

STUDY OF EARLY APPEARANCE OF SKIN LESIONS IN COAL  
GASIFICATION WORKERS

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A retrospective cohort morbidity study was conducted among workers employed at the Kosovo coal gasification plant and a reference population of open-pit lignite miners. The aim was to determine the rate of early skin cancer and pre-cancerous skin lesions. In 15 years of commercial operation of the coal gasification plant, seven workers were diagnosed with benign skin tumors, six with pre-cancerous skin diseases, but none with skin cancer. The lesions were significantly fewer than were reported earlier over a shorter time period and in a smaller population at a coal hydrogenation plant. Compared to the reference population who received medical care in the same clinic, gasification workers had a lower skin cancer rate, but a higher rate of benign skin tumors and potentially pre-cancerous skin diseases.

*Key terms:* coal gasification plant, lignite coal miners, occupational exposure, precancerous skin lesions, skin cancer.

This paper addresses the question of whether a high, early incidence of skin cancer and pre-cancerous lesions, reported at a coal hydrogenation plant in the 1950's, also occurred at the Kosovo coal gasification plant in Priština, Yugoslavia.

Conversion of coal to gaseous and liquid products liberates various chemical agents into the work environment. Potential exposure to carcinogens arises from tars and oils on work surfaces and gases and particles including aromatic hydrocarbons, polycyclic organic matter, oxygenated and nitrogenated organic materials and trace metals released to the workplace air (1). Concern arose for potential cancer hazards at coal conversion plants based on carcinogenic and mutagenic properties of these intermediate products and emissions and on a report by *Sexton* of a high incidence of skin cancer and pre-cancerous lesions in coal hydrogenation plant workers after only

five years of exposure (2). Sexton and other authors reported skin abnormalities in 14% of 359 men employed at a coal hydrogenation plant which operated in Institute, West Virginia, during the 1950's (2-5). This was a large-scale pilot plant for production of chemicals with a design capacity of 300 tons of coal per day (2, 3). Initial diagnosis ranged from less than three months to nine years, eight months after first employment at the plant. Of these, 10 were diagnosed with skin cancers; these diagnoses ranged from nine months to over nine years after first employment in the plant, with an average of 4.9 years (6). This contrasts with a typical latent period for chemically induced occupational skin cancers of 15-50 years (7). The number of skin cancers was reported to be significantly elevated over expected (3). Forty workers were determined to have pre-cancerous lesions of the skin, including pitch acne, chondrodermatis helioides, keratoses, acanthoses and hyperkeratoses (2, 6). Early skin cancers at the Institute plant seemed to indicate either high exposure levels or presence of potent carcinogens. In addition to their clinical importance, these cancers were viewed as possible harbingers of a future increased cancer mortality.

Exposure of animals in inhalation chambers to a simulated coal-tar aerosol increased the incidence of skin tumors as well as tumors of the lung (8). Based on cutaneous applications of various oils and tars on mice, *Bingham and Horton* found that a 4- or 5-ring polycyclic aromatic hydrocarbon must be present to produce cancer, but the rate of appearance of tumors is significantly affected by other compounds present; such co-carcinogens may be as important as the carcinogenic materials in determining the skin cancer risk (7). In response to concerns for risks associated with synthetic fuel production and use, the U.S. Department of Energy sponsored studies spanning 10 years which, among other factors, evaluated about 40 materials for dermal carcinogenicity in two-year animal exposures or in six-month initiation/promotion bioassays (9). High molecular-weight, high-boiling range polycyclic aromatic hydrocarbon fractions were found to be most carcinogenic to mouse skin.

The Health Effects Study at the Kosovo Coal Gasification Plant was a comprehensive study of industrial hygiene practices, exposure and health effects at a commercial-scale coal gasification plant. The epidemiological data base for the study was described in an earlier paper (10). Background information will be summarized briefly below. A broad range of potential health effects were investigated (11, 12). This paper addresses the question of whether an early, high incidence of skin cancer and pre-cancerous lesions similar to that reported by Sexton existed at the Kosovo plant during its first 15 years of commercial operation. Insufficient time has passed since the plant start-up for any more traditionally occupationally-induced cancer to be seen in Kosovo workers yet, but the population size and exposure time are sufficient to find the early skin cancer effect if it existed. In addition to comparisons with the Sexton study, a sample of 500 Kosovo open-pit lignite miners was used as a reference population.

## SUBJECTS AND METHODS

### *Facility description*

The Kosovo coal gasification plant began commercial operation in 1971. It is located near Priština, Yugoslavia, in the Autonomous Province of Kosovo. It is operated by Electro-Economy of Kosovo (EEK), which employs about 20 000 people overall and operates lignite coal mines and large coal-fired electric power plants in addition to the gasification plant. The gasification plant consists of six Lurgi gasifiers and is designed to convert 80 Mg/h (88 tons/h) of lignite coal into 60 000 Nm<sup>3</sup>/h (35 000 scfm) of clear product gas with an energy content of 17 million J/m<sup>3</sup>N (450 BTU/scf) that is used as an industrial fuel source. Additional products include a variety of liquid hydrocarbons and anhydrous ammonium hydroxide. The Kosovo plant has a larger capacity and a larger workforce than the Institute, West Virginia plant studied by Sexton.

### *Cohort description*

The plant has a workforce of about 530; a total of 747 people had ever been employed at the plant through 1980. The study population consisted of all males who were ever assigned to the gasification plant through 1980 and a comparison sample of 500 open-pit lignite miners. Women were excluded from the analysis because of the small number in the population. Subjects were characterized by date of birth, sex, dates worked, smoking habits, and for smokers, number of cigarettes smoked per day, and number of years smoked. This information came from their employment and medical records. In a few cases, information on date of birth or employment was not available; these individuals were excluded from the analysis. Characteristics were similar in both populations except that there was a higher job turn-over rate at the coal gasification plant (Table 1).

### *Medical data*

Workers at both the gasification plant and lignite mine received all primary medical care at the EEK Department of Occupational Health. Medical records were maintained using a standard medical records system which exists throughout Yugoslavia. Under this system, all diagnoses were encoded by trained physicians at the time of diagnosis using the three-digit International Classification of Diseases (ICD) code (13). Workers received periodic (typically annual) medical examinations. Gasification plant workers and lignite miners were examined at the same clinic by the same physicians using the same diagnostic criteria. These examinations were part of the routine occupational medical care at EEK, and no specific research protocol was applied. All suspected tumor cases identified at the EEK Clinic were referred to the University of Kosovo Medical Center in nearby Priština for biopsy and pathologic diagnosis. Reports of pathology and subsequent treatment are retained in the patient's medical records at the EEK Department of Occupational Health. Workers who left the gasification plant or mine to work in other parts of EEK (the majority of those who left) continued to receive the same periodic medical exams at the Occupational Health Clinic; although

Table 1.

*Characterization of population in 1980*

	Coal gasification plant	Lignite mine
Total number	757	500
Excluded		
Women	88 (11.6%)	21 (4.2%)
Incomplete data	47 (6.2%)	9 (1.8%)
Underground mining experience	0	28 (5.6%)
Included in analysis	622	442
Statistics on those included in analysis:		
Person-year exposure	6615	5053
Average years experience	10.0	11.4
Average age	34.2	35.5
Left job before 1980	156 (25.1%)	8 (1.7%)
Percent smokers	28%	31%

they were no longer included in the calculation of person-years exposure, medical follow-up continued in an uninterrupted manner. Workers who left EEK were lost to follow-up.

All diagnosed cases of skin cancer, benign skin tumors, and other skin lesions were abstracted from the medical records of the gasification plant workers and the lignite miners from their date of first assignment through 1985 or earlier termination from EEK. Only those diagnosed after commercial operations began were included in this analysis. The analyzed data set characterized data only by 3-digit ICD code. Sexton's characterization of «precursors of skin cancer» was more detailed than 3-digit ICD code (2). Following his definitions, however, we included all cases of benign skin cancer, ICD 701 (hypertrophic and atrophic conditions), and ICD 706 (diseases of sebaceous glands). The result was a broader range of diagnoses than included by Sexton.

*Exposure data*

Exposure data were collected during several multi-day campaigns conducted between 1981 and 1985 using area and personal sampling (14). Since there were no significant changes in the physical plant or operating conditions over the life of the plant, it is assumed that measurements made in the 1980's were representative of exposure workers received during the period 1971-1980. Air exposures in the plant were highly variable even within limited areas and over short time periods. No measure of direct contact exposure was available. There was, however, obvious extensive surface

contamination throughout the gasification plant and little use of personal protective equipment by workers. In this analysis, length of employment in the gasification plant after commercial operations began in 1971 was used as a surrogate for exposure (some workers were assigned several years earlier for training, design and start-up operations).

#### *Analysis*

Incidence rates were calculated on a person-year basis by age group and age-adjusted rates determined, adjusting all groups to the combined Kosovo population age distribution. Although medical follow-up continued through 1985, tracking of employment and exposure ended in 1980. Thus, person-years exposure for the Kosovo population are underestimated, leading to an overestimate of incidence rate. A separate calculation was made of incidence rates as of 1980. Rates are compared among the three populations.

### RESULTS

Exposure sampling results are summarized in Table 2. Eight-hour personal sampling results showed that coal tar pitch volatiles (benzene soluble particulate substances) at the plant ranged from 22480.01 to 1.2 mg/m<sup>3</sup>; detailed analysis, however, showed only 2- and 3-ring polycyclic aromatic hydrocarbons (15). In contrast, air measurements of benzo(a)pyrene, a 5-ring compound, averaged 0.1 mg/m<sup>3</sup> at the Institute plant (5).

Table 2.

*Summary of personal sampling results, Kosovo Coal Gasification Plant  
(from Brandt and co-workers, ref. 14)*

Contaminant	Mean (mg/m <sup>3</sup> )	Range (mg/m <sup>3</sup> )
Benzene	0.16	<0.02 - 20.
Total hydrocarbons	0.42	<0.02 - 43.
PAH	0.03	<0.002 - 0.62
CTPV	0.03	<0.01 - 1.2
Total particles	0.22	<0.01 - 10.

There were no cases of skin cancer among the gasification plant workers and two cases among the lignite miners. In contrast, Sexton reported five cases of verified skin cancer in his 342 workers over five years; this is a significantly higher rate than found in either the gasification plant workers or miners. Among gasification plant workers there were 13 cases of potentially pre-cancerous lesions (seven benign skin tumors and six other potentially pre-cancerous skin diseases) with exposure ranging from less than one to nine years (average 4.9 years). Five of these were followed for more than 10 years

Table 3.  
*Incidence of skin cancer and precancerous lesions*

Age	Institute, WV <sup>a</sup>		Kosovo Gas		Kosovo Miners	
	Per-y	Cases	Per-y	Cases	Per-y	Cases
<25	60	0	1962	4	922	3
25-34	815	14	2930	6	1990	1
35-44	625	18	1358	3	1384	3
45-54	185	9	268	0	539.5	0
55>	25	1	10	0	120.5	0
Total	1710	42	6528	13	4956	7
Rate <sup>b</sup>		18.1		1.9		1.5

<sup>a</sup> From Sexton, ref. 2

<sup>b</sup> Rate per 1000, age adjusted to combined Kosovo population

since first diagnosis and the others at least five years without any sign of progression. Among lignite miners there were two skin cancers and seven cases of potentially pre-cancerous lesions (all potentially pre-cancerous skin diseases other than benign tumors) with exposure ranging from 5 to 17 years (average 5.2 years). With the exception of one case diagnosed in 1984, all these were followed over 10 years since first diagnosis without any sign of progression. The comparison of pre-cancerous skin lesions is given in Table 3. The difference between Sexton's population and the Kosovo gasification workers is statistically significant. The difference between the Kosovo gasification workers and miners is not statistically significant.

#### DISCUSSION AND CONCLUSIONS

The experience of a high, early skin cancer rate at the Institute plant did not occur at the Kosovo coal gasification plant. This is seen by direct comparison between the two populations and by comparison of the Kosovo population with lignite miners who received primary medical care in the same clinic. No cases of skin cancer were diagnosed in the workforce of the Kosovo coal gasification plant during its first 15 years of operation. The number of benign skin tumors and other potentially pre-cancerous skin diagnoses was an order of magnitude lower than reported by Sexton for workers in a coal hydrogenation plant, a statistically significant difference. Neither the skin cancer rate nor the incidence of pre-cancerous lesions was significantly different in the gasification plant workers than in the reference lignite miners. Both populations continue to be followed.

Several reasons can be offered for the findings. Exposures in the gasification plant

were most likely lower and of lower carcinogenic potency. Concentrations of SO<sub>2</sub> at the Kosovo plant were low; SO<sub>2</sub> has been shown experimentally to increase the rate of cancer formation from exposure to polycyclic aromatic hydrocarbons synergistically (15). The average age of Kosovo workers was younger than the Institute workers. Finally, Institute, West Virginia is the center of an industrial and agricultural chemical industry. It is possible that the Institute workers had earlier exposure in other processes which pre-sensitized them.

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#### Sažetak

#### PROUČAVANJE RANE POJAVE TUMORA KOD RADNIKA GASIFIKACIJE UGLJA

Kod radnika zapošljenih na gasifikaciji uglja obavljena su proučavanja morbiditeta i nalazi su uspoređeni s nalazima kod rudara lignita. Svrha ove analize sastojala se u proučavanju da li se kod radnika gasifikacije uglja pojavljuje visoki procenat ranog ispoljavanja raka kože i prekanceroznih lezija sličnih onim opaženim kod radnika zapošljenih na hidrogenizaciji uglja. U toku 15 godina komercijalnog rada postrojenja za gasifikaciju uglja utvrđeni su kod sedam radnika benigni tumori kože, kod šest radnika prekancerozno stanje kože, a ni kod jednog od njih nije nađen karcinom kože. Učestalost ovih poremećaja bila je znatno manja nego kod manje grupe radnika koji su radili kraći vremenski period na hidrogenizaciji uglja. Broj malignih poremećaja bio je znatno niži, ali benigni tumori kože i potencijalne prekancerozne promene kože bile su nađene kod većeg procenta u radnika gasifikacije uglja nego u komparativnoj grupi rudara sa otvorenog kopa lignita, koji su inače praćeni u istoj zdravstvenoj ustanovi.

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*Ključne riječi:* postrojenje za gasifikaciju uglja, rudari u rudnicima lignita, profesionalna izloženost, prekancerozne promene kože, karcinom kože.