〔報 文〕

KOR. J. ENVIRON. TOXICOL.
Vol. 4, Nos. 3～4, 87～95 (1989)

Present Status of Nonregulated Pollutants and their Management in Korea

Yong Chung*

Professor & Director, Department of Preventive Medicine & The Institute for Environmental Research
Yonsei University College of Medicine

1. Introduction

The use of new chemicals has increased dramatically over the last forty years. utilization of synthetic organic chemicals has increased more than 300 fold in the 1980's compared to the 1950's. At the end of the 1970's more than 60,000 natural and synthetic chemicals were used in daily life and perhaps 1,000 more new chemicals have been introduced into the market every year[3].

Production and consumption of these chemicals, and their residues in the environment pollute ambient air, water, food and soil. As a result, the enviroment pollute ambient air, water, food and soil. As a result, the environmental pollution of toxic substances and their adverse effect to public health has greatly increased. In an effort to set up regulations for toxic substances in the ambient air, only the ambient air quality standards of primary pollutants such as SO_2, NOx, oxidants, CO, TSP and HC (hydrocarbons) etc, were established.

The U.S. EPA has proceeded with enormous continuous studies concerning the regulation of air toxic substances since the Clean Air Act in 1970. The Clean Air Act reguired NAAQS (national ambient air quality standards) to regulate any pollutant which may endanger public health and welfare. Pollutants in the air result from numerous diverse mobile and/or stationary sources[3].

Six primary pollutants were regulated in 1971, and later on October 5, 1978, one more pollutant, lead, was added. The EPA has periodically reviewed and revised the NAAQS which at first were intended to establish emission standards for non-criteria air toxic substances; the last NAAQS have hot been established for any recent air toxic substances within the last 10 years.

In Korea, national ambient air quality standards (NAAQS) were established for sulfur dioxide, carbon dioxide, nitrogen oxide, TSP, oxidants, and hydrocarbons. As the demand for a healthy environment increases, NAAQS nowaday emphasize the study of the risk of air toxic substances and this salient problem. In order to protect public health from air pollution and to avoid conflict between economic growth and pollution, intense preliminary studies for controlling air toxic substances are needed.

Environmental acts and standards and air monitoring systems should have been first established during short periods between 1963 to 1980.

*This paper was presented at the 1st Korea-Japan Environmental Science & Technology Symposium on November 22～24, 1988 Seoul

The Korean NAAQS for primary pollutants has been adapted from foreign regulations without a scientific review of the applicabilty to the situation in Korea. As a result, the national levels of ambient air pollution have not been evaluated.

As the national consensus for a better life has increased, it is now necessary to control and regulate air pollutants more strictly according to Korea's present social and economical status.

This report shows the results of the author's research on ambient air pollution by nonregulated pollutants such as heavy metals and polycyclic aromatic hydrocarbons. Also, the author comments on recommendations for the direction of the study and policy.

2. Present status of air toxic substances in Korea

The important nonregulated air pollutants in Korea, such as polynuclear aromatic hydrocarbons and heavy metals, were studied.

The greater part of the survey was conducted in Seoul, the capital city where about ten million people reside. This most important area for risk assessment of air pollutants in Korea. The author has researched the increasing ambient air pollution throughout Seoul.

a. Polynuclear aromatic hydrocarbons (PAHs)

As many of the PAH species have been demonstrated to be carcinogenic to animals and probably to human beings, concerns regarding environmental contamination have arisen.

The major PAHs identified by capillary GC —Mass spec. in Seoul are listed in Table 1, 4 Many carcinogenic PAHs, for example, isomers of benzofluoranthen, benzo(a)pyrene, benz(a) anthracene, indeno (1,2,3-c.d) pyrene, dibenzopyrene, and so on were determined in Seoul ambient air.

Table 1. Polynuclear aromatic hydrocarbons identified in Seoul and their carcinogenic activities as reported in literature

Compounds	Carcinogenic activity
1. Phenanthrene	0
2. Anthracene	0
3. Methylanthracene	0
4. Methylphenanthrene	0
5. 4H-cyclopenta(d,e,f)-phenanthrene	—
6. Ethylphenanthrene	0
7. Ethylanthracene	0
8. Fluoranthene	0
9. Benzacenaphthylene	—
10. Pyrene	0
11. Ethyl 4H-cyclo(d.e.f)-phenanthrene	—
12. Benzofluorene	0
13. Benzo(a)fluorene	0
14. Benzo(b)fluorene	0
15. Ethylmethyl-phenanthrene	—
16. Ethylmethylanthracene	—
17. Methylpyrene	0
18. Benzo(g,h,i)fluoren	0
19. Benzo(a)anthrancene	+
20. Chrysene	+
21. Benzo(j)fluoranthene	++
22. Benzo(b)fluoranthene	++
23. Benzofluoranthene	++
24. Benzo(e)pyrene	0/+
25. Benzo(a)pyrene	++
26. Perylene	0
27. Methylbenzopyrene	++
28. Querterphenyl	—
29. Indeno(1,2,3-c,d)-pyrene	+
30. Dibenzanthracene	+
31. Benzo(g,h,i) perylene	+
32. Anthanthrene	—
33. Dibenzopyrene	++
34. Coronene	0/+

0: Noncarcinogenic
+: Weakly carcinogenic
++: Strongly carcinogenic
—: Not reported in literature

Table 2 shows the monthly variation in the ambient concentrations of major carcinogenic PAHs measured in Shinchon-dong in 1986.

The concentrations of all of the PAHs in the atmosphere are higher in the winter than in the summer because the winter season reguires more building heating than the other seasons. In order to precisely evaluate the air pollution of PAHs in Seoul, the monthly variation must be considered.

Table 2. The atmospheric concnetrations of several carcinogenic polynuclear aromatic hydrocarbons in Seoul during 1986 (*unit* : ng/m^3)

Compounds	Traffic area (Shinchon)	Residential area (Bulkwang)
Benzo(a)anthracene	3.31	3.31
Chrysene	4.10	3.40
Benzo(b)fluoranthene	1.68	1.76
Benzo(e)pyrene	1.23	1.02
Benzo(a)pyrene	3.01	2.02
Indeno(1,2,3-cd)pyrene	2.23	1.68
Dibenz(a,h)anthracene	0.50	0.21
Benz(g,h,i)perylene	2.76	1.50

The annual average concentration is similar to that in March, although more measurement is needed. Thus, in the case where the measurement period is limited because of economic reasons and so on, measurement of the carcinogenic PAHs in March only would be adequate.

Table 3 shows the atmospheric concentration of carcinogenic PAHs in a residential and traffic area of Seoul. Almost all of the carcinogenic PAHs investigated, especially benzo (a) pyrene, dibenz (a,h) anthracene and benz (g,h,i) perylene, show a higher atmospheric concentration in the traffic area than in the residential area. Therefore, in Seoul, the PAHs in the ambient air may pose a greater health risk to people living in traffic areas than to the people in residential areas.

b. Oxygenated neutral compounds

The oxygenated neutral compounds represent o-heterocyclic hydrocarbons, epoxides, perox-

Table 3. The annual average atmospheric concentration of polynuclear aromatic hydrocarbons in a residential area and traffic area of Seoul (Sep. 1987-Jul. 1988) (unit: ng/m^3)

Month	Benzo(a)anthracene	Chrysene	Benzo(b)-fluoranthene	Benzo(e)-pyrene	Benzo(a)-pyrene	Indeno(1,2,3-cd)-pyrene	Dibenz(a,h)-anthcacene	Benz(ghi)-perylene	Coronene
Jan.	1.57	3.60	1.98	1.94	2.66	1.89	0.44	2.76	1.36
Feb.	1.35	2.11	0.88	1.36	2.52	1.84	0.40	2.21	0.92
Mar.	1.08	1.95	1.03	0.76	1.31	1.21	0.41	1.23	0.79
Apr.	0.45	0.85	0.57	0.44	0.47	0.60	0.13	0.72	0.52
May.	0.39	0.73	0.61	0.46	0.58	0.68	0.13	0.80	0.52
Jun.	0.13	0.27	0.31	0.27	0.46	0.38	0.12	0.47	ND
Jul.	0.07	0.29	0.10	0.22	1.10	0.24	ND	ND	ND
Sep.	0.10	0.15	0.17	0.12	0.19	0.13	0.05	0.05	ND
Oct.	0.25	0.42	0.31	0.22	0.35	0.30	0.06	0.04	0.24
Nov.	2.41	3.25	1.88	1.42	2.31	1.74	0.29	1.94	1.09
Dec.	3.07	3.94	2.40	1.70	3.65	2.27	0.52	2.46	1.43
Mean ±SD	0.99±1.02	1.60±1.45	0.93±0.80	0.81±0.67	1.33±1.24	1.02±0.79	0.23±0.18	1.15±1.03	0.62±0.54

ides, aldehydes, ketones, sugars, quinones, esters, and lactones. Several of the oxygenated neutral compounds are very toxic to experimental animals.

According to the mutagenic risk assessment for suspended particulate collected in Seoul, the oxygenated neutral compounds showed the highest mutagenic effect of the organic fraction[5].

Oxygenated compounds identified and determined in the Seoul atmosphere were 9-fluorenone, anthracenedione, benzanthrone and several phthalates[5]. The atmospheric concentrations of these compounds determined in Seoul during 1986 are shown in Table 4. The atmospheric concentrations of these compounds are also higher in winter than in summer. More research on these compounds is necessary to develop the risk assessment.

c. Heavy metals

Table 5 shows the annual average atmospheric concentration of heavy metals in Seoul. Lead, nickel and vanadium were higher in the Shinchon area than in the Bulkwang area. This might be due to the heavy oil for vehicles and space heating in the Shinchon area, which is a local center of Seoul for commerical and transportation needs. Mercury, arsenic and iron were higher in the Bulkwang area than in the Shinchon area. This might be due to the anthracite coal which is the main fuel in residential areas of Korea such as the Bulkwang area.

Table 4. The atmospheric concentrations of several oxygenated neutral compounds in Seoul during 1986 (unit : ng/m^3)

Month	9-Fluorenone	Anthracenedione	Benzanthrone
Jan.	0.24	0.79	1.39
Feb.	0.20	0.12	0.68
Mar.	0.04	0.24	0.78
Apr.	0.08	0.12	0.30
May.	0.32	0.12	0.28
Jun.	ND	ND	0.11
Jul.	0.11	ND	ND
Sep.	ND	ND	ND
Oct.	0.14	0.05	0.06
Nov.	0.16	0.18	0.11
Dec.	0.20	0.65	1.41
Mean±SD	0.14±0.10	0.74±0.19	0.47±0.53

Table 5. The annual average atmospheric concentration of heavy metals in Seoul (May. 1987 -Mar. 1988) (unit : ng/m^3)

Heavy metals	Traffic area (Shinchon)	Residential area (Bulkwang)
As	0.017	0.028
Hg	0.00029	0.00044
Pb	0.224	0.172
Cd	0.007	0.010
Cr	0.005	0.006
Ni	0.048	0.038
Fe	0.787	0.873
Zn	0.362	0.351
V	0.234	0.170

Table 6 shows the monthly concentrations of several heavy metals in the atmosphere. The atmospheric concentrations of these heavy metals did not reveal any special trends.

3. Direction of management of nonregulated air pollutants

a. Scientific issues for controlling and regulating air toxic substances

In order to protect human health from the toxic substances of the ambient air, regulations and standards must be established. It is very complicated to control all air toxic substances because of the limitations of present knowledge, technology capability and financial investment.

It is recommended to set priorities in control-

Table 6. The monthly variation of the atmospheric concentration of several toxic heavy metals at two site in Seoul. (May 1987-Mar. 1988) (unit: $\mu g/m^3$)

Metals / Sites / Month	As		Hg		Ni		Cd		Cr	
	S*	B**	S	B	S	B	S	B	S	B
1987 May.	0.015	0.027	0.00057	0.00067	0.085	0.066	0.0096	0.0101	0.0123	0.0144
Jul.	0.013	0.032	0.00039	0.00140	0.046	0.071	0.0074	0.0242	0.0061	0.0147
Sep.	0.020	0.021	0.00033	0.00035	0.022	0.014	0.0054	0.0081	0.0031	0.0006
Nov.	0.017	0.024	0.00033	0.00018	0.044	0.018	0.0061	0.0047	0.0012	0.0035
1988 Jan.	0.017	0.038	0.00012	0.00002	0.054	0.032	0.0084	0.0056	0.0060	0.0035
Mar.	0.019	0.026	0.0002	0.0004	0.035	0.025	0.0056	0.0046	0.0028	0.0010

* : Shinchon (traffic area)

** : Bulkwang (residential area)

ling and regulating air toxic substances through the risk quantitation and assessement of those substances most dangerous to public health.

The three following major scientific issues are felt to be the most useful to define the scope and direction of a national program for controlling toxic air substances[6]:

(1) What is the approximate magnitude of the air toxic problem, represented by the estimated cancer risk associated with selected air pollutants?

(2) What is the nature of the air toxic problem? In other words, what pollutants and sources contribute most to the problem and what is their relative importance?

(3) Dose the problem vary geographically, and if so, in what ways?

b. Risk assessment

Risk assessment has meant different things to different people. It is basically an attempt to define the probability of adverse health consquences of a specific hazardous situation[3].

Risk assessment consists of four components as shown in Fig. 1. These are[7]:

(1) Hazard identification: the determination of whether a particular chemical is or is not causally linked to a particular health effect.

(2) Dose-response assessment: the determination of the relation between the magnitude of exposure and the probability of occurence of the health effects in question.

(3) Exposure assessment: the determination of the extent of human exposure

(4) Risk characterization: the description of the nature and magnitude of human risk.

The results of risk assessment will be used as the basic information for risk management with the evaluation of public health, economic, social and political consequences of regulatory options.

Risk management for air toxic substances could be performed through the establishment of standards and through the many regulation processes.

c. The problem of the regulation of non-regulated air pollutants

The U.S. EPA's air pollutant regulatory program was initiated under section 112 of the Clean Air Act in 1971.

In August 1983, the General Accounting Office (GAO) released a report entitled "Delays in EPA's Regulation of Hazardous Air Pollutants"

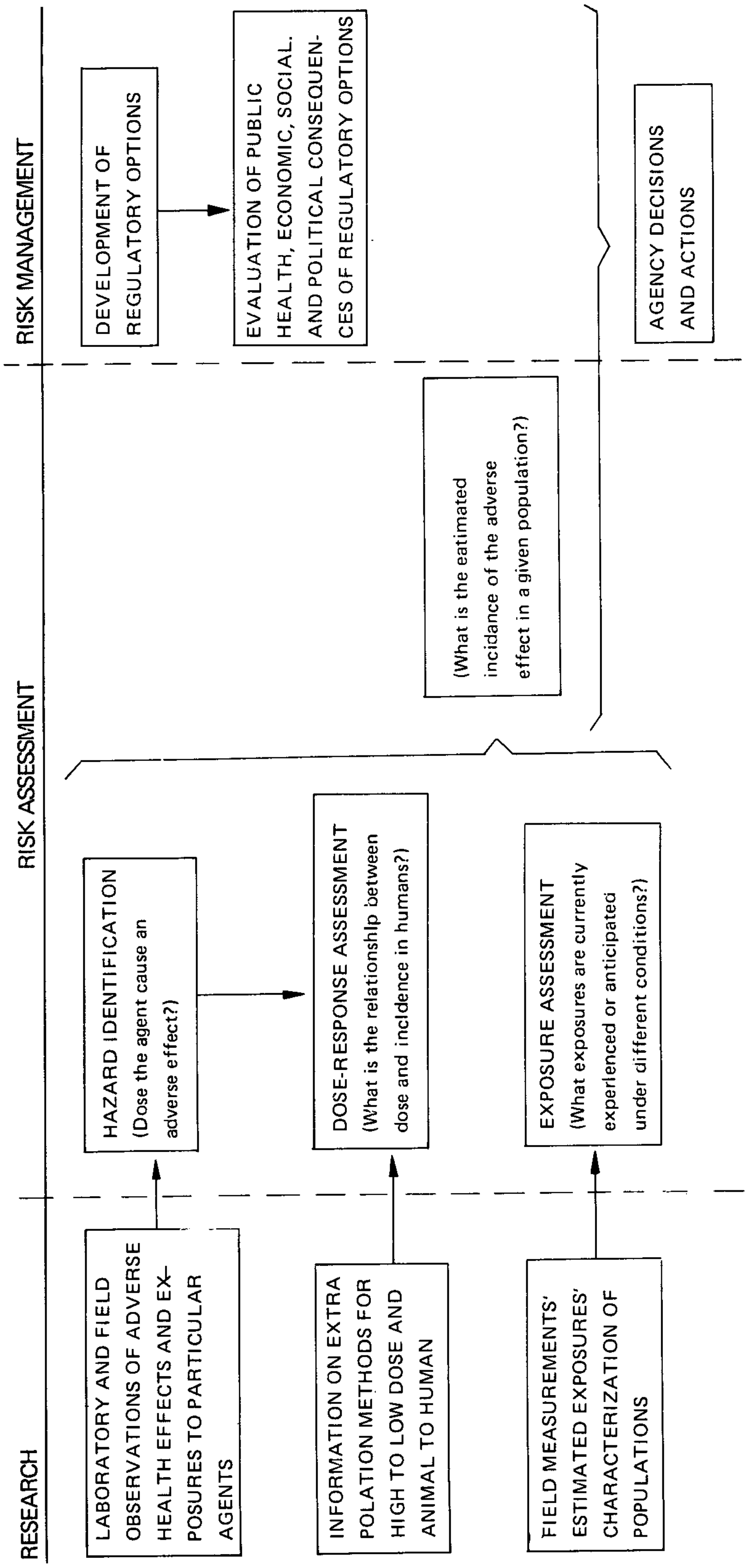

Fig. 1. Elements of risk assessment and risk magagement

and accused the EPA of acting too slowly to list and regulate hazardous air pollutants.

In response to the report, the EPA administrator was summoned by Congressmen and the Commerce Committee[6].

During internal EPA discussions about the delay in regulation, it was concluded that the magnitude or cause of the human health risk associated with toxic air pollutant exposure was not understood. This led the EPA to commission a broad study of the air toxic substances problem in the United States. As shown by a foreign country's experience, the process of regulating air toxic substances and the risk assessment of them is very complex and requires a long research period to accumulate basic data.

d. Risk assessment of nonregulated air toxic substances in Korea

Risk assessment of air pollutants as well as any toxic substances has not been established in Korea, and there are many difficulties in the immediate practice. But risk assessment should be carried out in the near future in order to manage the air quality; therefore, possible and necessary processes should be planned and practiced now.

The processes that have priority in risk assessment are as follows:

1) Listing of air toxic substances.

The first requirement is to list the toxic air pollutants for which regulation is to be established.

The survey of pollutants emitted from diverse source which have high risks to public health should be considered. There are over 1000 toxic air pollutant chemicals[3] that may cause public health problems. The U.S. EPA has listed seven substances as hazardous air pollutants under section 112 of the Clean Air Act: inorganic arsenic, asbestos, beryllium, benzene, mercury, radionuclides, and vinyl chloride. Of these, emission standards have been promulgated for asbestos, beryllium, mercury and vinyl chloride and benzene is under consideration[9]. Evaluation of 37 other agents for listing is in progress.

A NESHAP (National Emission Standards for Hazardous Air Pollutants) study has been set to estimate population exposure and risk for 42 compounds. Considering these cases for risk assessment, the Korean administration must list the prior air toxic pollutants.

There are a number of different scientific approaches that are employed to obtain pertinent data for understnading the risk of chemicals to human. These approaches can be divided into human studies, including controlled exposure experiments and epidemiology, animal studies, and short term tests such as the Ames test.

It is possible to put research results from other countries into practice. But in the case of epidemiological studies, the results and important risk factors are different for different races. So epidemiological studies of the risk of air toxic pollutants in Korea must be performed.

The utility of various short term assays in regulatory risk assessment has recently been reviewed and it was found that the cost and study duration of short term tests are less than that of epidemiological and animal tests. Short term test are frequently used to screen the large number of compounds under consideration and, therefore this is an adequate method to be developed and applied in Korea. The most commonly used short term assay is the Ames test which assays for mutagenic chemicals.

The correlation of mutagenicity in the Ames test with carcinogenicity has been reported to be as high as 90% in the Ames's laboratory to as low as 69%[10,11].

Although the ablity to use the findings for performing quantitative risk assessment is in question, there is no question that at present the various short term tests are of great value in prioritizing compounds.

The mutagenicity test is continuously developing, and its utility is probably increasing. It seems to be necessary to develop and apply the short term test actively in Korea.

2) Measurement and monitoring of toxic pollutants in air

The second step is to initiate an evaluation of the national pollution status and to establish a monitoring program for the pollutants which are known to be present in ambient air and to have adverse effects to human health. In risk assessment, exposure assessment is an important required process. This process is performed using the environmental concentration of toxic pollutants and analysis of the population exposed to toxic pollutants[7].

Monitoring data are employed to estimate ambient levels to which people are exposed to. Because of this, limited coverage and monitors are often intentionally located away from major sources. Monitoring data are often unsuitable for estimating exposure assessment, although the use of such data avoids uncertainties. So the use of dispersion modeling has an adantage in its ability to characterize the contribution of various sources and to provide more extensive geographical coverage. Modeling requires verification because of incomplete information on emission inventories, current control status, and so on. Monitoring data is necessary in the verification process. Measurement and monitoring of air toxic pollutants is required immediately to clearly present the national pollution status and seasonal and geographical variations.

Using these results, a scientific method can be established with respect to the area, period and number of survey and modeling could also be possible. Before measurement and monitoring, emphasis should be placed upon developing reliable and accurate measurement tools for the detection and quantification of a multitude of air pollutants. If the air pollutants concentrations are very low, those analyses are very difficult and complex.

Standardization of analytical methods and reduction of the difference between the analytical agencies are necessary.

3) Emission source management

The third step is to regulate the sources which emit large quantities of hazardous pollutants.

It is improtant to investigate the present status of emission sources and to regulate the emission sources even with temporary standard. National emission standards for hazardous air pollutants are to be established through risk assessment. But some temporary standards used in foreign countries seem to be useful until risk assessment and standard establishment are completed.

The application of the same standard to all emission sources in unsuitable, setting different regulated toxic pollutants to different types of sources is necessary and standards of different levels are to be applied according to the emission quantity.

Conclusion

As the use of toxic chemicals and fuels increases, it is anticipated that various pollut-

ants which have not been regulated might affect human health. A lot of air pollutants have been proved to be potent carcinogens, mutagens and/or teratogens. Some carcinogenic PAHs (poly aromatic hydrocarbons), oxygenated neutral compounds and heavy metals have been found in municipal and industrial areas. The nonregulated micropollutants must be considered in health risk assessment. According to the health risk assessment of them, the priority pollutants which can greatly affect human health should be considered and managed as soon as possible.

REFERENCES

1. United States, Environmental Protection Agency: First Annual Report to Congress by the Task Force on Environmental Cancer and Heart and Lung Disease. Washington, D.C., (1978)
2. Maugh, HT: Cancers; How many are there? Science **199**, 162 (1978)
3. Padgett, J and Richmond, H: The Process of Establishing and Rivising National Ambient Air Quality Standards. *J. Air Pollut. contro. Assoc.* **33** : 13 (1983)
4. Jang, J.Y., Chung, Y. and Jo, S.J.: Isolation and identification of polynuclear aromatic hydrocarbons in Seoul atmosphere. *J. KAAPRA* **4**(2) : 1988 in press.
5. Jang, J.Y.: Analytical studies on mutagenicity and microorganic pollutants of suspended particulate in atmosphere, Ph.D. Thesis, College of Pharmay, Seoul National University (1988)
6. Thomson, V.E., Jones, A., Haemisegger, E. and Steigerwald, B.: The Air toxics problem in the United States: An Analysis of cancer risks posed by selected air pollutants. *J. Air Pollut. Control. Assoc.* **35**(5) : 535 (1985)
7. Preuss,P.W. and Ehrlich, A.M.: The Environmental Protection Agency's Risk Assessment Guidelines, *ibid,* **37**(7) : 784 (1987)
8. Goldstein, B.D.: Toxic Substances in the Atmospheric Environment. *Ibid.,* **33**(5) : 454 (1983)
9. Patrick, D.: Status Report on Hazardous Pollutants, Technical Conference on Toxic Air Contaminants, APCA Mid-Atlantic State Section, Philadelphia (1982)
10. McCann, J., Choi, E., Yamasaki, E. and Ames, BN.: Detection of carcinogens as mutagens in salmone/microsome test: part I: assay of 300 chemicals. Proc. *Natl. Acad. Sci. U.S.A.* **72** : 515, (1975)
11. Heddle, J.A. and Burce, W.R.: Comparison of tests for mutagenicity or carcinogenicity using assays for sperm abnormalities, formation of microunclei and mutations in Salmonella, Origins of Human Cacer, Spring Harber, New York, p. 1549 (1977)