TITLE: Technological Development and Population Health in Poland

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NCSEER NOTE

This paper is the Executive Summary with Tables and Figures, of a 120 page report on the pilot phase of a major, long term, collaborative American/Polish investigation of technological development and population health in Poland. Pilot as it is, the project was intended to produce and test design rather than conclusions, and the latter are few, although the concluding hypothesis; that social uprooting and urban social pathologies have affected public health (cancer incidence) more than pollution, occupation or other technological hazards; may prove highly significant. This summary and the full report are for specialists. The full 120 page report is available from the Council upon request: Tel. (202) 387-0168.

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EXECUTIVE SUMMARY

Background and Research Objectives

Since 1945 Poland has undergone fundamental and irreversible transition from a primarily agricultural economy to one heavily dependent on industrial production and energy generation. Between 1950 to 1990 employment in agriculture dropped precipitously from 53.6% to 26.8% while employment in industry, commerce, communications and transport has grown from 30% to 41.9% of the workforce. Heavy industries, such as coal and petroleum extraction and processing, construction materials, machinery, and metal smelting, have experienced particularly strong growth during the post-war decades. Percent of urban population has grown during that period from 36.8 to 61.6%, a testimony to extensive urbanization of the country.

Industrialization and urbanization processes in the post-war Poland did not affect all regions equally. The southwestern part of the country, most richly endowed with natural resources such as metal ores and coal, and having a long history of industrial activities during the German pre-1945 rule, experienced the greatest rate of growth. The eastern and southeast parts of the country were the most rural at the commencement of the post-war period, and remained that way until the present.

The industrial and economic growth during the modern era of Polish history were achieved at a substantial human and environmental price. Increasing personal wealth was accompanied by doubling of per capita consumption of fats, mostly of animal origin, thus increasing the risk of heart disease and certain cancers. Smoking and alcohol consumption have grown at an alarming rate between 1950 and 1980, accompanied by dramatic upward trends in mortality rates from liver cirrhosis, cardiovascular disease and male cancer. In addition, a large number of Polish workers have been exposed to occupational hazards such as noise, dust, vibrations, noxious gases, lead, carcinogenic agents, and others, in excess of legally acceptable limits. When expressed as worker equivalents (which assumes one haz-
ard per worker), in the mid 1980s that number equaled approximately 540,000, or over 7% of all industrial workers in Poland. Among the industrial sectors, electromachinery, coal mining and processing, metallurgy, and light manufacturing have been particularly hazardous, having 33%, 24%, 18%, and 16%, respectively, of its workforce threatened (again, expressed in worker equivalents). Occupational hazards in Poland are primarily associated with the more industrialized southwestern voievodships.

The most visible and measurable adverse effect of Poland's intense industrialization has been environmental degradation (Ember, 1990; Institute of Environmental Protection, 1990; National Bureau of Statistics, 1980-1991, 1990, and 1991, Atmospheric Pollution, 1988). By 1989 air emissions of sulfur dioxide, nitrogen oxides and particulates reached 3.9, 1.5 and 2.4 million tons per year, respectively, with approximately 60-70% of air emissions attributable to industry (10-15% to transportation and 15-20% to residential heating). In addition, Poland is a recipient of substantial mass of transboundary air pollution; for example, in the late 1980s over 40% of total sulfur dioxide deposition in Poland was estimated to originate abroad, mostly in the former East Germany and in Czechoslovakia.

Air pollution is higher in the more industrialized southwestern part of the country, as shown in Figure 1, both from domestic and foreign sources. In Silesia, the average emission of sulfur, nitrogen and particulates per km² during the late 1980s were more than an order of magnitude higher than in the rest of the country, resulting in the ambient concentrations much in excess of the acceptable standards. In 1987 ambient concentrations of suspended particulates and sulfur dioxide in the Katowice region were 114-314 and 18-96 µg/m³ (with localized peaks of 200), respectively, and for lead 0.2-0.5 (with localized peaks of 2.6). Much of the industrial particulate emissions are rich in toxic metals, such as cadmium, lead, arsenic, mercury, and others, leading to significant human exposure through inhalation and food chain contamination.

Water resources have been also severely damaged by industrial, as well as municipal, discharges. By 1987, 75% of all rivers were classified as too polluted biologically for any, including industrial, use. Of the remaining rivers, 21%, 14% and 0% were classified into categories III, II and I, respectively, by biological criteria. Using physicochemical criteria of purity, classes I, II and III were represented by only 5%, 31% and 30% of all rivers, respectively. According to the 1989 statistics, on the
average only 83% of the population served by surface water systems in Poland had drinking water of high quality. For groundwater the situation was much worse, with only 34% of consumers having access to high quality water.

Poland's industrial development was accompanied by distinct trends in mortality. Following dramatic increase in the average life expectancy during the 1950s, 60s and early 70s, the rate of progress markedly declined, and by the late 1980s the life expectancy has actually dropped among some groups (such as middle age men). Circulatory disease and cancer—the two most common causes of death—largely explain the life expectancy statistics: between 1950 and 1985 mortality from cancer among middle age men has been increasing by approximately 2% per year, and mortality from circulatory disease has almost tripled.

Cancer mortality in Poland is also characterized by marked geographical differences and by higher rates among urban as compared to rural populations. In 1986 the U/R ratios for lung, pancreatic, bladder, and kidney cancers, were 1.2, 1.3, 1.2, 1.7 and 2.2, 1.3, 1.4, 1.4 for males and females, respectively. With the exception of female lung cancer, the U/R ratios were lower in 1986 than during the preceding three decades, suggesting an increasing homogenization of risk factors among the two social groups.

Geographic distribution of cancer rates between the early 1960s and late 1980s manifests a number of regularities. For several sites, such as lung, pancreas, bladder, and kidney, as well as for all sites combined, voyevodships experiencing the highest rates tend to be located in the western part of the country, while the easternmost and southeastern voyevodships experience the lowest rates. During that period, the ratios of highest-to-lowest rates for pancreatic, kidney, and bladder cancers ranged from 1.6 to 2.9, depending on the year, anatomical site, and sex. The East-West gradient in cancer mortality has generally increased for women and declined for men during that period. The latter changes have been most pronounced for lung cancer, where the High/Low ratio in 1989 was 2 and 4.2 for men and women, respectively.

The general decline in the life expectancy that accompanied industrial development in Poland has been repeatedly attributed to the effects of environmental pollution on human health. The distinct patterns in mortality rate from lung and other cancers, which are the major contributors to the mortality rate in Poland, such as upward temporal trends, the tendency for high rate voyevodships to be located in
the more industrial sections of the country, and the higher rates among urban populations, relative to rural populations, are consistent with that proposition. On the other hand, other factors associated with industrial development, such as diet, alcohol and tobacco consumption, hard living and working conditions, and various sociopolitical and economic factors, may be the key contributors to the observed cancer mortality trends, with relatively minor contribution from pollution.

The goal of the present study is to identify the key factors that are likely to explain the temporal and geographic patterns of cancer in Poland and to put to test the hypothesis that pollution is a major contributor to lung cancer among Poles. Its specific objectives are:

1. To estimate the magnitude of mortality from lung cancer that can be reasonably explained by industrial development and the associated changes in the living conditions of the population in Poland between 1945 and 1990.
2. To interpret, on an exploratory basis, the industrialization-linked excess lung cancer mortality (if such is found), in terms of environmental pollution, occupational exposures, and other social factors.

The results, aside from enriching the data base for development of environmental and public health policy in Poland, are likely to significantly contribute to the current understanding of the effects of technological development on human health. For the latter purpose, Poland represents an unparalleled—though grim and inadvertent—laboratory. First, in contrast to its former communist neighbors in Europe, Poland has, in only four decades, been transformed from an overwhelmingly rural to a largely industrial society, with its accompanying changes in the living and working conditions. Second, there are substantial regional differences in the extent of these changes. Third, the internal migration of the population has been relatively small, once the initial post-war population shifts ended, thus reducing the degree of confounding of the analysis. Fourth, Poland has an extensive network of centrally and regionally collected statistics on social, economic, and health indicators of the population status, as well as on the industrial activity, tobacco and cigarette consumption, and environmental degradation.
Conceptual and Methodological Approach

In the first stage of the analysis the expected voivodship-specific mortality rates from lung and pancreatic cancers, both age standardized to the same fictitious world population, were estimated and compared with the corresponding observed rates. The portion of observed mortality that would exceed the calculated rate was assumed to include the effects of industrialization, if such exist.

Starting with the premise that cigarette smoking is the major risk factor in lung cancer, and an important one in pancreatic cancer, the calculated mortality rate is a sum of rates among smokers, former smokers and nonsmokers, weighted by their proportions in the population. Since there are large differences in the prevalence and rate of smoking between males and females, and urban and rural populations, the total mortality rate is a weighted sum of the rates contributed by each group.

In the absence of statistics on cancer rates among smokers, nonsmokers and former smokers in Poland, the rates established through the American Cancer Society-sponsored Cancer Prevention Study were used. The ACS survey was by far the most ambitious of several such studies, both in terms of design (prospective), size (1.2 million participants in 25 states), and duration of follow-up (between 1959 and 1972 (I), and again starting in 1982 (II)).

The relative risk among continuing smokers was calculated separately for men and women in urban and rural areas, and for each voivodship, based on their corresponding average smoking rates (number of cigarettes per person per day). The relative risk among former smokers was assumed to be 0.4 of that of continuing smokers, as calculated by Brown and Chu (1987), and irrespective of the smoking rate and of the number of years since cessation. The smoking rates were estimated from the data generated by random population surveys and from sales statistics in Poland, and additionally checked for consistency with each other. The quantitative relationship between smoking rate and cancer mortality rate derived from the American Cancer Society Study formed the basis for the calculations of the relative risk among continuing smokers.

The presumed latency period was imposed by the time interval covered by the available data: the earliest reliable smoking statistics extend back to 1975 while the most recent voivodship-specific cancer mortality statistics are from the 1985-88 period. This may be too short, for in the traditional ecological observations of na-
tional trends in lung cancer mortality following trends in cigarette consumption the observed lag time has been generally between 20 and 30 years. On the other hand, Kocot has found that when a 10-year latency period is assumed, the per-capita annual consumption of cigarettes in Poland gives the best statistical correlation with mortality rates from lung cancer, for both men and women (Kocot, 1991).

Results

The results of the calculations for lung cancer are summarized in Table 1. The estimated rates are well below the observed rates, for both sexes—on the average 44% and 53% for males and females, respectively—although the magnitude of the underestimation is smaller for the 9 most rural voyevodships (defined as having less than 35% of urban population). For pancreatic cancer the calculated rates also underestimated the calculated rates, on the average 60% and 37% for males and females, respectively.

Several plausible explanations for the apparent underestimates are possible: risk factors other than smoking, such as pollution, occupational exposures and/or others, may play significant roles; Polish cigarettes, which have until recently been mostly unfiltered and which are made of the heavy in tar content black tobacco, may have higher carcinogenic potency than American cigarettes made of blond tobacco; we may also be underestimating the effects of environmental tobacco smoke, especially on rural women who are the most likely to be nonsmokers married to smokers, although the magnitude of that unaccounted effect would be relatively small.

In order to further explain the spatial inhomogeneity of cancer rates in Poland, and the possible origins of the "unexplained" fraction of cancer, in the second part of analysis the calculated and observed rates of lung cancer and pancreatic cancer were plotted against voyevodship-specific percent of urban population (Figs 3 and 4). In both figures, degree of urbanization is a good predictor of calculated rates. This is because voyevodship-specific average per capita cigarette consumption is associated with the degree of urbanization, especially for women for whom urbanization is a key determinant of smoking prevalence.

In all cases there is a notable correlation between observed rates and degree of urbanization. This may be due to the underestimation of the potency of Polish cigarettes, the magnitude of which would increase proportionally to the calculated
rate. Alternatively, it may additionally reflect other factors related to the degree of urbanization, such as pollution, occupational exposures, and other hazards. The convergence of the calculated and observed regression lines for female lung cancer at zero urbanization at a level corresponding to the rate among nonsmokers is consistent with both explanations. In that hypothetical entirely rural voyevodship only approximately 7% of women are smokers: with the smoking effect small and no effect of urbanization and industrialization, the factors responsible for the gap between the calculated and observed rates are insignificant so that the lung cancer rate in that county closely approximates that for nonsmokers. The coherence of these observations gives additional credence to the methodology used in the analysis.

In contrast to females, the prevalence of male smokers in a hypothetical zero voyevodship is approximately 50%, so the effect of smoking (including the difference between Polish and American cigarettes) is present even at that point. Assuming that at that point other factors that contribute to the correlation between urbanization and cancer and to the discrepancy between calculated and observed rates are nonexistent, the difference between observed and calculated rates can be entirely attributed to the potencies of the two types of cigarettes. Since the prevalence of smoking among urban and rural males is similar, the ratio of observed to calculated rates, approximately 2, is the measure of that potency ratio.

The correlation between degree of urbanization and pancreatic cancer in men and women in Poland resembles that for lung cancer in men. Clearly, the observed and calculated rates for women neither converge at zero nor approach the rate of nonsmokers because smoking is not an overwhelming risk factor in the etiology of pancreatic cancer. For comparison, little correlation can be observed between mortality from stomach cancer and degree of urbanization (not shown here).

In order to examine the possible effect of factors other than cigarette smoking on cancer rate, voyevodship-specific rates were calculated using the potency factor of 2, and the resulting difference between observed and calculated—expressed as (O-C) and O/C—were plotted against degree of urbanization, percent of population employed in industry, and annual particulate emissions from heavy industry per unit surface area (tons/km²). The latter two variables are rather indirect measures of population exposure to occupational and environmental pollutants and should not be overinterpreted.
Executive Summary

As shown in Figures 5 and 6, degree of urbanization can partially explain the variability in (O-C) and O/C among voyevedships, while no such correlation was observed between cancer and either percent employed in industry or air pollution index (not shown). For pancreatic cancer little correlation between O-C or O/C and any of the above variables could be observed (not shown). The ratio of the average O/C values for 9 most urban and 9 most rural counties—which we term "urban factor" in lung cancer—was 1.2 for men and 1.4 for women.

Discussion and Conclusions

The excess rate of cancer among urban dwellers, relative to their rural counterparts, has been observed as far back as the 50s in other industrialized countries. There is a considerable agreement, though by no means a consensus, that this excess, which persists after correcting for smoking, and which is known as "the urban factor" in lung cancer, can be at least partially attributed to air pollution. Estimates of the contribution of air pollution to lung cancer in urban areas, based on different methodological and conceptual approaches, and all saddled with considerable uncertainty, have ranged from 2 to over 10% (Clement Associates 1983; Pershagen, 1990; Greenberg 1983; Doll and Peto, 1981; EPA, 1990; Jedrychovski, 1990a).

Our initial estimate of the magnitude of the urban factor in Poland —1.2 and 1.4 for men and women, respectively—is consistent with earlier observations in the U.S. and other industrial countries. Two very different interpretations suggest themselves. From one perspective, if technological development and associated changes, including urbanization and environmental degradation, had a major effect on population health, a larger magnitude of the urban factor would be observed. On the other hand, considering the relatively short time that has passed since Poland departed from its predominantly rural character (the process had began only four decades earlier), and given the slow response of cancer mortality in a population to any environmental and social stimuli, this is a significant difference indeed.

Furthermore, the outliers in Figures 5 and 6 tend to lower the slope of the regression curves and lead to underestimation of the urban factor.

To what extent can the urban factor in Poland be attributed specifically to air pollution? Two lines of evidence point in favor of a significant contribution from air pollution. First, the factor exists for lung but not for pancreatic cancer, which is consistent with the biological hypothesis that the lung is the primary target organ.
Executive Summary

for the effects of airborne carcinogens. (The absence of the urban factor in pancreatic cancer must be interpreted with caution, however, because it may be only a statistical phenomenon due to the lower statistical power of the pancreatic mortality data. It will be helpful to perform a similar analysis for kidney and bladder cancers which should behave analogously to pancreatic cancer). Second, no relationship was observed between urbanization and mortality from stomach cancer (not shown) which is presumably not affected significantly by either air pollution or smoking.

On the other hand, percent of urban population only partially explains the regional differences in the magnitude of the unexplained fraction of lung cancer in Poland. The variability in data is large and there are several significant outliers. Furthermore, although no correlation with either percent employment in industry or with the spatial density of particulate emission rates from heavy industry in individual vojvodships were found, these are rather poor indicators of actual population exposure to carcinogenic air pollutants in ambient air and in the workplace. A correlation between direct human exposure measures such as average concentrations of airborne particulate matter, and cancer (so far impossible because of the lack of data) is necessary for further interpretation of these results.

Another indication that air pollution may not play a prominent role in lung cancer mortality in Poland comes from the geographical distribution of the vojvodships with the highest "unexplained" fraction of lung cancer. While these tend to be located in the western part of the country (Fig. 7), the overlap with the vojvodships with most extensive environmental degradation (Fig 1) is poor. In contrast, there is a striking similarity between the geographic distribution of the vojvodships with the highest intensity of social pathologies, namely alcohol abuse, crime rate and divorce rate (Fig. 8) and the map of the "unexplained" fraction of lung cancer in Poland.

Noting that the vojvodships with high rates of social pathology tend to be located in the territories that were annexed from Germany in 1945, Halik (1992) hypothesized that the population living in these areas, largely migrants from the east during the post-war resettlement period, continues to experience the aftershock of that uprooting after several decades. It is plausible that the excess of lung cancer not attributable to tobacco consumption may be related to the same history of social stress. That hypothesis is consistent with the findings made by Rychtarikova in Czechoslovakia (1992) that spatial distribution of life expectancy inversely corre-
related with divorce rate and percent of Gypsy population, and not with ambient concentrations of air pollutants.

The hypothesis that social factors other than environmental and occupational pollution largely explain the lung cancer mortality not accounted for by smoking—possibly in a synergistic or cocarcinogenic mode with smoking or/and minor pollution effects—needs to be rigorously tested. If valid, it may explain why the observed lung cancer rates for men and women in Warsaw voyevodship and for men in Lodz voyevodship—the two most urbanized districts of Poland—are significantly lower than calculated on the basis of cigarette consumption (the outliers in Figures 5 and 6). Both voyevodships are located in the region that is at the heart of traditionally Polish territory and therefore would not have experienced this post-war syndrome. The high rate of cancer among women in Lodz, who also exhibit the highest rate of infant mortality and pregnancy complications in Poland, may be linked to their extensive employment in the textile mills of Lodz voyevodship, where working conditions have traditionally been hazardous to health. Social pathology may be therefore higher among women in Lodz voyevodship than among men but for different reasons than in other highly urban voyevodships. A rigorous analysis of the spatial dependence of individual voyevodships on each other, implicitly and incorrectly assumed in our analysis to be independent variables, combined with a deeper sociological analysis, may shed light on this question.

In summary, no strong evidence has emerged in support of an association between pollution and lung cancer in Poland. The results show that percent of urban population—and not employment in polluting industries or emission of air pollutants—can partially explain geographic variations in the urban factor in lung cancer, though the relationship must be viewed as tentative. The magnitude of that factor is in the range of 1.2 and 1.4 for men and women, respectively. The voyevodships with the highest fraction of "unexplained" lung cancer seem to correlate with the regions of high alcoholism, divorce and crime rate, and other social pathologies, and are not consistently located in the areas of either high air pollution, percent of population employed in industry, or the highest air emission factors in Poland. Furthermore, these leading voyevodships also tend to be located in the territories that were annexed from Germany at the end of the second world war (and which are also among the most urbanized in Poland).
Based on these results, and echoing the work of others in Poland, we hypothesize that the social uprooting associated with major population resettlement in Poland during the post-war years may have produced living conditions adverse to good public health, and that indicators of social pathologies—and not those for pollution, occupation, or other technological hazards—may best explain the geographic patterns of cancer in Poland. This hypothesis will be tested through follow-up studies.
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Many other individuals in Poland made significant contribution to this work, through discussions, constructive criticism, sharing data, and compiling statistics. Particularly important among those were, in no particular order: Professors Jan Kopeczynski and Janusz Halik at the Institute of Social Medicine in Warsaw, Dr. Jan Sobotka at the National Hygiene Society, Professor Jan Indulski and Dotzent Neonila Szeszenia-Dobrowska at the Institute of Occupational Medicine in Lodz, Professor Lucyna Frackiewicz at the Economic Academy in Katowice, Mr. Ryszard Janikowski at the National Center of Environmental Protection in Katowice, Professor Wladyslaw Jedrychowski at the Medical Academy in Krakow, Professors Stefan Rywik, Witold Kupsc, Janusz Bejanrowicz and Dr. Bogdan Jasinski at the Cardiology Institute in Anin, Professor Witold Zatonski and Dotzent Wronkowski at the Institute of Oncology in Warsaw, Professor Danuta Koradecka at the National Institute of Worker Protection in Warsaw, Dr. Wojtyniak at the National Institute of Hygiene, and Mr. Lech Gradowski at the National Bureau of Statistics.
Dr. Clark Heath, Jr. of the American Cancer Society provided the unpublished data from the Cancer Prevention Study II on cancer mortality among smokers, ex-smokers, and non-smokers, for which we are grateful.

Reiner Morgan, a Master's degree candidate in the Program in Environment, Technology, and Society at Clark University, expertly and patiently performed calculations and statistical analysis for this project, and made contribution to the preparation of the final report.

*Halina S. Brown*

*October 1992*
Figure 1

Sulfur Deposition and Concentration in Poland in Mid 1980's

Concentration, expressed as ug/m$^3$ of S

Deposition, Expressed as t/km$^2$-year of S

From: Institute of Environmental Protection, 1990
Figure 2

Distribution of Cancer Mortality in Poland 1985-88 (All Sites)

A. Females

B. Males

From: Tycynski, 1990
Table 1

Percent of Observed Lung Cancer and Pancreatic Cancer Calculated

<table>
<thead>
<tr>
<th>Cancer Site</th>
<th>Potency Factor</th>
<th>Average for 49 Counties</th>
<th>Average for 9 most Rural Counties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>F</td>
</tr>
<tr>
<td>Lung</td>
<td>1</td>
<td>44</td>
<td>53</td>
</tr>
<tr>
<td>Pancreas</td>
<td>1</td>
<td>60</td>
<td>37</td>
</tr>
</tbody>
</table>

Calculated from 1975 cigarette consumption patterns in Poland observed rates in 1985-88.
Table 2

Smoking-Related Factors Contributing to Under- and Over-Estimation of Lung Cancer Risks in Poland on the Basis of U.S. Data

<table>
<thead>
<tr>
<th>UNDERESTIMATES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of filtered cigarettes</td>
</tr>
<tr>
<td>Black vs. blond tobacco</td>
</tr>
<tr>
<td>Synergistic effects of smoking pollution, occupational exposures and other carcinogenic factors</td>
</tr>
<tr>
<td>Effects of environmental tobacco smoke (especially among rural women)</td>
</tr>
<tr>
<td>Time since cessation among ex-smokers</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OVERESTIMATES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration of smoking (especially women)</td>
</tr>
<tr>
<td>Age at start of smoking (especially women)</td>
</tr>
<tr>
<td>Latency period</td>
</tr>
</tbody>
</table>
Figure 3

Observed and Calculated Lung Cancer Rates vs. Percent of Urban Population

A. Females

B. Males
Figure 4

Observed and Calculated Pancreatic Cancer Rates vs. Percent of Urban Population

A. Females

B. Males:
Figure 5

O-C Mortality Rate from Lung Cancer vs. Percent of Urban Population (potency factor 2)
Figure 6

O/C Mortality Rate from Lung Cancer vs. Percent Urban Population (potency factor 2)

A. Females

B. Males
Figure 7

Geographic Distribution of the "Unexplained" Fraction of Lung Cancer in Poland (O-C)

A. Females

B. Males
Figure 8

Geographic Distribution of Divorce Rate, Crime Rate, and Alcohol Consumption in Poland

From: Halik, 1992