Detection of pathogenic micro-organisms on children’s hands and toys during play

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Keywords
children, hands, human pathogens, outdoor activities, playgrounds, toys.

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2013/1754: received 27 August 2013, revised 21 January 2014 and accepted 7 February 2014
doi:10.1111/jam.12473

Abstract
Aims: This study aimed to determine if the children’s leisure activities impact the presence of pathogens on their hands and toys.
Methods & Results: To assess the microbiological hazard in playground areas, a pilot study that included 12 children was conducted. We then conducted an intervention study; children’s hands and toys were washed before playing. Faecal coliforms, pathogenic bacteria and Giardia lamblia were quantified by membrane filtration, selective media and flotation techniques, respectively; rotavirus, hepatitis A and rhinovirus by RT-PCR. Pilot study results revealed faecal contamination on children’s hands and toys after playing on sidewalks and in public parks. Pathogenic bacteria, hepatitis A and G. lamblia on children’s hands were also found. In the intervention study, Staphylococcus aureus and Klebsiella pneumoniae were found on children’s hands at concentrations up to 2.5 × 10⁴ and 1 × 10⁴ CFU hands⁻¹, respectively. E. coli and Kl. pneumoniae were detected on toys (2.4 × 10³ and 2.7 × 10⁴ CFU toy⁻¹, respectively). Salmonella spp, Serratia spp and G. lamblia cysts were also present on toys.
Conclusion: Children’s play activities influence microbial presence on hands and toys; the transfer seems to occur in both ways.
Significance and Impact of the Study: Control strategy needs to be implemented to protect children from infectious diseases.

Introduction
Young children spend a considerable amount of their time engaged in various forms of play either at outdoors areas or with playground equipment and toys exposed to human lower respiratory infections (WHO 2006). Epidemiological estimates from Mexican and Sinaloa Epidemiology Departments reflect WHO reports in terms of infections and causative agents (Santamaria and Toranzos 2003; Savio et al. 2005). Several studies have proved that faecally contaminated soil in public parks harbours large numbers of opportunistic and microbial pathogens including bacteria, parasites and viruses (Córdoba et al. 2002; Flores et al. 2007; Martínez et al. 2008). The combination of inefficient sanitation programmes and the presence of microbial pathogens on playground equipment and toys might put children at risk (Toledo et al. 1994; Davies et al. 2000; Merriman et al. 2002). However, this risk might be significantly reduced when children practice effective hand-washing techniques. The aim of this study was to determine whether the children’s recreational activities favour the presence of indicator organisms, pathogens and nonhuman faecal material on their hands (Santamaria and Toranzos 2003; Gauci and Borg 2007).

The World Health Organization (WHO) estimates that the environmental burden of diseases among children between 0–14 years of age is mainly attributed to diarrhoeal and hands and toys (WHO 2006).
Materials and methods

This research was divided in a pilot and a control study. The pilot study was performed between August and September 2009 in the urban zone of the city of Culiacán, Sinaloa, México to estimate the presence and concentration of faecal coliforms, *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Streptococcus pyogenes* and *Giardia lamblia*, as well as the presence of *Salmonella* spp, *Serratia* spp, *Shigella* spp, rotavirus, rhinovirus and hepatitis A virus on children’s hands and toys (doll, bicycle, tricycle, ball and soccer ball) used to play at public parks and on sidewalks. Parents were verbally informed about the study process and child participation consent was signed. A total of twelve children (a girl and two boys from 2 to 6 years old and a girl and two boys from 7 to 12 years old playing with toys evenly distributed in parks and a girl and two boys from 2 to 6 years old and a girl and two boys from 7 to 12 years old playing with toys evenly distributed in sidewalks) were included in the pilot study. The hands and toys of the same 12 children were sampled weekly for five consecutive weeks to evaluate the presence of faecal indicators and potential microbial pathogens giving a total of 60 samples. The data obtained from the pilot study informed the research approach of the control study.

The control study, which was carried out between March and April 2010, was conducted to determine if the children’s recreational activities had an effect on the presence of pathogenic micro-organisms on children’s hands and toys. To confirm the absence of micro-organisms on children’s hands at the beginning of the control study, a washing and disinfecting procedure that included antibacterial soap (Escudo®; Procter and Gamble, Cincinnati, OH) was performed on the hands of the participating children. Twenty girls and twenty boys between the ages of 2–12 years old were included in the study. Parents were verbally informed about the study process and child participation consent was signed. Children carrying their own toys (ball, bicycle or doll) were preferably chosen to perform trials in parks and sidewalks, and a total of 26 toys were sampled at parks and 11 toys from the sidewalks.

Parks and sidewalks included within the pilot study were the same along the study but different from those parks and sidewalks included within the control study.

Sample collection

Pilot study

For the pilot study, the weekly sampling period was extended for 5 weeks. Samples were taken after 1 h of playing by washing both children’s hands and toys in 200 ml of phosphate buffered saline (PBS) solution contained in a sterile plastic bag and vigorously washed for 2 min to allow the release of micro-organisms. The same procedure was implemented for bicycles where only the handle was rinsed, by submerging it in 200 ml of PBS contained in a sterile plastic bag and vigorously washed for 2 min to allow the release of micro-organisms.

Control study

The sampling of the CS was extended for 2 months on a weekly basis. Children washed their hands with Escudo® antibacterial soap (sodium oleate, sodium palmitate, water, sodium laureate, Zea mays (Corn) starch, glycerine, fragrance, triclocarban, sodium chloride, titanium dioxide, sodium citrate, citric acid, tetrasodium EDTA), rinsed their hands in a sterile plastic bag containing 50 ml of PBS and vigorously washed for 2 min, this rinsing water was analyzed to determine the absence of micro-organisms. After hand washing, children spent 1 h playing with toys at either public parks or sidewalks. After that time, both children’s hands and toys were introduced in a sterile plastic bag containing 200 ml of PBS and vigorously washed for 2 min to allow the release of micro-organisms. In the case of bicycles, only the handle was rinsed by submerging it in a sterile plastic bag containing 200 ml of PBS and vigorously washed for 2 min to allow the release of micro-organisms. All samples were transported in a cooler at 4°C to the Food and Environmental Microbiology Laboratory, CIAD Culiacan for immediate sample processing for the microbial analyses.

Bacterial identification and quantification

The identification and quantification of bacteria were performed by diluting and extending 0.1 ml of the sample in selective and differential culture media (APHA 1998). The culture media used for bacterial identification and quantification were as follows: CHROMagar ECC at 45°C for faecal coliforms and *Escherichia coli*; Mannitol Salt Agar at 37°C for *Staphylococcus aureus*; McConkey Agar at 37°C for *Klebsiella pneumoniae*; CHROMagar ECC at room temperature for *Serratia* spp; Blood Agar at 37°C for *Streptococcus pyogenes*; and Xylose Lysine Deoxycholate Agar at 37°C for *Shigella* spp. All plates were incubated during 24 h. The *Salmonella* spp detection was carried out according to ISO 5679. Fifty millilitre of sample were filtered using membranes with a pore size of 0.45 μm (GN-6 Metrical Grid 47 mm, PALL) (APHA 1998). Membranes were placed into 50 ml of buffered peptone water and incubated for 24 h at 37°C. After incubation period, 0.1 ml of sample was inoculated for enrichment in 10 ml of Rappaport Vassiliadis broth and incubated at 37°C during 24 h. Then, 0.1 ml was plated on selective culture media Xylose Lysine Deoxycholate, Agar and Hektoen Agar and incubated at 37°C.
Table 1 Specific primers for each target bacterium

<table>
<thead>
<tr>
<th>Bacterium</th>
<th>Specific primers</th>
<th>Gene</th>
<th>Fragments (pb)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Serratia</em> spp</td>
<td>Fpsf1 (5'CCGCGACGGCAGGAGGTCAT') Fps2 (5'ATCTGGCCCCGCTGCTAGCC/AT) Fluxs1 (5'GCTGAAACACTGGTCCGG/AT) Fluxs2 (5'ATGGAGAAGCCGGTGGCGG/AT)</td>
<td>PfsfloxS</td>
<td>193/102</td>
<td>Zhu et al. (2008)</td>
</tr>
<tr>
<td><em>Klebsiella pneumoniae</em></td>
<td>Pr1 (5'TTCTAATCTAATGTTTCTCAGCTGATC/AT) Pr/Pr2 (5'CCGAAAGGTTCATTTCCCTG/AT)</td>
<td>Internal transcribed spacer region</td>
<td>130/260</td>
<td>Liu et al. (2008)</td>
</tr>
<tr>
<td><em>Salmonella</em> spp</td>
<td>INVA 1 (5'ACAGCTGCTGTTACGACTGCA/AT) INVA 2 (5'AGACGACTGCTGACTGCTGAAAA/AT)</td>
<td>invA</td>
<td>244</td>
<td>Chiu and Ou (1996)</td>
</tr>
<tr>
<td><em>Shigella</em> spp</td>
<td>Shi 1 (5'CTTGACGGCCTTTCGAGA/AT) Shi 2 (5'CGACCCACCTCTGGAGA/AT)</td>
<td>Ipah</td>
<td>610</td>
<td>Wang et al. (1997)</td>
</tr>
<tr>
<td><em>Streptococcus pyogenes</em></td>
<td>Spy1258F (5'AAAGACCCGCTTAACACC/AT) Spy1258R (5'TGCCAAGGTGAACTTCAAAGCA/AT)</td>
<td>Spy1258</td>
<td>407</td>
<td>Liu et al. (2005)</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>SA1 (5'GGATGATGCGTATGACG/AT) SA2 (5'CAAGCTTGAGAACACTAAA/AT)</td>
<td>Nuclease</td>
<td>276</td>
<td>Wang et al. (1997)</td>
</tr>
</tbody>
</table>

After the selected incubation time according to the temperature required for each type of bacteria, presumptive colonies of *Staph. aureus*, *Kl. pneumoniae*, *Strep. pyogenes*, *Shigella* spp, *Serratia* spp and *Salmonella* spp were confirmed by PCR using the GoTaq® PCR Core System I (Promega, Fitchburg, WI). The specific primers and fragment sizes are shown in Table 1. A positive control for each target bacterium and a negative control were used to conduct the PCR analyses.

Viral concentration

Viruses were concentrated with an adsorption-elution technique (APHA 2001). Fifty millilitres of sample were pH adjusted (3-5) with 6 mol l⁻¹ HCl. Aluminium chloride was added to the 50 ml to reach a final concentration of 0.0015 mol l⁻¹ for virus flocculation. Then, samples were gently stirred at room temperature for 30 min and passed through a negatively charged membrane filter with a 47 mm diameter and 0.45 μm pore size (GN-6 Metricel® Grid; Pall Corporation, Port Washington, NY). Membrane with adsorbed viruses was washed with 5 ml of 0.14 mol l⁻¹ NaCl. Viruses were eluted by adding 5 ml of 2.9% tryptose phosphate broth containing 6% glycerine, pH 9. Eluates were pH adjusted at 7–7.4 with 6 mol l⁻¹ HCl.

Viral nucleic acid extraction

Nucleic acid was extracted by the QIAamp Viral RNA Mini Kit (Qiagen, Hilden, Germany) according to the manufacturer's instructions. Samples were stored at −70°C until further processing.

Retro transcription

Retro transcription (RT) was performed by the method described by Schwarz et al. (2002). For denaturalization of dsRNA, 2 μl of random primer were added to 10 μl of each sample, and incubated at 97°C for 5 min and then at 70°C for 5 min in a thermocycler. Mixtures were then cooled on ice for 2 min. The Access RT-PCR system 137 (Promega) was used for RT. RT mixtures of 25 μl (10 μl of buffer, 2 μl of MgSO4, 1 μl of dNTP’s, 1 μl of retro transcriptase, 10 μl of free-nucleases water and 1 μl of RNA) were used. RT mixtures were incubated at 42°C for 1 h and 95°C for 5 min in a thermocycler, and then cooled on ice for 2 min to obtain cDNA.

Polymerase chain reaction

For virus PCR, a GoTaq® PCR Core System I (Promega) was used. A 10 μl portion of each cDNA sample was added to 40 μl of PCR mixture containing 5× Colorless GoTaq® Flexi Buffer, 25 mmol l⁻¹ MgCl₂, 10 mmol l⁻¹ of each of dATP, dTTP, dCTP, dGTP, 10 μmol l⁻¹ of each primer and 5 U μl⁻¹ of Taq polymerase. PCR specific primers and fragment sizes are shown in Table 2. The PCR was conducted in a Mastercycler® Personal (Eppendorf, Hamburg, Germany). The amplification conditions for Rotavirus identification were one cycle of 94°C for 5 min, then 34 cycles of 94°C for 30 s, 55°C for 30 s and 72°C for 1 min, and finally, one cycle of 72°C for 5 min. For VHA and Rhi- novirus identification, the amplification conditions were one cycle of 94°C for 2 min, then 40 cycles of 94°C for 30 s, 60°C for 1 min and 68°C for 2 min, finally, one cycle of 68°C for 10 min. A positive control for each target virus and a negative control were used to conduct the study.
Detection of *Giardia lamblia* cysts

Detection of *G. lamblia* cysts was performed using the method described by Dryden et al. (2006). Samples contained in sterile plastic bags were manually agitated, and 50 ml of sample were centrifuged at 1000 g for 10 min. Supernatant was removed and 3/4 parts of sugar solution (SG 1-27) were added to the sediment and centrifuged again at 250 g for 5 min. Samples were allowed to stand for 5 min and then 1-8 ml was loaded in a McMaster chamber for microscopic observation using the 10× objective.

Statistical analysis

For site comparison, two proportions probe for nominal dates and a t probe for comparing accounts were used. Statistical analyses were carried out using Minitab 15. Results are presented in frequency tables.

### Results

**Pilot study**

**Micro-organisms on children’s hands**

The presence of faecal coliforms (FC) was confirmed on every child’s hands (Table 3). The six pathogenic bacteria (excluding Shigella) were present on children’s hands at concentrations up 1 × 10e6 CFU hands−1. *Streptococcus pyogenes* was present only on children’s hands of those who played on sidewalks (Table 3). Hepatitis A virus (HAV) was detected on 17% of children’s hands who played in parks and on sidewalks (Table 3). *Giardia lamblia* cysts were found on 67% of children’s hands whom played in parks and on sidewalks (Table 3) as high as 58-33 cysts hands−1 (Table 4).

**Micro-organisms on toys**

Faecal coliforms (FC) were found on all evaluated toys used by the children playing at both parks and on sidewalks; some pathogenic bacteria were present in some samples of parks and sidewalks (Table 5) at similar concentrations as those found on hands (Table 6).

**Giardia lamblia** cysts were found only on toys of children playing at parks (Table 5). *Streptococcus pyogenes* and Shigella spp were not detected and viruses were not analyzed on toys.

**Control study**

**Micro-organisms on children’s hands**

In the control study, children washed their hands with antibacterial soap prior to initiate the trials. After that, children played for 1 h and samples were collected. FC were present on children’s hands after playing in parks on 12.5% of the samples (Table 3), while children playing on sidewalks showed no presence of FC; no statistical difference between parks and sidewalks were observed (P = 0.054). Pathogenic bacteria, except *E. coli* and *Salmonella* spp, were found on up to 5% of samples from...
Table 4 Micro-organisms concentration on children’s hands playing at parks and sidewalks, during the pilot and main studies

<table>
<thead>
<tr>
<th>Micro-organisms</th>
<th>Pilot study†</th>
<th>Main study‡</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Parks (min-max)</td>
<td>Sidewalks (min-max)</td>
</tr>
<tr>
<td><strong>Faecal coliforms</strong></td>
<td>3.9 × 10³*</td>
<td>(0.1-10 × 10³)</td>
</tr>
<tr>
<td><strong>Escherichia coli</strong></td>
<td>8.9 × 10³</td>
<td>(0.6-6 × 10³)</td>
</tr>
<tr>
<td><strong>Staphylococcus aureus</strong></td>
<td>2.6 × 10³</td>
<td>(0.6-6 × 10³)</td>
</tr>
<tr>
<td><strong>Klebsiella pneumoniae</strong></td>
<td>1.7 × 10³</td>
<td>(0.5-1 × 10³)</td>
</tr>
<tr>
<td><strong>Streptococcus pyogenes</strong></td>
<td>0</td>
<td>(0-4.8 × 10⁵)</td>
</tr>
<tr>
<td><strong>Giardia lamblia</strong></td>
<td>58-33†</td>
<td></td>
</tr>
</tbody>
</table>

*Colony forming units.
†Number of cysts on hands.
‡Mean concentrations of six children sampled at each site (park and sidewalk) for five weeks.
§Mean concentrations of forty children sampled at each site (park and sidewalk).
¶(Minimum–maximum).

Table 5 Micro-organisms on toys used at parks and sidewalks, during the pilot and main study

<table>
<thead>
<tr>
<th>Micro-organisms</th>
<th>Number of positive samples (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pilot study*</td>
</tr>
<tr>
<td></td>
<td>Parks</td>
</tr>
<tr>
<td><strong>Faecal coliforms</strong></td>
<td>6 (100)</td>
</tr>
<tr>
<td><strong>Escherichia coli</strong></td>
<td>4 (67)</td>
</tr>
<tr>
<td><strong>Staphylococcus aureus</strong></td>
<td>4 (67)</td>
</tr>
<tr>
<td><strong>Klebsiella pneumoniae</strong></td>
<td>3 (50)</td>
</tr>
<tr>
<td><strong>Streptococcus pyogenes</strong></td>
<td>0 (0)</td>
</tr>
<tr>
<td><strong>Salmonella spp†</strong></td>
<td>1 (17)</td>
</tr>
<tr>
<td><strong>Serratia spp†</strong></td>
<td>3 (50)</td>
</tr>
<tr>
<td><strong>Shigella spp†</strong></td>
<td>0 (0)</td>
</tr>
<tr>
<td><strong>Giardia lamblia†</strong></td>
<td>2 (33)</td>
</tr>
</tbody>
</table>

*Six toys sampled at each site (park and sidewalk) for five weeks.
†Twenty-six toys sampled at parks and 11 toys sampled at sidewalks.
‡Lower detection limit for methods are *Staphylococcus aureus* (20 cells ml⁻¹); *Klebsiella pneumoniae* (1.2 × 10² CFU ml⁻¹); *Salmo-
PELLs spp (40 cells ml⁻¹); *Serratia* spp (1 × 10⁴ UFC ml⁻¹); *Shigella* spp (5 × 10⁴ CFU ml⁻¹); HAV (15 UFP ml⁻¹); *Giardia lamblia* (100 EPG).
–, Not evaluated.

Micro-organisms on toys

The presence of FC and most of the pathogenic bacteria was found on toys used at parks (Table 5), and less presence was observed on toys used at sidewalks. *Klebsiella pneumoniae* and *Serratia* spp was detected on 9% of samples (Table 5), while no *Staphylococcus aureus* was detected during this period.

Discussion

During the pilot study, children’s hands and toys showed the presence of faecal contamination during play. According to Capelli and Fontoura (2007), faecal contamination is used as a faecal indicator, and its presence suggests inadequate health care and hygienic conditions. The same results were observed in the control study where faecal coliforms were present on children’s hands after washing their hands with antibacterial soap, proving that the contamination at parks or sidewalks is acquired during play and the transfer of faecal contamination from soil to children’s hands and a toy and vice-versa is occurring. *E. coli* was predominant on hands and toys; thus, care must be taken as some strains can be highly pathogenic (Camacho et al. 2009). *Staph. aureus*, *Kl. pneumoniae* and *Serratia* spp on children’s hands in parks and on sidewalks was commonly found in the pilot and control study. However, their presence and concentration at each point was not statistically significant (*P > 0.05*) meaning an equal probability of contamination can occur at either site. This study showed that children had contact with soil and recreational equipment contaminated with faecal material in parks. The Food and Drugs Administration (FDA) (1992)
and Flores et al. (2007) have stated that pathogenic bacteria can be found in soil and on inanimate surfaces. The bacterial concentrations found in this study are similar to the infective doses of some of these pathogens. Kampf and Kramer (2004) found *Kl. pneumoniae* on a hospital worker’s hands at concentrations up to $1.0 \times 10^5$ CFU hands$^{-1}$, indicating that these numbers increase with time. Frequency and concentrations of bacteria found on toys showed inadequate cleaning processes that could lead to biofilm formation, which facilitates their survival on these surfaces (Lasa et al. 2005). Results show that toys are reservoirs of potentially pathogenic bacteria; therefore, toys must be washed and disinfected on a regular basis to prevent bacterial aggregation and dissemination. Jiménez et al. (2010) suggests that the use of ready-to-use chlorine-based disinfecting products can be considered an effective disinfectant for contact surfaces and toys.

In the pilot study, *G. lamblia* cysts were found on the hands of children who played at parks and sidewalks; while during the control study, the presence of the protozoan was found only on children playing at parks. Concentrations of *Giardia* cysts found in this study must be considered with caution as ingestion of at least 10 cysts could initiate giardiasis (Luján 2006). One possible source of *Giardia* cysts in recreational parks is dog faecal material. In Mexico, legislation fining dog owners for not picking up their pet’s residues is not yet established. Toledo et al. (1994) mentions that parks are considered risk areas for children as dogs are allowed to defecate without any control of waste disposal. These places designated for family recreation are also for animals and, according to this study, can result in contamination of children’s hands. Hepatitis A virus was detected in one sample of children’s hands who played in parks and one sample of children’s hands who played on sidewalks. This represents a risk of transmission among children playing because the HAV persists for several hours on hands (Kampf and Kramer 2004). It also represents a health risk because of the small infectious dose required to trigger an infection (Santamaría and Toranzos 2003). Recreational activities influence the contamination of children’s hands, thus it is recommended that hands be washed and disinfected with soap after play time to help reduce the presence of micro-organisms and to reduce the risk of infection. Also, as public recreation areas commonly lack adequate installations (bathrooms, sinks), the use of alcohol gels when visiting these places is recommended. Park staff, parents and children should have continuous communication with public health authorities, including educational sessions and immediate reporting of possible contamination.

This study demonstrates that children acquire microbial contamination while playing at public areas by means of contaminated soil and toys. Children are one of our most vulnerable subpopulations making them at particular risk of severe health consequences when exposed to pathogens. In addition, because of the faecal-oral route of transmission, the likelihood of exposure by children to these pathogens is increased due to the handling of the (potentially) microbial-laden toys within contaminated play areas, and the possibility of less than optimal hand washing.

The specific results of the microbial analyses from this study can inform risk assessments by providing the critical information necessary for comprehensive exposure.

### Table 6 Micro-organisms concentration on toys used at parks and sidewalks, during the pilot and main studies

<table>
<thead>
<tr>
<th>Micro-organisms</th>
<th>Parks (min-max)*CFU</th>
<th>Sidewalks (min-max)*CFU</th>
<th>Parks (min-max)*Cysts</th>
<th>Sidewalks (min-max)*Cysts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faecal coliforms</td>
<td>$1.3 \times 10^3$</td>
<td>$3.6 \times 10^4 - 1.8 \times 10^5$</td>
<td>$1.0 \times 10^2$</td>
<td>$3.0 \times 10^2$</td>
</tr>
<tr>
<td><em>Escherichia coli</em></td>
<td>$1.2 \times 10^7$</td>
<td>$1.0 \times 10^9$</td>
<td>$9.5 \times 10^6$</td>
<td>$2.4 \times 10^3$</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>$2.8 \times 10^8$</td>
<td>$2.0 \times 10^9$</td>
<td>$1.3 \times 10^8$</td>
<td>$8.6 \times 10^7$</td>
</tr>
<tr>
<td>Klebsiella</td>
<td>$7.1 \times 10^6$</td>
<td>$2.0 \times 10^9$</td>
<td>$2.0 \times 10^6$</td>
<td>$1.2 \times 10^5$</td>
</tr>
<tr>
<td><em>Streptococcus pyogenes</em></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>Giardia lamblia</em></td>
<td>33-33‡</td>
<td>0†</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Colonies forming units.
†Number of cysts on hands.
‡Six toys sampled at each site (park and sidewalk) for 5 weeks.
§Twenty-six toys sampled at parks and 11 toys sampled at sidewalks.
¶Minimum-maximum.
scenario building. This information can define exposure parameters related to different transmission routes for various recreational activities within different settings, and for a variety of pathogens that cause a range of health outcomes. Such risk assessments can then be conducted that will appropriately identify key exposure-related factors to target during the development of effective risk mitigation strategies.

Acknowledgements

The authors thanks Celida Martinez Rodriguez for her technical support.

Conflict of interest

No conflict of interest declared.

References


