

# **Entrapment accidents caused by drainage systems in swimming pools: A statistical study of accident victims and unsafe environments found in field research**

J. P. Avezaat\* and A. Göb\*\*

\* The Blue Cap Foundation, P.O. box 154, 2370 AD, Roelofarendsveen, The Netherlands  
(E-mail: [joost@thebluecap.com](mailto:joost@thebluecap.com); [info@thebluecap.com](mailto:info@thebluecap.com))

\*\* Parents4Safety, Sicherheit in Hotelpools e.V., Wemmstraße 37, 63619 Bad Orb, Germany  
(E-mail: [a.goeb@parents4safety.de](mailto:a.goeb@parents4safety.de))

## **Abstract**

Fatal accidents occur in swimming pools worldwide. Several of these accidents are the result of the entrapment of swimmers on submerged drainage intakes. Entrapment that is caused by the suction forces of drainage intakes and the entanglement of hair, clothing, jewelry and limbs to parts of the intake. Accident registration has made it possible to make a distinction in various types of entrapment. Entrapment accidents are often reported to occur in swimming pools of hotels and aqua parks and in particular children are the victims. In the last five years an increase in reported accidents is seen in Europe, while the number of reports in North America has been declining. Field research, in which a hundred pools of hotels and aqua parks were subjected to an undercover inspection, shows that these accidents are not an unfortunate combination of unforeseen circumstances. Instead these are the result of unsafe pool construction, insufficient safety inspections and a lack in responsibility of pool owners.

## **Keywords**

pool accidents; suction entrapment; hair entrapment; pool safety; field study; drainage intake

## **POOL ENTRAPMENT**

Annually, dozens of sometimes fatal accidents occur in swimming pools worldwide. A major cause of several of these accidents is that a swimmer is sucked onto the drainage intake of the swimming pool. In swimming pools water is circulated for quality control and to feed water slides and other water attractions. In general two types of drainage systems are used to circulate the water. Draining water by free fall in overflow gutters is nowadays becoming a conventional way to remove the most polluted top layer of water from the pool. Nevertheless, the removal of water by suction through drainage intakes in the swimming pool is still a widely used method as well. It is known for decades that suction through drainage intakes can cause serious and sometimes fatal injuries to swimmers. Swimmers who intentionally or unintentionally block the intakes of drainage systems can be exposed to large amounts of negative gauge pressure. The suction force with which they are held against the drainage intake can be of such magnitude that the victims are no longer able to free themselves, nor with the help of bystanders. As a result drowning or severe internal injuries can occur. In addition, there are reports of swimmers getting stuck by entrapment with long hair, clothing, jewelry and limbs on drainage intakes.

## **ACCIDENT REGISTRATION**

Dozens of severe and fatal accidents have been reported not only in Europe but also in Asia, Africa, North and South America. Worldwide over 250 accidents have been reported between 1999 and 2015 involving entrapment caused by drainage systems in bathing and swimming areas. Only a few

agencies keep a detailed record of these pool entrapment accidents caused by drainage systems in bathing and swimming areas. These agencies are The Blue Cap Foundation in the Netherlands, Parents4Safety in Germany and the Consumer Product Safety Commission (CPSC) in the United States. Both The Blue Cap Foundation and Parents4Safety were founded by the relatives of deceased pool entrapment victims and keep a record of all known pool entrapment accidents and incidents in the world. The CPSC only keeps a record of accidents that occur within the United States and releases a report annually (Gipson, 2012, 2013; Hnatov, 2014).

### **Categorization of entrapment accidents**

Pool entrapment accidents can be categorized into four distinct groups based on the circumstances that have led to the entrapment to occur and the injury that was incurred (US Consumer Product Safety Commission, 2005; World Health Organization, 2006). The first group is the entrapment of body and limbs by suction. This type of entrapment is reported to occur when a swimmer gets too close to the covering grate of a submerged drainage intake while fully or partially blocking the grate with body and limbs. The swimmer is held against the grate when a large amount of negative gauge pressure builds up behind the blocked grate. Experimental research in a scientific study has demonstrated that within seconds the victims can be unable to free themselves nor with the help of bystanders (Avezaat, 2013). Getting trapped on a submerged drainage intake can lead to drowning and the exposure of the body to suction can cause fatal injuries before drowning occurs.

The second group in which accidents are categorized is the entrapment of hair. This type of entrapment occurs when the hair of a victim gets stuck on the grate covering a drainage intake. Long hair can get stuck on or in a grate when it is carried by the flow through the grate of a drainage intake and gets caught on or entangled behind that grate due to a vortex spiral in the flow. As a result, the head of the victim is held under water. Drowning can occur and of those who survived hair locks and even parts of the scalp had to be removed to free them from the entrapment.

The third group concerns the entrapment of jewelry, clothes or small limbs like fingers, toes, hands and feet in the grate, drain sumps or pipe ends of intakes. These types of entrapment are referred to as mechanical entrapment and can occur when a drainage intake is not covered sufficiently by a grate, i.e. when a grate is damaged, missing or not mounted properly.

The fourth group in which accidents are categorized is evisceration or disembowelment. Disembowelment can occur when a large negative gauge pressure is exerted on the intestines of the victim when sitting on a drainage intake (Hultman & Morgan, 1994; Juern et al., 2010). Pool entrapment accidents with disembowelment are often categorized as a separate group because of the horrific and rare type of injury. However, the cause of the accident, an overexposure to a negative gauge pressure, makes this type of entrapment very similar to body entrapment by suction.

### **STATISTICAL STUDY**

A statistical study was carried out by Parents4Safety in cooperation with The Blue Cap Foundation to determine the magnitude of the pool entrapment issue. The aim of this statistical study was to gain more knowledge about the victims and the type of environment in which accidents occur. An additional aim of this study was to determine whether changes in legislation and standardization have led to a decrease in reported accidents.

### **Method**

Information about accident victims was collected from news articles and accident reports on the internet and the annual reports of the CPSC (Gipson, 2012, 2013; Hnatov, 2014). A list of all

accidents and the links to related news articles and reports can be found on the website of the Blue Cap Foundation (The Blue Cap Foundation, 2015). For some accidents detailed information was obtained from relatives of victims. The internet search was conducted using search engines and keywords related to swimming pool entrapment in 22 different languages. Swimming pool entrapment accidents were found in 36 different countries. The results were categorized by the type of entrapment accident, the type of injury, the age group of victims, the type of pool environment and location. In all categories a distinction was made between the last two 5 year periods. The search for reported entrapment accidents started in 2011 when The Blue Cap Foundation was founded and is ongoing for all periods.

## Results

During the search 96 individual pool entrapment accidents were identified in the period from 2004 to 2009 and 110 individual accidents were identified in the period from 2010 to 2015. All entrapment accidents were categorized by the type of entrapment of which the results are displayed in table 1. Only one case of disembowelment was reported in 2011, but this case was categorized as a suction entrapment.

**Table 1.** This table shows the type of entrapment of all individual accidents reported in the period from 2004 to 2009 and from 2010 to 2015. The last column shows the sum of the two periods.

<i>Type of entrapment</i>	<i>Period</i>		
	<i>2004 - 2009</i>	<i>2010 - 2015</i>	<i>2004 - 2015</i>
Suction entrapment	65	85	150
Hair entrapment	11	18	29
Mechanical entrapment	1	5	6
Unknown entrapment	19	2	21

From the descriptions of the accidents was determined whether the accident resulted in the death of the victim or whether they incurred any kind of injury. The results are displayed in table 2.

**Table 2.** This table shows the type of injury of all individual accidents reported in the period from 2004 to 2009 and from 2010 to 2015. The last column shows the sum of the two periods.

<i>Type of injury</i>	<i>Period</i>		
	<i>2004 - 2009</i>	<i>2010 - 2015</i>	<i>2004 - 2015</i>
Fatality	37	40	77
Injured	57	65	122
No injury	0	2	2
Unknown	2	3	5

In table 3 the age groups of the victims is displayed. In particular, a distinction is made between the age groups of children because the majority of the victims are young.

**Table 3.** This table shows the age groups of the victims of all individual accidents reported in the period from 2004 to 2009 and from 2010 to 2015. The last column shows the sum of the two periods.

<i>Age group of victims</i>	<i>Period</i>		
	<i>2004 - 2009</i>	<i>2010 - 2015</i>	<i>2004 - 2015</i>
2-6 years	12	30	42
7-11 years	28	37	65
12-16 years	21	18	39
17-80 years	11	11	22
Unknown	24	14	38

In table 4 the type of swimming pool environment in which all accidents occurred is displayed. Pools at hotels, campsites and aqua parks are in principle also public pools. However, for some accidents it could not be determined with certainty that they occurred at these specific environments. It is not excluded that some accidents which have occurred in public swimming pools might have taken place at a hotel, campsite or aqua park.

**Table 4.** This table displays the type of environment at which all individual accidents occurred in the period from 2004 to 2009 and from 2010 to 2015. The last column shows the sum of the two periods.

<i>Type of environment</i>	<i>Period</i>		
	<i>2004 - 2009</i>	<i>2010 - 2015</i>	<i>2004 - 2015</i>
Hotelpool	21	34	55
Campsite pool	0	3	3
Aquapark	8	12	20
Public pool	15	31	46
Private pool	0	7	7
Unknown	52	23	75

In table 5 the location at which accidents occurred is displayed by continent. No documented information was found about entrapment accidents that occurred on the continent of Australia within the period from 2004 to 2015, though entrapment accidents have taken place in Australia before the year 2004. It is of interest to highlight the number of accidents in certain countries in addition to table 5. In the United States 37 accidents, causing 5 fatalities, were reported in the period 2004-2009 and 26 accidents, causing no fatalities, were reported in the period 2010-2015. Most European accidents in the period 2004-2009 were evenly distributed, led by Spain (5), Bulgaria (4), Italy (3), Turkey (3), Romania (3) and Belgium (3). In the period 2010-2015 accidents occurred in particular in Spain (17), France (6), Germany (5), Italy (4) and the Netherlands (4). Brazil accounts for most entrapment accidents in South America. It is particularly noteworthy that 7 of these accidents occurred in January and February of 2014 before the FIFA World Cup took place.

**Table 5.** This table displays the location of all individual accidents by continent, that occurred in the period 2004-2009 and 2010-2015.

<i>Accident location by continent</i>	<i>Period</i>	
	<i>2004 - 2009</i>	<i>2010 - 2015</i>
North America	41	29
Europe	32	47
South America	13	20
Asia	7	11
Africa	1	3
Unknown country	2	0

### **Discussion**

Suction entrapment of body and limbs is by far the most common type of entrapment that is described in accident reports as shown in table 1. More cases of hair and mechanical entrapment have been reported in the last 5 years, though these accidents are still rarer than suction entrapment. In addition, it cannot be excluded that in some cases a mechanical entrapment of limbs has resulted in a suction entrapment.

It is particularly striking that most victims have died or were injured in the accident as table 2 displays. This indicates that mild cases of entrapment are not reported by the victims. The true incidence of entrapments in pools is unknown, but the number of swimmers that has experienced a entrapment may be much higher.

Table 3 clearly shows that the majority of the victims are children, especially found in the age group of 7-11 years old. Especially children that are young of age learn by using all of their senses to experience the physical world (Blaustein, 2005). They have a tendency to touch objects and play with drains by sticking their hands and feet into apertures and open pipes (World Health Organization, 2006). From the age of 7, children are not always accompanied or supervised by an adult when entering the pools. They make extensive use of the available water attractions and are exposed to drainage intakes close to these attractions. The flow of water into drainage intakes and the flow from inlet nozzles can be seen as a water attraction. There are accidents known in which more than one child got entrapped by suction simultaneously while blocking multiple drainage intakes as a game. Young children are not always aware of invisible risks, their bodies are more vulnerable and they have limited force to resist the suction of a drainage intake.

Many entrapment accidents were reported to occur predominantly in swimming pools of hotels and aqua parks at popular holiday destinations. Table 4 confirms that accidents take place mainly at hotels and aqua parks, but also shows that accidents frequently take place in other public pools, including municipal swimming pools.

In the last 5 years more entrapment accidents have been reported in particular in Europe as table 5 shows. The number of accidents reported in North America has started to decline. The United States accounts for most entrapment accidents and a decline may be related to changes in pool and spa legislation that have been implemented in the United States in recent years. In December of 2007 the Virginia Graeme Baker Pool and Spa Safety Act was signed into law . The act was named after the granddaughter of former Secretary of State James Baker. Virginia Graeme Baker died in a tragic

entrapment accident in 2002 after the suction of a drainage intake entrapped her under the water. This new law aims specifically at reducing pool drain deaths and injuries by making pools and spas safer. Not only a decline in accidents is reported, there have also been no fatalities reported in the United States since 2009 (Gipson, 2012, 2013; Hnatov, 2014). In the last 10 years there have been no reports of accidents in Australia either. Stricter legislation and standards in both the United States and Australia prove to be more effective than legislation and standards in Europe and South America. In the United States all parts of drainage intakes and their grating have to meet the ASME/ANSI A112.19.8-2007 standard with documented testing procedures to rule out entrapment and at minimum one additional layer of protection is required by law.

## **FIELD STUDY**

In the last 3 years Parent4Safety has been conducting extensive field research in swimming pools at popular holiday destinations. This research aimed at finding an explanation why so many entrapment accidents occur primarily at pools of hotels and aqua parks. The goal was to determine whether these accidents are an unfortunate combination of unforeseen circumstances or whether these are the result of unsafe pool construction and insufficient safety inspections.

### **Method**

During a period of 3 years, swimming pools at hotels and aqua parks were subjected to an undercover investigation. The owners of the hotels and the staff of the pools were not aware of an investigation taking place, but were occasionally confronted with the findings afterwards. These hotels and aqua parks were located at popular holiday destinations in Spain (Canary and Balearic Islands), Turkey and Egypt. For each pool a visual assessment was made of the general condition of the swimming pool and the pool's environment. Each assessment included a visual inspection of the way into the pool (stairways and lifts for the disabled), inlet nozzles, cleaning intakes, pool lighting, the separation and identification of swimming and non-swimming areas, the tiles and foil in the pool's wall and floor and the drainage intakes. Photographic evidence was taken of serious technical defects and construction flaws, which may endanger the safety of the swimmers.

Each inspection included a hair test and a measurement of the water velocity on each drainage intake. The water velocity was measured with an anemometer and turbine probe designed specifically for the measurement of the flow of liquids, e.g. water. Flow measurements were conducted across the entire surface of the grate of each drainage intake, wherein the probe was placed directly on one or more apertures of the grate. Hair tests were conducted in accordance with the European Standard EN 13451-3, using a hair sample of 50 gram, medium fine, straight, light colored, 400-millimetre-long hair.

### **Results**

In each pool various technical defects and construction flaws were found, some of those could not only cause injuries but were potentially life-threatening. Defects and flaws were discovered in all hotel and aqua park classifications. In total, 100 pools were subject of an undercover investigation.

*The surroundings of the pool.* In 84 out of 100 cases serious defects and flaws were found in the surroundings of the swimming pool. These defects and flaws included primarily broken grates of overflow gutters and broken skimmer covers on which swimmers could cut or bruise themselves.

*The way into the pool.* In 32 out of 100 cases stepladders and lifts for the disabled were unsecured or unsafe. Swimmers could become trapped with limbs in submerged spaces behind the stepladder or injure themselves on pipe ends that were not secured with the required caps. In one case

Parents4Safety was the eye witness of a disabled person falling into the pool along with the poorly constructed lift.

*Inlet nozzles.* In 96 out of 100 cases, one or more inlet nozzles were found to be broken or removable by hand. Thereby, allowing swimmers to stick their fingers and toes into the remaining aperture of the nozzle.

*Drainage and cleaning intakes.* In 89 of 100 cases, the pools had submerged cleaning intakes which were not secured with the required covering cap. The grates of drainage intakes were found to be broken, damaged, removable by hand or severely blocked by dirt.

*Pool lighting.* In 36 out of 100 cases, pools had flaws in the way lighting is mounted into the wall or how the lighting was designed. The lighting along with the wiring could often be pulled out of the wall with only a little tensile force.

*Separation and identification of swimming and non-swimming areas.* In 22 out of 100 cases, pools had an unsafe transition from non-swimmer to swimmer areas. Young children could slip underneath a separation between shallow and deep pools or become trapped in the construction used for the separation. The depth indication of pools was not always legible or absent and the transition to a deeper part of the pool was not always visible or marked.

*Measurement of water velocity.* In 39 out of 100 cases the water velocities at drainage intakes exceeded the permitted 0.5 m/s considerably.

*Unsafe constructions.* In 22 out of 100 cases, pools had constructions that are not allowed by the European Standard EN 13451 and could endanger the swimmers.

## **DISCUSSION**

Entrapment in a swimming pool is a serious problem and has devastating long term consequences for survivors and relatives of victims. The relatives of victims are often dragged into lawsuits, which may last more than ten years, before they can start the mourning process of their lost loved ones. This study indicates that an increase of reported entrapment accidents is seen in Europe, while a decline in reported accidents is seen in North America. The large amount of technical defects and flaws that were found in undercover inspections condemns many swimming pools at hotels and aqua parks to be rated as unsafe for its users. Some major defects could not only cause minor injuries, but were so dangerous that they could be life-threatening. That these pools passed a safety inspection of both travel agencies and highly regarded European safety institutions is highly questionable. None of the 100 investigated pools passed our safety inspection in accordance with European Standard EN 13451, 69 of those were rated as being in a poor condition and 31 were condemned to be very dangerous and contained life-threatening hazards. In some pools swimmers could even be electrocuted. Both tour operators and owners of hotels and aqua parks have little awareness and understanding of pool entrapment and seem to take the safety of their clients for granted (Davison & Puntis, 2003). Current safety inspections mainly consist of visual assessments. Inspectors walk around the pool without entering it, checking off a list. It should be mandatory by law that the owners of pools, but also those who inspect pools on safety for tour operators and safety institutions, have to prove that the offered pool facilities are safe for their users. A detailed and documented assessment of drainage intakes is urgently required in European safety inspections to guarantee the safety of swimmers and should include hair tests and measurements of the water velocity and negative gauge pressure.

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