Message in a Bottle

The Impacts of PVC on Plastics Recycling

A Report to the GrassRoots Recycling Network
From RecycleWorlds Consulting

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CONTENTS

EXECUTIVE SUMMARY

PVC Bottle Recycling Does Not Exist

- Over 10 years, the PVC recycling rate averaged less than 1 percent, 0.8 percent, and has now fallen to barely trace levels.
- The only time PVC bottle recycling went as high as 2 percent was during the Vinyl Institute's heavily subsidized attempt to jump-start PVC bottle recycling in 1993.

PVC Bottle Recycling Cannot Exist

- PVC's share of the bottle market is simply too small to sustain successful recycling programs.
- PVC's already small share of the bottle market fell by 50 percent over 10 years.
- Even advanced sorting technologies used at recycling plants cannot economically sort PVC bottles from the more commonplace and higher-value PET bottles.

PVC Bottle Recycling is Not Wanted

- PVC bottles are a contaminant to PET bottle recycling.
- PVC complicates the recycling process to the point where its minor presence significantly undermines PET recycling.

The Vinyl Industry's Support for PVC Bottle Recycling is Questionable

- Industry-initiated attempts to jump-start PVC recycling appear to be hasty responses to deflect the threat of legislation as well as mitigate the harm imposed on the environment by PVC.
- Industry-subsidized PVC bottle recycling programs, despite their enormous expense, resulted in 98 percent of all PVC containers going to landfills and incinerators.

PVC's lingering presence in the bottle market jeopardizes successful PET recycling. There are almost no cases in which bottles made from PET cost more than PVC. Furthermore, PVC use in bottles is a small fraction of the market. Therefore, the economic case for accelerating PVC's final phase-out is overwhelming.

Community recycling managers must first resist efforts that may otherwise delay PVC's demise from the bottle market. "All-bottles" curbside collection programs, for instance, will encourage more PVC use with the false promise that the resin will be recycled.

In addition, abandoned efforts to discourage the use of PVC in bottles need to be rejuvenated, including campaigns to educate consumers, producers, packagers and retailers about PVC's debilitating impacts on plastics recycling.

PREFACE

While plastics commonly used today have become widely accepted, some raise concerns about the impact of their manufacture, use and disposal on public health and on the environment.

Leading the list of controversial plastics has been polyvinyl chloride (PVC). The concerns over PVC have largely revolved around three core issues:

! *Chlorine*. The production, use and disposal of vinyl's chlorine-based molecules are linked to several health concerns, including cancer, immune system damage, neurological problems, hormone disruption, infertility and reproductive abnormalities. Chlorine makes up more than half of the compound by weight and results in the generation of dioxin when PVC is manufactured or burned, a known human carcinogen.

! *Additives*. PVC contains many toxic additives, stabilizers and plasticizers, such as phthalates, lead and cadmium, which are used to impart versatility and enhance performance to what would otherwise be a very low-quality and essentially useless resin. These are not chemically bound and can readily leach out.

! *Fire*. Firefighters have safety concerns about office buildings replete with products made from PVC that produce poisonous hydrogen chloride gas and dioxin when burned in large fires.

Among the vinyl industry's response to these concerns has been the assertion – and accompanying public relations push – that major efforts will be undertaken to recycle PVC in order to provide positive environmental benefits to offset any costs the resin may impose.

The recycling of PVC has been the subject of many false starts. For that reason, the vinyl industry's response raises questions regarding the validity of their effort. However, even if a bona fide effort were being made, PVC's problematic nature raises questions about its compatibility with recycling efforts.

For instance, PVC's resemblance in appearance and density to other resins (types of plastic), namely PET (the "#1" coded plastic of soda bottles and similar products), makes separation difficult. Furthermore, due to its lower melt temperature, PVC will burn when molded with PET. The chlorine molecule in PVC, which is considered a possible threat to public health, also has an intense capacity to contaminate other resins. In addition, its low volumes in many applications make it difficult to sustain the necessary handling infrastructure.

Therefore, these key underlying factors must first be evaluated to determine whether the recycling of PVC would override the health and other environmental issues at stake.

Each market in which a resin, including PVC, is sold exhibits different characteristics important to recycling's success. The record to date allows us to establish the following:

- The most mature, economically viable market for post-consumer plastics recycling is the bottle and packaging container market.
- There are no data from any market that suggest positive trends in PVC bottle recycling.
- Proponents of limited PVC recycling arenas (e.g. carpets) do not suggest that such efforts can accommodate any other PVC waste.

Bottle recycling represents the most successful post-consumer plastic recycling effort in the nation to date, and as such serves as a bellwether for recycling in general. In this report the PVC Recycling Evaluation Project (PREP) examines whether PVC recycling in the bottle market is occurring and is desirable or whether the very practice of PVC bottle recycling undermines recycling's overall success.

INTRODUCTION

There are two broad classes of plastics. The first, called “thermoplastics,” is a type that can be remelted and molded repeatedly. The second, called “thermoset” plastics, cannot be remelted and remolded. Theoretically, all thermoplastic resins can be recycled. However, in actual practice there are many constraints on whether a particular resin can be recovered and recycled.

The first major consideration for recycling relates to *volume* of material and the second to *contamination* of resins. Both come down to a question of economics that, in our free market, limits the resources available to recycle a specific product. Moreover, some resins have an intense propensity to contaminate others they contact. They may also be difficult to separate from other resins. Thus, their presence in the marketplace is inherently hostile to recycling. In particular, for those packaging materials that have a potential recycling market, polyethylene terephthalate (PET, the coded #1plastic of soda bottles and similar products), the following two limiting conditions must be met to validate its inclusion in recycling efforts:

Volume. An extensive infrastructure (for collection, sorting, transportation, processing, etc.) is necessary to recycle materials. That infrastructure requires, among other things, major volumes of a material to spread out the investment and accumulate enough bales of the collected plastic to regularly ship to market. Consequently, small-volume plastics, such as PVC, will never reach the economies of scale necessary to justify investments in its recycling infrastructure.

Contamination. Processing facilities generally receive all plastic bottles commingled. Successful recycling requires separating the bottles by discrete resin in order to produce a product that can be sold into markets and offset the costs of collecting and processing the material. Therefore, selecting resins that can be effectively and inexpensively sorted from each other is essential. This is especially important when there is extreme sensitivity to contamination in the event sortation is less than complete. The particular characteristics of some resins, most prominently PVC, can make that task extremely difficult.

Although PVC poses such limitations on its value as a recycling commodity and on the willingness of processors to accept it, the threat of legislative bans on PVC in the early 1990s led the Vinyl Institute – the major trade association defending and promoting PVC – to announce an ambitious program to jump start PVC recycling for bottles in 1993. The program continued for three years and failed.

The Vinyl Institute’s 3-year subsidized PVC recycling program failed.

The Vinyl Institute’s initial focus on recycling bottles rather than building materials, reflected the strategy of the plastics industry that focused on single-use packaging in the solid waste stream. In part, this emphasis resulted from the developments that unfolded in the wake of the infamous garbage barge, the Mobro.

The decade following the Mobro Garbage Barge's long journey in 1988 galvanized public attention on the need to recycle. Between 1989 and 1999, the number of curbside recycling programs increased from 1,042 to 9,349.[1]

As the modern recycling movement took form at the beginning of the 1990s, there was an infrastructure already in place to process and market glass bottles, steel and aluminum cans, newspapers, and cardboard. Such an infrastructure, however, did not exist for plastic bottles.

Organized around the Council for Solid Waste Solutions, the plastics industry became concerned that plastics could not be recycled and that its market share inroads against competing packaging materials might be impeded in the future. The industry quickly moved to insure that plastic bottles were also included in the new curbside collection programs. On March 28, 1991 the plastics industry announced to the national media its commitment to recycle 25 percent of all rigid plastic bottles by 1995, a declaration that grabbed headlines around the world.[2]

Plastic bottles are produced from many different resins. Due to their attractive performance, price and appearance attributes, almost all plastic bottles are made from either PET or high density polyethylene (HDPE, coded #2; the typical milk jug). Very minor fractions were made from polyvinyl chloride (PVC), polypropylene (PP) and low-density polyethylene (LDPE), in that order. FIGURE 1 shows the proportions of each resin used in bottles in the U.S.[3]

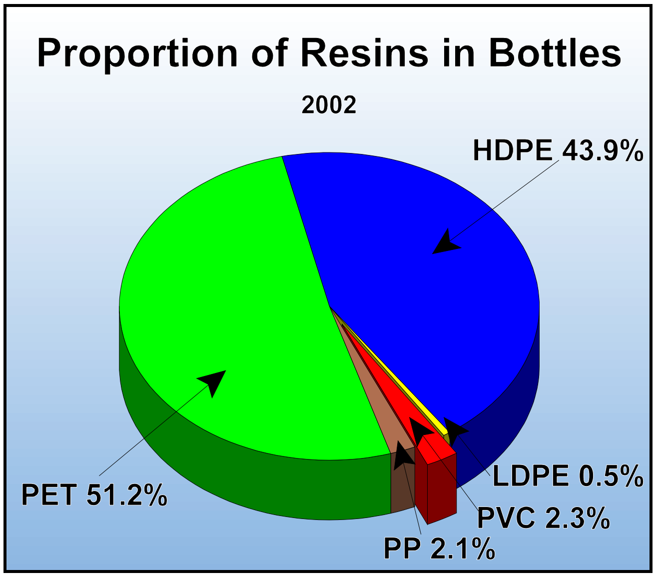


FIGURE 1

This report is one in a series that analyzes the extent to which PVC recycling is occurring. More importantly, it evaluates whether PVC bottles should be recycled at all and whether PVC itself is an unacceptable threat to recycling.

PVC BOTTLE RECYCLING DOES NOT EXIST

1 *BioCycle* "State of Recycling," April issues 1989-1999.

2 Steve Toloken, "Lofty Recycling Goals Fall by the Wayside," *Plastics News* (March 8, 1999).

3 R.W. Beck, *National Post-Consumer Plastics Recycling Rate Study* © American Plastics Council, 2002).

In general, recycling items that only exist in small volumes is not cost effective, with the exception of high-value materials.

That is the predicament confronting PVC, which constituted barely more than 2 percent by weight of resins going into bottles in 2001 (see Figure 1, page 6)

The plastics industry reports that a maximum of 0.3 percent of PVC bottles were recycled in 2001, the last year that data were compiled. There is good reason to be skeptical of this figure, despite its small size, since there are currently no PVC bottle recycling facilities operating in the U.S. During the 1990s, the PVC recycling rate ranged between 0 percent and 2 percent, as shown in FIGURE 2 [4]. Between 1994 and 1996, PVC bottle recycling reached it high of 2 percent. That increase related to the short period of time that the Vinyl Institute provided major price support to induce a supply of used PVC bottles where otherwise there would have been none.

After more than 10 years, PVC recycling has fallen to barely trace levels. In recent years no PVC bottles have been recycled. Furthermore, this is unlikely to change in the future.

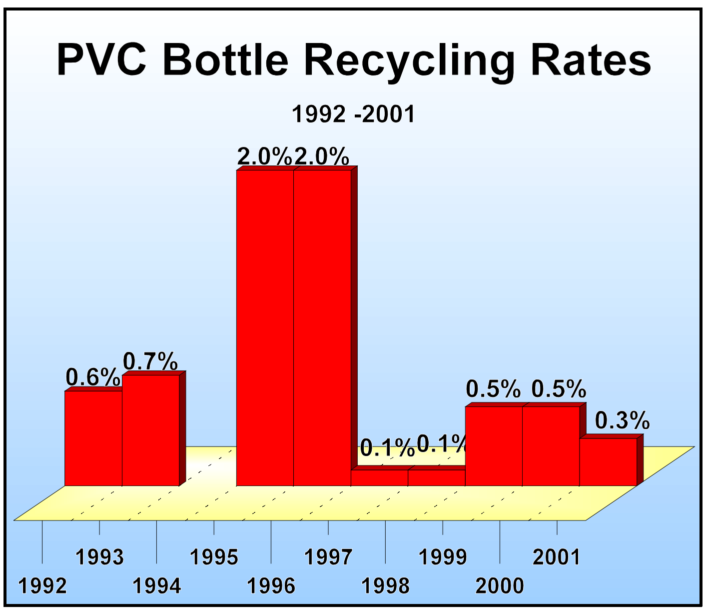


Figure 3

PVC BOTTLE RECYCLING CANNOT EXIST

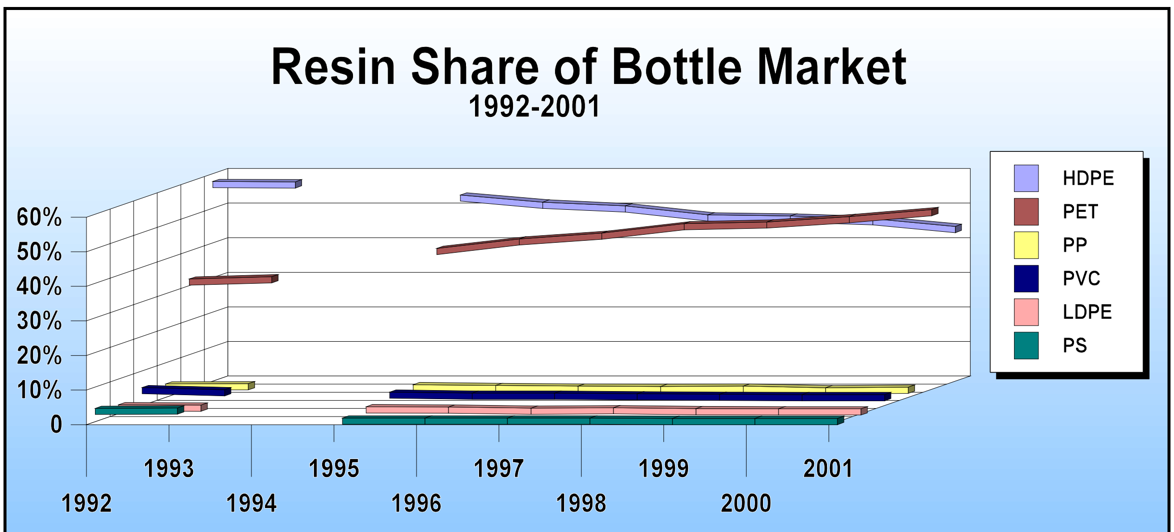
[4] R. W. Beck, *National Post-Consumer Plastics Recycling Reports* ©American Plastics Council, 1992-2001., Table 1s. Note: APC's published annual reports for 1994 omitted this data, and that year's data in the tables that followed.

Regardless of the motivation behind the Vinyl Institute's efforts to recycle PVC bottles, vinyl's share of the bottle market is too small to be successful and sustainable. As stated by the American Plastics Council (APC), "the relatively small volumes of these bottles [such as PVC] in the marketplace make it difficult to achieve critical mass for these bottles for effective recycling programs."[5]

In order to recycle a material, it must be set apart for separate collection from the trash. Once separated, the material is sorted from a stream of similar materials at a material recovery facility (MRF) to be densified – packed tightly together – for efficient shipping. When truck load quantities are accumulated the bales are shipped to intermediate processors or end markets.

Recycling efforts are generally limited to items for which there are significant volumes that can be easily separated from the discard stream. Note that this is a distinct and additional consideration from any problems that make separation from other materials difficult or costly, and from possible cross-contamination.

As shown in FIGURE 3, the plastic bottle market in the U.S. has long been dominated by



HDPE	56.9%	56.8%		53%	50.9%	49.8%	47.2%	46.9%	46.1%	43.9%
PET	31%	31.7%		39.9%	42.6%	44.3%	47%	47.5%	49.1%	51.1%
PP	3%	3.1%		2.8%	2.6%	2.4%	2.3%	2.4%	1.9%	2.1%
PVC	4.3%	3.7%		3%	2.7%	2.7%	2.5%	2.4%	2.3%	2.3%
LDPE	1.7%	1.6%		1.1%	1%	0.7%	0.8%	0.6%	0.5%	0.5%
PS	3%	3.1%		0.2%	0.2%	0.2%	0.2%	0.1%	0.1%	0.1%

FIGURE 3

5 R. W. Beck, *National Post-Consumer Plastics Recycling Reports* (©American Plastics Council, 1992-2001), at p. 5

HDPE and PET. The other one-trip bottle resins, PP, PVC, LDPE and PS, each occupy minor niches in rigid packaging. Together they make up less than 5 percent by weight. FIGURE 4 highlights the market position of PVC over time, which began in the 1990's at 4.3 percent of plastic bottles. Since then, concerns about its problematic recyclability have led to further erosion in its share to 2.3 percent, as packagers shifted largely to PET. That equates to 167 million pounds annually in a more than 7 billion pound market, or approximately four PVC bottles per person in an entire year.[6]

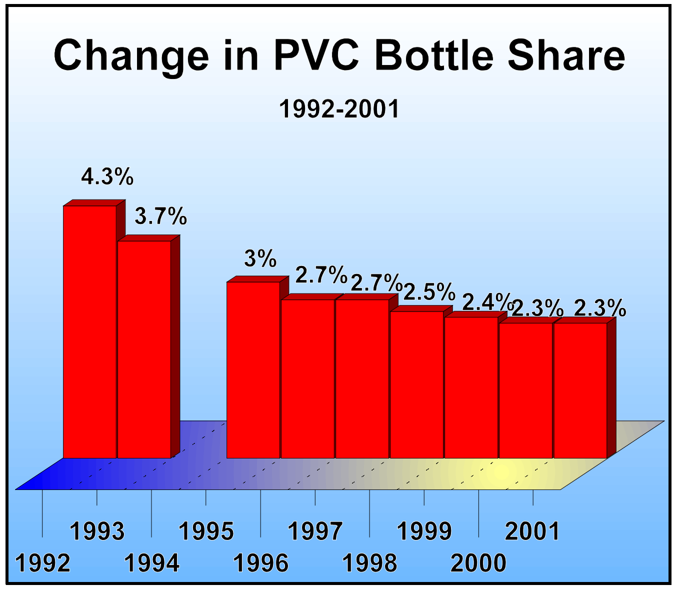


FIGURE 4

Among the recyclables collected in typical curbside programs PVC is 1.5 percent of the separated plastic bottles, by weight, and 0.04 percent of all the separated recyclables.[7]

In a 250 ton-per-day, two-shift MRF – typical for a city of approximately 750,000 people – fewer than 100 PVC bottles would pass in front of the sorters each hour, or about one or two per minute. Generally, manual sorters are assigned to sort one material, and they are expected to pull close to 100 plastic bottles per minute from a conveyor belt moving as fast as100 feet per minute.[8] Simply put, there are too few PVC bottles in the container stream to assign sorters to them, even for those PVC bottles that have handles and can be easily visually identified.

Furthermore, even if one sorter was assigned to identify PVC and pull the bottles, these bottles would have to be kept loose and undensified in gaylords – large cardboard and wood boxes common to recycling operations – for one week to accumulate enough to bale. After baling the material, the equipment would have to be carefully cleaned so as to not contaminate the bales of other plastic resins. It would take almost one year to accumulate enough volume for a truckload to ship to market. This does not conform to the space constraints or logistical needs of a competitive MRF.

Vinyl's share of the bottle market is too small to sustain viable recycling programs.

Moreover, because plastic bottles have to be upgraded before they can be remolded,

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6 R. W. Beck, *National Post-Consumer Plastics Recycling Reports* (©American Plastics Council, 1992-2001), Table 1.

7 American Plastics Council, *How to Collect Plastics for Recycling: Lessons from the Model Cities Demonstration Program* (1995), at p. 19, Table VIII).

8 American Plastics Council, *Sorting Plastic Bottles for Recycling* (1998), at p. 16, TABLE 16.

much of the plastic bottle processing is ultimately done at intermediate processors to which the MRFs ship the material.

CAVEAT EMPTOR: COMMON PRODUCTS IN PVC CONTAINERS

Johnson & Johnson
Product: Harry Potter Bubble Bath and Hand Soap

Hawaiian Tropic
Product: Aloe Vera Gel

Pure and Basic Products
Product: Bath and Body Wash

St. Ives Laboratories
Product: St. Ives Body Wash

The Republic of Tea
Product: Blackberry Quince Tea

Usually, MRFs will sort HDPE from PET and send each of those two streams to reclaimers, which have automated optical equipment to split out different colors and reject unwanted resins. Less often, all plastic bottles are baled together and shipped to a plastic recycling facility (PRF) that sorts many different resins.[9] But, in either case, the same problem of too few PVC bottles, compounded by the limitations of the optical systems to distinguish visually similar PVC from PET bottles, further stymies vinyl recycling at the processor level.

A study done for the Environmental Protection Agency, EPA, found that these optical systems produce high numbers of false positive readings. In addition to varying bottle colors and density, the degraded state of the bottles when they arrive at the reclaimer as bales make accurate optical readings difficult. Therefore, the reject stream at a PET reclaimer is not pure PVC – rather it also includes a substantial fraction of PET that was incorrectly rejected by the optical sorter.

For example, the study reported that 2 percent of the bales were rejected as PVC by the optical systems. False readings, however, also rejected more than twice as much PET, a significant economic loss to the reclaimer. The false negative rate, or the proportion of PVC bottles which failed to be detected is not known.[10]

Even advanced sorting technologies installed at recycling plants cannot economically sort PVC bottles from more commonplace, visually similar and higher value PET bottles.

In addition to sorting complications, small quantities of PVC also work against recycling due to the difficulties of recycling such low-volume materials at the intermediate processor. Although the processor aggregates flows from many MRFs, thereby accumulating volumes, the small volume of PVC cannot economically justify the additional expense of repeated cycles through sorting machines necessary to adequately purify the stream.

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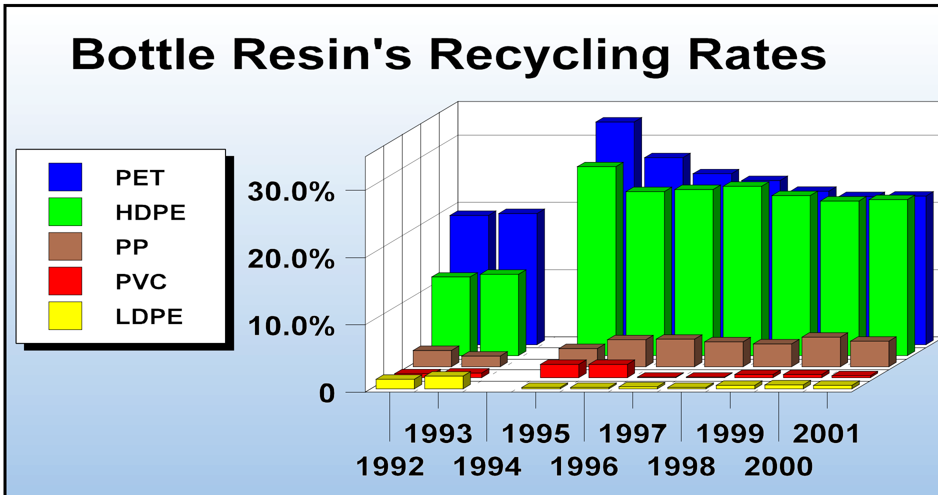
9 American Plastics Council, *How to Develop a Viable Post-Consumer Plastics Handling Business* (1992), at p. 41.

10 Environmental Protection Agency, *Evaluation of an Automated Sorting Process for Post-Consumer Mixed Plastic Containers* (Sept. 1993), at p. 8.

Consequently, the reject stream where PVC is sent when detected, is too contaminated with other materials to be marketed as PVC. Reclaimers report they usually landfill the material and on occasion export it to China in mixed bales, where its final application is unclear to industry observers.



PET	19.>	19.>		33.>	27.>	25.>	24.>	22.>	22.>	22.>
HD>	11.>	12.>		28.>	24.>	24.>	25.>	23.>	23.>	23.>
PP	2.4%	1.6%		2.7%	4.0%	4.1%	3.7%	3.4%	4.4%	3.8%
PVC	0.6%	0.7%		2.0%	2.0%	0.1%	0.1%	0.5%	0.5%	0.3%
LD>	1.4%	1.9%		0.2%	0.2%	0.3%	0.2%	0.5%	0.6%	0.5%

FIGURE 5

For this reason alone, almost all plastic bottle recycling has been devoted to recycling, HDPE and PET, the two resins with sufficient scale to make economic sense. HDPE and PET together have 95 percent of the plastic bottle market (see FIGURE 5).

The quantity of plastic bottles recycled swelled from 234 million pounds to 1.4 billion pounds between 1989 and 1998.[11] From 1991 to 1998, HDPE reclamation capacity more than doubled from 480 million pounds to over one billion pounds. PET reclamation capacity experienced similar growth, increasing from 424 million pounds to 1.3 billion pounds over the same time period. Today, over 8,000 curbside collection programs include plastics.

By contrast, PVC reclamation capacity for bottle recycling existed only for three years when the vinyl industry artificially supported its price between 1994 and 1996.

As shown in FIGURE 5, in the last decade only HDPE and PET had recycling rates greater than 20 percent. PP had recycling activity slightly less than 5 percent, and LDPE and PVC, had barely detectable trace levels substantially below 1 percent.[12]

Thus, it is infeasible to recycle a material with as slight a presence in the market as PVC bottles.

[11] American Plastics Council, *1998 National Post-Consumer Plastics Recycling Report* (1999), at pp. 1 and 7, Figures 1, 5, 6 and 7.

[12] R.W. Beck, *National Post-Consumer Plastics Recycling Rate Study* (American Plastics Council, 1992-2002).

PVC BOTTLE RECYCLING IS NOT WANTED

After years of unsuccessful attempts to develop a sustainable PVC bottle recycling infrastructure, and following long and considered evaluation of its future prospects, the two main plastics recycling organizations – National Association of Plastic Container Recovery (NAPCOR) and the Association of Post-Consumer Plastic Recyclers (APR) – have reached the same conclusion. Namely, that the issue is not whether PVC bottle recycling is successful; it is not. Nor is the issue how to improve the poor recycling rate of PVC; it cannot be. Rather the matter is how to keep PVC out of the bottle market to avoid the enormous costs its presence imposes on recyclers.

As stated by APR, the trade association of the plastic bottle processing industry:

> "Due to a similar appearance to PET bottles, PVC bottles are commonly mistakenly included in recycling bins by householders. Once at a materials recovery facility (MRF), PET and PVC bottles are typically not separated and end up being baled together for delivery to PET reclaim markets. ... While the amount of resin used to manufacture PVC bottles is small compared to the amount of resin used to manufacture PET bottles, only a small fraction of PVC can ruin or significantly downgrade a load of reclaimed PET. Due to different material properties, including differences in melting temperature, PVC is a major contaminant to the PET bottle recycling stream. Recycled PET must be very pure for many recycled product applications, such as bottles or sheet products."[13]

In 1998 the APR "declar[ed] officially that PVC bottles are a contaminant to the recycling of PET ... after the failure of joint efforts between the APR and the Vinyl Institute to establish economically viable, long-term markets."[14]

The Plastic Redesign Project, a multi-state coalition of public recycling officials, followed the APR's logic but went further to specifically recommend:

> "Polyvinyl chloride (PVC) is disfavored in bottles for products that are also packaged in bottles made of other resins that look like PVC such as polyethylene terephthalate (PET)."[15]

These groups reached their conclusions based upon the fact that even the most minute contamination of PVC's chlorine molecule in PET cripples the ability to economically produce clean recycled PET (RPET). PVC complicates the recycling process to the point where its minor presence significantly undermines PET recycling.

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13 R. W. Beck, *Final Report: PVC Cost Survey* (Associated Postconsumer Plastics Recyclers, 1999), at p. 1

14 "APR Declares PVC a Recycling Contaminant," *Plastics in the Environment* (May '98).

15 Plastic Redesign Project, *Recommendations for the Design of Plastic Bottles* (Nov '98), RECOMMENDATION NO. 14.

As curbside recycling became institutionalized during the 1990s, the persistence of even small quantities of PVC in the bottle stream threatened the burgeoning PET recycling industry. Just one mistaken PVC bottle in 100,000 PET bottles can ruin a load due the extreme cross-sensitivity of the two resins. This means that PET containing 0.001 percent PVC is contaminated. To sell RPET into high-end bottles, 99.999 percent reliability is required. 99.98 percent reliability is required for low-end fiber markets (such as carpeting and strapping).[16]

> ***"... PVC bottles are a contaminant to the recycling of PET."***
> ***Association of Post-Consumer Plastic Recyclers, 1998***

Furthermore, as previously discussed, because both resins are clear, it is nearly impossible to visually distinguish the two on a manual sorting line at a MRF. Close examination shows a seam on the PVC bottle and a nib at the bottom of the PET bottle. This is too subtle to be of any use on a MRF sorting line with a conveyor 3 feet wide covered one or two layers thick with bottles moving in front of the sorters at a rate of 100 feet per minute.

Consequently, at the beginning of the 1990s, recycling programs were forced to discourage residents from recycling anything but carbonated soft drink (CSD) containers, which are exclusively sold in PET bottles when packaged in plastic. Any clear bottles that were not CSDs were pulled for rejection, because they could be of products (such as salad oils or window cleaners) that were sometimes packaged in PVC as well as in non-CSD PET (known as custom PET). At that time, this meant abandoning collection and recycling of custom PET bottles, which were 32 percent of the PET bottle stream. However, their usage continued to grow. Ten years later custom bottles were 52 percent of the PET stream, which made their continuing exclusion from recycling systems unacceptable.[17]

Shortly afterwards, optical sortation systems were commercially offered to detect PVC. However, their exceedingly high costs increased the cost of PET recycling and undermined its economics. Moreover, optical sortation systems are not 100 percent effective. They cannot ensure that the sorted PET stream will contain less than 0.001 percent PVC.[18]

As a result of the extreme cross-sensitivity of PET and PVC and stringent accuracy needed to insure that end-market specifications can be met, reclaimers cannot economically process any level of PVC contamination. In fact, there are significant, near-in limits on how much can be coped with on a technical basis, and that is before reaching the question of whether the economic costs of insuring PVC-free RPET threatens PET recycling's financial viability.

16 *PVC Cost Survey*, *supra*, at p. 1.

17 R.W. Beck, *National Post-Consumer Plastics Recycling Rate Study* (American Plastics Council, 1992 and 2002).

18 *PVC Cost Survey*, *supra*, at p. 1.

As previously noted, the theoretical efficiency of the vendor's optical sortation unit is limited in the real world by the physical quality of the material of the incoming bales; including the level of material degradation, resin type and material color. All of these can confound optical readings, which take place as bottles tumble across the "detection box" at 5,000 pounds per hour (65,000 bottles per hour). To improve optical readability, extensive additional efforts and investments are needed in front-end handling systems; including debaling, declumping, and separating the bottles from one another. Labels and dirt must also be removed. Furthermore, these additional sorting efforts are only partially successful due to bottle clumping and other distortions, where some bottles rejected are PET due to false positives.[19]

TABLE 1 illustrates the precision with which the automatic detection systems must be attuned in an exceedingly adverse environment as the percentages of PVC contamination in the incoming stream of PET bales increases when the public is asked to recycle, instead of discarding.

Resulting Reliability of Processed PET Bales as a Function of PVC Removal Efficiency and Incoming PVC Contamination Levels					
Equipment Removal Efficiency	**Incoming PVC Contamination Level**				
	1%	**2%**	**3%**	**4%**	**5%**
98.0%	99.9800%	99.9600%	99.9400%	99.9200%	99.9000%
99.0%	99.9900%	99.9800%	99.9700%	99.9600%	99.9500%
99.1%	99.9910%	99.9820%	99.9730%	99.9640%	99.9550%
99.2%	99.9920%	99.9840%	99.9760%	99.9680%	99.9600%
99.3%	99.9930%	99.9860%	99.9790%	99.9720%	99.9650%
99.4%	99.9940%	99.9880%	99.9820%	99.9760%	99.9700%
99.5%	99.9950%	99.9900%	99.9850%	99.9800%	99.9750%
99.6%	99.9960%	99.9920%	99.9880%	99.9840%	99.9800%
99.7%	99.9970%	99.9940%	99.9910%	99.9880%	99.9850%
99.8%	99.9980%	99.9960%	99.9940%	99.9920%	99.9900%
99.9%	99.9990%	99.9980%	99.9970%	99.9960%	99.9950%
NOTE: Shaded boxes show the first removal efficiency rate that achieves the fiber market PVC specification of 99.98% PET. Higher-paying bottle grade flake from curbside requiring 99.999% removal generally cannot be met with this technology.					

TABLE 1

19 In one measured test of advanced x-ray type detection systems commissioned by the Environmental Protection Agency, 6.8 percent of the incoming PET was rejected: 2 percentwas PVC; 4.8 percent was PET and HDPE incorrectly rejected. See Environmental Protection Agency, *Evaluation of an Automated Sorting Process for Post-Consumer Mixed Plastic Containers* (Sept. 1993), at page 8. Therefore, as a function of the same conditions of the incoming stream and intake systems, there will also be a value for the proportion of PET that will be incorrectly rejected due to false positives for any given setting on sensitivity dial. All of this creates a very narrow band within which to set the sensitivity setting that is driven by the proportion of PVC contamination in the PET. The maximum PVC contamination in clean PET flakes or pellets permitted by the end markets defines how high the sensitivity must be set. But, the maximum acceptable false positives, which vary with the commodity price for PET at any particular time, will restrict how high the sensitivity can be set to improve the purity of the PET stream in at attempt to deal with additional volumes of PVC. Irreducible problems arise when the two collide.

When there is only 1 percent PVC contamination in the incoming bottle stream, a processor which can achieve 98.0 percent real-world removal efficiency can satisfy lower-value fiber end-markets. At up to 2 percent PVC contamination — the percent at which PVC may be in today's typical PET bale from curbside programs [20] — removal must be 99.0 percent efficient. Double that to 4 percent — which is what a curbside program collecting "all bottles" could cause if such programs were to be adopted in more communities — an overwhelmingly accurate 99.5 percent removal efficiency is necessary without, at the same time, losing too much of the PET through false positives. If such results cannot be achieved, then the plant operator is faced with the choice of using two passes over the detection box or multiple detection units in tandem, nearly doubling his or her costs to the point where it would be impossible to compete with virgin PET. And that is just for the forgiving fiber markets — none of these types of systems can produce bottle quality RPET material.

Combine these factors, and each reclaimer in the U.S. has a maximum proportion of PVC contamination in the bales that it buys to operate economically and meet end-market specifications. Ten reclaimers reported maximum PVC contamination levels ranging from 1 percent to 5 percent (see TABLE 2). [21] Ten other reclaimers — Certified Polymer (CA), ITW Plastics Recycling Alliance (IL), Goodwill Industries (IN), Paragon Polymers (KY), Johnson Controls (MI), Clean Tech (MI), Wellman (NJ), Plascycle America (NY), Primus (OH), and Piper Plastics (TX) — reported zero tolerance standards. [22]

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20 Environmental Protection Agency, *Evaluation of an Automated Sorting Process for Post-Consumer Mixed Plastic Containers* (Sept. 1993), at p. 8. The false negative rate, or the proportion of PVC bottles which failed to be detected is not known, but the true PVC rate would be higher by that amount. However, this data is rather old, and the proportion of PVC bottles in the plastic stream has declined since then. A more recent survey by the American Plastics Council found in its field survey 1.67% average incoming PVC off the collection vehicle as a fraction of PET and PVC, Table 3.2, and 0.86% leaving the MRF, Table 5.6, American Plastics Council, *Sorting Plastic Bottles for Recycling* (1998). Unfortunately, data is not readily available on the variability of the proportion of PVC from bale to bale, or customer to customer, or season to season. Because the PVC problem stems from the worst — not the average — case, the greater the variability, the more even low mean PVC values can be a matter of significant concern.

21 National Association of Plastic Container Recovery, *Market List* (1995). This specification list has not been updated.

22 Ibid.

Maximum PVC Contamination Accepted by Reclaimers	
Image Industries (GA)	1%
Plastic Resource Tech (IN)	1%
Phoenix Recycling (MN)	1%
Ozark Mountain Resins (MO)	2%
Recycled Plastic Resins (MO)	5%
Pure Tech APR (NY)	5%
Nationwide Recyclers (NC)	5%
St. Jude Polymer (PA)	2%
Martin Color (SC)	2%
Enviroplast (VA)	1%

TABLE 2

Beyond that posted PVC threshold, either the cost of producing clean RPET flake for domestic reclaimers becomes too high to compete with virgin resin, or the price paid for PET bales for local recyclers falls too low to attract supply. This is why current proposals, such as APC's all-bottle programs (wherein all plastic types are collected) may increase the proportion of PVC collected beyond the system's ability to continue producing minimum RPET quality for fiber markets.

Moreover, even within the boundary of permissible PVC contamination in the incoming plastics stream, reclaimers must contend with the costs of removing enough of the PVC to ensure the PET is 99.98 to 99.999 percent pure. Understanding costs illustrates the need to phase out PVC from the container stream entirely, rather than falsely legitimizing its presence through all-bottle programs.

A CLOSER LOOK AT THE NUMBERS

The average industry cost to autosort PVC is an estimated 2.6¢/lb with x-ray type optical sorters - when the inefficiencies of these systems are accounted for due to yield losses and revenue losses caused directly by PVC.

Even after incurring that 2.6¢/lb for sortation, these systems are unable to commercially produce sufficient quality for high paying RPET bottle and sheet markets, that pay about 6¢/lb more than RPET for fiber with just the current proportion of PVC presently found in PET bales. Other strategies as well as less well developed techniques with their own set of limitations must be deployed to reach bottle quality standards.

Thus, PVC can be seen to create an impediment that is today undermining the economics of recycling PET that is sold into domestic markets at its current contamination levels. The price to sort PVC out of the PET has to be subtracted by the reclaimers from the price they can afford to pay local recyclers for their PET bales.

Further, 6¢/lb of PET's latent value is lost because the quality RPET that can be produced by optical devices with the current PVC contamination levels is still inadequate for bottle markets.

Average Annual Incremental Cost to Autosort PVC

FIXED		
Equipment		$ 55,485
Building		800
VARIABLE		
Maintenance		7,715
Conveyor Energy		2,496
Compressor Energy		5,827
Labor		63,003
Storage Bunkers		5,825
SUBTOTAL		$141,151
S.G.A*		35,288
TOTAL		$176,439
TOTAL COST/HR.		$ 0.014
Rejected PET	*ADD*	$121,648
PVC Yield Loss	*ADD*	25,343
ADJUSTED COST/LB.		**$ 0.026**

The total 8-9¢/lb PVC loss is proportionally very significant. It compares to an average price paid to recyclers for mixed PET bales freight on board, FOB, (price paid at the MRF's door) of only 7.8¢/lb when averaged across the commodity cycle.

The reduced bale price that local recyclers receive due to the residual PVC contamination would seem to be one of the contributing reasons for the poor recovery of plastics that has created the supply problem discussed earlier. Over time, PET bale prices across the commodity cycle of 7.8¢/lb could increase to 15.8¢-16.8¢/lb. were PVC phased out and the price savings passed along. That price dynamic could supplant the torpor that afflicts recyclers' efforts with ardor to recover more.

NOTE: Based upon the following assumptions from discussions with optical detection vendors: installed cost of x-ray detection box and infeeding and takeaway conveyors and enhanced singulation, $200,000; after tax capital cost, 20%, straight line depreciation life, 7 years; rated capacity, 5000 lbs./hr.; unscheduled downtime, 2%; plant utilization rate, 55.5%; extra inspector, 1; $10/hr. + 30% benefits; feedstock cost, 10¢/lb.; gross margin, 20¢/lb.; incoming stream consisting of PET, 51.4%; HDPE, 36.7%; PVC, 1.8%; PP, 2.8%; trash, 7.3%; correctly rejects 2% PVC/PET; false positives, 4.8%. The key values for accounting for inefficiencies are from R. W. Beck, *Cost Evaluation of Automated and Manual Post-Consumer Plastic Bottle Sorting Systems* (U.S. Environmental Protection Agency, 1994), at p. 8.

* Sales General and Administration

THE VINYL INDUSTRY'S SUPPORT FOR BOTTLE RECYCLING IS QUESTIONABLE

As recycling burgeoned in the early 1990s, plastics in general and PVC, along with polystyrene (PS), in particular found themselves under attack from recyclers and environmentalists. In addition to contamination and cost issues, there were concerns that dioxins would be produced when PVC bottles were burned in incinerators.

California, Massachusetts, Oregon, New York and Wisconsin were among the states introducing legislation that either threatened to directly ban PVC bottles, tax them or impose generic recycled content requirements that vinyl could not meet. The Federal Drug Administration seriously entertained a petition to ban PVC from liquor bottles because of possible complications when burned in waste-to-energy facilities, the International Joint Commission on the Great Lakes recommended phasing out chlorine production, Greenpeace and the Public Interest Research Group prioritized anti-PVC campaigns, Sweden and the Netherlands achieved a phase out of PVC packaging, and some of America's largest consumer products companies, such as Procter & Gamble and SC Johnson, decided to phase out the use of PVC bottles for their products,[23] a shift that reduced the PVC bottle market almost in half.[24]

In an attempt to deflect the political damage, the vinyl industry first issued position papers that represented PVC could be recycled.[25] Then it commissioned life cycle analyses and technical studies that suggested PVC bottles could be recycled.[26]

When those efforts failed to deflect critical attention, in 1993 Occidental Chemical ramped up a program it began in 1989 that established a price support program and helped reclaimers purchase equipment to recycle PVC. It guaranteed 10¢ per pound for recovered PVC bottles from local programs (6-8¢/lb for other types of PVC bottles). Most importantly, inasmuch as only one facility was established to process the vinyl, the subsidy also covered the cost of shipping to New Jersey, which in the case of West Coast shippers, could approach another 10¢ per pound.[27]

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23 Jonathan Gardner, "Recycling Still Hot Topic for Legislation," *Waste News* (January 17, 1994); Raymond Communications, *State Recycling Laws Updates* (1991-1994).

24 See FIGURE 3.

25 Advertisement *You're Looking at Tomorrow's Drain Pipe* (Vinyl Institute, 1989-1991); *Vinyl: Part of the Recycling Solution: Recovering PVC Packaging from the Solid Waste Stream* (The Vinyl Institute, 1988); Facts about...PVC in Solid Waste (The Vinyl Institute Fact Sheet, 1989).

26 A. S. Pazur, *PVC Packaging Recycling* (Journal of Vinyl Technology, September 1988).

27 Occidential Chemical News Release, "OxyChem Announces Plan for Recycling," (September 25, 1989); Raymond Communications, *State Recycling Laws Updates* (1991-1994).

The PVC recycling rate soon jumped up from a reported 1percent, in APC studies, to 2 percent (See Figure 2, p. 7).

However, the costs of artificially sustaining this recycling effort, which had no economic rationale, were very high, conceivably costing the company in the order of $5 million a year, and that substantial expenditure left 98 percent of the PVC bottles unrecycled and discarded in a landfill or incinerator. Presumably, Occidental was motivated to make this significant investment in order to show that legislation that would require plastics recycling was not required, rather than by a desire to keep its bottles out of the landfill or incinerator.

In the last analysis, only an ordinance in Suffolk County, NY banning PVC and polystyrene packaging was enacted, and even that never really took effect. Then, in 1995, the Republican Party takeover of the Congress demarcated the end of the era when legislative bans held trepidation for the plastics industry as a whole.

Industry subsidized PVC recycling programs, despite their enormous cost, still resulted in 98 percent of all PVC containers going into landfills and incinerators.

All the industry's earlier efforts to increase plastics recycling began unraveling shortly afterwards. As *Plastics News*, the industry trade journal, noted about the motivation of resin manufacturers, "many of the large North American recycling operations were organized quickly in the early 1990s to dilute or forestall any effort at the state level to legislate 'manufacturer's responsibility.'"[28] In the end, the magazine reported, the producers dropped out "because government recycling mandates did not materialize."[29]

Rigid plastics recycling rates peaked at 22.2 percent in 1995, 10 percent short of the goal the industry had committed to in 1991 for the middle of the decade, and have been declining ever since.[30] The Center for Plastics Recycling Research at Rutgers University closed in the face of "industry indifference."[31] Union Carbide closed its HDPE recycling plant in 1996, "claiming it was just not sufficiently profitable, [32] In 1997, the National Polystyrene Recycling Company began shuttering its PS recycling operations,[33] and also in 1997, the APC withdrew its price support of a Plastics Recycling Facility in Portland, OR, which had been processing all plastic

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28 Tom Ford, "Union Carbide to close HDPE recycling plant," *Plastics News* (July 22, 1996).

29 Don Loepp, "Phillips joins recycling exodus," *Plastics News* (October 12, 1998).

30 R.W. Beck, *National Post-Consumer Plastics Recycling Rate Study* (American Plastics Council, 1995-2002).

31 Roger King, "Rutgers to close recycling center," *Plastics News* (September 9, 1996).

32 Tom Ford, "Union Carbide to close HDPE recycling plant," *Plastics News* (July 22, 1996).

33 Steve Toloken, "NPRC to shut failing PS recycling plant," *Plastics News* (August 4, 1997).

bottles to respond to state legislation requiring 25 percent recycling rates.[34] The next year, 1998, Phillips Petroleum's exited from HDPE recycling. [35]

As regards the vinyl industry, in July of 1996, Occidental ended its support of PVC recycling.[36] By April of the following year Bayside, the small recycler who tried to keep operating the plant, shifted its line to recycling post-industrial PVC scrap instead.[37] Two months after that, the APR urged the vinyl industry to reestablish the lost markets for post-consumer PVC, and the Vinyl Institute "pledged to find markets for PVC bottles [and to] continue to find leads for APR members."[38]

A year later the APR wound up "declar[ing] officially that PVC bottles are a contaminant to the recycling of PET ... after the failure of joint efforts between the APR and the Vinyl Institute to establish economically viable, long-term markets."[39]

34 Steve Toloken, "APC to stop support of Ore. recycling site," *Plastics News* (March 8, 1997).

35 Megan Defendis, "Phillips Plastics to close facility," Plastics News (September 28, 1998).

36 Sarah Smith, "Bayshore buys line of recycled PVC, *Plastics News* (July 22, 1996).

37 "Bayside Vinyl returns to PVC scrap business," *Plastics News* (April 14, 1997).

38 Sarah Smith, "APR urges Vinyl Institute to find markets," Plastics News (July 14, 1997).

39 "APR Declares PVC a Recycling Contaminant," *Plastics in the Environment* (May 1998).

FOCUS: PVC IN CARPET

Another tale of too little material, too much cost

During the past several years, two carpet manufacturing firms, Collins & Aikman and Interface, have invested in PVC carpet recycling efforts. Both companies (which together occupy less than 10 percent of the carpet market share) produce as part of their lines a commercial carpet tile with a backing containing PVC content. Post-consumer recycling rates for PVC between the two companies were approximately 21.7 percent in 2002. The results of their recovery programs, however, require significant interpretation and, in any event, are slender in scale.

Although these two companies are at the forefront of sustainability and environmental design, their PVC recovery efforts are at best a partial answer to the problem of carpet waste and, by no means, point to the viability of PVC recycling in the bottle and container sector. PVC carpet recycling efforts to date have done nothing to support the recycling of the carpet's face fiber, which is greater in volume and higher in value than the PVC backing. Facing can comprise up to 60 percent of the carpet tiles by weight, while secondary backing makes up less than 20 - 30 percent.

Efforts to produce nylon facing with adequate quality for commercial use from post-consumer sources containing PVC have yet to succeed. Mechanical separation methods such as those currently used by Interface leave too much PVC contaminant residue in the nylon. As with bottle recycling, small amounts of PVC contaminants can wreak havoc on recycling efforts. The presence of PVC destroys the separated nylon during the recycling process, as PVC burns at the same temperature as nylon's softening point. Interface continues to research alternatives and it remains to be seen if they can find a technically and economically viable method of separation.

While the Collins & Aikman recycling program appears economically viable, it is still downcycling - reducing to a lower-quality end use. In the C&A process the entire carpet, including the high-volume and higher-value nylon face fibers are recycled into the lower value carpet backing. This sacrifices much of the original quality and value inherent in the dominant facing fibers and means the face fibers still need to be made from virgin materials.

So far, PVC in carpets has not proven compatible with true closed loop recycling in which each major resin of the carpet is recycled back into its original form. Furthermore any nominal success that carpet recycling may have is an exception not necessarily transferable to other markets. Carpet recyclers have the advantage of access to relatively large volumes of consistent formulations of PVC whereas other post-consumer PVC recyclers face the problem of multiple additive blends that confound the efforts to reuse the PVC for its original purpose.

In the end, PVC carpet recycling by Collins & Aikman and Interface represent unique investments by two niche companies as an element of their corporate sustainability agendas. But their practices so far have still fallen short of true closed loop PVC recycling and do not provide examples that can be transferred to other sectors.

CONCLUSION

The use of PVC has become increasingly controversial. Among the concerns raised about its use are:

- # PVC production exposes workers and local communities to high levels of vinyl chloride and other potent carcinogens.
- # PVC products such as medical equipment and children's toys leach toxic additives during their useful life .
- # When vinyl building materials catch fire, they release acutely toxic acid gases.
- # PVC products release toxic substances into the environment when they are burned in incinerators or rural trash barrels, or buried in a landfill.
- # Dioxin, a potent human carcinogen that threatens everyone's health at extraordinarily low concentrations, is released when PVC is burned, either intentionally or accidentally, and when PVC is manufactured.

In response to these concerns, many product companies are eliminating their use of PVC containers. However, the vinyl industry as a whole has taken a different approach. It seeks to mitigate the environmental and public health impacts of PVC by promoting PVC recycling operations.

In the case of PVC bottles, the industry has never made good on its claims that PVC can be effectively recycled and institutional limitations make it impossible for it to ever do so. The unique chemical and economic characteristics of PVC plastic make extensive PVC recycling almost impossible. At any scale, PVC recycling threatens the viability of recycling operations for more common plastics, most prominently PET.

PVC bottle recycling is a myth. PVC containers are a threat to cost-effective recycling operations. Claims to the contrary seem to be little more than an attempt to influence the general public's perception that recycling is a comprehensive solution and can alleviate the harm posed by the material on the environment.

The only comprehensive solution is to phase out PVC containers from the marketplace. Meanwhile, the vinyl and other plastics industries promote so-called "all bottle" curbside recycling programs, which would accept PVC and other resins in addition to #1 PET and #2 HDPE. These programs, in essence, propagate the myth that PVC can be recycled, thus delaying public recognition of the need to phase out PVC bottles in order for PET recycling to succeed.

PVC's lingering presence in the bottle market jeopardizes economically successful PET recycling. Fortunately bottles made from recyclable PET generally do not cost more than PVC bottles, and PVC use in bottles is a small fraction of the market. Thus, the economic case for accelerating the final phase out of PVC containers is overwhelming.

To truly mitigate PVC's environmental and public health impacts as well as its detrimental effect on PET recycling, concerned citizens, public interest groups, industry, recycling managers, and decision-makers can take the following steps:

1. Reject all-bottle plastic recycling programs, which encourage collection and use of more PVC with the false promise that the resin will be recycled; and

2. Rejuvenate efforts to phase out PVC use in bottles.