. Y. Li et al., 2020

Around 40 million metric tons of electronic trash are produced globally each year, with the European Union and the United States producing 22.5% and 24%, respectively, of that total (Flora et al., 2012). More than 13% of the world's electronic garbage is handled and recycled by developing countries, which also handle waste from rapidly expanding and industrialized economies. In China, India, Pakistan, Vietnam, and the Philippines, informal recycling markets have grown to handle 50% to 80% of the e-waste managed by developing countries. There are occasions when "backyard operations" are undertaken informally and involve shredding, burning, and disassembling garbage cans (Anderson, 2015).

Electronic devices can contain thousands of parts made of potentially harmful compounds like lead, cadmium, chromium, mercury, beryllium, antimony, polyvinyl chlorides (PVC), brominated flame retardants, and phthalates, making e-waste more dangerous than many other municipal trash (Zhang et al., 2015).

The neurological system, kidneys, bones, reproductive, and endocrine systems are all impacted

Table 1. Result synthesis matrix

No	Main Idea	Findings
1	Electronic Waste (E-Waste)	The recycling process can recover valuable components from e-waste, such as precious metals. The neurological system, kidneys, bones, reproductive and endocrine systems are all negatively impacted by prolonged exposure to these substances. DNA methylation suggests one possible mechanism for how environmental influences may influence genetic expression over time. DNA methylation disorders have been associated with ADHD symptoms in childhood.
2	Exposure of Electronic Waste to the incidence of ADHD	Due of the millions of components made of potentially harmful materials that electronic devices might include, e-waste is more hazardous than many other municipal garbage. Lead has been a risk factor for ADHD and interacts with gene variants in early life. Lead is thought to cause methylation disorders in DNA, thereby changing gene expression patterns.
3	Attention-Deficit/Hyperactive Syndrome	Numerous brain regions have been linked to the various symptom sets of ADHD, which is recognized to have a strong neurological component. Glial cells, which serve as support cells for neurons by protecting neural axons and detoxifying toxic compounds, may be harmed by lead in the brain. Additionally, they might be connected to behavioral inhibition.
4	Attention-Deficit/Hyperactive Syndrome Etiology	Many studies have concluded that ADHD is the result of impaired neurological function by an imbalance of neurotransmitters belonging to the category of executive function of the brain. The etiology of ADHD is not clearly known. Neurobiological factors are thought to be a strong enough factor for the onset of this disorder.
5	How to Prevent?	E-waste recycling should rely primarily on appropriate recycling technology, and sloppy and outdated recycling methods need to be drastically scaled back or abandoned. Limiting children's exposure to excessive amounts of e-waste toxicants at both the home and community levels is the best course of action to follow to prevent the development of ADHD in children. To stop toxicant exposures linked to e-waste, a methodical approach supported by exposure evaluations and health effects studies is required. Engineers, environmental scientists, and other experts can take part in this research and work to reduce the exposure of vulnerable people to these toxicants.

by long-term exposure to these substances. Women who relocated to an E-Waste recycling site at the time of marriage would have a shorter exposure history and a lower body burden in physiologic deposits (such as bones and adipose tissues) than pregnant women who grew up in a recycling site.

There are several recognized and suspected developmental neurotoxicants in E-Waste that are especially dangerous to developing fetuses and children. These neurotoxicants can be found in contaminated indoor and outdoor air, water, and soil, which can expose infants and children to them (Choi et al., 2020).

The exposure to dangerous substances will increase if the food and drinking water are also obtained from tainted community wells (Munoz et al., 2020). Young children and developing fetuses are in critical stages of neural migration, development, differentiation, and myelination, which might magnify the negative consequences of exposure. E-Waste toxicant exposure has a number of distinctive features. First, a combination of toxicants from e-waste are released during unregulated recycling procedures (Stawski et al., 2015).

Persistent organic pollutants (POPs) and heavy metals frequently coexist in the air in recycling facilities and close-by neighborhoods. Second, the exposure to E-Waste toxicants is not uniform (Goodlad & Marcus, 2015). The variety is due to a number of factors, including the type of E-Waste, the duration of recycling history, the volume of recycling, specialization in recycling processes, workshop locations, parental involvement in recycling, and the child's daily activities. Third, exposure to toxicants found in e-waste lasts a long time (Zhang et al., 2015).

Since many recycling facilities have been in operation for more than ten years, the cumulative exposure to the environment in the area is typically substantial. In this post, we'll talk about how lead exposure from electronic trash affects the prevalence of ADHD.

Exposure of Electronic Waste to the Incidence of ADHD

Due to the millions of parts made of potentially harmful substances including lead, cadmium, chromium, mercury, beryllium, antimony, polyvinyl chlorides (PVC), brominated flame retardants, and phthalates that can be found in electronic devices, e-waste is more dangerous than many other municipal trash. (Wermter et al., 2010).

One of the most harmful environmental toxins is lead. Lead is one of ten substances that the WHO has designated as being of considerable public health concern and calling for Member States to take appropriate action to safeguard the health of workers, children, and women of reproductive age (Wermter et al., 2010). 540,000 people have died as a result of lead exposure, and 13.9 million years have been lost to disability and death as a result of long-term effects on health. When it comes to the weight of this disease, developing areas bear the greatest financial cost (Kim et al., 2013). Due to the fact that different contaminants are rarely present in isolation in environmental exposure, lead exposure in combination with other pollutants or risk factors may have greater detrimental effects (Departement of Health and Human Services Public Health Services, 2022; Kim & Sharma, 2015). The frequency and causes of lead exposure, the incidence of lead poisoning, and the severity of the effects vary substantially from one country and one area within a country (Carfield et al., 2003). People are exposed to lead in various ways and from various sources (such as air, food, water, dust and soil). The most common and harmful high-dose source of lead exposure for young children is lead-based paint (Costa et al., 2004).

Lead has been a risk factor for ADHD and interacts with gene variants in early life. Lead is thought to cause methylation disorders in DNA, thereby changing gene expression patterns (Nigg et al., 2018). One potential mechanism for how environmental factors may affect the expression of genes throughout time is suggested by DNA methylation. DNA methylation disorders have been associated with ADHD symptoms in childhood (Kim et al., 2013).

Children who are exposed to lead experience a range of negative health impacts. Hand-eye coordination and reaction time issues, deficiencies in motor, behavioral, or intellectual functioning, as well as poorer scores on cognitive tests, are all possible consequences. (Surkan et al., 2007). Long-term lead exposure can also damage the kidneys and nervous system and increase the risk of high blood pressure in adults (Nigg et al., 2008). Furthermore, maternal exposure to high levels of lead during pregnancy may be associated with increased incidences of miscarriage, stillbirth, premature birth and low birth weight (Goodlad & Marcus, 2015; Guirlarte, 1998). There is currently no safe level of lead exposure, however it is understood that as lead exposure rises, so do the variety and severity of symptoms and effects (Lau et al., 2002).Scientific evidence has shown that even low levels of lead exposure, BLLs >5 ug/dL, may cause a decrease in intelligence and an increase of behavioral and learning difficulties in children (Costa et al., 2004).

A persistent neurodevelopmental disease called ADHD affects 2.5% of adults and 5% of children and adolescents globally. The significant significance of environmental factors in the susceptibility to the disorder is shown by ADHD heritability, which is believed to be between 60% and 80%. (Waldman et al., 2006). It is recognized that environmental and biological variables can both influence the emergence of ADHD. Exposure to environmental contaminants by people can be a risk factor for ADHD, according to several studies. For instance, exposure to harmful chemicals such as bisphenol A, polycyclic aromatic hydrocarbons, and pesticides in the environment as well as dietary variables and heavy metal intake may all play a role in ADHD (Hong et al., 2015; Ikemoto & Pankspp, 1999; Eubig et al., 2010).

Attention Deficit/Hyperactivity Disorder (ADHD)

ADHD is acknowledged to have a sizable neurological component, and a number of distinct brain regions have been linked to various symptom combinations. Inadequate executive functioning may come from injury to neurons in the frontal lobe and cortex, which are believed to be the origin of the majority of the executive activities previously addressed. The intensity of executive functioning-related ADHD symptoms may be attributed to damage to brain regions such as the thalamus, globus pallidus, and basal ganglia (Stawski et al., 2015). The basal ganglia, which is closely linked to the cerebral cortex, is involved in the regulation of movement, cognition, and the acquisition of certain abilities.the basal ganglia's caudate nucleus, which is connected to learning and memory (Davison et al., 2010). Another area of the basal ganglia, the putamen, is connected to motor movement. The basal ganglia may be the source of disturbances in motor movement (hyperactivity or fidgeting), although the cerebellum and other brain regions also play a role. Glial cells, which serve as support cells for neurons by protecting neural axons and detoxifying toxic compounds, may be harmed by lead in the brain. They might additionally contribute to behavioral inhibition. (Master et al., 1998; Anderson, 2015).

Furthermore, it is well known that the frontal and prefrontal cortex are closely related to the nucleus accumbens, a key dopamine-producing region. The mesolimbic route of dopamine runs from the ventral tegmentum region through the nucleus accumbens to the prefrontal cortex and frontal lobes, and it has been closely linked to motivation and rewards. (Ikemoto & Pankspp, 1999).

The diagnosis of hyperkinetic impulse disorder was first proposed by Laufer in 1957 to describe children with a collection of symptoms of inattention and hyperactivity. Approximately 2 decades later, the diagnosis of Hyperkinetic Reactions was included in the Diagnostic and Statistical Manual (DSM) II. The diagnosis was based on the psychodynamic view that developed at the time, that this disorder was considered a reaction to stressors (Andres et al., 2018; Guilarte, 1998).

In subsequent developments, it is known that the cause of this collection of symptoms of inattention and hyperactivity is more complex than just a reaction to stressors, so DSM III describes it in phenomenological terms without causal implications, namely Attention Deficit Disorder (ADD) and ADD with Hyperactivity. The diagnosis of Attention Deficit Hyperactivity Disorder (ADHD) began to appear in DSM IIIR, and was maintained in DSM IV through DSM V (Andres et al., 2018).

Attention Deficit/Hyperactivity Disorder

(ADHD) Etiology

Many studies have concluded that ADHD is the result of impaired neurological function by an imbalance of neurotransmitters belonging to the category of executive function of the brain. The 6 executive functions that are usually impaired in ADHD are flexibility, organization, planning, working memory, separation of affect and cognition, as well as the function of regulating verbal and motor actions. The organ responsible for carrying out the function is the frontal lobe (Adiputra dkk., 2015).

The etiology of ADHD is not clearly known. Neurobiological factors are thought to be a strong enough factor for the onset of this disorder. Prenatal exposure to toxic substances, prematurity, and birth mechanisms that disrupt the nervous system are thought to be associated with this disorder (Franke et al., 2017). Psychosocial factors are also thought to have a role in ADHD. Factors that trigger the occurrence of ADHD include genetic factors and environmental factors. Given that hereditary risk factors cannot be changed in the short term, lowering exposure to environmental risk factors is important to lower the risk of ADHD (Nicolescu et al., 2012).

How to Prevent?

Based on the results of the synthesis of previous research articles, several ways were found to overcome problems related to lead exposure from electronic waste to the incidence of Attention-Deficiency / Hyperactivity Disorder. Prevention includes (Agawa et al., 2020; Munoz et al., 2020; Kenneth & Lii, 2011; Lin et al., 2019) :

1. To prevent toxicant exposures linked to e-waste, a systematic approach informed by exposure assessments and health effects research is required. Engineers, environmental scientists, and other experts can participate in this research and work to reduce exposure to these toxicants among impacted populations.
2. The first step in preventative measures will be to limit the use of harmful chemicals in the production of electronic gadgets, but there are also significant adjustments that need to be made to the way that waste is now recycled.
3. The amount of exposure that children receive to excessive amounts of E-Waste toxicants should be minimized at both the household and community levels, and appropriate recycling methods should be the mainstay of the E-Waste recycling industry.
4. To prevent excessive exposure to toxicants, effective environmental rules in the treatment of e-waste are also required.
5. Developing and developed nations are jointly responsible for regulating the production of electronic devices and the international circulation of e-waste.
6. In nations with subpar recycling systems, the regulation and management of recycling operations should be based on the welfare of people, particularly children.
7. Restricting the use of hazardous chemicals in the production of electronic gadgets would also assist in minimizing unwanted exposures to these compounds.
8. The World Health Organization of the United Nations is creating a special plan of action in response to the paucity of data on the consequences of e-waste on children's health. This project includes: 41
9. highlighting the negative effects of e-waste in order to raise public awareness
10. creating programs and training techniques for health workers;
11. E-waste study should be encouraged, and interested parties should be gathered to advance this cause.

Conclusion

From various data analyzes and discussions of the findings in previous studies, it can be concluded that lead poisoning from electronic waste is either directly exposed to children or to mothers who are pregnant. Various environmental factors such as exposure to substances and toxins during pregnancy, childbirth complications, nutrition, psychosocial problems, exposure to heavy metals and chemicals, have a role in increasing the risk of ADHD. The study might have policy ramifications for how the local government regulates e-waste recycling, limiting children's access and requiring improved recycling techniques to lower exposure. E-waste recycling should rely primarily on appropriate recycling technology, and sloppy and outdated recycling methods need to be drastically scaled back or abandoned. The best course of action is to limit children's exposure to harmful substances found in excessive amounts of e-waste at both the household and community levels.

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