

The impact of airborne dust on respiratory health in children living in the Aral Sea region[†]

Polly Bennion,¹ Richard Hubbard,^{1*} Sarah O'Hara,² Giles Wiggs,³ Johannah Wegerdt,¹ Sarah Lewis,⁴ Ian Small,⁵ Joost van der Meer⁶ and Ross Upshur⁷ on behalf of the Médecins san Frontières/Aral Sea Respiratory Dust and Disease project team

Accepted 17 July 2007

Background Anecdotally, people living in the Aral Sea region report an increase in the prevalence of respiratory illnesses, particularly in children, and there is widespread belief that this is due to dust from the Aral Sea bed.

Methods We conducted a survey of respiratory symptoms and lung function in children aged 7–10 years living in 18 communities in 6 geographical regions in the Aral Sea area. We monitored dust deposition rates monthly for the duration of the study.

Results The overall prevalence of recent wheeze was low at 4.2%, but this figure varied with region and was higher in the more accessible urban and delta regions and lower in the more remote regions. We found no evidence of an association between local annual dust deposition and specific respiratory symptoms. Lung function results also showed variation between geographical regions not explained by annual dust deposition. After allowing for region of residence, however, there was some evidence of an inverse association between percentage predicted forced expiratory volume in 1 s (FEV1) and dust exposure during the summer months (change in percentage predicted FEV1 per 1000 kg/ha annual dust deposition -1.465) (95% confidence interval -2.519 to -0.412); however, in winter, the reverse was true.

Conclusions The prevalence of asthma is low in the Aral Sea area and appears to be unrelated to dust exposure. Exposure to dust did not explain the main variations in lung function between geographical regions but high levels of dust exposure during the summer may have an adverse effect on lung function.

Keywords Aral Sea, dust, lung function, asthma

Introduction

The massive decline of the Aral Sea represents one of the worst examples of human mismanagement of the environment. Since the 1960s, the rivers feeding the Aral Sea have been over-exploited for irrigation and the sea has lost 80% of its volume and now covers only a third of its former area (Figure 1).^{1,2} This has created a new dust source and a marked increase in local dust storm activity.³ Karakalpakstan is located to the south of the Aral Sea, and since the prevailing winds in the region come from the northeast and northwest, the people living in this region are those most exposed to ecological disaster. We have recently demonstrated that the airborne dust deposition rates in eastern Turkmenistan, an area which borders Karakalpakstan, are amongst the highest in the world.⁴

¹ Division of Epidemiology and Public Health, University of Nottingham, Nottingham, UK.

² Division of Geography, University of Nottingham, Nottingham, UK.

³ Division of Geography, University of Sheffield, Sheffield, UK.

⁴ Division of Respiratory Medicine, University of Nottingham, Nottingham, UK.

⁵ Oxfam, East Asia.

⁶ Médecins san Frontières, Holland.

⁷ McMaster Institute of Environment and Health, McMaster University, Hamilton, Canada.

[†] Work attributed to: Division of Epidemiology and Public Health, Nottingham University.

* Corresponding author. Clinical Sciences Building, City Hospital, Hucknall Road, Nottingham NG5 1PB, UK.
E-mail: richard.hubbard@nottingham.ac.uk

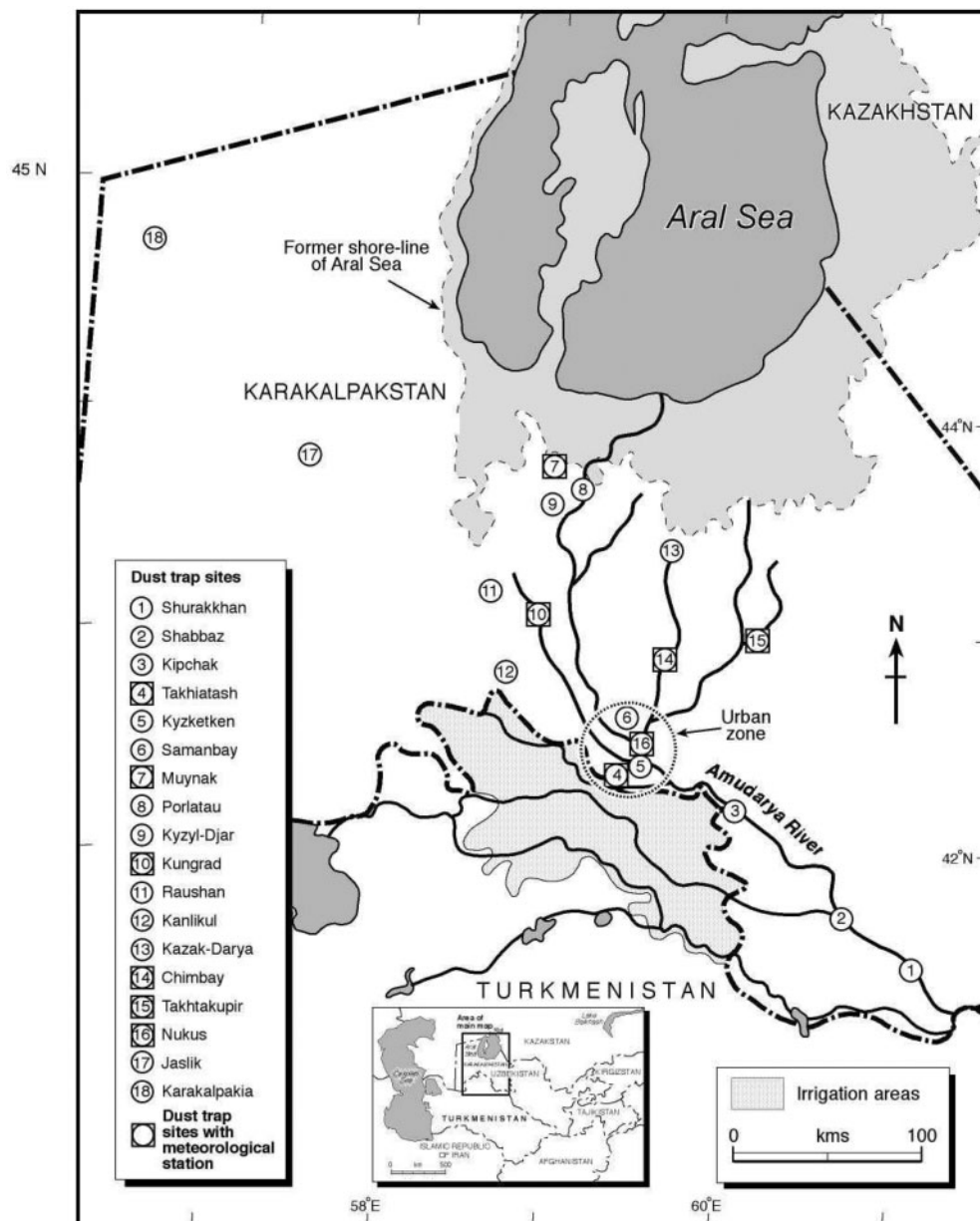


Figure 1 Map of study area

A recent survey in Karakalpakstan has revealed that 'self-rated health' is poor, with many people citing the ecological disaster as the main causal factor.⁵ Other studies in the Aral Sea region have revealed a high prevalence of multidrug-resistant tuberculosis, anaemia and renal tube dysfunction.⁶⁻⁸ At present there have been no studies of the impact of airborne dust on respiratory health in the Aral Sea area.

In the last few years a number of projects aimed at reducing levels of airborne dust and dust storm activity in the region have been proposed, including a costly project designed to increase the vegetation in large parts of the exposed sea bed. In order to provide more definitive data on the impact of dust levels on the prevalence of respiratory symptoms and the levels of lung function in this region, we have performed a cross-sectional survey of children aged 7-11 years living in

Karakalpakstan and analysed these data in conjunction with local dust deposition data. Our main hypotheses were that the prevalence of respiratory symptoms and/or the levels of lung function would vary according to the amount of annual dust exposure.

Methods

Study population

We collected data on respiratory health in children and dust deposition rates at 18 sites in 6 distinct geographical regions in Karakalpakstan (Figure 1). The sites were selected independent of any knowledge of local childhood health. We used a combination of local government population lists and school



Figure 2 Dust trap

registries to generate a sampling frame of all children aged between 7 and 11 years living in each region. Our information from local researchers suggested that using this system would capture the vast majority of children living in the area. We used simple random sampling to select a study population of ~100 children living within a 5 km radius of the dust collection site.

Collection of health data

A research assistant visited each household during the summer months (June, July and August, 2000) and, after obtaining signed informed consent from the child's guardian, collected data on respiratory health and environmental exposures using a questionnaire based on the international study of asthma and allergy in childhood (ISAAC) study questionnaire.⁹ In addition we included questions from a pneumonia surveillance questionnaire developed in Peru.¹⁰ The translation of the questionnaire into Karakalpak was checked by appropriate back translation. We collected anthropometric data and information on lung function using a portable spirometer (Ferraris OneFlow). The accuracy of the spirometers (two were used) was checked and confirmed before, at the mid-point, and after the study using calibrated syringes in the Nottingham City Hospital Lung Function Laboratory. Children performed at least three measurements and the best reading was selected for analysis. Lung function and anthropometric measurements were repeated during the autumn/winter months (October, November and December). The centres Jaslik and Karakalpakia were recruited into the study at a later point because of practical difficulties, and so questionnaire data were collected during the winter months and no summer lung function data were available.

Collection of dust data

Monthly dust deposition rates were measured during the period June 2000–May 2001 using our established methods.⁴ Briefly this involved setting our dust traps, which were made of discs of Astroturf protected with coarse netting, at a height of 2 m above the ground level in open ground away from buildings, trees and roads (Figure 2). The Astroturf dust trap was renewed monthly, and used dust traps were labelled and returned to Nottingham for the analysis of the total dust

deposition rates (kg/ha) and the distribution of grain size, using a CILAS laser granulometer (Model 940). Our main exposure variable was the total annual dust deposition rate, hereafter referred to as the annual dust deposition, but we also calculated the annual deposition rates for dust particles of PM₁₀ size and below and PM_{2.5} size and below, and calculated the dust deposition rates for the summer (June, July and August) and winter (December, January and February) months.

Statistical analysis

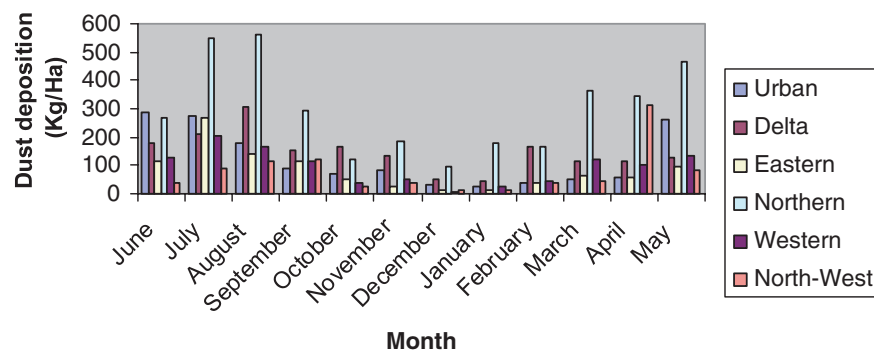
All analyses were performed using STATA version 7 and likelihood ratio tests were used for all hypothesis tests. Initially we examined the prevalence of symptoms of asthma (wheeze in the last 12 months) and allergic rhinitis and also the prevalence of self-reported pneumonia during the previous 12 months in each of the 6 geographical regions. We then used logistic regression to compare the prevalence of these outcomes between regions and by measures of annual dust deposition (total annual dust deposition, annual PM₁₀ and PM_{2.5} deposition, dust deposition during the summer and winter months). We examined the impact of a number of potential confounders including parental age, parental history of allergic disease, household income, parental occupation, parental smoking history, parental history of tuberculosis, animal ownership, cooking and heating methods, household size, birth order and housing material by initially establishing whether these variables were associated with any of the outcomes. We retained any variables that were associated with the outcomes with a $p \leq 0.1$ in a multivariate model containing annual dust deposition and respiratory symptom, together with our a priori confounders—age, gender and ethnic group.

For our lung function data, we initially calculated the mean percentage predicted forced expiratory volume in 1 s (FEV₁) for each child during the summer and the winter, using a linear regression model that included age, gender, height, weight and ethnic group to predict FEV₁ values. We then used linear regression to compare the association between lung function and both geographical region and our dust deposition variables. Using a similar modelling strategy to that outlined above, we examined the impact of a number of potential confounders including parental age, parental history of allergic disease, household income, parental occupation, parental smoking history, parental history of tuberculosis, animal ownership, cooking and heating methods, household size, birth order and housing material by initially establishing whether these variables were associated with the percentage predicted FEV₁. We retained any variables that were associated with percentage predicted FEV₁ with $P \leq 0.1$ in a multivariate model that included percentage predicted FEV₁ and annual dust deposition.

Our aim for this study was to collect data for ~1000 children. Power calculations were difficult because of the lack of any baseline data in this area, but in our study planning we assumed that ~20% of the children would have at least one respiratory symptom and that exposure rate to high levels of dust exposure would be present in about 20% of the non-symptomatic children. This means that a sample size of ~1000 provides in excess of 90% power to detect an odds ratio of 2.0 or greater. In the event, our subject recruitment was more

Table 1 Descriptive analysis of the communities sampled

	Urban	Delta	Eastern	Northern	Western	Northwest
Communities sampled	Kyzketken, Nukus Samanbay and Takhiatash	Kipchak, Shabbaz and Shurakhan	Chimbay and Takhtakupir	Kazakhhdarya, Kyzil-Jar, Muynak and Porlata	Kanlikul, Kungrad and Raushan	Karakalpakia and Zhaslik
Number (response rate)	370 (90%)	241 (95%)	162 (90%)	317 (96%)	259 (94%)	150 (89%)
Mean age	8.5	8.4	8.7	8.6	8.8	8.9
Number of boys	165 (45%)	125 (52%)	78 (48%)	162 (51%)	140 (54%)	92 (61%)
Wheeze in the last year	19 (5.1%)	15 (6.2%)	6 (3.7%)	12 (3.8%)	11 (4.3%)	0
Wheeze ever	57 (15.4%)	38 (15.8%)	21 (13%)	47 (14.8%)	41 (15.8%)	14 (9.3%)
Hay fever	40 (10.9%)	19 (7.9%)	8 (5.0%)	16 (5.1%)	13 (5.0%)	5 (3.4%)
Pneumonia	22 (6.0%)	16 (6.7%)	3 (1.9%)	3 (1.0%)	10 (3.9%)	2 (1.4%)
Total annual dust deposition (kg/ha)	1471	1784	995	3513	1131	934
Total annual PM10 deposition (Kg/ha)	744	751	500	1397	597	746
Total Annual PM2.5 deposition (kg/ha)	268	280	180	525	231	300
Mean summer FEV1 in litres (mean percentage predicted)	1.49 (101)	1.49 (100)	1.49 (99)	1.51 (101)	1.51 (100)	No data
Mean winter FEV1 in litres (mean percentage predicted)	1.72 (102)	1.67 (99)	1.64 (97)	1.67 (101)	1.65 (97)	1.68 (98)

**Figure 3** Monthly dust deposition rates by geographical region

efficient than we expected and so we extended our sample size to 1500.

Ethical considerations

The detailed protocol for this study was reviewed and approved by the Karakalpak Ministry of Health, the local science community (Academy of Science) and the University of Nottingham's Ethical Review Committee.

Results

Basic demography

Our sampling frame included 1615 children from whom we obtained questionnaire data for 1499 (93%). The commonest

reason for non-response was because the child's address could not be found and 16 families refused to take part in the study. Overall the mean age of the children was 8.6 years, 762 (51%) were boys, 599 (40%) were Karakalpak, 572 (38%) were Uzbek, 301 (20%) were Kazakh and 17 come from a different ethnic group (Table 1).

Dust deposition

The median annual dust deposition for the 18 communities over the 12-month study period between June 1, 2001 and May 31, 2002 was 1392 kg/ha (Interquartile range 990–2479 kg/ha). In general, monthly dust deposition levels were at their highest during the summer months and lowest during the winter months (Figure 3). There was considerable heterogeneity between the sites in the annual dust deposition, for example,

as expected, the sites in the northern region, closest to the original shoreline, had the highest levels of annual dust deposition whilst those sites in the northwest and eastern regions tended to have the lowest annual dust deposition rates. There was little variation in the relative contribution of the PM₁₀ fraction (median proportion 0.50, IQR 0.44–0.57) and PM_{2.5} fraction (median proportion 0.19, IQR 0.16–0.21) to the total annual dust deposition rates; and for this reason, our analysis has focused on annual dust deposition.

Symptom data

The overall prevalences of wheeze, allergic rhinitis and pneumonia in the last year were 4.2%, 6.8% and 3.8%, respectively. There was a evidence of variation in the prevalence of symptoms by geographical area (Table 1) such that the prevalence of wheeze in the last year was the highest in the delta region, followed by the urban region, whilst none of the 150 children studied in the northwest region reported recent wheeze. Amongst the potential confounders, increasing age reduced the risk of recent wheeze, whilst a history of parental allergy increased the risk. However in our multivariate model, the adjusted odds ratios were similar to those from the univariate analyses. The prevalence of symptoms of allergic rhinitis was lower in all regions in comparison to the urban region, particularly in the northwest. A history of parental allergy increased the risk of rhinitis. Again the adjusted odds ratios were similar to the univariate ones. The prevalence of pneumonia was again the highest in the urban region closely followed by the delta. The risk of pneumonia was increased in children whose parents reported allergy. In the multivariate analyses, children living in the eastern and northwest regions had a lower level of pneumonia. We found no evidence of an association between levels of dust exposure and any of these symptoms either before or after adjusting for the effects of geographical region (Table 2).

Lung function results

During the summer, we were able to collect lung function data on 1117 children, given that we did not include children in the northwest during the initial part of the study; this gave a response rate of 83%. The figure for the winter was 1229 (82% response rate). The mean percent predicted FEV₁ values did not differ greatly between the geographical regions, but were marginally higher in the northern and urban regions. We found no evidence of an association between annual dust deposition and summer percent predicted FEV₁ in our univariate analyses (Table 3), but after allowing for geographical region and our a priori confounders, there was some evidence of an inverse relationship between level of annual dust deposition and percent predicted FEV₁. Similarly in our multivariate analysis, there was some evidence of heterogeneity with children in the northern region having the best lung function, followed by those living in the urban region. The results for the winter lung function were strikingly different. Here there was evidence of a positive association between annual dust exposure and lung function, and the best overall lung function was present in the urban region.

Table 2 Relation between the presence of symptoms and the geographical area and the annual dust deposition

	Univariate odds ratio	95% CI	Multivariate odds ratio ^a	95% CI
Wheeze in the last year				
Region				
Urban	1.00	–	1	–
Delta	1.23	0.77–2.19	1.50	0.63–3.60
Eastern	0.71	0.49–1.15	0.75	0.28–2.02
Northern	0.73	0.50–1.12	0.67	0.20–2.26
Western	0.82	0.50–1.95	0.75	0.33–1.74
Northwest	–	–	–	–
Annual dust deposition (per 1000 kg/ha)	1.04	0.86–1.25	1.04	0.72–1.51
Rhinitis				
Region				
Urban	1	–	1	–
Delta	0.70	0.40–1.24	0.61	0.31–1.19
Eastern	0.43	0.20–0.94	0.49	0.22–1.11
Northern	0.44	0.24–0.79	0.35	0.14–0.88
Western	0.43	0.23–0.83	0.51	0.26–0.99
Northwest	0.28	0.11–0.74	0.45	0.16–1.28
Annual dust deposition (per 1000 kg/ha)	0.96	0.82–1.12	1.11	0.84–1.47
Pneumonia				
Region				
Urban	1	–	1	–
Delta	1.12	0.58–2.18	0.97	0.44–2.12
Eastern	0.30	0.09–1.01	0.34	0.10–1.20
Northern	0.15	0.04–0.50	0.10	0.02–0.50
Western	0.63	0.29–1.36	0.68	0.34–1.51
Northwest	0.21	0.05–0.93	0.26	0.10–1.28
Annual dust deposition (per 1000 kg/ha)	0.83	0.65–1.05	1.16	0.79–1.69

^avariables in multivariate model: age, gender, ethnic group, annual dust deposition, geographical region, parental history of allergy.

Discussion

In this large and detailed survey of respiratory health, children living in the Aral Sea area had a low prevalence of symptoms of asthma and allergic rhinitis in comparison to northern Europe, North America and Australasia.⁹ There was evidence of heterogeneity within the Aral Sea area, however, with a higher prevalence of both asthma and allergic rhinitis in the more accessible central urban area and delta area and a lower prevalence in the more remote eastern, western regions and northwest regions. We found no evidence to suggest that dust exposure was an important determinant of either symptom. Children living in the northern region, i.e. those living closest to the Aral Sea, generally had the best lung function results, despite having the highest levels of exposure to dust, whilst the lung function measurements were the lowest in the more

Table 3 Relation of summer and winter percentage predicted FEV1 to annual dust deposition and geographical region

	Coefficient ^a univariate analysis	95% CI	Coefficient ^b multivariate analysis	95% CI
Summer FEV1 (percentage predicted)				
Annual dust deposition (per 1000 kg/ha)	-0.278	-0.854 to 0.297	-1.465	-2.519 to -0.412
Urban	Reference	-3.633 to 0.825	-1.019	-3.259 to 1.221
Delta	-1.404	-4.492 to 0.692	-2.657	-5.298 to -0.016
Eastern	-1.900	-2.597 to 1.726	3.254	-0.164 to 6.672
Northern	-0.435	-3.476 to 1.162	-1.511	-3.837 to 0.815
Western	-1.157		No data	
Northwest	No data			
Winter FEV1 (percentage predicted)				
Annual dust deposition (per 1000 kg/ha)	1.196	0.550-1.841	2.021	0.745-3.297
Urban	Reference		Reference	
Delta	-3.058	-5.894 to -0.221	-3.244	-6.073 to -0.415
Eastern	-4.462	-7.678 to -1.247	-3.061	-6.386 to 0.263
Northern	-0.972	-3.653 to 1.709	-5.674	-9.669 to -1.679
Western	-4.423	-7.174 to -1.672	-3.558	-6.353 to -0.763
Northwest	-3.372	-6.532 to -0.213	-1.798	-5.100 to 1.504

^aunivariate analysis: coefficient is for change in percentage predicted FEV1.

^bmultivariate analysis: variables in models are percentage predicted FEV1, annual dust deposition and geographical region.

remote eastern and western regions. These regional differences in lung function did not appear to be due to dust exposure, but after allowing for the region of residence, there was some evidence to suggest an inverse association between dust exposure and summer FEV1. The results for winter lung function, when dust levels were universally low, showed that if anything those areas with the highest levels of dust exposure had the best lung function.

We choose the ISAAC questionnaire for our study, because this questionnaire has been used in a number of different cultural and language settings and its validity has consistently been found to be high.⁹ The questions designed to detect pneumonia come from a questionnaire designed by Lanata and coworkers to detect pneumonia in a longitudinal sample in which families were being surveyed on a repeated basis every 3 months.¹⁰ In this setting the validity of the questionnaire was good, but given the more limited experience with this questionnaire, we cannot be certain that the same is true in our population. Furthermore, we found evidence of a strong correlation between our pneumonia variable and our asthma and allergic rhinitis variables, and thus it is possible that our pneumonia variable is merely acting as another proxy marker for asthma or *vice versa*. Our study was cross-sectional in design and so we are not able to test associations separately for children with transient or persistent wheeze, and we did not collect data on skin prick tests and thus we are unable to determine the impact of dust exposure on allergic and non-allergic wheezing illness. Our method of measuring dust deposition was simple and cheap and designed for multiple-site

data collection and has been validated in the previous studies in Central Asia.⁴

The finding of a low prevalence of asthma and allergic rhinitis in this area is consistent with the findings of the ISAAC study that included two centres in Uzbekistan (Tashkent and Samarkand), neither of which is located in the Aral Sea region. This low prevalence is similar to the levels currently observed in Africa.^{11,12} It is of interest that the prevalence of asthma appears to vary within this defined geographical region and appears to be higher in the more accessible central urban and delta regions and lower in the other more remote regions. These data are again similar to the data from Africa, which consistently show that as asthma emerges for the first time as a clinical problem in a country, it tends to appear in urban communities before rural ones.¹¹ The reason why the prevalence of asthma and allergic disease may increase with increasing 'urbanization' is unclear, although there are data that suggest that a decrease in the prevalence and severity of parasite infection with more urban living is an important risk factor for allergic disease.¹³

We found no evidence for an impact of annual dust deposition levels on symptoms of asthma, and our data suggest that it is unlikely that dust is the major cause for respiratory symptoms in this region. We did not specifically look at the incidence of viral respiratory illness and so we cannot exclude an important impact of dust on these illnesses. But a more plausible explanation for local concerns about the emergence of respiratory symptoms is that an asthma epidemic is now starting in this region and that the area is about to undergo the

change from a low prevalence of asthma to a high prevalence of asthma, witnessed in the UK in the 1960s and currently ongoing in Africa.^{11,14} Longitudinal cohort studies are therefore needed to follow the prevalence of disease in this region carefully. In addition we found no evidence to suggest a relation between annual dust deposition and reported episodes of pneumonia, although as mentioned above, this may reflect the lack of validity of our pneumonia measure.

During the winter months, when the levels of dust deposition were universally low, we found evidence of heterogeneity in the children's lung function in this region, such that lung function appear to be the highest in children living in the urban and northern regions. Furthermore, during the winter, we found that children living in areas with the highest annual levels of dust deposition had the best lung function. The reasons for these findings are not clear, but it seems unlikely to us that this reflects a latent beneficial effect of higher levels of summer dust exposure and more likely that other environmental exposures have an important impact on lung function in this region. One such factor may be socio-economic status, since nutrition both in utero and early in life has an important impact on lung function, and historically communities in the urban and northern regions have been more affluent than other regions, in part because of the influence of the fishing industry. We did attempt to allow for socio-economic status in our analyses and could not demonstrate evidence of confounding, but it is possible that our simple measures of income and educational attainment are not appropriate in post-Soviet countries. Interestingly, the differences in winter lung function between regions are similar to those reported in an earlier survey of self-reported health in the region.⁵

During the summer months, when dust deposition levels were high, there was less evidence of an association between geographical region and lung function. Furthermore, the association between annual dust deposition and summer lung function was in the opposite direction to the winter results, raising the possibility that when dust levels are high, they may have an adverse impact on lung function.

Another study has collected data on respiratory symptoms and lung function in the Aral Sea region—though this study was in Kazakhstan, to the north of the Aral Sea, and only included two geographical regions.¹⁵ Although no dust measurements were made, the researchers collected data on symptoms and lung function on 383 children living within 200 km of the Aral Sea (high-risk region) and an age and sex match control group living some 500 km away from the Aral Sea. In keeping with our findings, the prevalence of recent wheeze was low in both population, but was higher in the children living nearer to the Aral Sea (6% vs 3%). The prevalence of ever wheezing and frequency of wheezing was similar between the two groups. There was also evidence of marginally lower lung function in children living closer to the Aral Sea.

In summary, children living in the Aral Sea area are at low risk of symptoms of asthma and allergic rhinitis, and these risks are the lowest in the more remote areas. The reasons for our findings are not clear, but the situation needs monitoring

carefully as it shows a number of parallels with the emergence of asthma as a clinical problem in Africa. We found no evidence that symptoms of asthma were related to dust exposure. There are notable variations in lung function between the geographical regions in the Aral Sea area, but in the main, these do not appear to be due to dust exposure. After allowing for region of residence, there was some evidence that high levels of dust in the summer may have an adverse effect on lung function—but in the winter, the opposite was true. Our findings suggest that although dust exposure may have an impact on lung function, it is not the major determinant of respiratory health in children in the Aral Sea region.

Acknowledgements

Sources of Funding: Médecins sans Frontières – Holland.

Conflict of interest statement and contributions There is no conflict of interest for any of the authors. Corresponding author, RH, had access to all of the data for the study and had final responsibility for the decision to submit for publication. The original ideas for the study and the study design were developed by RH, SO'H, GW, IS, JvdM and RU. The field-work supervision was undertaken by JW, IS, JvdM, SO'H and JW. The data analysis was performed by PB, JW, RH and SL. PB and RH led the writing of the paper, but all authors contributed to this.

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