



# Disposable Diapers: Impact of Disposal Methods on Public Health and the Environment

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## Abstract

Disposable diapers contain traces of dioxin, an extremely toxic by-product of the paper-bleaching process and a carcinogenic chemical, the most toxic of all cancer-linked chemicals. However, they are wonderfully convenient than cloth diapers and it has become the diaper of choice for mothers and care-givers. Disposable diapers are thrown away indiscriminately and this presents some challenges, environmental and health-wise. The environmental pollution caused by these indiscriminate disposal methods of used diapers is becoming obvious in many African countries, and globally, disposable diapers create large quantities of waste. This review recommends that disposable diapers should be disposed appropriately and indiscriminate dumping of disposable diapers by mothers and care givers should be discouraged. Waste management authorities should create awareness on proper disposal and environmental effects of used diapers on our environment.

**Keywords:** Disposable; Diapers; Waste; Degradation; Pathogens

## Introduction

Disposable diapers are clothed or synthetic disposable materials which contain absorbent chemicals that allows discreet defecation or urination [1]. Disposable diapers have become indispensable in the list of our day to day baby care products [2]. Approximately 90% and 95% of diapers used in the developed world are disposable diapers [3]. A baby uses an average of 4 to 5 disposable diapers a day [3], which shows they are generally used in many parts of developed and developing world as a replacement for cloth (reusable) diapers [4]. The advent of disposable diapers somehow resulted in the death of the napkin culture. There are a lot of disposable diaper in the market now with different Brand names and sizes [5] e.g. pampers [6], huggies, bamboo [7] etc. Some companies include fragrance, lotions or essential oils to their disposable diapers in order to help mask the smell of a soiled diaper, or to protect the skin. According to Assadourian et al. [8], since their entrance into the market, disposable diapers have become a symbol of affluence and sophistication. Disposable diapers have become highly commoditized and a necessity rather than a luxury in fast paced lives [9].

Disposable diapers represent about 4% of solid waste and are third largest single consumer item in landfills which are discarded after a single use. These disposals pose great burden on landfill sites and health related impact on our environs. However, soiled diapers are burnt, buried in the ground or thrown dumped in illegal dumpsites by mothers or caregivers and this could result in the spread of communicable diseases such as cholera [4]. Due to indiscriminate disposal of these disposable diapers, they either find their way to disposal sites and landfills, or litter public spaces, including farmlands, where they constitute an aesthetic nuisance [10]. The refuse disposal systems in developing countries are inadequate and it is common to find refuse containing human waste such as disposable diapers due to their traditional methods of mixing waste and dumping it at the tipping sites or unguardedly along road sides [11]. These negligent disposals of soiled disposable diapers carry bacteria (enterics), viruses, and when in the environment can be transmitted directly or indirectly. Some waste pickers use bare hands to salvage materials disposed of at the landfills [12]. According to studies by Stenstrom et al. [13], unprotected waste pickers are exposed to more than 120 different types of viruses including enteroviruses, rotavirus, enteric adenoviruses and human caliciviruses (noroviruses) that may enter the environment through faecal matter.

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## Disposable diapers and its components

A diaper is a type of underwear that allows the wearer to defecate or urinate without the use of a toilet, by absorbing or containing waste products to prevent soiling of outer clothing or the external environment. Diapers are primarily worn by infants, toddlers, and by children who are not yet potty trained or who experience bedwetting. They are also used by adults with incontinence or in certain circumstances where access to a toilet is unavailable. These can include those of advanced age, patients' bed-bound in a hospital, individuals with certain types of physical or mental disability, and people working in extreme conditions, such as astronauts.

### Components of disposable diapers

Generally, a typical disposable diaper consists of Wood pulp fluff, Sodium polyacrylate (also referred to as SAP or absorbent gel), polyolefin nonwoven fabric, adhesives, polyolefin film and synthetic rubber elastic strands [14].

**Wood fluff pulp:** Fluff pulp is a type of chemical pulp, a product made by combining wood chips and chemical in a large tank (digester) where lignin, a protein that binds cellulose fibers together, is broken down [15]. The pulp is made from long fiber softwoods, which are conifers such as pines, cypresses, and spruces. Many conventional diaper brands use fluff pulp made from a whitening process that employs the chemical, chlorine dioxide in its bleaching.

**Chemical compounds in diapers:** Aside from the sheer volume of waste, disposable diapers contain many harmful substances.

- Tributyltin (TBT) are organic derivatives of tin ( $\text{Sn}^{4+}$ ) characterized by the presence of covalent bonds between three carbon atoms and a tin atom. They conform to the following general formula  $(n\text{-C}_4\text{H}_9)_3\text{Sn-X}$ , where X is an anion or a group linked covalently through a hetero-atom [16].

- Dioxins consist of two benzene rings connected by two oxygen atoms and contain four to eight chlorines, for a total of up to 75 compounds or congeners [17].

- Adhesives, synthetic dyes, and perfumes: Adhesives are used to hold the entire diaper together. Synthetic dyes create the cute pictures found on diapers, as well as the colored straps and the convenient strip telling you whether the baby needs to be changed. Diapers use perfumes to hide odors.

- Sodium polyacrylate is used as the absorbent stuffing. Menstrual pads containing this compound have been implicated in cases of toxic shock syndrome.

- Volatile Organic Compounds (VOCs) like toluene, xylene, ethylbenzene, and dipentene are used to produce dyes, polymers, and adhesives with great health risk when released into the air under heat. Many diapers are made using disperse blue 106, disperse blue 124, disperse yellow 3, and disperse orange 3, all of which have been known to cause contact dermatitis (diaper rash) and an increased sensitivity to allergens (Figure 1) [18].

- Plastics/polymers - Mainly polypropylene and polyethylene, but also includes polyester, polyurethane, and polyolefin. They're the primary materials used in product packaging, household products, and the production of plastic grocery bags, respectively. Most diapers are composed of these non-recyclable plastics.

- Phthalates are esters of phthalic acid, also known as esters of



Figure 1: Diapers allergies [18].

benzene-1,2-dicarboxylic acid. Phthalates contain a benzene ring with two functional (ester) groups. Their solubility in water decreases with an increase in the length of the carbon chain or molecular weight. Phthalates are oily liquids characterized by high boiling temperature, weak solubility in water and satisfactory solubility in most organic solvents [19]. Phthalates are classified into two groups: Low-molecular-weight phthalates such as Di-N-Butyl Phthalate (DBP) or Butyl Benzyl Phthalate (BBP), and high-molecular-weight phthalates such as Diisodecyl Phthalate (DIDP) or Diisononyl Phthalate (DINP) [20].

- Petroleum/petrolatum is used to keep diapers from leaking.

**Design of disposable diapers:** A disposable diaper, by design, consists of an absorbent pad between two sheets of non-woven fabric, one of which is permeable (the layer closest to the skin) and one which is impermeable (the outer larger). The pad is comprised of a hydrophilic polymer and a fibrous material (cellulose), leading to maximum absorption capacity [21]. These polymer molecules (sodium polyacrylate) comes in contact with water, a chemical rearrangement of atoms transpires which causes water molecules to 'stick' to the ions (sodium and carboxyl). This leads to the formation of a gel that expands in volume to a great extent [14] and have the ability to interact with water molecules and to link with other polymer molecules to create cross-linked chains that are not water soluble, but can hold large amounts of water, thus prevent the liquid from leaking onto the baby's skin and clothing. The pad is held in place by nonwoven fabric sheets that are made from plastic resins and assembled by interlocking the plastic fibers [21]. The permeable layer is often made from polypropylene while the impermeable sheet is made from polyethylene.

## Popular Disposal Options for Soiled Disposable Diapers

Soiled disposable diapers are solid waste, and are therefore disposed using popular disposal methods for solid waste. These include methods such as burning, composting, landfilling, and open dumping. However, the very primitive open dumping seems the most popular method of disposable diaper disposal [22]. A study by Remigios et al. [4] reported that most women using disposable diapers resorted to either burning the diapers, burying them in the ground, flushing them in the toilet, or simply dumping them in open spaces in the evening when no one was watching.

### Burning

Incinerators are designed for satisfactory burning of combustible refuse, provided air pollution standards are met. However, the use of incinerators for disposing solid waste is now obsolete even in western countries, because of the high capital and operating costs involved. Air pollution also makes it unattractive. Incineration is still not



**Figure 2:** Unguarded disposal of soiled disposable diapers in land depressions [26].



**Figure 3:** Unguarded disposal of soiled disposable diapers in vacant plots [27].

best option even when heat recovery is possible in this method, and volume reduction and residue sterilization are real [1,23]. Burning of disposable diapers is not done under controlled condition as provided by incinerators but open burning of diapers along other refuse is popular comprising 10.34% and 40% of total disposal methods in Kenya [24] and Zimbabwe [25], respectively. The wet condition of disposable diapers due to it being soiled with feces makes it very difficult to be burnt by fire [4].

**Burying**

Some users bury soiled disposable diapers in the ground. According to Remigios [4], some women revealed that they dug holes within their yards to bury these diapers. It accounts 4.60% of total disposal methods in Kenya [24]. Most of the disposable diapers that are disposed with household garbage, in waste [23-25] are eventually taken to the municipal landfill. Landfill (or controlled tipping) is a system of waste disposal that is based on an arrangement in which solid waste are shifted from one area to another and dumped into trenches which are covered up at the end of each day or as one day’s collection from a particular locality is completed [1]. In this method of refuse disposal, refuse is dumped in accordance with a preconceived plan, compacted and covered during and at the end of each day. It is not open dump. If it is poorly managed, it may result in spontaneous ignition accompanied by smokes and smells. It might also result in leachates that pollute underground water [1,22].

**Open dumping**

Disposable diapers are indiscriminately thrown away or dumped openly at various points (Figure 2 and 3) [26,27]. Tembo and Chazireni [22] stated about 50% of care givers in Mberengwa district, Zimbabwe, dispose of soiled diapers in open places especially in bushes and on road sides. This practice is evident in Nigerian rural and urban communities [28]. Even when some refuse receptacles have been erected at collection points, the refuse dumped into such closets may not be removed over a long period of time.

Some rural communities in Nigeria hold the noxious believe that infant excreta, if disposed in the bush, are blessing to their farms and this encourages the dumping of soiled disposable diapers into vacant plots (Figure 3) [27], being completely unaware of the near non-degradability of those materials [29].

**Impact of Disposed Disposable Diapers**

Disposable diapers contribute to the comfort, hygiene and convenience of consumers but in spite of these benefits, there are several environmental issues and challenges associated with its eventual disposal. These include, but not limited to, issues such as, waste generation & environmental pollution, exposure to chemicals, exposure to pathogens and aesthetic concerns.

**Waste generation and pollution**

Solid waste generation possibly may be the most perplexing impact of disposable diapers on the environment and are reputed as the third largest individual constituent of municipal solid waste just after newspaper and bottles accounted for 1.5% and 4% of the total [30,31]. According to the National Customer Service Conference Focus Group Project (1999), “the amount of solid waste generated by disposable diapers is legendary, and in many people’s minds somewhat exaggerated”. Meseldzija et al. [32] noted that, “the most obvious environmental impact of disposable diapers lies in the fact that they are thrown away indiscriminately (Table 1) [33]. Research findings reveal that the average baby goes through 5,000 diapers before being potty-trained, and that 95% of these diaper changes are disposable diapers; one baby produce one ton of trash over one year when using disposable diapers (Table 2) and that in a house with a child in diapers, disposables make up 50% of household waste [31,32].

According to an EPA [34] report, the number of disposable diapers discarded in 2013 alone was about 3.6 million tons, the equivalent of more than 20 billion diapers. From birth to the time they are potty-trained, a single child will use around 7,000 diapers. That figure translates to more than 2 tons of waste per kid.

The most obvious impact of disposable diapers on environment is that they are thrown way piling up garbage every day [35]. Disposable diapers are not easily biodegradable after their entry into the environment because of its durable plastics and superabsorbent polymer and they pollute the environment for very long periods [22,36,37] and persist approximately up to 250 to 500 years to degrade [36,38]. Figure 4 [39] below shows photograph of disposable diapers that had stayed in the landfill for some years but still remain intact.

The non-collection of refuse has encouraged people to bury waste such as diapers in the ground. This however has devastating effects on water supplies as through sewage, waste will eventually mix with underground water and the probability of contaminating the source

**Table 1:** Average baby disposable diapers composition [33].

Material	Weight Percentage (%)
Cellulose pulp	35
Superabsorbent Polymer (SAP)	33
Polypropylene	17
Polystyrene	6
Adhesives	4
Elastics	1
Others	4

**Table 2:** Average diaper production per child. Source: Colo'n et al. (2010).

Age (months)	Children wearing	Number of Changes per Day	Average diaper weight (kg)	Diapers weight per child (kg/year)
Up to 6	100	7		536.55
6 to 12	95.7	7		513.48
12 to 18	82.8	5	0.21	317.33
18 to 24	45.6	5		174.76
				67.45
24 to 30	17.6	5		18.4
30 to 36	4.8	5		



**Figure 4:** Soiled disposable diapers after three years in the landfill [39].



**Figure 5:** Showing Waste blocking Drainage and Stream Channels [41].

of drinking water by pathogens such as bacteria and viruses [40,13].

Almost 95% of solid waste is inappropriately thrown open in the fields and streets and creating severe problems and plots or houses near the landfills or dumping site could not attract tenants or property dealers due to unhygienic and unpleasant conditions surrounding those [41]. These disposable diapers, when disposed indiscriminately, especially into drainages, they block the free flow of runoff water (Figure 5) [41] and this practice gives rise to flooding and the communities are adversely. When dumped on the road side, they reduce the width of the road and esthetics of the cities especially in Nigeria [42]. This is evident as one walk across the nook and the crannies of Nigeria; you find heaps of refuse littering the entire landscape, road sides, parks, gardens, commercial centers and other land use [43].

Chinyama and Toma in a study on understanding urban sewerage systems that was conducted in Chinhoyi in Zimbabwe observed that, diapers were amongst the solid waste dumped in sewers that contributed to blockages. Also, in the event where soiled disposable diapers are burnt, they emit dioxins and furans and other toxic greenhouse gases, chlorine and carbon monoxide and toxic ash smokes and some toxic gases including carbon monoxide, phthalates,

furans and others are released into the atmosphere. The ash which may be dispersed by the wind or leached by the water may contain toxic contaminants, which may be inhaled leading to respiratory problems. Toxins may be leached from remaining ash which could lead to the contamination of surface water or ground water. These increase the atmospheric concentration of suspended particulate matter, aerosols and other airborne contaminant, and provided the threshold conditions are satisfied, this will result in serious respiratory injuries.

**Exposure to chemicals**

The accumulated billions (or trillions) of disposable diapers sitting in landfills all over the world right now are leaching dangerous chemicals such as: Dioxins, Sodium Polyacrylate (SPA), phthalates, heavy metals, and other toxic substances into the soil and water [44]. These harmful chemicals found in disposable diapers may be accumulated in fish and other edible life forms found in receiving water bodies. The accumulation of such chemicals in biota over time may result in related food chain problems such as bioaccumulation and biomagnifications (WHO, 2016).

**Dioxin:** Dioxin is carcinogenic, and had been listed by EPA as the most toxic of all cancer-linked chemicals [45]. Dioxin, in very small quantities (parts per trillion), causes birth defects, skin diseases, liver disease, immune system suppression and genetic damage [46] in laboratory animals [47] consequently, dioxin was banned in many countries of the world. In humans, it causes cancers particularly reproductive cancers (breast female, endometrium, breast male, and testis) but, overall, the pattern is inconsistent. In addition, it changes the concentration of reproductive hormones [48]. A study by DeVito and Schechter [49] tested four brands each of diapers and tampons, and found dioxins in all samples, however in much lower concentrations. While one may believe that the tiny amount of dioxin exposure from diapers is insignificant, it is however of much concern that a substance reputed as the most carcinogenic chemical known, is found in a baby care product.

**Sodium polyacrylate (SPA):** SPA is the chemical added to the inner pad of a disposable diaper that makes it super-absorbent. They are the small, shiny, gelatinous crystals that are sometimes found in baby’s genitals during diaper changing. Studies by Sutton et al. and Prasad et al. [50,51] made the following assertions with regards to SPA in disposable diapers:

- Can absorb up to 100 times its weight in water;
- Can stick to baby’s genitals, causing allergic reactions;
- Can cause severe skin irritation, oozing blood from perineum and scrotal tissues, fever, vomiting and Staphylococcal infections in babies;
- Was banned from tampons in 1985 because of its link to Toxic Shock Syndrome;
- When injected into rats, has caused hemorrhage, cardiovascular failure and death;
- Has killed children after ingesting as little as 5 grams of it.

**Phthalates:** The plastic in all disposable diapers contains phthalates. These are the plastic softeners that were recently banned from children’s teething rings and other toys because of toxicity. Phthalates are endocrine disruptors, meaning they mimic human hormones and send false signals to the body. Phthalate toxicity targets

the reproductive [52,19] and respiratory systems primarily, but they also may be involved in the processes of carcinogenesis and even in autism spectrum disorders [20].

According to Prasad et al. [50], “children are uniquely vulnerable to phthalates exposures given their hand-to-mouth behaviors, floor play, and developing nervous and reproductive systems”.

**Heavy metals:** A study by Greenpeace [53] confirms that some disposable diapers contain Tributyl Tin (TBT) and other heavy metals. TBT is considered a highly toxic environmental pollutant, as upon exposure it spreads through the skin and has a hormone-like effect at the tiniest concentrations. TBT harms the immune system and impairs the hormonal system, and it is speculated that it could cause sterility in boys [51,54] also found that the dyes used on diapers can contain heavy metals - and heavy metals are not desirable as long as baby skin is concern.

**Other toxic concerns:** A study by Anderson and Anderson [47] showed that childhood respiratory problems, including asthma, might be linked to inhaling the mixture of chemicals emitted from disposable diapers. The study identified these chemicals in emissions from some undisclosed brands of disposable diapers: m-xylene, p-Anisaldehyde, ethylbenzene, styrene, isopropylbenzene, dipentene, m-methoxybenzaldehyde, methyl cinnamate, Toluene, 1,3,5-Trimethylbenzene, Trichloroethylene, 1-Methylcyclopentylamine, and 1,2,3, Trimethylcyclopentane. Toluene is a known central nervous system depressant; ethylbenzene is a carcinogen; dipentene is a skin irritant, while styrene is a respiratory irritant [50,51].

## Exposure to Pathogens

Microorganisms can be transmitted to people and other surfaces from droplets leaking from a child's diaper, as well as improper disposal of soiled disposable diapers, such as placing a soiled diaper on the ground. These microorganisms can include gastrointestinal pathogens. Because infants (younger than 12 months old) are especially effective carriers of enteric pathogens (pathogens present in the human gastrointestinal tract), soiled diapers increase microbial pathogens in solid waste and impact human health [55]. Pathogens in human feces can pose health problems in the long term [23]. According to ENVIS Centre on Hygiene, Sanitation, Sewage Treatment Systems and Technology [56] human excreta has been implicated in the transmission of many infectious diseases including cholera, typhoid, hepatitis, polio, cryptosporidiosis, ascariasis, and schistosomiasis. Residents at locations of indiscriminate refuse dumping are often noted to have symptoms like frequent passage of watery stools, typhoid, skin infections, vomiting, sore throat, abdominal pains and malaria [28].

Amuda et al., Udoakah and Akpan US, Kaoje et al. [57,58,59] all established various perspectives on the poor environmental governance, irritable environmental behavior and the challenges confronting human health due to improper management of waste. This negligent disposal of soiled disposable diapers exposes people who deal with solid waste such as Municipal employees and waste pickers to contaminants which could cause serious illnesses as they may handle raw faecal matter in the course of disposing of soiled disposable diapers [4]. Some waste pickers use bare hands to salvage material disposed of at the landfills. They are therefore exposed to different types of human pathogens that may enter the environment through faecal matter. These pathogens include more

than 120 different viruses such as: *Entero-viruses*, *rotavirus*, enteric adenoviruses, and *human caliciviruses (noroviruses)*; also, bacterial pathogens such as: *Escherichia coli*, *Salmonella species*, *Shigella*, *Vibrio*, *Clostridia*, *Streptococcus*, and *Bacillus species* among others [60]. Some of these pathogens have the potential to harm people long after they have been discarded, since they are preserved in the excrement contained in diapers for several months. Chipunza [61] noted that diapers recklessly dumped at illegal dump sites are usually ravished by stray dogs thereby exposing faecal matter which attracts the huge green flies. This is a serious health hazard because these flies later visit the nearby homes since, according to Prickford [62]; they have the capacity to fly up to 5 kilometers. Pathogens are also transferred from soiled disposable diapers to humans through vectors, as most of wastes are thrown into the streets and stagnant there for many days [41]. These indiscriminate dumping of soiled disposable diapers creates breeding ground for insects, flies and mosquitoes. Disease transmission by houseflies is greatest where inadequate refuse storage, collection and disposal is accompanied by inadequate sanitation [63]. A previous study found that there is key connection between the inappropriate waste disposal and occurrence of vector borne diseases [64]. Health risks comes from areas with heaps of indiscriminately dumped soiled disposable diapers as they are sources of many diseases particularly diarrheal diseases caused by bacteria, viruses or parasites. A study by Mohsin et al. [41] and Chinyama reported that areas with heaps of wastes frequently come-down with malaria, typhoid fever and some were suffering allergies and skin diseases also. Generally, the insects and rodent vectors are in the refuse and spread diseases such as cholera and dengue fever [65].

A study by Murage [66] conducted in Kenya, contends that poor disposal of disposable diapers is a leading cause of diseases as well as blockage of drainage. Meseldzija et al. [32] had also reported that once in the landfill, soiled diapers are very toxic as they are prone to leach chemicals, pathogens, and other contaminants which may eventually contaminate underground water leading to various health disorders in the long run. Bacteria such as *Salmonella* and *Shigella* which cause diarrhea and dysentery are spread through contaminated water. Once enteric pathogens such as *E. coli*, *Shigella* and *Salmonella* are introduced into flowing water they can survive for up to 117 km from the point of discharge [10].

## Aesthetic Concerns

Soiled diapers are often rolled with the feces and placed in bins or dumped illegally along road sides. The smell from the diapers attracts disease vectors such as flies. They also attract dogs which often tipped the bins in order to retrieve the diapers. The dogs either carry the messy diapers to their homes or simply litter them in open spaces creating an aesthetic nuisance. Ramaswamy and Sharma [67] observed that disposable baby diapers were a common sight at illegal dumping sites, and that dogs often tore plastic bags containing the disposable diapers.

Furthermore, there is a repulsive and ugly look christened on containers, cans or dumpsites rich in diaper waste, also dried diapers are easily blown away by wind, and some get carried along; hence may become strewn approximately two hundred meters away from disposal site [4]. This may constitute a serious clamp down on the aesthetic values of estates and sites rich in spent disposable diapers.

## Conclusion

An increased number of women are using disposable baby diapers

compared to earlier years when they used cloth diapers. This is due to their perceived advantages (principal among which is the issue of convenience) over cloth diapers. It is however overtly clear that very little attention is being given to the product after its use and therefore unguarded dumping, burying, and burning of soiled disposable diapers seems the popular disposal practices. The use of disposable diapers leads to unimaginable increase in the volume of human faecal matter with its attendant frank pathogens in the landfill. This, under poor management condition, may result in the contamination of underground water by pathogens in leachates from diapers thereby causing outbreaks of communicable diseases such as cholera. The presence of soiled diapers in municipal waste receptacles increases the rate of contamination with pathogens and chemicals such as Sodium Polyacrylate (SPA), phthalates, and dioxin. In view of the above, it is essential for critical review in the production, use and disposal of disposable diapers. Waste managers and relevant authorities also have to proffer a sound disposal method of soiled disposable diaper in line with the requirement for a sustainable environment.

## Recommendations

(i) It is imperative to use a women-centric approach in dealing with the problem of disposable diapers. The women need to be educated on the negativities that are associated with the used diapers to the environment.

(ii) Those responsible for changing baby diapers should be educated on the awareness to clean off soiled diapers before disposing them. This will reduce the incidence of flies taking advantage of the soiled diapers.

(iii) Urgent practical steps should be taken to enforce how diapers should be handled as a way of ensuring sustainable development. This will then cascade down to local authorities such as urban councils for example systems that encourage separation of garbage at the household level should be put in place.

(iv) Households should be encouraged to place diapers in plastic bags which they should tie at the end and then place these in bins or refuse bags. The bags containing solid waste such as diapers should not be taken to the waste disposal site. Somehow, they should be incinerated.

(v) It is important at both international and national levels to insist on corporate responsibility so that companies that produce disposable diapers should be able to account for the entire life cycle of their products. The companies should put instructions on the wrappers on how to dispose of diapers in a sustainable manner.

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