



Review

Environmental risks of *Pseudomonas aeruginosa*—What to advise patients and parents

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ABSTRACT

Pseudomonas aeruginosa (PsA) is commonly found in soil and water so is impossible to avoid completely. Parents/carers of children with cystic fibrosis (CF) are concerned about them acquiring PsA from the environment, and different families view risk differently. Our ethos is to enable children with CF to take part as much as possible in educational and fun home activities, in order to maintain their quality of life (and their family's), and not have them feel different from other children. This review presents advice for families as to what they must definitely avoid, what they must take precautions with but can allow, and what they must not avoid. It is mostly evidence-based, but where evidence is lacking it a consensus view from the Paediatric CF Unit at the Royal Brompton Hospital.

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Abbreviations: PsA, *Pseudomonas aeruginosa*.E-mail address: i.balfourlynn@ic.ac.uk

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1. Introduction

Given the adverse effect on the lungs and overall prognosis, many parents of children with cystic fibrosis (CF) are concerned about their child acquiring *Pseudomonas aeruginosa* (PsA) from the environment [1]. The term parents in this article includes parents and all types of carers. Our CF team is frequently asked questions, especially when parents are considering which nursery or school is most appropriate for their child, so in order to ensure a consistent message, we included a section in our guidelines (www.rbht.nhs.uk/childrencf). It is a consensus view, based on a comprehensive literature search. For some environments, there is strong evidence and we can be firm in our views. However, for many situations, the evidence is lacking or inconsistent. In those instances, parents will need to decide for themselves what to allow. The guide is also relevant to adults with CF, although some of the issues will only apply to those with children themselves. This review will not focus on the hospital environment and nosocomial infection, nor medical equipment used in the home.

2. Principles of risk

Assessing risk is a personal issue and families view things differently. Parents' views may also change with time, dependent on their child's age and clinical status. In their guide for parents of pre-school to primary school children, the UK CF Trust states 'It's important to remember that life can be risky – we all have to weigh up risk against quality of life' [2]. We agree and would like children to lead as normal a life as possible, and not miss out on fun activities at home or school. Healthcare teams often view issues of risk differently to families and there are a variety of opinions expressed by CF teams on what precautions to take [3]. Lack of clear advice about acquisition makes some parents restrict their child's activities [4]. Some parents may overdo daily precautions to the detriment of the child's and their own quality of life, particularly as a number have major misunderstandings over how to avoid PsA [1,5]. Many parents report the considerable emotional impact of PsA - particularly fear [4], and some report feeling guilty when their child acquired PsA [1]. A survey answered by 73 parents in our unit found 19% worried 'nearly every day' about their child getting PsA, and 81% of parents imposed restrictions at home [6].

3. Sources of PsA in the environment

Although cross-infection of transmissible and epidemic PsA strains is known to occur, it is likely that much PsA acquired is

from the natural environment and not hospitals or other people with CF, given that many patients are infected with distinct strains [7]. It is impossible to avoid contact with PsA, it is often said that it is ubiquitous in soil and water. However, Crone et al., sampled environmental soil, water and faeces from multiple sites in 3 countries (Colombia, USA and Denmark); using culture plates and PCR, they found PsA in 83% of oil or pesticide-contaminated samples vs just 12% uncontaminated [8]. In the uncontaminated samples, PsA was detected in only 7% soil/rhizosphere samples, compared to 32% animal faeces/compost samples and 40% of a small sample of mushrooms [8]. They also did a meta-analysis and assessed 62 papers involving 94 studies with over 22,000 samples [8]. The main findings were that pooling the samples gave an overall PsA environmental detection rate of 25%, which broke down into 43% where there was intense human activity, defined as regular daily human contact, compared with 19% where it was non-intense. Water sources had high levels of PsA detection, particularly waste water (92%), and urban rivers (68%). Contaminated soil (oil and hydrocarbons) had high levels (81%) of PsA whereas it was only 18% in non-contaminated soil. It seems that PsA is closely associated with human activity, and is not commonly found in unpolluted soil and water; animal and human faeces are the main natural sources. A case control study showed that adults without PsA infection lived significantly further away than those with chronic PsA infection (walking distance and 'as the crow flies' direct distance) from blues spaces, i.e., open water spaces including rivers, lakes, ponds and streams [9].

The risk of PsA acquisition is greater if the bacteria are inhaled directly into the lungs, and this can happen when water is aerosolised. An aerosol is a suspension of liquid (or solid) particles within a gas i.e., the air; liquid particles are in the form of droplets or droplet nuclei (in the latter, most of the water has evaporated) [10]. Thus airborne transmission may be feasible when droplet nuclei or small particles in the respirable range containing PsA are inhaled. This is relevant when considering risk from contaminated water as it will depend on the physical form of the water. There is an additional risk that if a child has PsA on their hands, and puts their fingers in their nose or mouth, it can be inhaled, hence the importance of hand washing after certain activities. There is a dose effect, so the longer the exposure or the higher the bacterial content, the more likely the bacteria will be acquired and contaminate the lungs. Nevertheless, the quantity of bacteria required to cause infection in a person with CF is unknown (although has been studied in mice and human volunteers [11]). It is difficult to know whether drinking PsA in contaminated water affects the lungs as PsA can be commonly found in stool samples of healthy people,

Table 1
Things to definitely avoid.

<i>Soil-based</i>
Compost & manure
Cleaning stables and other animal enclosures
<i>Water-based</i>
Hot tubs, whirlpools, spa pools, Jacuzzis, hydrotherapy pools
Tropical greenhouses, butterfly houses
Outdoor misting systems
Squirting bath toys
Swimming in stagnant ponds & canals
Fish tanks

ranging from 1–24% [12–14], and up to 56% of babies in the first 10 days of life in a hospital nursery has PsA in their stools [15].

4. Things to definitely avoid (Table 1)

Soil based

4.1. Compost and manure

Compost heaps and purchased bags of compost are essentially decayed vegetation, and are like enriched soil, but can contain multiple fungi, including *Aspergillus* spores [16], and also bacteria such as *Pseudomonas* species [8]. Manure should definitely be avoided as animal faeces is an important source of PsA [8]. We would recommend compost and manure are not used in gardens of people with CF, especially if the children want to help with gardening.

4.2. Cleaning stables and other animal enclosures

Exposure to mouldy straw inside stables is particularly bad for potential contamination with *Aspergillus*. However a warm mucky stable is also likely to be a source of PsA, and horses can be infected with PsA [17]. The US 2013 'Infection, Prevention and Control Guideline for CF' recommends that people with CF avoid cleaning stalls (as well as pens and coops that contain other animals) [7], so this recommendation applies to many animal enclosures including small cages.

Water -based

4.3. Hot tubs, whirlpools, spa pools, Jacuzzis, hydrotherapy pools

There is strong evidence of the presence of PsA in warm water that is aerosolised and easily inhaled with the person's head just above the water; and reported cases of acquired infection in children [18] and adults with CF [19], as well as a previously healthy adult [20]. PsA has been isolated from culture plates held 15 cms (6 inches) above the water surface when the tub was turned on [20], and also direct water samples and swabs from sides, gutter, drains etc. [21,22]. A 2002 Northern Ireland study found PsA in 4/13 (31%) hydrotherapy pools and 37/51 (73%) Jacuzzis [23]; a further N. Ireland study in 2018 found PsA in 21% of 243 hot tubs and 7% of 5811 Jacuzzis [21]. There is guidance to reduce survival and growth of PsA in these environments (e.g. levels of free chlorine and bromine, pH of water), but the complex piping systems are difficult to clean, and high water temperature with water agitation make chlorine-based disinfectants less effective [22]. Furthermore, in 2013, over 20,000 public hot tubs/spas were inspected by 16 public health agencies in 5 states in the USA, and 19% violated recommended disinfectant concentrations [24]. When concentrations are inadequate, PsA biofilms build up that then protects the organism once adequate disinfectant concentrations are regained [24]. *Mycobacterium avium* complex have also been isolated from spas

and hot tubs, particularly when poorly maintained with inadequate disinfection, and have been associated genotypically and epidemiologically with lung infections in immunocompetent adults [25]. We recommend total avoidance and there is strong evidence for this.

4.4. Tropical greenhouses, butterfly houses

A study in 20 greenhouse watering systems in Germany found PsA (and other strains of *Pseudomonas*) in 70% systems, when sampling from central taps and at the outlets of spray nozzles [26]. These misting systems to water plants in tropical greenhouses, and presumably also butterfly houses, are a risk as the fine aerosols are easily inhaled.

4.5. Outdoor misting systems

Some restaurants or other public areas have an outdoor misting system that sends a spray of mist downwards to keep people cool. This is also found inside some restaurants with tropical jungle themes. There is nothing published on this regarding PsA (a few mentions re potential *Legionella*), although there is a theoretical risk that the mist may contain PsA from the local water supply, so we would recommend avoidance as again inhaling the aerosol is a risk.

4.6. Squirting bath toys

Bath toys that have a valve on the base (e.g. plastic ducks) or that can squirt out water can be a problem if the water sits inside the toy for a long time, as they cannot be fully emptied and dried. There is evidence of a multidrug-resistant PsA outbreak on a children's cancer ward that originated in the toy box containing water-retaining bath toys and a nail brush [27].

4.7. Swimming in stagnant ponds & canals

Small natural stagnant ponds contain rotting vegetation, and are in contact at the bottom with earth; there is also faecal pollution from wildlife, so going in them must be avoided. Canals also usually contain stagnant water that usually looks dirty. We would definitely recommend avoiding this.

4.8. Fish tanks (especially with warm water for tropical fish)

Multiple species of bacteria, including PsA, have been isolated from fish tanks and diseased ornamental fish [28,29]. Furthermore, PsA was isolated from over half of 92 aquarium plants bought in 33 retail outlets in British Columbia; and they also isolated PsA from 29% of the samples of water that purchased goldfish came in, and 17% of the tropical fish water [30]. There is a case report of an 11-month old infant with CF who isolated PsA and *Aeromonas* spp. repeatedly until the four fish tanks with murky water were removed from the home [31]. The oxygen pumps will lead to bubbles and aerosolization of water, and tropical fish are kept in warm water ideal for PsA. We believe they should be avoided but not all will agree. The US Guideline simply suggests that gloves should be worn when cleaning out a fish tank [7].

5. Things to take precautions with but allow (Table 2)

Soil based

5.1. Digging in the garden soil, playing in the park, playing outdoor sport

As discussed above (Section 3), PsA is known to reside in soil, particularly when contaminated. Nevertheless, in the meta-analysis

Table 2

Things to take precautions with but allow.

<i>Soil-based</i>
Digging in the garden soil, playing in the park, playing outdoor sports
Muddy puddles
Mud kitchens
Clay
<i>Water-based</i>
Swimming – sea, freshwater lakes, rivers, swimming ponds, swimming pools
Inflatable paddling pools
Water pistols and ‘super-soakers’
Water amusement parks
Play fountains / splash pads / spray pool / garden water sprinklers
Sandpits and sandy beaches
Touch pools in a public aquarium
Petting zoos and farm visits
Caves
Snow
Showers, sinks & bath taps
Flushing toilets
Flower vases
Humidifiers & vaporisers
Air conditioning

of 94 studies, it was still present in 18% of non-contaminated samples, that you would expect to find in private gardens [8]. Soil that is contaminated by organic fertiliser or animal manure must be avoided. Any PsA present in someone’s garden is only a potential source of infection if the child gets the soil on their noses or in their mouths. PsA will not normally be aerosolised from soil. We therefore suggest playing in the garden or park should not be stopped, as long as the children’s hands and face are cleaned properly afterwards. Carrying hand sanitisers is helpful when outdoors.

The same applies to older children playing outdoor team sport on grass pitches which we encourage as exercise is so beneficial. We believe running through piles of damp leaves would also seem to be safe (although it is better not to play in them); the UK CF Trust advises against ‘extensive contact’ with rotting leaves [2]. The US guidelines suggest that people with CF should limit prolonged exposures to activity that generates dust from the soil or organic matter e.g. lawn mowing to decrease exposure to *Aspergillus* and *B cepacia* complex. There is the additional hazard from *Aspergillus* and other fungi in bags of potting soil and on the top of soil in potted plants [16]. If a child wants to garden they can always wear gardening gloves.

5.2. Muddy puddles

Mud is a mixture of compressed soil and water; a puddle that has dirty stagnant water in it may contain many bacteria. A study in Northern Ireland sampled 18 freshly formed puddles in two city hospitals, and 8 puddles from two countryside locations [32]. A large number of bacteria were isolated, more often from the hospital locations. The commonest type were gram-negative organisms, and particularly *E.coli*. PsA was isolated only from one hospital puddle (and was a type not found in any CF patient in N. Ireland); there were three other strains of *Pseudomonas (oleovorans, putida and fluorescens)* found in the countryside and hospital. However, if a child steps in it or even splashes in it, the water is unlikely to be aerosolised sufficiently to be inhaled in significant quantities, so we believe this is not a significant risk and need not be avoided. There are some though who would recommend staying out of puddles that have settled on top of mud. Pavement puddles generally dry quickly so the water does not stagnate and is also not in contact with soil/mud, so is safe to splash through.

5.3. Mud kitchens

These are toy kitchen units made of wood, plastic and metal (often found in UK nursery schools), where mud is used as the ingredient for all the food being made, so gets all over the children’s hands and probably faces. The same applies as digging in the garden, any PsA in the mud will not be aerosolised, so as long as the children’s hands and face are cleaned properly afterwards, we believe the risk is minimal. There is no published evidence to further guide us, although the UK CF Trust advises against ‘extensive contact’ with mud [2].

5.4. Wet clay

Clay is fine-grained natural soil material. Modelling clay usually comes in a bag and is wet, often with loose water at the bottom of the bag. The clay should be allowed to dry out first although needs to be moistened again for it to be usable.

Water-based

5.5. Swimming

It is important children learn to swim for safety reasons. The water will not usually be aerosolised (apart from near waterfalls), although there will be droplets from splashing about; so it is unlikely to be an issue as long as it is not inhaled. Washing afterwards is obviously a good idea. PsA grows in water at temperatures ranging from 5 to 42°C., but optimally at 37°C., hence the water temperature is an important factor in the risk of acquiring infection [33]. It is known that PsA acquisition is higher in the summer and autumn than winter, whereas this does not apply to *Staphylococcus aureus* acquisition [34].

- **Sea** – PsA has been grown out in the open ocean (away from human activity) [35]. However, sea water by a beach is most likely contaminated from humans. The saline concentration of the seawater will inhibit growth of many organisms. It is worth checking the cleanliness of beaches, and for example, this can be done online for UK beaches (<https://www.gov.uk/quality-of-local-bathing-water>). We suggest swimming in the sea is safe.
- **Freshwater lakes** can also be contaminated in a similar way to the sea and in a hot summer in Holland, there was an outbreak of otitis externa and PsA was isolated from five lakes (that did comply with European Commission standards for faecal pollution) and the ear swabs of 78 cases, so a strong association was clear; there was no mention of airway infections though [36]. Overall though, it is likely to be safe to swim in a large lake.
- **Rivers** –PsA has been isolated in rivers, particularly in cities, and is more likely after heavy rain has led to sewage overflow [8]. We would advise caution in an urban river, but would not discourage swimming in an open countryside river (as long as it is deemed safe for bathers)
- **Swimming ponds** –large swimming ponds and ‘natural’ swimming pools are not chlorinated nor sterilised, but rely on biological filters and plants, although in some the bottom surface is lined [37]. Water safety standards for natural ponds are being legislated for in Europe as they are not included in swimming pool standards [33]. Nevertheless, PsA has been isolated in low levels in 11/13 Dutch swimming ponds [33], as well as in 4/4 ponds in Spain [37]. It may be safe in a large pond that looks clean with clear water, but if the water is turbid it implies increased bacterial contamination, increased growth of algae, runoff from surrounding surfaces, and airborne dirt, and it should be avoided [33]. PsA is also more likely to be found in ponds during prolonged periods of hot weather [33].

Pond-dipping is collecting pond life in a jar attached to a net that is dragged through the water, and is an activity many schools engage in. It is likely that the pond water (that may be stagnant) will get on the children's hands and of course may end up being flicked around when an adult is not looking, especially when there are a lot of children involved. It is likely to be safe as long as it is supervised properly, and the child cleans their hands properly afterwards. There is no evidence to guide us, and it is difficult to know what is best, so parents will have to decide whether they believe it to be a sufficient risk to stop the child joining in.

- **Swimming pools** – as long as the pool is disinfected (usually with chlorine or bromine) to recommended levels then this should not be a problem, and public pools are under clear legislation. The US guideline recommends that people with CF can swim in pools with adequate disinfection [7]. Having said that, in 2013, over 43,000 public pools were inspected by 16 public health agencies in 5 states in the USA, and almost 4000 (9%) violated recommended disinfectant concentrations [24]. PsA has been isolated from both indoor and outdoor public pools in multiple studies [21–23,38], although in a Swiss study of about 100 pools, they only identified PsA in the paddling and hydrotherapy pools but not the actual swimming pools [39]. Caution is needed with some hotels and renting holiday villas with private pools in case the pool is not treated properly. Biofilms harbouring PsA have been shown to accumulate in the filters, pool carpets and shower floors of swimming pools [40]; and also vinyl-canvas and foam teaching aids and toys, particularly if stored wet [41]. It is safest for people with CF to only use pools that are well maintained and have an associated quality assurance monitoring programme to eliminate PsA [21].

5.6. Inflatable paddling pools

These will be fine as long as they are emptied after each use & dried out, then filled up again with fresh water when they are to be reused. The CDC recommend leaving the pool out in the sun for four hours once it is emptied and completely dry [42]. In general, water play should be safe as long as the water is fresh and has not sat stagnating in containers; toys should be dried out at the end.

5.7. Water pistols and 'super-soakers'

Similarly, to squirting bath toys, this could be a problem if the water is kept inside the toys for a long time. A forceful super-soaker could aerosolise the water and can be squirted in the face. However, we suggest as long as they are emptied fully after use and dried out they can still be played with. Cleaning may also help, although less so once PsA biofilms have formed [41]; soaking in disinfectant such as dilute bleach is an option but the toys must be rinsed thoroughly afterwards so the child does not get chemicals in their eyes if squirted in the face.

5.8. Water amusement parks

The water will be aerosolised so on some rides, spray can be inhaled. However as long as the facility uses disinfected (usually chlorinated) water to industry standards this should be safe and can be checked in advance. The US guideline recommends that people with CF can swim in water parks with adequate disinfection [7].

5.9. Play fountains / splash pads / spray pools / garden water sprinklers

The water spouts up from pavement jets or a recreation area, and there is minimal standing water. Some of the water is likely to be aerosolised so does present a risk. It is said that typically the water is treated (usually chlorinated) to similar standards as a swimming pool, in which case they should be safe. However, the water is recycled and will wash contaminants off people that will then be resprayed [43]. As part of an Australian study of first acquisition of PsA and geographical locations, an association was found between acquisition of PsA and households that used water sprinkler systems in the garden, the significance of this is unclear [44].

5.10. Sandpits and sandy beaches

In a sandpit with clean dry sand the risk is low, although the sand is often damp; nevertheless, we believe the risk is only significant in a sandpit with free standing stagnant water. So, we suggest sandpits are fine as long as there is no visible standing water; this will be easier to control in a private garden. It is worth keeping a lid on the sandpit to reduce the amount of rainwater that might collect. Also, when filling up the sandpit from large bags, the sand is usually wet in the bag and should be left to dry out before use. The CF Trust advises schools that fresh dry sand should be used but do not say how often it should be changed [2]. A sandpit in a park is less likely to be clean, but by far the most frequent contaminant is *Toxocara* from cat and dog faeces.

Sand on beaches can be contaminated with PsA (and *Staphylococcus aureus*), presumably due to human contamination, land runoff, and sewage in the sea [45,46]. Indeed, sand has the ability to filter bacteria out of the seawater and sustain its growth whereas most organisms rapidly die in seawater due to the high salt concentration [45]. PsA is therefore more often found in dry than wet sand on beaches, although it is the converse if it has rained in the previous 24 hours [46].

5.11. Touch pools in a public aquarium

It is most likely that there will be bacteria in the water, including Non-tuberculous *Mycobacteria*. However, the water will not be aerosolised, and there are usually good hand-washing facilities in place, so we believe the children can take part as long as they definitely clean their hands well and are supervised carefully.

5.12. Petting zoos and farm visits

Clearly stagnant water or small ponds should be avoided. Caution also in chicken coops, stables and contact with mouldy hay for *Aspergillus*. Hand hygiene is important after stroking the animals and most places will have hand washing facilities for all the children. There have been no reports of transmission of pathogens from farm animals or pet therapy animals to people with CF, although animals are a potential source of several types of infection (e.g. PsA from horses, MRSA from pigs).

5.13. Caves

These are often damp environments with water dripping down the sides of the walls. The water is not aerosolised, and the child will not be in direct contact with the water. Whilst multi-resistant PsA has been isolated from water in a remote cave in Guayana [47], on balance, we believe a visit to a cave need not be avoided.

5.14. Snow

A 2018 study analysed fallen snow from 37 sites in parks, gardens, public open spaces and footpaths [48]. Although a number of bacterial species were detected in the majority of samples, PsA was not detected in any. Caution should be taken in dirty slushy melted snow especially lying over mud, but there should be no harm in playing in freshly fallen white snow.

5.15. Showers

The shower heads can be a source of PsA with colonised biofilms, and the shower spray contains aerosolised droplets that can be inhaled. It is best to run the shower for 1-2 minutes before the child gets in. Shower heads with smoother surfaces may be less prone to retaining microbes than those with more crevices [7].

5.16. Sink and bath taps

PsA is definitely found in people's homes. A study that took over 11,000 samples during multiple visits to homes of 7 people with CF and 8 without, found just 6% of samples from drains yielded PsA, far more than from other sample sites in the home, with no difference if there was someone with CF living in the home [49]. On the other hand, a larger study from the homes of 102 people with CF in Germany, found PsA in 72% of the homes; it was in 40% shower drains, 35% kitchen sink drains, 35% of bathroom sink drains, and 27% toilet drains [50]. Interestingly the intensity of cleaning measures undertaken had no influence on PsA detection rate. Taps can contain PsA (in the form of biofilms) but the risk to the patient is reduced compared to showers as the water spray is not being inhaled. If the tap is in frequent usage the risk is also lessened but taps that are rarely used should have the water run through them for 1 minute every day [51]. A study in the homes of 50 CF patients with newly acquired PsA found PsA in just 6% of environmental samples with the majority (72%) from the bathroom [52]. PsA was isolated in the homes of just 18 of the 50 patients, but in 9/18 it was a different strain; when the strain was identical, it is unknown if the patient acquired it from their home or vice versa [52].

PsA has been isolated from the rubber seals of dishwashers in 6/30 (20%) machines tested (and *S.maltophilia* in 10/30) [53], so clearly these must be kept cleaned, and less bacteria are found when they are used at the higher temperature settings.

5.17. Flushing toilets

Toilets in PSA-infected CF households contain PsA twice as often (42%) as non-infected CF households (20%), but 20% is still high [54]. Aerosols containing bacteria can be created when flushing toilets, so the lids should be lowered before flushing [11].

5.18. Flower vases

There is no doubt that several bacteria species, including PsA, can be isolated from the water in flower vases within 3 days; whilst there is no evidence that this has caused hospital acquired infections [55], it is logical that one would not want contaminated water sitting in someone's home. Water should be changed regularly before it smells and leaves should be trimmed off stems so that they do not sit in the water. Dilute disinfectant (e.g. hypochlorite, chlorhexidine) can be added to the water with no harm to the flowers.

5.19. Humidifiers & vaporisers

Water sits in a reservoir which is evaporated and blown into the air. As long as the reservoir is kept clean, and fresh water put into it before use, it should be safe, but it should not be used if the water has been stagnating in the reservoir. Also, disinfectant must never be added to the water – there have been cases of interstitial lung disease developing in ventilated neonates with disinfectant added to the humidifiers.

5.20. Air conditioning

There is no evidence of PsA problems with air conditioning (including in cars) but these should best be avoided if poorly maintained units are dripping water.

6. Things that must not be avoided

6.1. Go to the dentist and brush teeth

A dental chair unit uses water to irrigate and cool dental instruments and the teeth, as well as providing water for rinsing; there are several metres of fine bore tubing to supply the water – the dental unit waterlines (DUWLs) [56,57]. Intermittent use can lead to water stagnation, some have independent reservoirs, and they run off the municipal water supply. The water is aerosolised in the mouth so clearly this is a potential infection risk. There can also be retrograde movement of water and saliva back into the system, especially if there are inefficient or absent anti-retraction valves [58]. PsA has been isolated, sometimes in high proportions, from DUWLs tested in studies from Jordan, Italy, China and Switzerland [56–59]. Flushing the dental water unit for 2 minutes significantly reduced the PsA counts but did not eliminate them [59]. Nevertheless, it is critical that children with CF attend the dentist regularly, especially given the effect of some of the antibiotics and aspects of their diet. Furthermore, rotten teeth can promote PsA in the mouth which can infect the airways. Some parents are concerned about wet toothbrushes, but a study in 102 homes of people with CF found in only 1% was PsA isolated from the brush [50]. Nevertheless, it has been shown that a simple steam cleaner used for baby bottles will eradicate PsA and other organisms, including MRSA, Non-tuberculous *mycobacteria*, and *B cepacia* complex from toothbrushes, and it has been recommended that this should be done after each use [60].

6.2. Drink water

PsA has been isolated in tap water, well water, drinking water dispensers (coolers), water from vending machines, bottled water, and even distilled water [11,21]. There is no evidence that drinking water with the low levels of PsA found will cause lung infections, and high levels are required to colonise the gut. Drinking water need not be avoided, nor need the water be boiled first. The US guidelines suggest that tap water or well water that meets local public health standards may be used for drinking, as can bottled and distilled water [7].

Many people use refillable water bottles. Mostly the filters are not antibacterial but are carbon filters to remove chlorine and improve the taste. Certain designs mean that the filters remain wet, possibly even holding water, so these should be avoided. Similar advice is given for water jugs with filters. Bottles with antibacterial filters do exist (for camping etc.) but again it is important to know if the filter remains wet and possibly holds on to the bacteria, in which case they should be avoided. Household water purifiers are also principally used to purify chemicals, and have been found to contain PsA, although in low amounts [61].

7. Conclusions

Clearly PsA is common in the environment and so is a concern to the CF community. Where possible, we have aimed to provide evidence-based data to help inform parents how to minimise risk to their children with CF, at the same time as allowing the children to play and be educated like all other children.

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Declaration of Competing Interest

None.

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