RISK OF CONGENITAL ANOMALIES IN THE VICINITY OF WASTE LANDFILLS IN DENMARK; AN EPIDEMIOLOGICAL STUDY USING GIS

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SUMMARY

Waste landfills are a potential hazard to health. Public concern exists about this potential hazard and researchers agree that further research is required on this field. The objective of the study was to investigate the association between waste landfill location and congenital anomalies risk in Denmark.

The study was a multisided epidemiological geographical comparison study of risk of congenital anomalies combined and congenital anomalies of the cardiovascular and nervous systems with maternal residence in the vicinity of 48 Danish waste landfills compared with those living further away in the years 1997 to 2001. We used routine health and population data in Geographical Information System (GIS) to investigate the risk. The subjects were 2,477 live birth with congenital anomalies.

All relative risks in the proximal zones of 0–2 km were set to 1 for comparison. For all anomalies combined relative risk in the middle zones of 2–4 km joint was 0.991 and in the distal zones of 4–6 km joint the relative risk was 1.013. For congenital anomalies of the nervous system, the relative risk in the middle zones was 1.226 and in the distal zones 1.113. For congenital anomalies of the cardiovascular system, the relative risk in the middle zones was 0.926 and in the distal zones 0.854. This result was not supported by the aggregated risk ratio mean.

We found no association between waste landfill location and congenital anomalies combined or of the nervous system. However, we found small excess risk for congenital anomalies of the cardiovascular system. No causal mechanisms are available to explain these findings, but alternative explanations include approximated birth rates and residual confounding. It is our recommendation that more comprehensive multisided studies will be executed to examine the safety of waste landfills.

Key words: congenital anomalies, waste landfills, multisided epidemiological study, GIS

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INTRODUCTION

In the industrialised world people are exposed in their every day live to chemicals from many different sources, some more obvious than others. Examples of these sources are emissions from traffic, food preservatives, additives in cosmetics, fertilisers in groundwater and, one of the less obvious, various substances stored at waste landfills. The use of a Geographic Information System (GIS) to visualise and analyse the possible health effects of the waste landfills on the nearby living population has been employed by several researchers in the past and is a superior method to assess the causal relationship and evaluate potential health effects from waste landfills.

The most comprehensive international study is the EUROHAZCON study by Dolk et al.(1). They found that residents living within 3 km of a landfill site were associated with a significantly increased risk of non-chromosomal congenital anomaly (adjusted odds ratio (OR) 1.33 [95% CI 1.11–1.59]). Odds ratios for specific congenital anomalies were also significantly raised for residents within 3 km of a site (OR for neural-tube defects: 1.86 [1.24–2.79], OR for malformations of the cardiac septa: 1.49 [1.09–2.04], for anomalies of great arteries and veins the OR were: 1.81 [1.02–3.20] (1).

In 2002 Vrijheid et al. (2) published an elaboration of the EUROHAZCON study. This time chromosomal congenital anomalies were being studied. The findings were very similar to the findings in Dolk et al.'s first study. (Adjusted OR for living near a site, for all chromosomal anomalies combined: 1.49 [1.03–2.17].)

In 2001, a British geographical study was published by Elliott et al.(3), where they study the risk of adverse birth outcomes in populations living within 2 km of 9565 landfill sites contra those living further away. This is by far the most comprehensive national study in this field. Elliott et al. found small excess risks of congenital anomalies in populations living near landfill sites [(adjusted relative risk (RR)] of all anomalies combined 1.01 [1.005–1.023], specific anomalies as neural tube defects 1.05 [1.01–1.10], cardiovascular defects 0.96 [0.93–0.99], hypospadias and epispadias 1.07 [1.01–1.10], abdominal wall defects 1.08 [1.01–1.15] and surgical correction of gastroschisis and exomphalos 1.19 [1.05–1.34] (3).

The presented work is based on a Bachelor Project conducted as a part of the Public Health study at the University of Southern Denmark in the spring of 2004.

A similar geographical comparison study was carried out in Scotland by Morris et al. in 2003 (4) who investigated the risk of adverse birth outcomes in populations living within 2 km of 61 landfill sites compared to those living further away. Morris et al. found the following: RR for congenital anomalies combined 0.96 [99% CI 0.89–1.02], specific anomalies RR neural tube defects 0.71 [0.36–1.42], RR cardiovascular defects 1.03 [0.85–1.26], RR hypospadias and epispadias 0.84 [0.58–1.22], RR abdominal wall defects 0.78 [0.27–2.23] and RR surgical correction of gastroschisis and exomphalos 1.22 [0.28–5.38] (4).

A retrospective ecological study by Fielder et al. 2000 (5) compared indices of health in a population living near a landfill site in South Wales with a population matched for socioeconomic status. Fielder et al. found an increased maternal risk of having a baby with a congenital anomaly in residents near the site, both before the sites opening and after (RR were 1.9 [95% CI 1.3–2.85] and 1.9 [1.23–2.95] respectively). Abdominal wall defect was also studied and a small increased risk was found, but a similar increase was seen in the whole country (5).

Croen et al. published in 1998 a case control study including 764 landfill sites in the area of California (6). An increase but not significant risk were found in both neural tube defects and heart defects when the mother lived within a 0.4 km radius of a hazardous waste site (OR 2.1 [0.6–7.6] and 4.2 [0.7–26.5]). Looking at all the sites combined, none of the malformations were significantly more likely to occur when the mothers lived in a census tract that included a site (6).

Another American case control study**,** published in 1992 by Geschwind et al.**,** looks at the relation between congenital malformations and residential proximity of 590 hazardous waste sites in New York State (7). They suggests that a small but statistically significant additional risk for birth defects is associated with maternal residence within 1.6 km of toxic waste sites (OR all congenital anomalies combined 1.12 [95% CI 1.06–1.18], OR nervous system 1.29 [1.05–1.59], OR musculoskeletal system 1.16 [1.06–1.26], OR integument system 1.32 [1.18–1.48], OR oral clefts 1.15 [0.87–1.51], OR digestive system 0.89 [0.71–1.07], OR chromosomal anomalies 1.18 [0.90–1.55] OR syndromes 1.15 [0.97–1.37] and other OR 1.01 [0.94–1.08] (7).

The main findings in the reviewed literature show that five of the six studies examining congenital anomalies combined suggested that a statistically significant increased prevalence of congenital anomalies is associated with the vicinity to waste landfills. Many different congenital anomalies subgroups have also been investigated. For example, cardiovascular anomalies have shown a significant increased risk with maternal residential in the vicinity of waste landfills in two out of five of the reviewed studies. Anomalies in the nervous system**,** mainly neural tube defects, also have been found to have an increased risk in three out of five studies.

The aim of this study was to answer the question: is there any association between waste landfill location and congenital anomalies risk in Denmark?

MATERIALS AND METHODS

Denmark has a very comprehensive data collection and registration. Individual data were obtained, containing address codes and maternal age on all life births with congenital anomalies in the years 1997–2001 from the Danish Birth Defect Register. Since congenital anomalies are fairly rare, a five-year study period was used, during which there were a total of 16,057 cases. The address codes follow a national standard and translate into geographical point locations using simple queries on standard tables within the GIS. Of the live births with congenital anomalies, we concentrate only on the following health outcomes: combined congenital anomalies (ICD-10, Q00-Q99), congenital anomalies of the nervous system (ICD-10, Q00-Q07) and congenital anomalies of cardiovascular system (ICD-10, Q20-Q28)**.** An individual child born with congenital anomaly was counted as one case. If there were multiple anomalies, as for example both of the cardiovascular system and of the nervous system, the case was counted in both categories as one case. Multiple anomalies within e.g. nervous system were counted as one case.

A proxy for the number of birth was calculated using data on the density of build-up floor space in Denmark, which is available in 100×100 m cells (8), together with data on female population and number of births in all 275 Danish municipalities. The total number of births within each municipality was then distributed relative to the residential floor space in each 100×100 m cell within the municipality. The precise data from one municipality are available for free on the Statistics Denmark homepage (www.statbank.dk); and when comparing these data to our proximate birth rate, we found that although there are considerable variation on the cell level, this inaccuracy somewhat levels out in our buffer zones, as the local inaccuracies levels out on a larger geographical scale (9).

In Denmark there are 103 operating waste sites. The sites are divided into three categories according to use, the categories being special, deposit and regular landfills. The sites of interest in this study were the deposit landfills because they are defined as sites, "*which immediately or in the future produces a risk of polluting groundwater surface water and/or air*" (Waste centre Denmark 2004). Currently there are 52 registered deposits in Denmark and 48 of these were included in the study. The remaining four deposits were either not functioning as a deposit or had not been operating for more than seven years prior to the beginning of our study. This time criterion was based on the assumption that it takes seven years for off-site contamination to occur (1).

Using the GIS MapInfo to work with our data, we marked the geographical location of the landfills. Not knowing the exact exposure made it necessary to use a proxy measure of the exposure which was the distance of maternal residence from the waste landfill which is a method used in similar ecological studies (3, 4). Three buffer zones of 0–2 km, 2–4 km and 4–6 km were constructed surrounding the 48 waste landfills, which is shown in Fig. 1. Risk ratios were calculated by counting the number of congenital anomalies and summing up the proximal number of births in each buffer zone for all the landfill sites. To calculate an aggregate level individual zone was geographically joined for the entire country, so that there was one 0–2 km zone, one 2–4 km zone and one 4–6 km zone. In the analysis we made the assumption that the risk rates were normally distributed. The risk rate (RR) was finally calculated by dividing the sum of congenital anomalies (CA) by the total proximal sum of births (PB): $RR = \sum CA / \sum PB$. These calculations were also made separately for the subgroups of anomalies of the cardiovascular and nervous systems.

Large local differences in the risks rates between the landfills can cause the mean values to hide signs of correlation. To overcome this problem we normalized the local risk ratios by the local average of the whole 6 km buffer zone of each landfill average and made a new regression analysis.

We also tried calculating the median for the normalized rates of cardiovascular congenital anomalies in order to check our aggregated risk ratios. Calculating the median gave a misleading picture of the numbers because the areas of the proximal zones are so small that some of them do not contain any cases. Instead, we excluded the outer 10% and 90% percentiles for the normalized rates of cardiovascular congenital anomalies and made new aggregated means.

Since no data on the maternal age on the mothers delivering babies free of congenital anomalies were available, we were unable to age standardize them. However, the age structures of mothers delivering babies with congenital anomalies within the three buffer zones do not differ significantly, indicating that age standardisation is not important to the result.

The study was carried out in accordance with the requirements of the national and regional ethics committees in Denmark.

Table 1. *Aggregated risk ratios per 1000 births for all congenital anomalies combined*

Zone	Combined birth defects	Births	Risk rate × 1000	Relative risk
1	331	6,639	49.9	1 000
2	910	18,409	49.4	0.991
3	1,236	24,467	50.5	1 013
Total	2,477	49,515		

Data 1997–2001

Table 2. *Aggregated risk ratios per 1000 births for all congenital anomalies in the cardiovascular system*

Zone	Cardiovascular system	Births	Risk rate × 1000	Relative risk
1	81	6,639	12.2	1 000
2	208	18,409	11.3	0.926
3	255	24,467	10.4	0.854
Total	544	49,515		

Data 1997–2001

RESULTS AND DISCUSSION

Congenital Anomalies Combined

In the study period from 1997 to 2001, there were 16,057 congenital anomalies observed in Denmark. In the buffer zones we counted a total of 2,477 anomalies during that period. Table 1 shows the aggregated risk ratios for all congenital anomalies combined.

The risk ratio – distance correlation coefficient (r) is 0.60. The t-test (0.76, p = 0.59) shows that the slope does not differ significantly from zero. Furthermore, the average risk rate of the country for anomalies combined is 48.6, which is lower than in all the zones. The results of risk calculations of all congenital anomalies combined show no increased in defects in the proximate zones compared with the middle and distant zones. This hopefully indicates that there is no general health danger connected with living in the vicinity of Danish waste landfills. Five of the six main studies on the field suggest a small but statistically significant increased prevalence all birth defects combined among people who live close to landfills. In our opinion these results do not greatly support any conclusions of no causality in our study. It is possible however, that all congenital anomalies combined might not be very efficient measure of the potential effect. Increased risks of certain specific malformations might be invisible in the combined estimate. For this reason we also calculated the risks for two subgroups of malformations.

Fig. 1. *Denmark with waste sites and buffer zones*

Congenital Anomalies of the Nervous System

In the buffer zones we counted a total of 85 congenital anomalies of the nervous system in the period. The risk ratio – distance correlation coefficient (r) is 0.50. The t-test (0.57, p = 0.67) shows that the slope does not differ significantly from zero. The calculations of the risk rates for the subgroup of congenital anomalies of the nervous system thus showed no increase in risk either. Three out of five main studies on this subgroup show a small excess risk. Since our result is based on a small group of cases, it is difficult to say whether it contributes to the picture of causality. In any case the average risk rate for the whole country for congenital anomalies of the nervous system is 1.7, the same as we found in the zones and therefore, we do not proceed with further analysis of this subgroup.

Congenital Anomalies of the Cardiovascular System

In the buffer zones, we counted a total of 544 congenital anomalies of the cardiovascular system. Table 2 and Fig. 2 show the aggregated risk ratios for all congenital anomalies of the cardiovascular system.

The risk ratio – distance correlation coefficient (r) is –1.00. The t-test (–120.3, p = 0.005) shows that the slope does differ significantly from zero. The average risk rate for the whole country is 10.8, which is lower than the risk rates in both zone 1 and 2. These results indicate an association between congenital anomalies of the cardiovascular system and maternal residence nearby the waste landfill that corresponded to that the number of congenital anomalies of the cardiovascular system would increase by 60 cases if all the mothers in the middle and distal zones had lived in the proximate zones.

The data above is aggregated, to check whether local differences in risk rates between landfills were "hiding" the real picture of the correlation we normalized the local risk ratios to the local average of the whole 6 km buffer zone of each landfill. Figure 3 shows the normalized risk ratios for congenital anomalies of the cardiovascular system. Figure 4 shows the risk ratios by buffer zones.

The risk ratio – distance correlations coefficient (r) is 0.06. As can be seen in Fig. 3**,** there are strong variations in the risk ratios between individual zones. On the basis of the normal risk ratios for congenital anomalies of the cardiovascular system we calculated the mean risk ratios for the three zones. The mean risk ratio in the proximal zone is 1.15 [range: 0–15.1], 0.87 [range 0–1.9] for the middle zone and 0.93 [range 0–2.3] for the distal zone. To check for positive association we observed that the aggregated risk ratios were caused mainly by a few local extreme values (as seen in Table 3). The median calculation is shown in Fig. 5. This, however, gave a wrong picture of the slope due to the lack of cases in small areas of the proximal zones. Instead, we found the 10% and 90% percentiles and calculated normalized risk ratio mean for congenital anomalies of the cardiovascular system shown in Table 3 and Fig. 5.

Table 3. *Normalized median and mean for all congenital anomalies in the cardiovascular system*

Zone	Median	10% percentile	90% percentile	Mean
1	0.299	0	2.781	1.264
2	0.931	0	1.617	0.890
3	0.960	0.057	1.382	0.964

Data 1997–2001

The risk ratio mean – distance correlations coefficient (r) is –0.76. The t-test (–1.16, p = 0.45) shows that the slope does not differ significantly from zero.

We have shown a small, but statistically significant, excess risk rate of cardiovascular congenital anomalies with maternal residence within 2 km of a waste landfill. When we exclude the extreme data, however, the results do not substantiate the calcu-

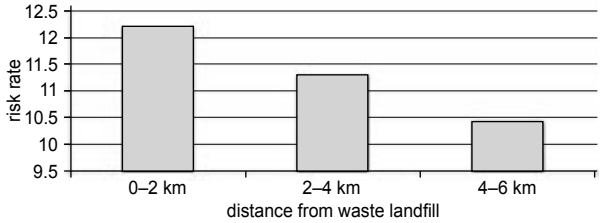

Fig. 2. *Aggregated risk ratios per 1000 births for congenital anomalies in the cardiovascular system.*
Data 1997–2001

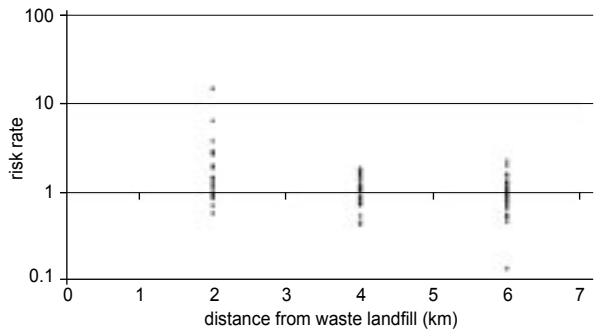

Fig. 3. *Normalized risk ratios per 1000 births for congenital anomalies in the cardiovascular system.*
Data 1997–2001

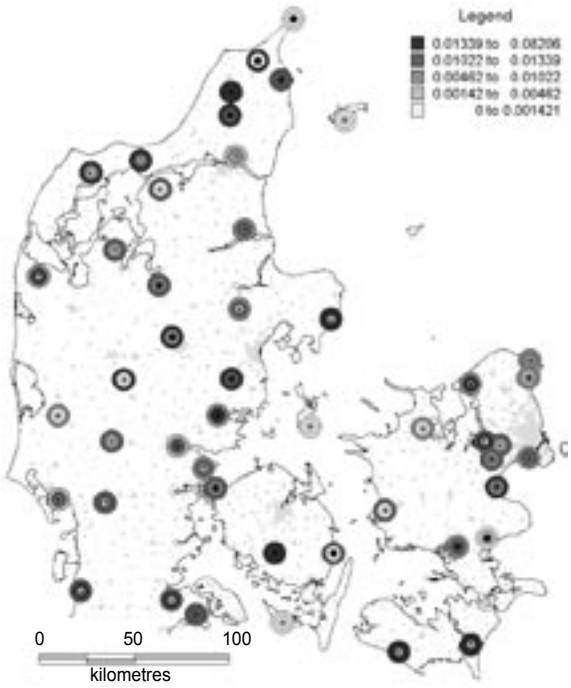

Fig. 4. *Waste sites with CVD anomalies and risk rates in buffer zones.*

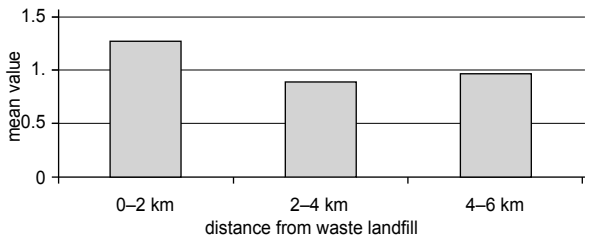

Fig. 5. *Normalized risk ratio mean for all congenital anomalies in the cardiovascular system, percentiles.*
Data 1997–2001

lations of the aggregated risk ratios for congenital anomalies of the cardiovascular system. The essential question is, of course, whether the observed relation is causal. The results of three out of six main previous studies of the association show this increased risk, which in our view supports our results of an excess risk.

It can be difficult to compare our results with other studies looking for association between waste landfill location and congenital anomalies prevalence. Of course the variations in methodology have a large impact on the results but especially the characteristics of the waste landfills with regard to what is placed there and what security regulation there exists is very important when comparing results. Most studies on the field are American or British and it is most likely that these countries now and in the past have had a very different waste handling than Denmark. On the basis of this study it is not possible to draw any conclusions of causality. The lack of exposure data, the proxy calculations of the birth rates and the assumptions that the risk rates are normally distributed in the population make the results only indicative. This is the nature of the ecological study, which was mentioned earlier and it can be used to initiate a further epidemiological investigation process.

There are many possible confounders in this type of study (10). Unfortunately we did not have time and the possibility in our study to control all relevant potential confounders. In collecting data from the whole of Denmark, we expect to have a large enough amount of data to presume that confounders such as hereditary diseases, smoking and drinking habits are normally distributed in the groups of cases and controls.

We would have liked to control the confounding effect of the age of the mothers in our study by age standardization. According to the Danish National Board of Health (11), the risk of having a child with congenital anomalies increases with maternal age. According to Dolk and Vrijheid (1, 2), this is true for Down syndrome and related abnormalities, but not for other non-chromosomal anomalies. Furthermore, very low maternal age is strongly related to gastroschisis. Age standardization would ensure that our results are not distorted by a possible geographical difference in the age distribution or maternal age in Denmark. Age standardization was not possible in our study since we did not know the age of all the mothers in the buffer zones but only in mothers who delivered babies with congenital anomalies. To evaluate if age standardization would have had an important effect on our risk ratios we calculated the mean age of the mothers who delivered babies with congenital anomalies. Without doing advanced statistical comparisons of the three means, we could see that they were similar; therefore age standardization would probably not have any great impact on our results. We were also interested in investigating whether the gender of the child could be associated with maternal residence in the vicinity of waste landfills. In order to do this we should have asked to get information on gender in our dataset from the Danish Birth Defect Register.

Spontaneous abortions and therapeutic abortions could be another important confounder in our study. Many embryos and foetuses with congenital anomalies are lost as spontaneous abortions, and indeed many chromosomal anomalies are never seen at birth as the malformations are not compatible with continuing in utero life. For this reason**,** congenital anomalies in foetuses which are lost as spontaneous abortions are not possible to control in a health study (1, 2). However, it might be possible and important to control late spontaneous abortions and therapeutic abortions (legally induced abortions to eliminate the risk that the child if born might suffer from physical or mental abnormality and be subsequently seriously handicapped). As this possible congenital anomalies of these foetuses are not taken into account and too low number of cases are recorded the possible risk may be underestimated. We are, however, uncertain how controlling these abortions would affect our results. Fielder et al. measures abortion rates in their study and found no consistent differences in these measures (5). We would also have liked to obtain data on anomalies for stillbirths, but the Danish Birth Defect Register did not have address codes to assist us in geographically place the cases of stillbirth.

Socioeconomic status is another possible factor that could have confounding effects. Socially more deprived people generally have higher morbidity and mortality (12), but scientists disagree on whether there is an increasing risk of congenital anomalies with increasing deprivation. Vrijheid (2) argues that more deprived populations have a higher risk of congenital anomalies of non-chromosomal origin and some specific anomalies. Stoltenberg (13) oppose this finding, saying that there is no significant increased risk among socially deprived populations. We would have liked to investigate whether the socio-economic situation differed in the different buffer zones and if necessary to consider the factor of deprivation. We do not know whether this would have changed our results but the EUROHAZCON study found no overall evidence that socially more deprived communities live nearer to landfill sites than others, and adjustment for socioeconomic status did not change the odds ratio greatly (1). If this is true, there is no reason to believe that our results will be greatly changed by this factor. On the other hand, we could not prove otherwise. We could have controlled the socioeconomic status by obtaining information on maternal education, household income, employment status or neighbourhood educational attainment as was done by Croen et al. through register data or interviews (6).

The establishment of an exposure–response gradient is particularly valuable in assessing causality. Geschwind et al. have found this in their multi-sited case control study from 1992 (7). They found that higher malformation rates are associated with a higher exposure risk. This was done by making an exposure risk index (incorporating the distance from and the hazard ranking score for each site within a 1.6 km radius of the birth residence) for all 590 sites. Findings were; OR no exposure: 1.00, OR low exposure: 1.09 [95% CI 1.04–1.15] and OR high exposure: 1.63 [1.34–1.99]. Investigating the exposure gradients are an advantage in multi-site studies and in our study we also started gathering information from the landfills through our telephone interviews on data which would be useful for formulating an exposure risk index. We asked about the area, capacity and type of waste, this, of course, should have been extended with a lot more data on groundwater abstraction points, agricultural activity, human activity and data from different monitoring systems. We did not follow up on making an index, but this would be interesting in an elaborated study.

The presence of other industrial sites, polluted areas or other toxic environmental exposures near landfill sites can also be possible confounders. Traffic pollution, for example, is associated with ascertainment of congenital anomalies. Dose-response associations with heavy road traffic (> 50,000 vehicles/day) are

observed for the risk of cardiac anomalies, skin anomalies and other major malformations (14). We could have controlled for the presence of other sources of environment exposure by gathering information from air pollution surveillance done in larger cities in Denmark or by creating a layer in MapInfo showing all larger roads, polluted areas and industrial sites.

A more complete reporting of congenital anomalies might take place in areas close to landfill sites because of an awareness of possible health effects. Because of the way our data on congenital anomalies were collected we do not believe that this constitutes a large problem in our study. The data are based on a very high quality registering system in Denmark. Even though the National Board of Health recognises potential minute inaccuracies in their reporting, we have absolutely no reason to suppose the data from the different buffer zones vary in quality.

It could also be relevant to investigate the residential history of the mothers during their pregnancy. The possible true excess risk would be underestimated if some of the women moved during their pregnancy. This is why migration would be part of the confounding effects. Dolk (1) calculated that migration could result in a 10% underestimation of the true increased risk. In order to control the effect of migration we should have merged the date on the mother's address that we received from the Danish Birth Defect Register with data from the Central Person Register (CPR).

PERSPECTIVES FOR FURTHER RESEARCH

As mentioned earlier a multisided study can be the basis for another type of study which more closely investigates the population around specific sites. A possible approach for such further investigations would be to conduct health surveys of populations living close to selected sites. A case-control study where past exposure to the suspected hazards is compared between the cases and the controls is extremely useful for the study of rare health outcomes (10). For example, a health survey like this could include investigations of the following circumstances. Mothers who are exposed to hazardous substances in a job have a risk of having babies with congenital anomalies. If the mothers who live close to waste landfills for some reasons have more occupational exposure, this can have a confounding effect on the results. The EUROHAZCON study estimates that it is unlikely that enough of the women in any area would be employed in high-risk industrial occupation for the mean risk of adverse birth outcomes for resident women to be significantly raised (1).

Reproductive history is another obvious factor to investigate when studying reproductive outcomes. It could be important to investigate whether there is a history of inherited congenital anomalies in the families of the parents. Inherited anomalies cannot be caused by the exposure to an environmental factor and should therefore not be included in the risk calculations. Parental consanguinity is another known risk factor related to congenital anomalies. Children of consanguine parents have a higher risk of being born with a serious handicap or disease. The risk of having a baby with a congenital anomaly is found to be 2–4 % for close related parents compared to non consanguine parents who have a risk of about 1–2 % (13, 15). Parental consanguinity should therefore also be taken in account.

CONCLUSION

The potential health risk connected with living near a waste landfill is a subject of big discussion and numerous studies have been conducted on the subject. Some have found a positive association and others not. Public concern exists about the potential health risks and one thing researchers agree on is that further research is required not only of hazardous waste landfills but also on sites that receive domestic, commercial and industrial waste. Denmark has a very comprehensive data collection and registration system that is very useful for geographical studies in many areas, such a history, demography and economy and also makes a vast foundation for geographical environmental health studies. These routine health and population data showed possible to use in the investigation of the risk of congenital anomalies in the Danish population who live close to waste landfills. Using the ecological approach, we correlated the rate of congenital anomalies with exposure to hazards from waste landfills in Denmark on a geographical basis. Not knowing the exact exposure from the waste landfills we used a proxy measure of the exposure, which was the maternal residence from the waste landfill. This proxy exposure was determined with residence in buffer zones of 0–2, 2–4 and 4–6 km around all Danish waste landfills. The results of risk calculations of all congenital anomalies combined showed no increase in defects in the proximate zones compared with the middle and distant zones (relative risks: zone 1:1, zone 2:0.992 and zone 3:1.013). The calculations of the risk rates for the subgroup of congenital anomalies in the nervous system showed no increase in risk either (relative risk: zone 1: 1, zone 2: 1.226 and zone 3: 1.113). We have shown a small statistically significant, excess risk rate of cardiovascular congenital anomalies with maternal residence within 2 km of a waste landfill (relative risk: zone 1: 1, zone 2: 0.926 and zone 3: 0.854), but further statistical calculations of the normal risk rates did not support this finding. The lack of exposure data, the proxy calculations of the birth rates and the assumption that the risk rated are normally distributed in the population makes the results only indicative. There are many possible confounders in the study. Spontaneous abortions and therapeutic abortions e.g. could be important confounders as would the presence of other industrial sites, polluted areas or other toxic environmental exposures near landfill sites. These and other factors would be relevant to investigate in future research.

Acknowledgements

We are grateful to Hans Christian Petersen Ph.D. for his assistance with the statistical analysis and to Bitten Friis Jensen and Lina Saem Støy for the technical assistance.

A major help in conducting the study had been provided by a grant from the University of Southern Denmark for which we are thankful.

We appreciate the cooperation with and the data provided by Waste Centre Denmark and Statistics Denmark, especially the Danish Birth Defect Register.

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Received March 9, 2005
Received in revised form and accepted May 16, 2005