A Short Communication:

Cancer Mortality in a Chinese Population Exposed to Hexavalent Chromium in Water

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Abstract

This report is a clarification and further analysis of our previously published mortality study regarding an incident of groundwater contamination with hexavalent chromium in the JinZhou area of China.[1] At the beginning of the contamination episode in 1965, average concentrations of hexavalent chromium (Cr^{+6}) in the affected groundwater of villages ranged from 0.004 ppm to 2.6 ppm. To assess the potential effect on local cancer rates of well water Cr^{+6} exposure for up to 7 years, we conducted a retrospective mortality study of approximately 100,000 residents living in selected regions and villages of the JinZhou suburbs during 1970-1978.[2] In the five Cr^{+6} contaminated villages combined, a significant excess of overall cancer mortality was observed ($p = 0.04$), but individual village mortality rates were inversely correlated with the amount of Cr^{+6} contamination in well water. Further analysis revealed no clear statistical increase in cancer mortality in the three villages adjacent to the source ($p = 0.25$) where 57% of the wells exceeded the WHO safe drinking water limit of 0.05 ppm Cr^{+6}. In contrast, a more substantial excess of cancer mortality ($p = 0.10$) was found in the two most distant villages that were last to receive Cr^{+6} contaminated groundwater and that had groundwater Cr^{+6} concentrations below 0.05 ppm. These results do not indicate an association of cancer mortality with exposure to Cr^{+6} contaminated groundwater. The observed pattern of cancer mortality might reflect the influence of lifestyle or environmental factors not related to Cr^{+6}. Further follow-up of this cohort is recommended to assess the possible influence of Cr^{+6} and other risk factors on cancer mortality.

Background

The JinZhou area of LiaoNing Province is composed of a downtown area and six suburb regions: Nuer River Region, ZhongTun Region, GuoShu Region, West Suburb Region, North Suburb Region, and XueJia Region (Figure 1). The suburb regions are primarily agricultural but are the home of several industrial plants. JinZhou Alloy Plant and No.6 Petroleum Plant are the two largest plants. JinZhou Alloy Plant started regular chromium production in 1965, at which time a

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large amount of Cr^{+6} containing waste water was discharged.[1] The discharged waste water contributed to the Cr^{+6} contamination via a shallow aquifer beneath a dry river bed at the beginning of this episode. Chromite ore processing residues from the plant was the main source of the Cr^{+6} contamination. The spent ore residue was stockpiled uncovered next to the plant, where precipitation caused rapid dissolution and leaching of Cr^{+6} to the shallow groundwater aquifer used for drinking water. A long and narrow contaminated area was formed along the dry river bed of the Old Nuer River soon after the Alloy Plant began operations in 1965 (Figure 1). The contamination source was not fully controlled until 1982 when a seepage prevention wall was built around the ore residue dump site; ~~however,~~ Interim remediation measures included the addition of ferrous sulfate to the ore residues, which reduced the Cr+6 but also polluted the aquifer with sulfates at concentrations up to several hundred ppm. Residents living in the villages located along the Old Nuer River were exposed to Cr^{+6} by using well water that had been contaminated with Cr^{+6}. The distribution of well water concentrations of Cr+6 investigated thoroughly in 1965 is shown for each of the five villages in Figure 2.

Retrospective Mortality Studies

We conducted a series of retrospective mortality studies of the approximately 100,000 residents living in the JinZhou suburb regions in 1970-1978.[2] Most residents were farmers (>95%) who had lived in the JinZhou suburb regions (>95%) for most of their lives. Residences were concentrated in agricultural villages, and there was minimal migration within the population. We examined the death records in the local police departments to locate all deaths that occurred in this population between 1970 to 1978. A standard form was used to abstract the data and to record the cause of each death. All survey staff received training, and a follow-up survey was conducted for part of the death records to ensure the quality of the abstracted data. Age-adjusted cancer rates were calculated for each of the six regions and for each of the five villages in the contamination pathway. The death rate was calculated by dividing the observed number of cancer deaths in 1970-1978 ~~by the size of the population in 1975 estimated from the 1982 census.~~ by the total number of Follow-up years. The total number of Follow-up years is estimated as the product of the length of Follow-up (9 years) and the ~~population~~ estimated size of the population in 1975, the midpoint of the follow-up period.

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Village-specific all cancer mortality rates were statistically compared to rates for LiaoNing Province ~~province rates based on~~ using the Poisson distribution (5, pg 69) ~~(Snedecor and Cochran, 1995)~~. ~~Breslow and Day~~

Groundwater Cr^{+6} contamination in 1965 was measured at drinking water wells for each village in the contamination pathway (Table 1, Figure 2). In general, higher levels of the Cr^{+6} contamination occurred in the villages closer to the pollution source. Dose-response relationships were examined using the distance of each village from the source as a surrogate for exposure. The Poisson regression model ~~(McCallogh and Nelder, 1991)~~ was used in which the expected rate of cancer depends linearly on distance from the contamination source: ln (Rate of Cancer) ~~Rate of Cancer~~ = a + (b x distance). Negative values for the slope b indicate that proximity to the source was associated with greater cancer death rates. (5, Chapter 4)

Results

The adjusted cancer death rate for the six suburb regions are as follows: Nuer River Region, 68.8 per 100,000 people per year; for ZhongTun Region, 68.4; for GuoShu Region, 64.7; for West Suburb Region, 54.3; for XueJia Region, 57.5; for North Suburb Region, 45.9. The rates for three of these regions are comparable to the 1973-1975 rate of 66.1 per 100,000 for LiaoNing province.

The death rates of total cancer, lung cancer and stomach cancer for each village in the Cr^{6+} contamination path are presented in Table 1. When the total cancer mortality for all five villages combined is compared to that of LiaoNing province, a statistically significant excess was observed (2-sided p-value = 0.04) ~~(p = 0.04)~~. However, none of the individual villages showed a statistically significant excess at a 2-sided p-value of ~~less than~~ 0.05. Further investigation of the statistical trends was performed by combining the three villages that were closest to the contamination source and that had frequent well water measurements (Figure 2) in excess of the World Health Organization safe drinking water standard of 0.05 ppm Cr +6 (WHO, 1989). Those three villages showed no significant excess of total

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cancer mortality compared to the province rates ~~with a p value of 0.25~~ (p-value = 0.25), while the two more distant villages with well water all below 0.05 ppm had a more substantial increase in total cancer mortality (p value = 0.10).

No statistical comparisons to province mortality rates could be made for ~~specific~~ site-specific cancer ~~types~~ rates due to the lack of appropriate rate information. ~~As shown in Table 1,~~ Stomach cancer comprises a large proportion of the total cancer rate for these villages and for all of China (Table 1). In general, villages closer to the contamination source do not have higher cancer rates, while one of the least contaminated villages, Shilitai, had a substantially higher rate of mortality from stomach cancer. ~~The available data on~~ Lung cancer mortality rates were highest ~~also showed excesses primarily~~ in the more distant villages with Cr^{6+} contamination below the World Health Organization limit of 0.05 ppm. The dose-response models indicated a nonsignificant ($p > 0.05$), weak positive correlation between cancer rates and the distance from the source, contrary to the expected direction of association if Cr^{6+} contamination were associated with higher cancer rates.

Discussion

The Cr^{6+} contamination followed long and narrow pathway that started near the JinZhou Alloy Plant in the Nuer River Region and extended to the West Suburb Region. Exposure to Cr^{6+} contamination was highest for the populations closest to the plant and lowest for the populations farthest from the plant. The cancer death rates for the six villages in the contaminated area were not correlated with the magnitude of Cr^{6+} contamination. Neither stomach cancer nor lung cancer indicated a positive association with Cr^{6+} contamination. The absence of a dose-response relationship between cancer and Cr^{6+} clarifies a translation and interpretation of our previous publication.[3] Although Cr^{6+} contamination cannot be ruled out completely as the reason for the high cancer death rates in these villages, these results do not ~~adequately~~ support such a relationship. The relatively short latency period (i.e., 13 years, 1965 to 1978) covered in this study limits the interpretation of these findings regarding cancer and Cr^{6+} contamination, although

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the number of person-years represented is substantial (~~about~~ approximately 99,000). A mortality study with a longer follow-up period is recommended. These results suggest that lifestyle or environmental factors not related to the Cr^{6+} contamination may be a source of the variation in cancer rates. Additional studies to identify these factors are also recommended.

References

(1) Zhang JianDong, Li XiLin. Chromium Pollution of Soil and Water in JinZhou. Journal of Chinese Preventive Medicine 1987; 21:262-264.

(2) Zhang JianDong, Li XiLin. Study of the Effect of Environmental Pollution in JinZhou Area on Residents' Health I. Mortality Analysis. ~~????~~. JinZhou's Health and Anti-Epidemic Station, 1979.

(3) Agency for Toxic Substances and Disease Registry. Toxicological Profile for Chromium. US Department of Health & Human Services, Public Health Service, TP-92/08, 1993, pg 57.

(4) World Health Organization. 1989.

~~(5) Snedecor and Cochran. 1995.~~ (5) Breslow NE, Day NE. Statistical Methods in Cancer Research Volume II – The Design and Analysis of Cohort Studies. International Agency for Research on Cancer, Lyon, 1987.

(6) McCallogh ~~and Nelder. 1991.~~

Gwen: Brent's citation

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Parallel heading as in Table 1.

Figure 2

Distribution in 1965 of Cr^{+6} concentrations in Well Water of Villages in the Contamination Pathway ~~in the Jin Chgu Area in 1965~~

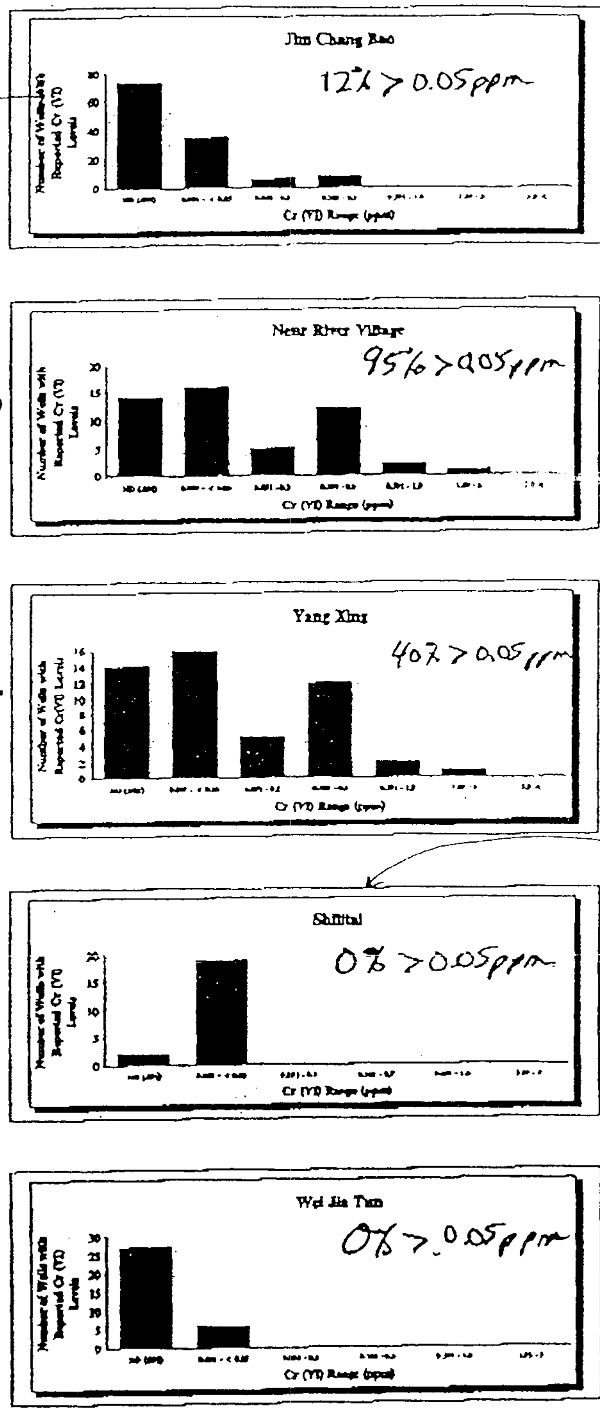

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Table 1

Well Water Hexavalent Chromium Concentrations and Cancer Death Rate Information for Villages in the Contamination Pathway

	Village					Range of Average Rates in China*	Dose-Response: Coefficient(p value)
	JinChangBao	Nuer River	Yang Xing Yanxing	Shi Li Tai Shilitai	WenJiaTun		
Distance (km) from the JinZhou alloy plant	1.4	1.5	3.0	3.5	5.0	-	-
Average Cr^{+6} concentration in water wells in 1965	0.031 ppm (123 wells)	2.6 ppm (170 wells)	0.18 ppm (50 wells)	0.02 ppm (21 wells)	0.004 ppm (33 wells)	-	-
Frequency of wells exceeding 0.05 ppm	12%	95%	40%	0%	0%	-	-
Cancer Death Rates per <u>100,000 for 1970-1978</u>							
All Cancer (p value)	83.6 (0.32)	71.9 (0.74)	76.8 (0.62)	93.0 (0.12)	91.1 (0.26)	29.8-102	0.05 (p=0.57)
Stomach Cancer	36.7	28.0	36.5	55.2	27.7	5.2-40.2	0.04 (p=0.74)
Lung Cancer	13.2	15.0	21.4	-	20.8	1.8-17.8	0.12 (p=0.59)
Person-years	26,179	24,792	9,703	23,225	14,950	-	-

* Range of the average cancer rates for the 30 provinces in China (National Cancer Control Office of China, 1979).

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