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Vinyl Chloride: Its Impact on Occupational Medicine Practice in Iran

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Upon the establishment of a positive relationship between occupational exposure to VCM and angiosarcoma of the liver, strict precautionary measures for the protection of VCM exposed employees in the Abadan Petrochemical Company have been instituted. All such workers have been required to have pre-employment and annual medical examinations with emphasis on liver functions. Among 43 such employees who have undergone regular medical evaluation in the past three years, no instance of liver dysfunction or angiosarcoma has been discovered.

The Iranian Standards Institute reviewing occupational health data and local conditions provisionally set in 1976 a TLV of VCM of 25 ppm TWA for 8 hours with revision foreseen for 1977.

It is believed that such precautionary measures should be revised and improved according to available data and knowledge and that variations in other environmental and local factors which may well play an important role in the potential pathogenicity of the exposure should be carefully considered in determining the extent of the precautionary measures and standards in each locality.

A bombshell hit the petrochemical industry worldwide when evidence in the USA was reported in 1974 linking angiosarcoma of the liver and exposure to vinyl chloride monomer (VCM) and polyvinyl chloride (PVC).¹ This was further supported by experimental and epidemiologic studies,² leading to the development of new standards and work practices.³ The suddenness of the identification of VCM as a carcinogen and its potential adverse effect on the health of the workers, on the health of the community in which the plant is located, and on the users of the product had a profound effect in Iran. Technical measures were immediately taken at the Abadan Petrochemical Company (APC) to improve

the working conditions in its VCM and PVC units. A new medical monitoring program was established for the workers in these units.

More important, perhaps, was the further realization by the industrial physicians in the National Iranian Oil Company that they had a vital role to play in the well being of their company. Three problems had to be addressed, and while all have not been entirely resolved, each has been examined thoroughly.

1. What TLV for vinyl chloride should be adopted in Iran? The 1 ppm TLV adopted as the OSHA/USA standard might not be applicable to the specific geographical and local conditions of Iran.

2. What should be the decision regarding the VCM entrained in the manufacture of PVC? In the Western countries, PVC containing more than a certain amount of VCM would have to be treated as a carcinogen.

3. Is our PVC plant improperly located? PVC manufacture and all supporting chemical processes are near a residential area.

The purpose of this article is to describe the medical protective measures taken to control the hazard during the manufacture of PVC and to examine the impact of this new occupational hazard on the practice of occupational medicine in Iran.

History of the Problem

Evidence of vinyl chloride's toxicity has been noted for many years. In 1938, when commercial production of PVC was begun by B. F. Goodrich Company, experiments showed that VCM used at the plant was dangerous to animals.⁴ A 1949 Russian report showed that VCM caused nonmalignant liver damage in 15 out of 48 workers exposed to the chemical.⁵ Surveys in the other European countries over the next decade and a half confirmed the above relationship.⁶

A connection between VCM and cancer was first made in 1971 by Viola et al, of the University of Rome, who found tumors in the lungs, skin, and bones of rats exposed to high concentrations of the gas.⁷ In January 1974 B. F. Goodrich Company reported that since 1971 three men who worked in its Louisville, Ky., PVC manufacturing plant had died of angiosarcoma of the liver.¹ Because of the extremely low incidence of this disease, estimated to be ap-

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Table 1. — Reported Cases of Angiosarcoma of the Liver Among Vinyl Chloride Polymerization Workers. (Up to February 1977)

Country	No. of Cases	Age at Diagnosis	Yrs. from 1st Exp. to Dia	Total Yrs. Exp.
Canada	10	(Awaiting Details)		
Czechoslovakia	2	40 & 46 (43)	15 & 16 (15.5)	15 & 16 (15.5)
Federal Rep. Germany	5	38 to 49 (42.8)	11 to 17 (14.2)	11 to 12 (11.6)
Federal Rep. Germany	2	(Awaiting Details)		
France	7	38 to 63 (48.4)	10 to 29 (20.8)	10 to 29 (19.4)
Great Britain	2	37 & 71 (54)	9 & 26 (17.5)	4 & 20 (12)
Italy	2	43 & 55 (49)	15 & 22 (18.5)	6 & 21 (13.5)
Japan	1	52	22	22
Norway	1	56	22	21
Sweden	1	43	19	18
United States	17	37 to 61 (48.2)	12 to 32 (20.4)	4 to 32 (17.9)
United States	4	(Awaiting Details)		
Yugoslavia	2	42 & 59 (50.5)	20 & 23 (21.5)	18 & 20 (19)
Total	56	37 to 71 (54 - median)	9 to 32 (20.5 - median)	4 to 32 (18 - median)

Of the 56 cases, there are 36 deaths, 4 alive, 16 awaiting details. Figures in brackets represent means.

Source: National Institute of Occupational Safety and Health, Department of Health Education and Welfare, Cincinnati, Ohio.

proximately 20 to 30 deaths per year in the United States, the appearance of four cases in a five-year period in one plant led to the conclusion that a new occupational cancer — angiosarcoma of the liver — had been discovered.³

This was buttressed by the animal work of Professor Cesare Maltoni,⁴ who demonstrated induction of angiosarcoma of the liver and other organs, as well as the production of other cancers in rats exposed to vinyl chloride.

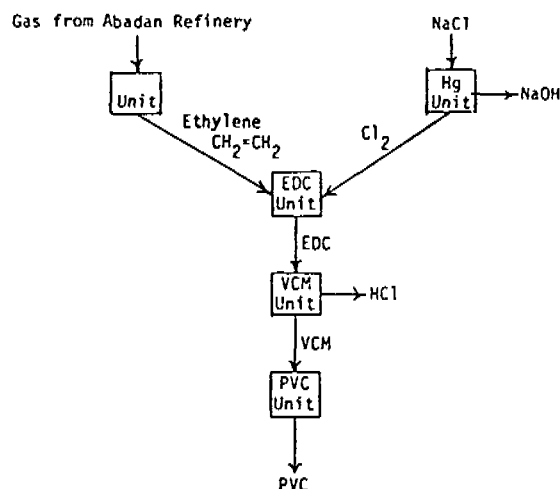
Later, Tabershaw and Gaffey released their industry-wide epidemiological study of vinyl chloride workers which suggested increased numbers of malignant neoplasms at other body sites.²

Up to the present time, a total of 56 identifiable cases of angiosarcoma of the liver have been uncovered throughout the world with at least 36 deaths⁶ (see Table 1).

Description of Plant and Operation

The manufacture of PVC in Iran started in 1969 by the APC as a joint venture of the National Iranian Petrochemical Company with the B. F. Goodrich Company. The initial annual production rose from 20,000 tons to 60,000 tons by the end of 1976. The plant employs approximately 650 people, of whom 43 are employed in VCM and PVC production.

At the APC the manufacture of PVC is a totally contained operation. That is, chlorine is first produced by the electrolysis of salt. Then ethylene dichloride ($\text{CH}_2\text{Cl}-\text{CH}_2\text{Cl}$) is made by the reaction of the gases ethylene and chlorine. Ethylene dichloride is transformed to vinyl chloride monomer ($-\text{CH}_2-\text{CHCl}-$) in special reactors. The VCM passes by pipe to the polymerization plant, where it is mixed with water, an emulsifier, and a catalyst and reacted under pressure in an autoclave (reactor) to produce a slurry of polyvinyl chloride. This slurry is then dried and further processed to produce PVC powder. PVC powder is packaged and supplied to other factories where it is used for the manufacture of PVC pipes, cable coverings, floor coverings, shoes, etc. A simplified



Simplified flow chart of PVC production at Abadan Petrochemical Company.

fied flow chart of the processes used at the APC is shown in the figure.

Control Measures

The possibility of a relationship between angiosarcoma of the liver and occupational exposure to vinyl chloride drew the attention of responsible management from the very beginning. Immediately after the receipt of the relevant information, urgent and important steps were taken to safeguard the health and safety of employees in the Abadan PVC manufacturing plants. The following areas of control have been established; training, area monitoring, personnel monitoring, restricting entry into regulated areas (these being areas that have a potential to cause exposure to VCM in excess of the permissible limits), rigid medical surveillance of employees exposed to VCM and comprehensive maintenance of employee records. Details of the program are very similar to those prescribed by the OSHA regulations.

Medical Surveillance Program. — Since 1971, 650 employees of the APC have been subjected to periodic medical screening. Since 1974, the 43 employees of the VCM and PVC units have been subjected to a complete annual medical examination requiring the following steps: (1) Medical history, (2) Occupational history, (3) Physical examination, and (4) Laboratory tests of CBC, urinalysis, SMA-12, chest x-ray and x-ray of the hands.

In addition, the pre-employment and periodic examination of these employees must include: (a) Physical examination methods to detect diseases of the liver or spleen. (b) History of alcoholic intake, hepatitis, exposure to hepatotoxic agents, blood transfusions, and previous hospitalization.

Thirty-four of these employees are 26 to 35 years old; nine are 36 to 40 years old. Thirty-nine have been working in VCM and PVC manufacturing units since the commissioning of the units in 1969, and the remaining four have worked in these units for three to five years. The incidence of cigarette smoking is relatively low among these employees (only nine of 43 smoke 5 to 20 cigarettes a day). Alcohol consumption is very low (only five drink a little beer or vodka occasionally). None has given a previous occupational history of exposure to any known hepatotoxic agent. Only one employee could recall having had hepatitis. Since hepatitis is endemic in the area, some of the other employees can be expected to have had mild or subclinical cases in the past.

The above mentioned annual check-ups have thus far been repeated in three consecutive years. None of the employees had

Table 2. — Threshold Limit Values for Vinyl Chloride Monomer in Different Countries.

Country	Year	Threshold Limit Value of Vinyl Chloride Monomer
Belgium	1975	25 ppm TWA (8 hours), 50 ppm (15 minutes)
Canada	1975	10 ppm TWA (8 hours), 25 ppm TWA (15 minutes)
Finland	1975	5 ppm TWA (8 hours), 10 ppm TWA (15 minutes)
France	1975	25 ppm TWA (8 hours)
Germany	1976	10 ppm Personal Maximum, 30 ppm ceiling
Iran	1976	25 ppm TWA (8 hours), 50 ppm TWA (1 hour) review in 1977
Italy	1975	50 ppm TWA (8 hours), Future 25 ppm TWA (8 hours), 50 ppm TWA (15 minutes)
Japan	1975	25 mg/m ³ , approximately 10 ppm
Netherlands	1975	10 ppm TWA (8 hours)
Sweden	1975	5 ppm TWA (8 hours), 20 ppm TWA (15 minutes)
	1976	1 ppm TWA (8 hours), 5 ppm TWA (15 minutes)
Switzerland	1975	100 ppm
	Future	10 ppm TWA (8 hours)
United Kingdom	1975	25 ppm TWA (8 hours), 50 ppm TWA (15 minutes)
October	1975	10 ppm Personal TWA, 30 ppm ceiling
United States	1975	25 ppm TWA (15 minutes)
	1976	1 ppm TWA (8 hours), 5 ppm TWA (15 minutes)
USSR	—	30 mg/m ³ , approximately 12 ppm

Source: Iranian Standards Institute

any complaints, such as excessive fatigue, somnolence, paresthesia or aches in bones or joints. The physical examinations and routine tests (urinalysis, complete blood count and other blood chemistries) have revealed no significant abnormalities. Liver function tests and radiologic examinations have all been within normal limits. No thrombocytopenia, finger clubbing, or signs or symptoms referable to Raynaud's phenomenon, acro-osteolysis, detectable liver damage, or cases of angiosarcoma of the liver were discovered.

Threshold Limit Value. — VCM had been identified as a hepatotoxic agent⁹⁻¹⁰ (it is a chlorinated hydrocarbon) and has been incriminated in producing the disease acro-osteolysis.¹¹ Its TLV (threshold limit value) before 1974 was set at 500 ppm. In 1974, the OSHA (USA) set the emergency standard of 50 ppm for VCM, and, in 1975, limited employee VCM exposure to 1 ppm 8 hours TWA (time weighted average) and 5 ppm 15 minute TWA, based upon its newly found carcinogenic properties.

Since 1974, most of the countries having PVC manufacturing plants have lowered their TLV for VCM. The USA and Sweden have lowered their TLV for VCM to 1 ppm 8 hours TWA; Canada, West Germany, Netherlands and UK have reduced this to 10 ppm; and Iran and many other countries have reduced their TLV for VCM to 25 ppm 8 hours TWA. (Table 2 shows the TLV of VCM in 14 different countries.)

Considering the marked differences which exist in various countries and PVC manufacturing plants (i.e., differences in climate, humidity, prevailing wind, plant location and design, ethnic group, alcohol intake, diet, prevalence of hepatitis, etc.), it seems appropriate that in setting the TLV for VCM, more consideration should be given to these geographical, ethnic and other differences.

The Iranian Standards Institute in 1976 set the TLV of VCM provisionally at 25 ppm TWA for eight hours with revision foreseen for 1977. The committee setting this standard consisted of the representatives of the Iranian Standards Institute, the Environmental Conservation Organization, the Ministry of Labor and

Table 3. — Environmental Measurement of Total Hydrocarbons in PVC Unit.

Location	Total Hydrocarbon Concentration
Outside of the poly building and supervisor offices	10—15 ppm
Phys No 1 to No. 16	17—30 ppm
Blend tank openings	50 ppm
Control room and control panel	14—25 ppm
Bagging station	30 ppm
PVC warehouse	20 ppm

Total Hydrocarbons has been determined using an OVA instrument and include VCM concentration.

Social Affairs, the Ministry of Health and Social Welfare, and the Abadan Petrochemical Company. The committee had to reach its recommendations entirely empirically based upon the local conditions.

In reviewing our results and comparing them with those of other countries, it seems that apart from such differences as ethnicity, low alcohol consumption, the endemic nature of viral hepatitis in the area and low incidence of cigarette smoking, dietary habits may also play a role. Rice, after all, comprises a greater part of the diet of these workers than of those on standard Western diets.

The climatic conditions of the working and living areas are also different from those in most of the other PVC plants of the world. In Abadan the average summer temperature is about 40° C (in the shade) with a maximum in 1975 of 49° C. The average humidity is 40% with maximum spells of 100% in summer. The average winter temperature is 13 to 15° C, with a minimum in 1975 of 1.1° C. The average wind velocity is 35 knots. All work is carried outdoors.

Among the 43 employees of the VCM and PVC manufacturing plants of the APC who have had varying degrees of exposure to VCM for a period of eight years, no evidence of acro-osteolysis, liver damage or angiosarcoma of the liver has been detected. Taking into account the relatively short exposure period of these employees (three to eight years) and the fact that in the USA the average latent period from first exposure to VCM to diagnosis of angiosarcoma has been about 19 years, perhaps one should not expect to find angiosarcoma cases in APC at the present time. Hence, our experience up to this time cannot be taken as a sufficient guide. Continued vigilance with area monitoring and medical surveillance will be carried out and reported upon at periodic intervals.

Entrained VCM. — The present PVC manufactured at the APC is for use in Iran. Studies are being carried out to determine the amount of VCM entrained in the APC product, but at this time no special techniques to limit the amount of VCM in the manufactured PVC have been instituted. It is unlikely that the entrained VCM liberated when the PVC is used would exceed the present threshold limit for Iran. This PVC is not used for the manufacture of food containers or wrapping material for food stuff. Studies are being planned to monitor workers exposed to PVC dust in the manufacture of the resin.

Community Effects. — The Abadan Petrochemical Company is located near residential and manufacturing areas. As far as is known, there has been no release of substantial amounts of VCM which might affect the community. However, on a few occasions, chlorine had been released from the manufacturing complex causing evacuation of a grade school at the edge of the industrial complex. The irritation from chlorine and the recognition that VCM

could be harmful motivated the Abadan Petrochemical Company to assist in relocating the grade school to a location at some distance away no longer in the path of the prevailing winds. The former school site is now used as warehouse with minimal personnel.

Summary

1. Awareness that VCM has been demonstrated to be a carcinogen producing a rare tumor, angiosarcoma, has led the company to tighten its medical monitoring and industrial hygiene controls.

2. A temporary TLV has been established for VCM at 25 ppm consistent with the operating procedures of the company and local geographical conditions.

3. The potential harm from industrial chemicals has stimulated the government and the company to support further control of in-plant and outplant environmental hazards from industrial operations.

Thanks are due to the management of Iranian Oil Industry for their permission for the publication of this article. Also thanks are due to my colleagues in Abadan for the preparation of the data.

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Some Words to the Wise on a Search Committee

Be wary of silent physicians,
Repressions erupt from within.
Be careful with smiling technicians,
Disasters lurk under the grin.
Consider the partly disabled,
They always seem eager to try.
Be cool to the Famous and Fabled:
They may say hello (and good-bye).
Resist the aggressive audacious,
Their courage may only be fear.
Take heed of the lucid loquacious,
They say what they want you to hear.
Beware the heroic unharried,
They'd rather be elsewhere instead.

Look out for the stoic unmarried,
They may take a bottle to bed.
Select the eclectic and gifted,
The CV will give you the clue.
Can someone be lured or conscripted,
Or is (s)he too good to be true?
Keep searching for something elusive,
The issue cannot be resolved.
You must be concisely conclusive,
Before you are ordered dissolved.
Assignment is finally finished,
A candidate seems to emerge.
Adrenal reserves are diminished,
Farewell! It is time to submerge.

— From a Letter to the Editor by Melvin Hershkowitz, MD., in *The New England Journal of Medicine*, July 14, 1977.