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# Personal protective equipment, hygiene behaviours and occupational risk of illness after July 2011 flood in Copenhagen, Denmark

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## SUMMARY

Incidence of various diseases can increase following a flood. We aimed to identify professionals in Copenhagen who became ill after contact with 2 July 2011 floodwater/sediment and determine risks and protective factors associated with illness. We conducted a cohort study of employees engaged in post-flood management activities. Participants completed a questionnaire collecting information about demographics, floodwater/sediment exposure, compliance with standard precautions, and symptoms of illness. Overall, 257 professionals participated, with 56 (22%) cases. Risk of illness was associated with not washing hands after floodwater/sediment contact [relative risk (RR) 2·45], exposure to floodwater at work and home (RR 2·35), smoking (RR 1·92), direct contact with floodwater (RR 1·86), and eating/drinking when in contact with floodwater (RR 1·77). Professionals need to follow standard precautions when in contact with floodwater/sediment, especially proper hand hygiene after personal protective equipment use and before eating/drinking and smoking.

**Key words**: Epidemiology, gastrointestinal infections, hygiene – professional, hand hygiene, occupation-related infections.

## INTRODUCTION

Floods are the most common natural disasters worldwide [1]. A flood can be defined as water accumulation on an area of land that is not naturally submerged caused by rising water levels, structural failures, reduced natural drainage or, most typically, precipitation [2]. At about 19:00 hours on Saturday, 2 July 2011 a torrential downpour hit the Greater Copenhagen area. The most intense rainfall lasted about 2·5 h and measured 135·4 mm over the span of 24 h resulting in a flash flood [3]. In addition to rain, there was also hail and severe lightning. It has been estimated that somewhere between 500000 and >1 million persons were affected in various degrees by this flood, resulting in insurance claims amounting to 6·2 billion DKK (>€833 million) [4]. No deaths or serious injuries were reported during the time of the

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rainfall; however, five persons with leptospirosis were notified to Statens Serum Institut (SSI). Two of the cases were hospitalized and one case died [5]. There were also other accidents resulting from damaged traffic lights. Nine persons were reported to have been burned by scalding steam rising up through grids on the streets. Within 4 h, the fire department in Copenhagen received 410 telephone calls [4]. Overall, the clean-up lasted for at least a week; however, less urgent work lasted weeks and even months in some areas. In many areas, in addition to the rain water, rising sewage water was the main cause of this flooding.

Diseases most frequently associated with flooding include respiratory infections and gastroenteritis [1, 6, 7]. A German study found a fivefold increase in diarrhoea in persons with skin contact with floodwater, and a fourfold increase in diarrhoea for persons involved in flood clean-up [8], while a study in Southern England showed that living in a flooded house was significantly associated with a trend (by depth of floodwater) in developing gastroenteritis [9]. A rapid needs assessment conducted within 1 week of flooding in Texas, also demonstrated a fivefold increase in diarrhoea/stomach conditions and a sixfold increase in respiratory symptoms/colds associated with flooding [10].

One way to decrease the risk of becoming ill and to reduce the spread of these diseases is to follow standard precautions, especially the use of personal protective equipment (PPE) when in contact with floodwaters. The U.S. National Institute for Occupational Safety and Health (NIOSH) advises that workers should avoid direct skin contact with floodwaters through the use of appropriate PPE and clothing [11]. PPE includes but is not limited to watertight boots, work gloves, and goggles.

Use of PPE and appropriate hand hygiene are two standard precautions that are the minimum preventive practices applied to all situations where cross-contamination can occur [12]. In Denmark, Arbejdstilsynet (Danish Working Environment Authority) has published special guidelines for different professional workers (rescue workers, sewage workers, etc.) concerning appropriate protective clothing and equipment [13]. The Danish National Board of Health and National Center for Infection Control at SSI have also recently issued guidelines specifically concerning the topics of cleaning and disinfection, washing of contaminated clothes, hand hygiene, and use of PPE [14].

The purpose of this study was to identify professionals who became ill after coming into contact with the 2 July 2011 floodwater in Copenhagen and to assess their PPE use. We decided to examine the compliance with PPE recommendations of professionals involved in post-flood activities. The need for this study became apparent when we encountered difficulties in finding relevant studies about this topic. The study also attempted to identify risk and protective factors associated with either becoming or not becoming ill, including hand hygiene, cleaning and disinfection, and washing of clothes.

## METHODS

### Study design

We conducted a cohort study to test if contact with floodwater/sediment was associated with increased risk of becoming ill. The cohort consisted of individuals from 25 firms/organizations from various professions, all having contact with floodwater/sediment. The firms/organizations were identified as operating in Copenhagen using a directory of all local business listings. This cohort included insurance agents, cleaners, engineers, maintenance workers, garbage workers, pest controllers, fire and rescue workers, and police officers.

### Questionnaire

Data collected included demographic characteristics (age and gender), detailed floodwater/sediment exposure information (type of exposure, location of exposure, type of contact, hours of contact), PPE use (gloves, masks, goggles, rubber boots), other hygiene-related behaviour information (eating/drinking when in contact with floodwater/sediment, being a smoker, hand hygiene after contact with floodwater/sediment, bathing after contact with floodwater/sediment, treatment of work clothes after contact with floodwater/sediment, and treatment of boots after contact with floodwater/sediment), chronic health conditions, travel history and symptoms of illnesses.

Professional firms/organizations were contacted by an email sent to their human resources department describing the study's purpose and asking if they would to forward study details to their employees. The email stated that only employees physically involved in the aftermath of the flood on 2–9 July should participate. The email contained a link to an online version of the questionnaire. For firms/organizations whose employees were not able to complete the questionnaire online, a paper version was provided. The human resources contacts were asked to report back the total number of individuals who were forwarded the email or who were given a paper copy of the questionnaire to complete. This information was used to calculate the response rate.

A pilot study of the questionnaire was conducted from 29 July to 5 August 2011. The results were assessed and the questionnaire was edited based on the collected information. The final version of the questionnaire became available and was sent out to the 25 identified firm/organizations on 24 August. The deadline for reply was initially set at 7 September but was extended until 29 September to maximize the number of respondents.

### Case definition

For the purpose of this study, a case was defined as a worker in Copenhagen who experienced diarrhoea, vomiting, upper respiratory illness (common cold/sore throat), allergic reaction, fever, or two or more of the following symptoms: severe muscle ache, headache, abdominal pain, nausea, or rash between 2 and 25 July after contact with floodwater/sediment. Workers not present in Copenhagen between 2 and 9 July, during the main clean-up, were excluded from the study. Any persons travelling outside of Denmark up to 14 days before 2 July were also excluded to ensure that reported illness was not acquired while travelling. Finally, persons with a history of chronic illness with symptoms similar to those reported post-flood clean-up were not considered cases.

### Statistical analyses

All questionnaire data were entered into Defgo (Defgo.net, Denmark) and statistical analyses was conducted using Stata v. 10 (StataCorp, USA).

Descriptive characteristics, exposure characteristics, PPE practices, and other standard precautions of cases and non-cases were examined. The $\chi^2$ test was used to compare the differences in proportions of cases and non-cases for categorical variables, while the *t* test was used to assess the significance of the continuous variables.

Univariate analyses were performed to calculate relative risks (RRs) for the association between case status and each PPE used and standard precaution to examine the relationships between each exposure and illness. Wald $\chi^2$ statistic P values were used to compare proportions between cases and non-cases. Potential risk factors with $P$ values $\leqslant 0{\cdot}2$ were included in the binomial multivariate main-effects model and manually dropped until only those with a $P$ value $< 0{\cdot}05$ remained.

## RESULTS

There were 257 professionals who completed the questionnaire (56 cases and 201 non-cases), with a response rate of ~47%. No information is available about the professionals who chose not to participate. The symptoms most frequently reported by cases were diarrhoea (54%), cold/sore throat (45%), headache (44%), allergic reaction (runny nose, red eyes, difficulty breathing; 25%), abdominal pain (24%), nausea (20%), and severe muscle pains (19%). Symptoms lasted from 1 day to over a month and nine (16%) of the cases reported visiting a doctor because of their symptoms. Furthermore, four (7%) cases missed at least 1 day of work as a result of their symptoms and one (2%) person visited a hospital.

Table 1 shows the descriptive characteristics, exposure characteristics, PPE practices, and other standard precautions of the cases and non-cases. Overall, cases were significantly younger than non-cases, 41 *vs.* 44 years, respectively ($P = 0{\cdot}05$). Cases were more likely to have direct contact with floodwater (71% *vs.* 52%, $P = 0{\cdot}03$), to consume food or drink when in contact with the floodwater (59% *vs.* 40%, $P = 0{\cdot}02$), and to be smokers (34% *vs.* 17%, $P = 0{\cdot}02$). Cases also did not treat their work clothes the same way as non-cases, with more non-cases putting their clothes in the wash at the end of the day (75% *vs.* 59%), and more cases using the same clothes when in contact with floodwater/sediment the next day (41% *vs.* 25%, $P = 0{\cdot}05$).

There were no significant differences between the cases and non-cases in gender, type of exposure (private, work related, or both), location of exposure (outside, inside, or both), indirect contact with floodwater or sediment, direct contact with sediment, washing hands before eating or drinking, bathing actions after contact with floodwater, location of clothes washing, temperature of clothes washing, or whether clothes were washed together or separately from non-work clothes (Table 1). However, cases spent more hours exposed to floodwater, 30 h *vs.* 26 h for

Table 1. *Descriptive characteristics, exposure characteristics, personal protective equipment practices, and other standard precautions of cases and non-cases*

| Characteristics | Cases | Non-cases | *P* value |
|---|---|---|---|
| Total, *n* | 56 (22) | 201 (78) | |
| Age (years), mean | 41 | 44 | 0·05 |
| Gender, *n* | | | |
| Women | 8 (14) | 25 (12) | 0·66 |
| Men | 48 (86) | 176 (88) | |
| Type of exposure, *n* | | | |
| Private | 0 (0) | 3 (2) | 0·08 |
| Work related | 41 (82) | 145 (91) | |
| Both | 9 (18) | 12 (8) | |
| Location of exposure, *n* | | | |
| Outside | 17 (33) | 63 (40) | 0·46 |
| Inside | 8 (16) | 31 (20) | |
| Both | 26 (51) | 65 (41) | |
| Direct contact with water, *n* | | | |
| No | 15 (29) | 77 (48) | 0·03 |
| Yes | 36 (71) | 84 (52) | |
| Indirect contact with water, *n* | | | |
| No | 12 (24) | 36 (22) | 0·85 |
| Yes | 39 (76) | 125 (78) | |
| Direct contact with sediment, *n* | | | |
| No | 32 (63) | 112 (70) | 0·39 |
| Yes | 19 (37) | 49 (30) | |
| Indirect contact with sediment, *n* | | | |
| No | 14 (27) | 69 (43) | 0·07 |
| Yes | 37 (73) | 92 (57) | |
| Total hours exposed, mean | 30 | 26 | 0·34 |
| Food or drink when in contact, *n* | | | |
| No | 21 (41) | 94 (60) | 0·02 |
| Yes | 30 (59) | 63 (40) | |
| Washed hands before food or drink, *n* | | | |
| Always | 17 (57) | 23 (37) | 0·18 |
| Sometimes | 10 (33) | 27 (43) | |
| Never | 3 (10) | 13 (21) | |
| Being a smoker, *n* | | | |
| No | 33 (66) | 131 (83) | 0·02 |
| Yes | 17 (34) | 27 (17) | |
| Hand hygiene after contact, *n* | | | |
| Nothing right away | 33 (64) | 70 (44) | 0·09 |
| Soap and water | 8 (16) | 39 (25) | |
| Water | 0 (0) | 4 (3) | |
| Sanitizer | 8 (16) | 26 (16) | |
| Soap, water and sanitizer | 2 (4) | 19 (12) | |
| Bathing actions after contact, *n* | | | |
| Bathing right away | 6 (12) | 31 (20) | 0·42 |
| Bathing at end of day | 34 (68) | 92 (59) | |
| Bathing next day or later | 10 (20) | 33 (21) | |
| What was done with clothes, *n* | | | |
| Went to the wash | 30 (59) | 117 (75) | 0·05 |
| Used the same clothes next day | 21 (41) | 38 (24) | |
| Discarded clothes | 0 (0) | 2 (1) | |

Table 1 (*cont.*)

| Characteristics | Cases | Non-cases | *P* value |
|---|---|---|---|
| Location of clothes washing, *n* | | | |
| Workplace | 15 (29) | 53 (34) | 0·61 |
| Home | 36 (71) | 102 (66) | |
| Temperature of wash at home, *n* | | | |
| <80 °C | 34 (94) | 97 (95) | 1·00 |
| ⩾80 °C | 2 (6) | 5 (5) | |
| How were clothes washed at home, *n* | | | |
| Together with other clothes | 20 (56) | 56 (54) | 1·00 |
| Separately | 16 (44) | 47 (46) | |
| Gloves used, *n* | | | |
| No | 26 (51) | 100 (64) | 0·14 |
| Yes | 25 (49) | 57 (36) | |
| Wash hand after glove use, *n* | | | |
| No | 10 (40) | 14 (25) | 0·19 |
| Yes | 15 (60) | 43 (75) | |
| Mask used, *n* | | | |
| No | 51 (100) | 153 (97) | 0·34 |
| Yes | 0 (0) | 5 (3) | |
| Goggles used, *n* | | | |
| No | 51 (100) | 148 (95) | 0·20 |
| Yes | 0 (0) | 8 (5) | |
| Rubber boots or waders used, *n* | | | |
| No | 32 (63) | 81 (52) | 0·20 |
| Yes | 19 (37) | 76 (48) | |
| How were boots treated after use, *n* | | | |
| Washed them | 4 (21) | 37 (50) | 0·09 |
| Disinfected them | 4 (21) | 10 (14) | |
| Threw them out | 0 (0) | 1 (1) | |
| Did nothing | 11 (58) | 26 (35) | |

Values given are *n* (%).

non-cases ($P = 0{\cdot}34$). Additionally, cases were more likely to perform no hand hygiene after contact with floodwater compared to non-cases (64% *vs.* 44%, respectively, $P < 0{\cdot}01$).

In terms of PPE use, there were no significant differences between cases and non-cases (Table 1). Cases were less likely to wash their hands after using gloves (60% *vs.* 75%, respectively, $P = 0{\cdot}19$), to wear rubber boots or waders (37% *vs.* 48%, respectively, $P = 0{\cdot}20$), and were more likely not to clean their rubber boots after use (58% *vs.* 35%, respectively, $P = 0{\cdot}13$).

Table 2 compares exposure characteristics, PPE use and hand hygiene practices between cases and non-cases. Risk of becoming ill was associated with not washing hands after contact with floodwater or sediment (RR 2·45, 95% CI 1·53–3·94), being exposed to floodwater both at work and home (RR 2·35, 95% CI 1·35–4·11), as well as being in direct contact with floodwater (RR 1·86, 95% CI 1·09–3·19). Being a smoker (RR 1·92, 95% CI 1·19–3·11) along with eating or drinking when in contact with floodwater (RR 1·77, 95% CI 1·09–2·87), were followed by an increased risk of becoming ill. In terms of PPE, an increased risk of becoming ill was also observed for those using gloves (RR 1·48, 95% CI 0·92–2·37) and those not performing any hygienic measures on their rubber boots after use (RR 1·60, 95% CI 0·91–2·80). A decreased risk of illness was observed for those washing hands after glove use (RR 0·62, 95% CI 0·33–1·18) and those using rubber boots or waders (RR 0·71, 95% CI 0·43–1·16).

Table 3 shows the multivariate model used to assess which exposure characteristics or PPE practices were associated with becoming ill. In the final model, there were two behaviours significantly associated with becoming ill, not washing hands after being in contact

Table 2. *Univariate analyses comparing exposure characteristics and personal protective equipment practices between cases and non-cases**

| Risk factors† | RR (95% CI) | *P* value |
|---|---|---|
| No hand washing after contact with water or sediment | 2·45 (1·53–3·94) | < 0·01 |
| Floodwater exposure at work and home (*vs.* work only) | 2·35 (1·35–4·11) | 0·01 |
| Being a smoker | 1·92 (1·19–3·11) | 0·01 |
| Direct contact with floodwater | 1·86 (1·09–3·19) | 0·02 |
| Food or drink when in contact with water or sediment | 1·77 (1·09–2·87) | 0·02 |
| Indirect contact with sediment | 1·72 (0·99–2·98) | 0·06 |
| No rubber boot cleaning or disinfection after use | 1·60 (0·91–2·80) | 0·12 |
| Glove use | 1·48 (0·92–2·37) | 0·11 |
| Floodwater exposure at work | 1·37 (0·80–2·34) | 0·25 |
| Direct contact with sediment | 1·27 (0·78–2·06) | 0·35 |
| Washing work clothes at home (*vs.* work) | 1·18 (0·70–2·00) | 0·53 |
| Clothes washed at temperature ⩾80 °C | 1·10 (0·33–3·68) | 0·88 |
| Clothes put in wash after use | 1·04 (0·65–1·66) | 0·88 |
| Indirect contact with floodwater | 0·97 (0·55–1·70) | 0·92 |
| Work clothes washed separately | 0·97 (0·55–1·70) | 0·90 |
| Never wash hands before eating or drinking | 0·93 (0·33–2·65) | 0·89 |
| Rubber boots or waders used | 0·71 (0·43–1·16) | 0·17 |
| Bathing right away after contact (*vs.* later) | 0·62 (0·29–1·35) | 0·21 |
| Wash hands after glove use | 0·62 (0·33–1·18) | 0·16 |

RR, Relative risk; CI, confidence interval.

* Goggles use, mask use, private exposure only and boots discarded, had no cases and are not included in the table.

† Ordered by descending strength of association.

Table 3. *Multivariate binomial regression main-effects model**

| | RR (95% CI) | *P* value |
|---|---|---|
| No hand washing after contact | 1·80 (1·08–2·99) | 0·03 |
| Being a smoker | 1·81 (1·13–2·91) | 0·01 |

RR, Relative risk; CI, confidence interval.

* Including age and gender in the model does not change the magnitude of the association or the significance appreciably.

with floodwater (RR 1·80, 95% CI 1·08–2·99) and being a smoker (RR 1·81, 95% CI 1·13–2·91).

## DISCUSSION

In our study, a high proportion of workers, 22%, who participated in the clean-up of the flood, became ill. We were able to demonstrate an increased risk of professionals becoming ill following not washing their hands after contact with floodwater and being a smoker, which remained significant even when adjusted for each other. This finding underlines the importance of proper hand hygiene regardless of whether PPE is used or not. The results of this study also stress the importance of washing hands before eating, drinking and smoking. NIOSH specifically advises workers to wash their hands with soap and water, unless unavailable, in which case alcohol-based sanitizers can be used, especially before eating and drinking [11].

Overall, fewer than 50% of professionals wore gloves and fewer than 40% wore rubber boots when in contact with floodwater. Furthermore, almost none of the workers wore a mask or goggles to protect themselves against splashes in the eyes, nose or mouth. Although not significant, the study was able to show that persons who became ill spent more time exposed to floodwater/sediment compared to those who did not become ill. The study found that although cases were more likely to use gloves than non-cases, they were less likely to wash their hands after using gloves. Most likely, individuals wearing gloves experienced a false sense of security and did not think it necessary to wash their hands or they did not have access to water for hand hygiene purposes. Washing hands after glove use is crucial because hands can become contaminated through the process of glove removal [15] or because latex gloves may develop holes or tears (not visible to the naked eye), creating an optimal environment for bacteria to rapidly multiply on gloved hands because of the moist and warm environment [16]. Cases were also less likely to wear rubber boots or waders then non-cases, and were more likely to not clean their rubber boots after use. This means cases may have contaminated their hands when putting on their rubber boots. Finally, more non-cases put their work clothes in the wash at the end of the day, while more cases used the same work clothes the next day. The Centers for Disease Control and Prevention recommends that all clothes worn during flood clean-up need to be washed in hot water and detergent, separately from uncontaminated clothes and linens [17]. These results underline the need to reinforce correct hand hygiene after PPE use, along with proper cleaning and laundry procedures.

Very few of the participants visited a doctor as a result of their symptoms. This probably means that they experienced illness not severe enough to warrant a visit; consequently, we were not able to obtain medical diagnoses of the illnesses. Furthermore, only two of the 10 cases who visited a doctor had biological samples taken, which limited the number of laboratory-confirmed diagnoses available. In reality, we were not able to trace back any of the laboratory results either because we were not given consent by the participant or because no results were recorded in the laboratory database.

A limitation of the study is that no information is available for non-respondents, therefore we do not have any demographic or exposure characteristics that can be compared with the participants. Another limitation concerns the response rate and its calculation. We conservatively approximated a response rate of $<50\%$. However, because we were unable to directly contact the participants ourselves, we are uncertain as to how many actually received the questionnaire. It is possible that the human resource departments did not forward our study information to email accounts which the participants actively use, making participation unfeasible. This situation would inflate the denominator, making the response rate appear lower than it actually is.

Assuming our conservative estimate of the response rate is correct, this suggests that the sample may be a reasonable representation of professionals working in post-flood conditions in Copenhagen. However, it may well be that workers who became ill after contact with floodwater/sediment were more likely to respond to the questionnaire thus limiting the generalizability of the incidence. Conversely, it is also possible that workers who did not use PPE as recommended, and were thus more likely to become ill, were also less likely to answer the questionnaire.

Two of the main strengths of the study are the exclusion criteria used and collection of information about participants' chronic disease status. This study was very specific in preventing the inclusion of ill persons who were either infected while travelling abroad or who were experiencing symptoms similar to those of the chronic disease they had.

To our knowledge this is the first study in Denmark relating illness with flooding, PPE use and other hygiene measures among professionals. This is noteworthy because the information collected can be used as a baseline for future studies examining professionals' response to flooding situations. Furthermore, this study demonstrates the need for professional firms/organizations to stress PPE use to their employees when in contact with floodwater/sediment left by the floodwater. Proper hand hygiene before eating/drinking and smoking, whether or not PPE has been used, also needs to be reinforced.

Although pathogens causing gastrointestinal and respiratory illness may often be diluted to non-infectious levels by rainwater, the present study indicates that in other situations, the risk of illness should not be ignored. This is particularly the case when a large share of the water stems from rising sewage effluent. It is important to consider episodes of extreme weather as natural experiments for obtaining evidence in order to inform public health on how to mitigate the health impact.

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## DECLARATION OF INTEREST

None.

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