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We hope our readers will excuse us on this occasion for mentioning a practical problem concerning our journal.

Ever since the change in the single-copy and subscription prices of Euro-Spectra was announced, fluctuations in exchange rates have frequently caused considerable complications.

It has therefore become necessary to make an adjustment in order to clarify the situation once and for all.

From now on, the Euro-Spectra prices will accordingly be quoted in Belgian francs only, and we feel sure that our regular subscribers and readers, both present and future, will appreciate this sensible decision.

Water, water everywhere, nor any drop to drink...

What is being done, and what should be done, to combat the pollution of fresh water and halt the gradual degradation of the aquatic environment?

OSCAR RAVERA

A HUNDRED YEARS AGO, pollution and the consequent degradation of the environment were already a problem in many parts of the world, but in the last 25 years they have assumed great, and more general, importance owing to the population increase and the growth and spread of industry and technology-intensive agriculture.

From research into the distribution of radioactive fall-out it has been estimated that radioactive particles released into the atmosphere circle the earth in about a month; conventional

pollutants are equally prone to spread, as has been demonstrated in the case of *DDT* and lead. The area affected by these substances is therefore so much larger than the pollution's source-area that projects for pollution control should be conducted at international level.

By the same token, certain forms of marine pollution, due to hydrocarbons, for example, should be combated on a world-wide basis.

Over the last few decades the chemical industry has patented an average of 200 000 new substances a year,



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4 000 of which have found applications and have to some extent been released into the natural environment. Many pollutants, such as various heavy metals and pesticides, accumulate in living organisms, and the effects of such accumulation may be extremely serious and show up after long periods.

In recent years this state of affairs has alarmed governments and public opinion alike. The effects of pollution have been featured in numerous articles in the press and in frequent radio and television programmes, as well as being the subject of conferences and meetings. In the last two years, indeed, pollution has become a fashionable topic.

Some people have reacted to this problem with headless optimism based on a presumed limitless capacity of man and other organisms to adapt rapidly to any change in the environment due to the effects of our technological civilisation.

Others, however, have prophesied disaster. According to them, the whole of nature is irrevocably doomed, and mankind with it. New words have been coined to describe this catastrophe, so

that people speak "terricide" and "ecocide".

Clearly, neither attitude informs the public objectively, even less do they make it ecology-conscious. If, in fact, both man and the biosphere are so adaptable to environmental changes, why be concerned if ecosystems are increasingly polluted? If, on the other hand, the situation is already hopeless, concern is wasted: increased pollution can do no harm because the point of no-return has been passed.

Pollution is a serious problem and should be approached objectively and as a whole, not emotionally or bit by bit, and it must be solved by the countries in which it is worst, i.e. the most highly industrialized ones. The situation can only be tackled with the values of our own culture: it is a mistake, in terms both of ethnology and of logic, to believe that a solution can successfully be based on the values of other cultures remote from ours in time or space (some people actually believe salvation to lie in Greek or Oriental philosophy, the latter being talked about more than it is understood).

How to state the problem?

As with other problems of paramount importance (and pollution, unfortunately, is not the only problem that troubles mankind), this one too must be evaluated in terms of costs and benefits.

It is plain, however, that the definition of "costs" and "benefits" in this context cannot be the nineteenth-century one, which was based solely on immediate or short-term economic usefulness. The costs will comprise not only research expenditure, but also the capital and operating costs of treatment facilities, expenditure on the monitoring of environmental conditions and the surveillance of public health, as well as possible economic penalties due to changes in production processes. The benefits will include not only the economic ones accruing to mankind's activities (industry, agriculture and animal husbandry, fisheries, etc.) from an undamaged or restored environment, but also the hygienic, aesthetic and social benefits likely to be enjoyed by a population living in unpolluted, or only slightly polluted, surroundings.

At the start of the industrial age, consideration was given chiefly to the economic aspect of productive activities; with the passing of time the social aspect acquired ever-increasing importance: now it is essential that the ecological aspect should also be borne in mind. The cost of cleaning up the environment and preventing pollution must be shown in the accounts of firms and public authorities, just as social security contributions.

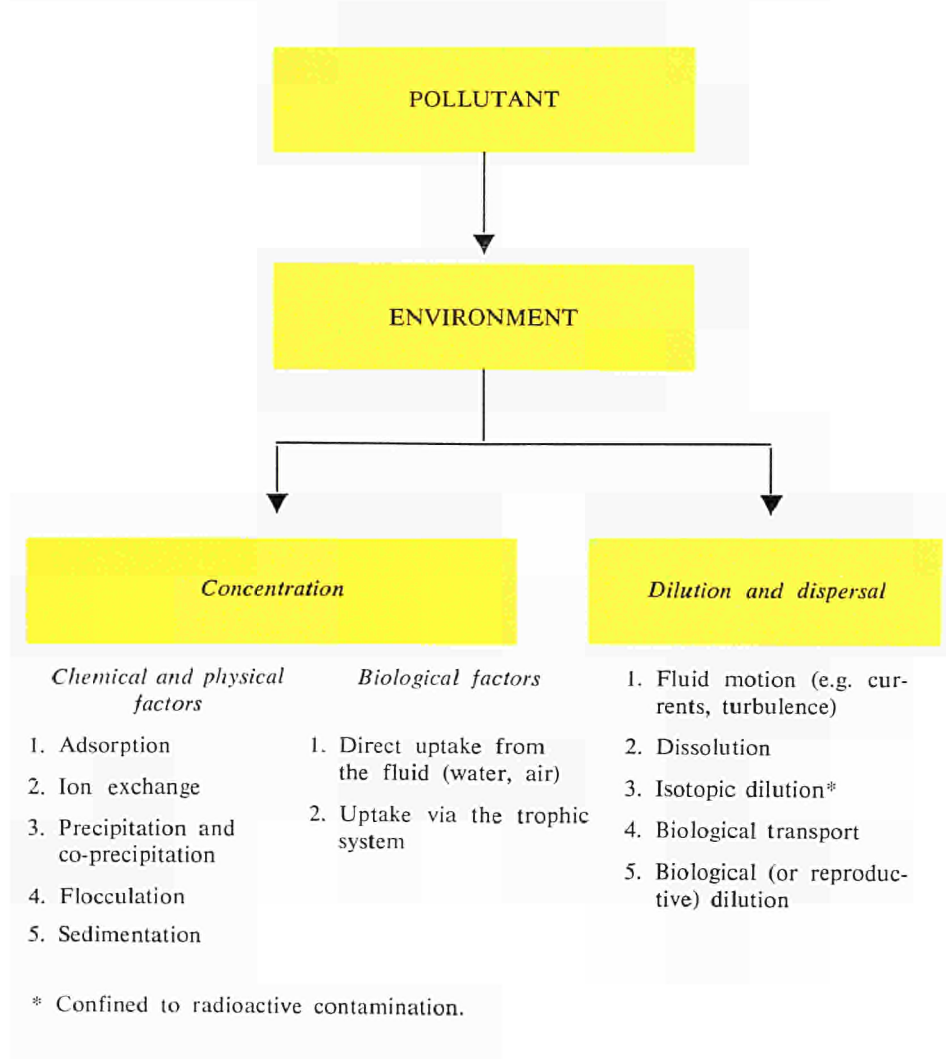
A solution to the problem of freshwater pollution, in both surface and underground waters, is becoming more and more urgent. Water requirements are growing constantly owing to the increase in the population and the rise in standards of living. At the same time, pollution of water reserves is worsening and becoming ever more widespread. The situation is aggravated by the fact that pollution is worst in the highly industrialized areas, which usually are also the most densely populated. As a result, the pollution level



Year	1967		2015	
Source:	m ³ /sec	%	m ³ /sec	%
Wells	81.0	48.1	125.5	37.3
Ground waters	71.1	42.8	119.9	35.6
Surface waters	15.2	9.1	91.4	27.1
Total	167.3	100.0	336.8	100.0

Table I: Data on water consumption in Italy in 1967 and forecasts for 2015, taken from the master plan for water resources prepared by the Italian Ministry of Public Works.

Table II: Processes causing concentration or dilution of pollutants (11).



is highest where the need for water is greatest. In the near future the protection of surface waters will assume increasing importance because they will account for a greater share of the overall public water supply.

As can be seen from Table I, the fraction of the water demand met by the use of surface waters will treble between 1967 and 2015, and consumption of such water, in absolute terms, will be six times the present figure. It was stated recently (11) that in Switzerland it will not be possible to exploit the ground waters any further, or to increase the offtake from springs, and it is therefore expected that in the future the use of lake water will take on considerable importance. At present 26% of the water consumed by the Swiss originates from lacustrine basins, and forecasts by the Italian Ministry of Public Works indicate that this level will be reached in Italy in the year 2015.

There would be no point in embarking on a general discussion of the effects of water pollution, since it would be only a rehash, good or bad, of what has already been said and written on the subject: it appears more appropriate to present in this article some considerations on the study of pollution and some of the basic concepts underlying the actions taken to combat the degradation of the quality of fresh water.

Organization of research work

The first point to make is that no form of pollution is harmful below a certain concentration. The question often asked: "Is this substance harmful?" should be rephrased to read: "In what concentration is this substance harmful?"

Unfortunately, a realistic answer to this question requires data which in most cases are lacking. Information would be needed not only on the effects of a given concentration on the most important organisms in the environmental economy as a whole, but also on its sublethal and long-term

Fig. 1: Mean life time (MLT), in hours, of the common goldfish (*Carassius auratus*) living in water contaminated with copper sulphate, with and without ABS detergent (5 mg/l) (10).

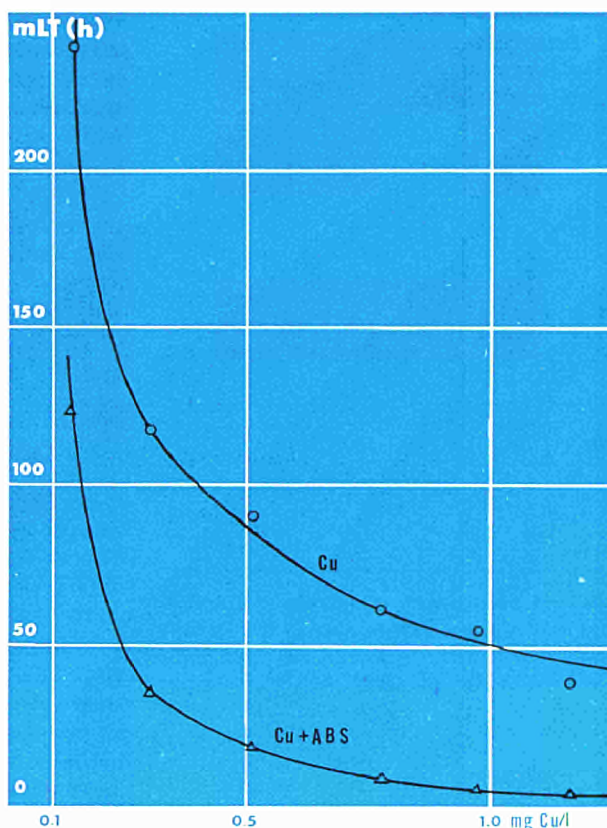
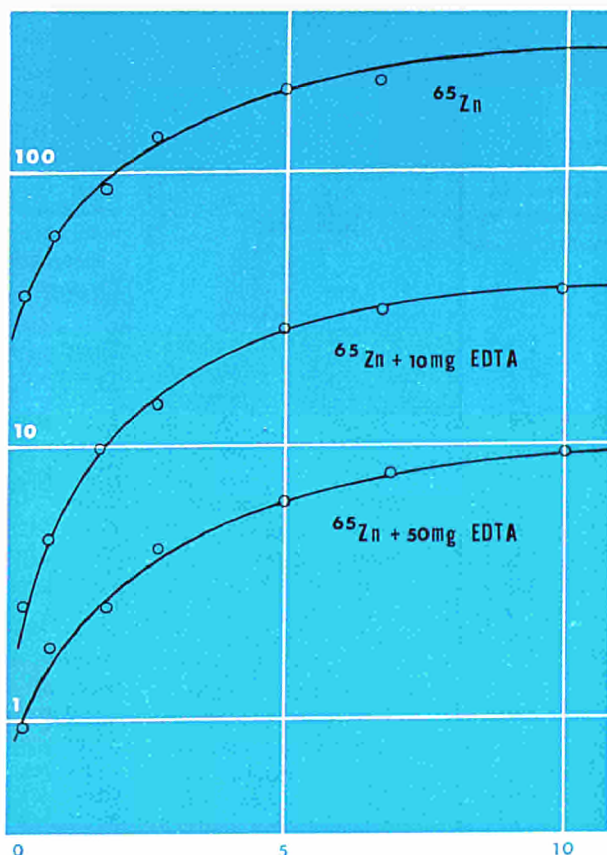


Fig. 2: Effect of various concentrations of the chelating agent EDTA on the uptake of zinc-65 by the soft tissues of the mussel (*Mytilus galloprovincialis*) (9). The concentration factor is referred to a period of ten days.



effects and on any genetic damage it may cause. We also need to know the extent to which the substance can accumulate in edible species, even—in fact, especially—when there are no obvious harmful effects. If an edible plant or animal accumulates a high concentration of a pollutant, persons eating them can ingest severe doses. In this case it would be necessary to study both the ability of the human organism to eliminate the pollutant thus ingested and the damage due to the uptake of acute and chronic doses.

In order to round off an investigation into the effects of one or more pollutants in an environment, it is necessary to know their fate in the ecosystem, and hence to study all factors tending to dilute them (currents, wave phenomena, etc.) or cause them to accumulate in the various elements of the ecosystem (sediments, aquatic plants, fish). Such investigations include studies in biology, morphometry, hydrology, water chemistry, climatology and on the sedimentological characteristics of the polluted body of water. If the water

Table III: *Tolerance limits proposed by Berbenni for effluents at the time of discharge. All values are expressed in mg/l (1).*

Characteristic	Effluents released into:	
	watercourses	sewers
pH	6.5 ÷ 8.5	6 ÷ 10
Temperature	Not exceeding 35°	Not exceeding 40°
Colour	Must not cause coloration when dissolved 1:10 in a 10 cm layer	
Matter in suspension	20-30	400-1 000
BOD ₅ at 20°C	20 (30 max)	300
KMnO ₄ demand	100	—
Free chlorine	0.1 (max 0.5)	1.2
Oils and greases extractable with petroleum ether	5	10
Detergents (ABS)	0.5	5
Phenols	0.1	1
Toxic substances — maximum values		
Total chromium: Cr ⁺³	2	—
Cr ⁺⁶	0.1	5
Cyanides: CN ⁻	0.1-0.2	—
Copper: Cu ⁺⁺	1	—
Zinc: Zn ⁺⁺	2	—
Nickel: Ni ⁺⁺	1	—
Cadmium: Cd ⁺⁺	2	—
Barium: Ba ⁺⁺	10	—
Silver: Ag ⁺	0.1	—
Arsenic: As ⁺⁺⁺	0.1	—
Mercury: Hg ⁺⁺	0.1	—
Total heavy metals	not exceeding 5	—
Sulphides (H ₂ S): S ^{- -}	1	—
Fluorides: F ⁻	10	—
Chlorides: Cl	—	1 000
Sulphates: SO ₄ ^{- -}	—	1 000

is used for agricultural purposes, drinking or recreation, these aspects must also be considered. The results of this multidisciplinary research will provide an answer to the question: "How much pollutant can be introduced into a body of water without causing direct or indirect harm to man and the environment?"

In the field of radiation protection, a similar question underlay the definition of the concept of the "radiological capacity" of an environment (7). The ecological surveys conducted before the construction of a nuclear installation, and the studies and checks carried out while it is in operation, are intended to provide the answer. True, the concept of the "radiological capacity" is concerned solely with the protection of mankind, not of the environment, but it is emphasized that the standards developed on this basis are so stringent that the environment is implicitly protected by them.

With regard to conventional pollutants, we are very far from being able to answer this question, because our knowledge is extremely limited.

In view of the admitted lack of the data needed prior to the launching of a project for controlling pollution and cleaning up bodies of water, the criteria on which the fight against pollution is based are very rough and ready.

The minor significance, in this context, of "tolerance limits for domestic and industrial effluents" will be obvious, but they are at present the sole criterion that can in practice be used to protect water from pollution (Tables III, IV and V). The reasons for their inadequacy can be given at once. First of all, these "limits" relate only to the most common pollutants and take no account of the very large number of new and highly noxious ones which are continually being added. "Limits" always have only local (e.g. provincial or national) applicability, and are not agreed upon internationally. Furthermore, they relate to the concentration and not to the quantity of pollutant discharged into the body of water, so that it may receive

various effluents, and therefore a considerable pollution burden, also if the concentration of the substances in the individual effluents remain below the predetermined levels.

Some quarters consider the "limits" in common use to be less than stringent. In the case of chlorine, nickel and copper, for example, toxic effects have been observed on fish exposed to concentrations below those resulting from limits generally regarded as somewhat severe, such as those proposed by *IRSA (Istituto di Ricerca Sulle Acque)*, the Italian Institute for Water Research.

Generally speaking, the "limits" are determined on the basis of short-term experiments (lasting a few days) conducted in conditions which, being standardized, are far from neutral, and on adult specimens of a single or only a small number of species. In most cases the criterion for assessment is the percentage survival of the exposed specimens. Very few conclusions can be drawn from these experiments; indeed, no information at all can be derived about the long-term and sublethal effects (morphological, physiological and biochemical) or the sensitivity of young and in-embryo specimens of those species experimented on in the mature, and usually most resistant, stage.

It should also be pointed out that this type of experimentation focuses on fish which are directly utilized by man, but ignores the other biological elements which are essential to the economy of their aquatic habitat, e.g. plants (algae and macrophytic plants) and invertebrates (both plankton and benthon).

The conclusion is that it would be advisable to extend both the scope and thoroughness of the experiments for the specification of "limits", and to identify organisms (or stages in their development) which are highly sensitive, typical of various environments (e.g. littoral, pelagic and deep-water) and readily usable as toxicity indicators.

Substance	Maximum permissible concentration mg/l
Aluminium	10
Arsenic	1.0
Barium	10
Lead	1.0
Cadmium	1.0
Chromium (trivalent)	2.0
Chromium (hexavalent)	0.1
Iron	1.0
Copper	1.0
Nickel	2.0
Mercury	0.1
Silver	0.1
Zinc	2.0
Tin	2.0

Table IV: Maximum permissible concentration of certain heavy metals for the discharge of waste waters into the receptors, under Swiss law (12).

Table V: Maximum permissible concentrations for certain pollutants in the water of receptors under Czechoslovakian law (12).

Substance	Maximum permissible concentration mg/l
Lead	0.1
Arsenic	0.05
Copper	0.1
Nickel	0.1
Selenium	0.05
Mercury	0.005
Cadmium	0.1
Zinc (bivalent)	5
Chromium (hexavalent)	0.1
Chromium (trivalent)	0.5
Cyanides	0.1
Hydrogen sulphide	0.5
Carbon disulphide	1
Petroleum and its derivatives, and dissolved hydrocarbons	0.1
Free chlorine	traces
Sulphides	0.5
Carbon tetrachloride	5

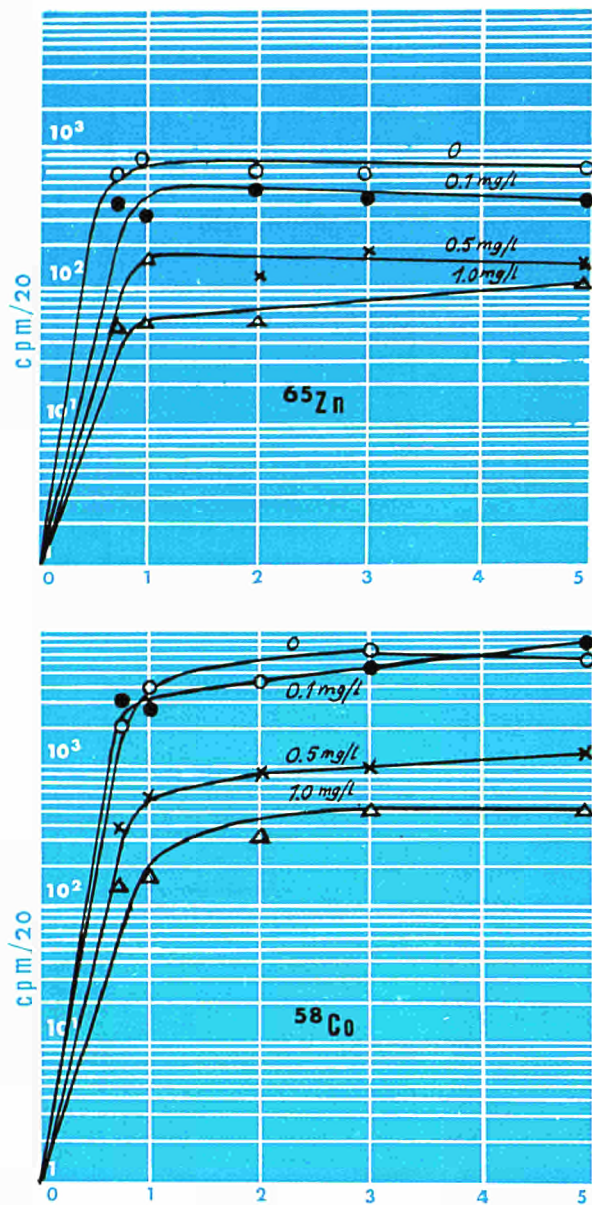
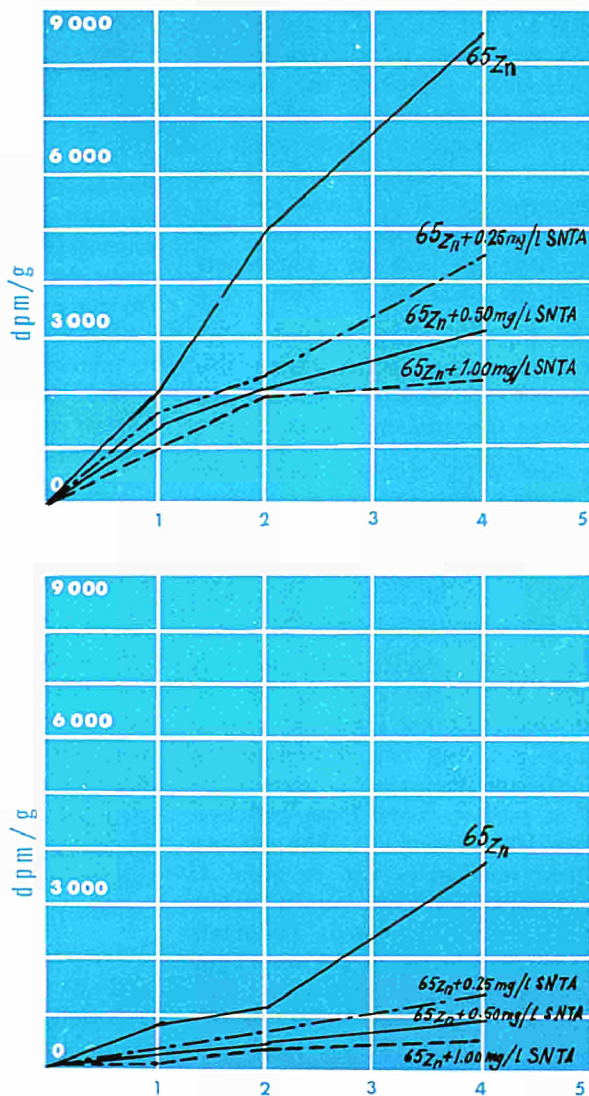


Fig. 3: Effect of various concentrations of the chelating agent SNTA on the uptake of zinc-65 and cobalt-58 by Eudiaptomus padanus (16). The data refer to the average concentration found in 20 specimens over a period of five days.

Fig. 4: Effect of various concentrations of the chelating agent SNTA on the uptake of zinc-65 by a lamellibranch mollusc (Unio mancus) (16). Quantities per gramme (fresh weight) are shown, referred to a period of four days. The upper and lower curves show the uptake of radioactive zinc by the gills and visceral sac respectively.



Number of kWh produced from 1 kg of:

Hard coal	3.31
Petroleum	4.41
Natural gas	4.85
Natural uranium	63 934.39

Table VI: *Electricity (kWh) generated from 1 kg of various fuels (6).*

Protection of water reserves

The protection of water reserves based on the classification of waters into categories relating to their pollution level has been criticized in many quarters, and recently by various delegates at the symposium held at Versailles last October by the *European Federation for Protection of Waters*. These criticisms arise from the fact that placing a body of water in a particular category will result in its being polluted up to the lower limit of the next, or more polluted, category, and will thus bring about a gradual deterioration in the quality of water generally.

The difficulty of finding an objective method of classification is considerable in that bodies of water are not normally isolated but belong to a system of ground or surface waters. Furthermore, the division of waters into categories could promote the concentration of industry along watercourses placed in the high-pollution categories, with a consequent concentration of human settlements in areas drained by the most polluted water. It will be clear that, from this point of view, the wisdom of classifying bodies of water according to their pollution level is, to say the least, doubtful.

Some European countries (e.g. the United Kingdom and France) have divided their territory into regions corresponding to the principal catchment areas, with an authority (the Water Authority) covering each one. This body has the task of preventing and suppressing the degradation of bodies of water and, in order that it

may function more efficiently, it enjoys a greater or lesser degree of independence of the existing administrative structure. The task of water pollution on the basis of hydrographical networks is better entrusted to an *ad hoc* authority than to the traditional politico-administrative system, in which areas of jurisdiction do not coincide with catchment areas.

Other things being equal, the hazard due to a pollutant depends on three characteristics: toxicity, concentration and degradability. The degradability of a substance is its ability to break down into simpler substances. The most obvious difference between the "degradability" of a pollutant and the "decay" of a radioisotope is that, whereas degradation processes for a chemical substance are highly dependent on environmental factors (biological, chemical and physical), radio-

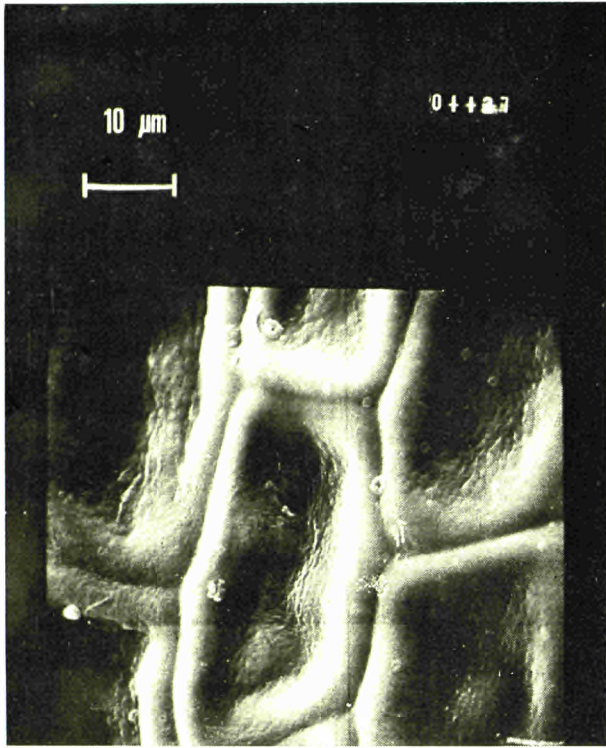
active decay is unaffected by the surroundings. It follows from this that we can predict the decay of a radioactive substance, but it is extremely difficult to forecast the rate of degradation of a pollutant in natural environments. For this reason, the results of laboratory tests on the degradability of contaminants, being difficult to extrapolate to the conditions prevailing in a natural environment, can be of little significance. Although certain pollutants, e.g. heavy metals, are undoubtedly persistent, others, such as certain detergents and pesticides, are certainly degradable, but in many cases it is difficult to make a realistic estimate of their degradability. It must also be pointed out that a substance cannot always be considered harmless simply because it is readily degradable, since the substances into which it breaks down may be dangerous and, in some

Table VII: *Algae production in oligotrophic and eutrophied lakes (17).*

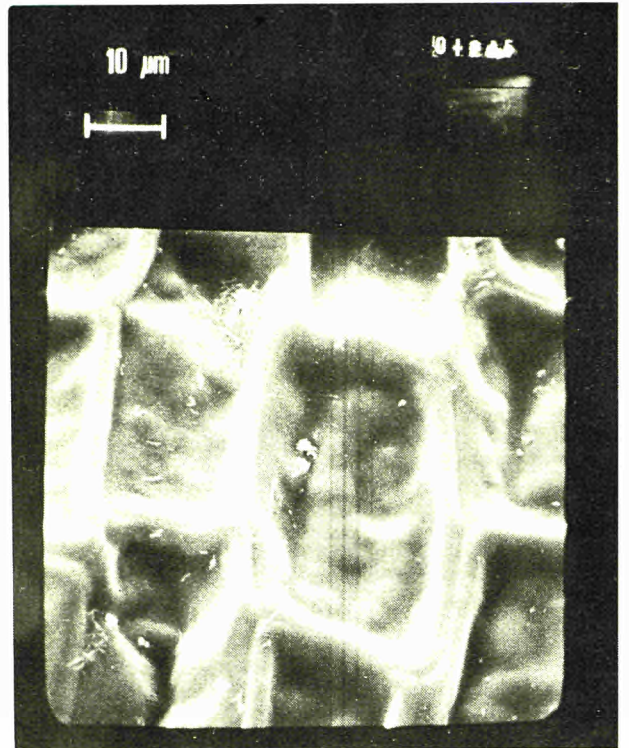
Algae production	Oligotrophic lakes	Lakes eutrophied	
		by natural causes	by pollution
During the period of maximum increase (mg C/m ² · day)	30-100	300-1 000	1 500-3 000
Annual average (g C/m ² · year)	7- 25	75-250	350-700

Table VIII: *Discharge of phosphorus (P-PO₄) into Lake Erie, United States (20).*

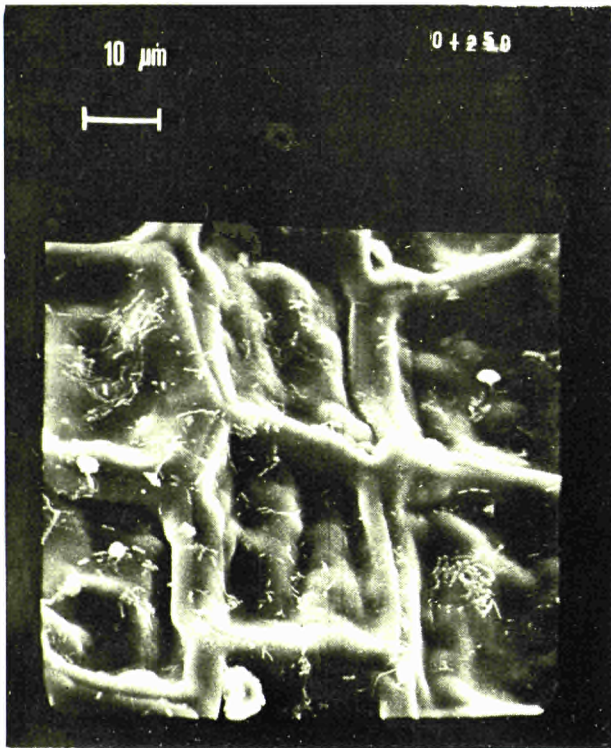
Source	kg/day
Lake Huron	> 9 080
Run-off from farmland	9 080
Municipal sewages:	
Detergents	31 780
Human excreta	13 620
Urban soil	2 724
Industrial effluents	2 724
Total	> 69 008



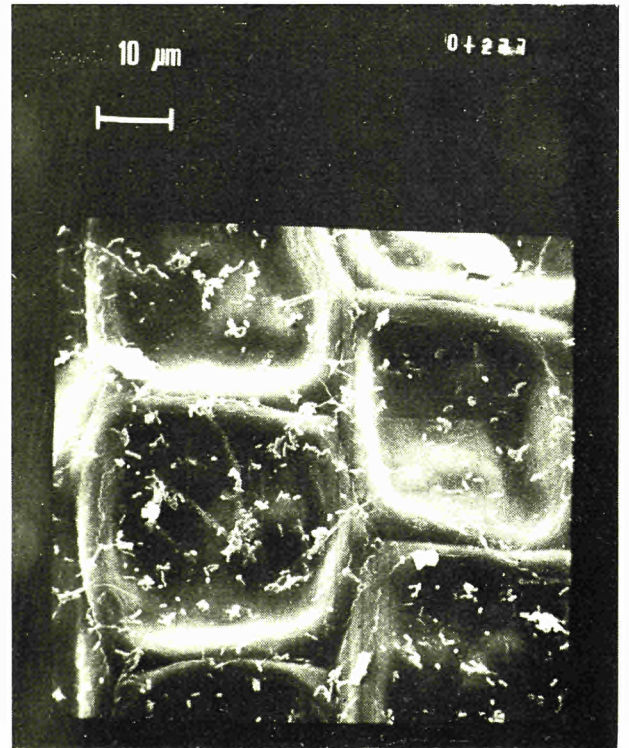
a



b



c



d

Fig. 6: Research programme on the trophic state of lakes (Ispra Establishment, Joint Research Centre).

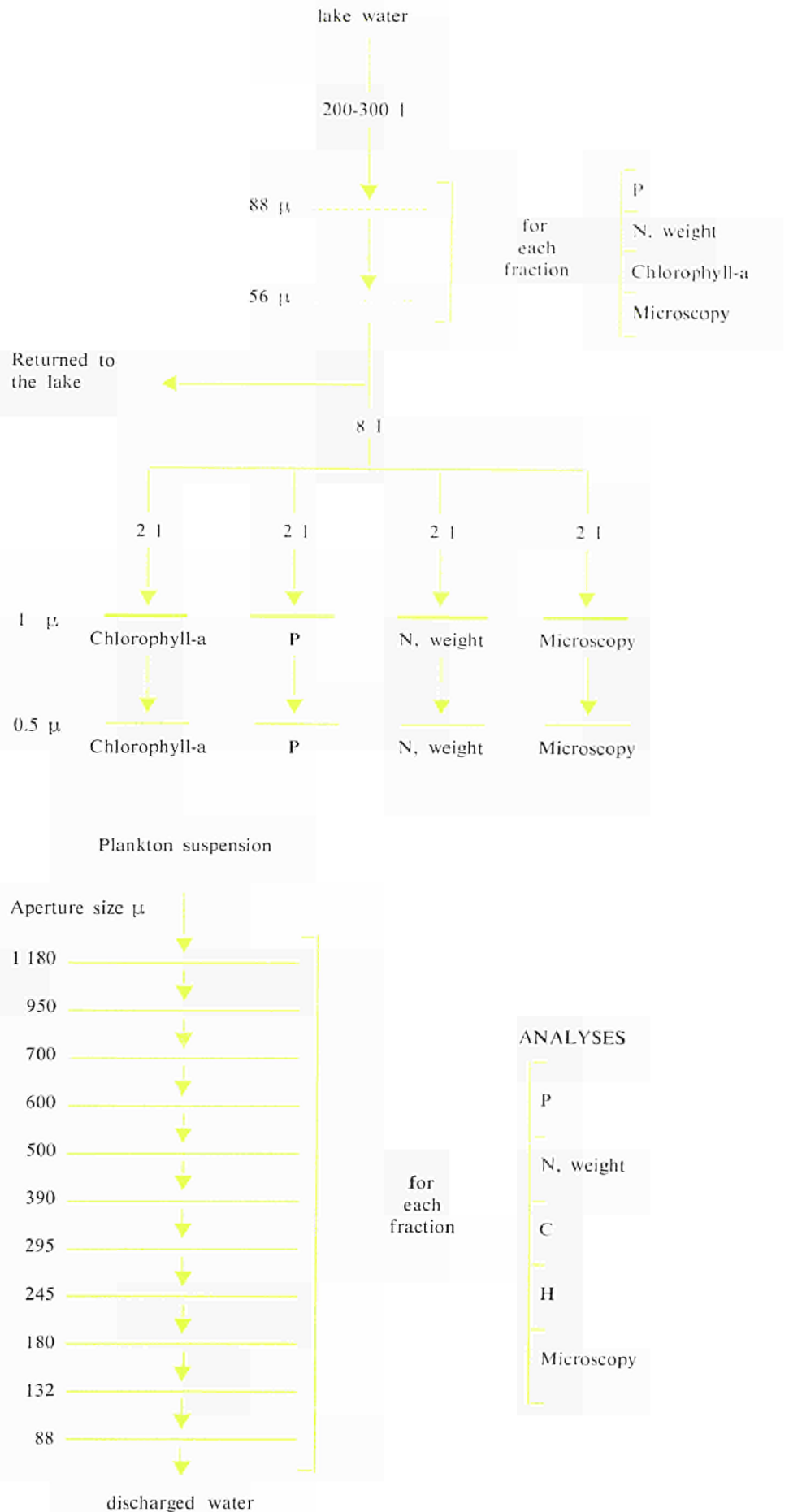
cases, even more toxic than the original one.

It is always somewhat difficult to extrapolate the conclusions drawn from laboratory tests and apply them to natural ecosystems. One of the chief reasons for the difficulty is that in the natural environment the organism is simultaneously exposed to several pollutants, whereas laboratory investigations are usually concerned with the effects of a single pollutant.

True, the effects of certain substances have been studied when they are present in combination with others, and the results show that synergism and antagonism are fairly common. It has been found, for example (10), that the toxic effects of copper salts on fish are aggravated by the presence of detergents (Fig. 1). It has also been shown (9) that the uptake of zinc by marine molluscs is reduced by the presence of chelating agents (Fig. 2). Similar results have been obtained in experiments carried out with fresh-water Copepoda and Molluscs (16), in which a lower uptake of zinc and cobalt was found when chelating agents were present (Figs. 3 and 4).

In order to assess the noxiousness of an element in an environment it is not always enough to know its overall concentration; often it is also necessary to know both the concentrations of its compounds and its physical form. Chromium, for instance, is considered a noxious pollutant, but the toxicity of trivalent chromium is comparatively

Fig. 5: Original microphotographs of the upper surfaces of Lagarosiphon leaves taken with a scanning electron microscope (magnification approx. 1100 times). Microphotograph A shows a normal leaf; B, C and D show the nature and extent of the changes due to a detergent (ABS) with concentrations of 1, 2 and 4 ppm respectively. The white spots in microphotographs B, C and D represent the cell material extracted by the detergent.



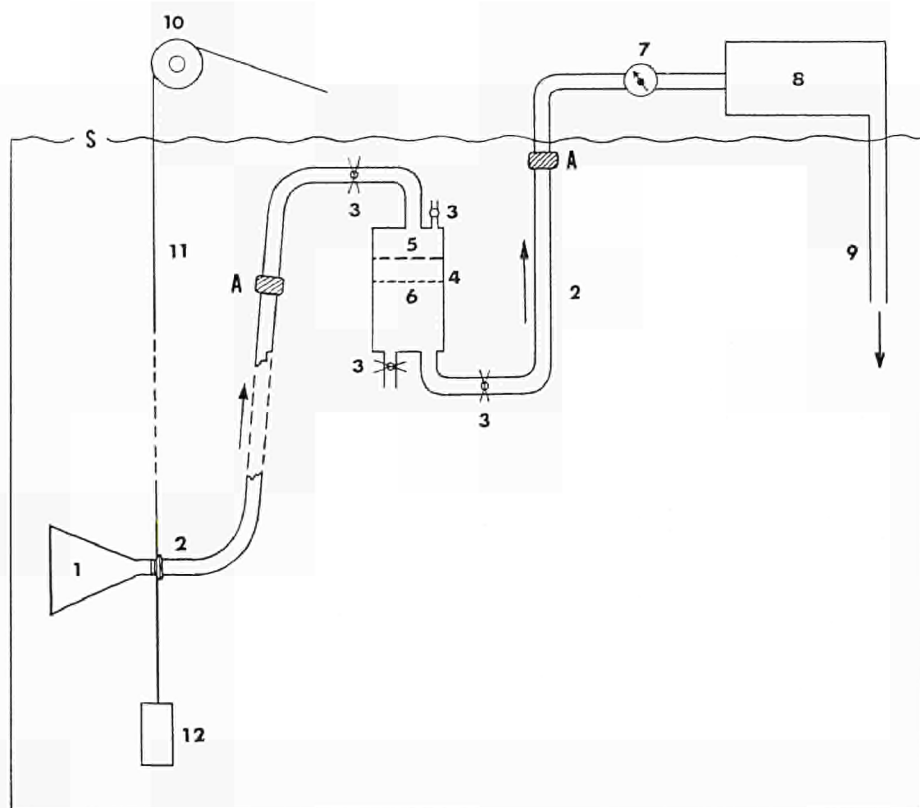
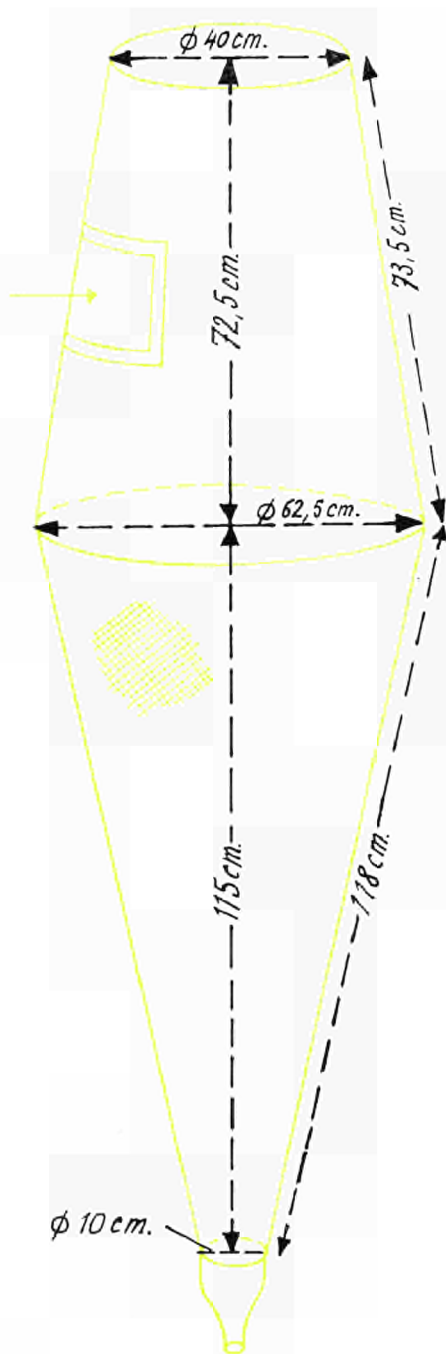


Fig. 8: Apparatus used for gathering seston and separating it into three granulometric fractions.

- S = water surface
- 1 = collecting funnel
- 2 = plastic tube
- 3 = cock
- 4 = filtration cylinder
- 5 = net ($88\ \mu$ mesh)
- 6 = net ($56\ \mu$ mesh)
- 7 = flow recorder
- 8 = pump
- 9 = outlet tube
- 10 = winch
- 11 = cable
- 12 = ballast
- A = three-piece coupling.

Fig. 7: Diagram of the net used for collecting plankton (the arrow indicates the opening).

low, whereas that of hexavalent chromium is extremely high, so that under Swiss law the permitted limit for hexavalent chromium in waste waters is one twentieth of the value for trivalent chromium (0.1 and 2.0 mg/l respectively).

Metallic mercury, being insoluble in water, cannot easily harm living organisms. Owing to its high specific gravity, when it is introduced into an environment it rapidly enters the sediments without causing damage. Some of its organic compounds, however, are extremely toxic, as has been shown by the tragic effects observed in inhabitants of the Bay of Minamata.

Conventional pollution and radioactive contamination

For some thirty years the biosphere has been subjected to a new type of pollution due to man-made radioisotopes, which especially at first alarmed public opinion and governments the world over. The hazard arising from the use of nuclear power should be assessed objectively and minimized, so that mankind can come to accept the exploitation of this energy source as the most practical answer (at least for the present) to the problem of its growing electricity requirements (Table VI).

A Conference on "Aspects Common to Conventional and Radioactive Pollution", held in Milan on 24-26 June 1971, provided an occasion for discussing the chief similarities and differences between these two types of pollution, as well as the advisability of applying—with due caution—the guiding principles of research on and control of radioactive contaminants to the study and control of conventional ones (14). For a variety of reasons, the precautions taken in order to protect man and the environment from radioactive contamination are much more punctilious than those taken to combat conventional forms of pollution. For example, radiological protection standards are internationally recognized and adopted, whereas standards relating to conventional pollutants never have more than local validity.

Furthermore, it should be emphasized that radiological protection standards and operations are designed not only to prevent harmful effects on individuals but also to preclude random damage, i.e. sublethal and late effects, among the general public.

It can be said that, in the field of radiological protection, contrary to what happens in the case of other forms of pollution, the action taken to protect man and the environment is adequate to cope with the increase in the sources of contamination. Whereas it would be unthinkable to reduce the number of studies and checks in the field of radiological protection, it would be advisable to concentrate most of our efforts on conventional pollution since this is now the most serious threat to the biosphere and hence to mankind.

Eutrophication of the aquatic environment

Aquatic environment can also be damaged by the introduction of non-toxic substances. For instance, phosphates, nitrates and all mineral and organic substances tending to promote primary growth find their way into bodies of water in excessive quantities, causing the phenomenon known as eutrophication (Table VII). The accumulation of nutrient substances in lakes and rivers is a natural process which may be speeded up enormously by inputs due to the hand of man.

The first sign of eutrophication is a build-up of inorganic substances owing to excessive biological productivity relative to the mineralization capacity of the bacterial population. The nutrients reach the affected bodies of water from domestic and industrial effluents, chemical fall-out (wet and dry), the run-off from catchment areas and, in particular, from heavily fertilized agricultural land (Table VIII).

In the more highly industrialized countries, a great deal of the phosphorus in domestic sewage comes from

the polyphosphates contained in detergents. These are believed to be the source of over 50% of the phosphorus reaching the Great Lakes at the present time, and it is forecast that unless suitable steps are taken the figure will reach 70% in 1986.

It should be noted, incidentally, that this is not the only harmful effect of detergents: they also set on the cell walls of organisms, increasing their permeability and thus promoting the uptake of substances dissolved in the water, including the pollutants. In addition, detergents promote the leaching-out of substances from the cytoplasm, as is apparent from Fig. 5.

Eutrophication is now widespread, and there are very few waters in the technologically advanced countries which still show no signs of it. The measures taken to control it are completely inadequate for the scale of the phenomenon, which is increasing both in extent and severity. An example of this situation is provided by Lake Maggiore which in the 'fifties was a typical oligotrophic environment [(2), (3)], whereas in the 'sixties there were already obvious signs of a gradual rise in the trophic level in this large lake, which contains 38 km³ of water and has a maximum depth of more than 300 metres [(18), (19), (4), (5), (13)]. So far nothing has been done to halt the eutrophication of this huge water reserve.

The chemical, and to some extent the physical, characteristics of the water in a eutrophied system are seriously impaired; consequently, the water quality deteriorates and the cost of treatment is increased.

In the study of any type of pollution it is of great importance to evaluate the trophic level in an aquatic environment and to monitor its development, since the same pollution burden causes different effects in environments with differing trophic characteristics. It is not possible to carry out a full limnological study in order to establish the trophic level in an environment within a reasonably short time and with modest resources; it is merely neces-

sary to consider certain parameters which are particularly good indicators of the trophic status of the water in question and to measure them with sufficient accuracy. To this end, instruments and methods were developed by the Biology Division at the Ispra Establishment of the JRC and have been tried out in more than two years of research on the lakes of the Province of Varese, Italy (e.g. Lakes Maggiore, Varese, Comabbio and Monate); they will also be used to investigate eutrophication in Lake Lugano. Institutions that have adopted the use of all or some of these instruments and methods have also obtained satisfactory results for other types of environment. Fig. 6 outlines the research programme on the trophic state of lakes undertaken by the Biology Division of the JRC, Ispra. Diagrams of the apparatus used for gathering plankton and seston are shown in Figs. 7-9.

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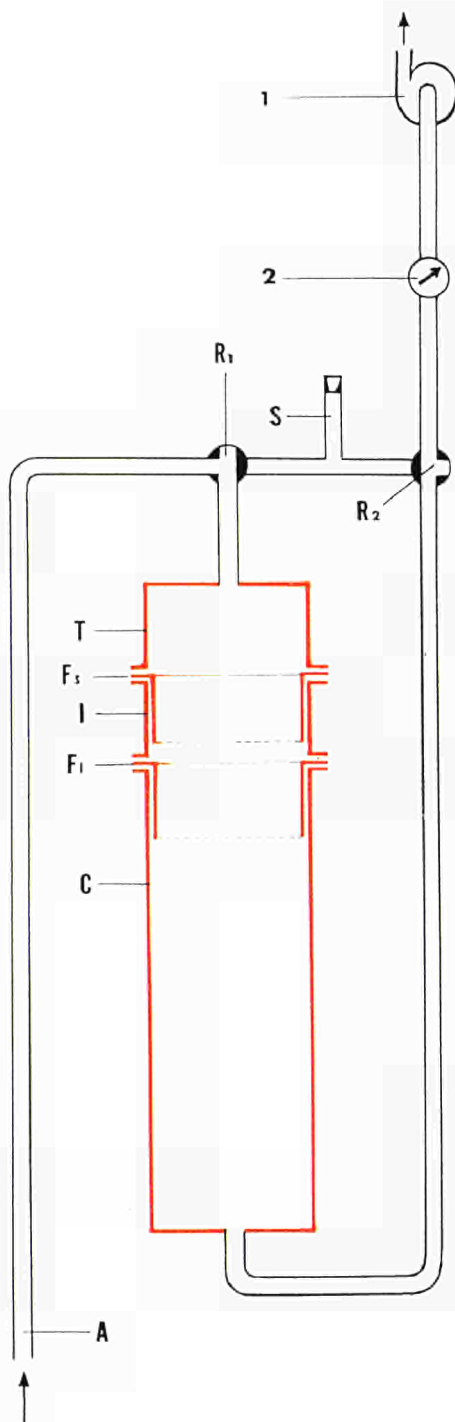


Fig. 9: Seston collecting and separating apparatus.

- A = suction line
- R_1 = inlet valve
- R_2 = outlet valve
- S = vent
- T = head
- F_s = net (88 μ mesh)
- I = mating cylinder
- F_i = net (56 μ mesh)
- C = filtration cylinder
- 1 = pump
- 2 = flow recorder.

Nuclear radiation exposes art forgers and coin counterfeiters

HEINRICH KOWALSKI

FROM TIME IMMEMORIAL forgeries have been made of practically everything which, either for material or for less mercenary reasons, is held to be of special value. Occasionally enthusiasm or ambition may be the motive, as in the case of fabricated chronicles and runes or the faked ape-man bones of Moulin-Quignon and Piltown. Generally, however, the motive is quite simply profit.

As far back as the time of the Pharaohs coloured glass-pastes were used to imitate precious stones, and worthless alloys to imitate precious metals. We know from Phaedrus that even in ancient Rome forgeries were made of “ancient” statues and of the works of “classical” authors. The number of forged documents produced for political purposes in the Middle Ages by the church or the temporal powers was immense. Many a pious crusader enriched himself from the sale of spurious relics, and from the time of the Renaissance the copying and forging of paintings, statues and gems became especially fashionable.

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In spite of the brutal punishments imposed in earlier times, the counterfeiting of coins has flourished in every age, as is shown by the amount of ancient, medieval and modern counterfeiters' tools and products which have been unearthed. Although the majority of counterfeiters produce only cash to cover their own needs, some also imitate and invent rare old coins for the “delight” of collectors. Those who have become famous or infamous in this field include Paduan medallists of the sixteenth century and the Privy Counsellor Becker of Offenburg, a contemporary of Goethe. Their artifacts are frequently “finer” than the real thing, today even have collectors' value, and have in turn—and hardly surprisingly—themselves been forged. Even the minting authorities, whether emperors, kings or republics, occasionally indulged in forgery by having coinage minted from inferior alloys in order to bolster up their shaky finances.

It is no secret that in recent years the demand for old works of art and craft products has rocketed. A parallel development has been the emergence of forgery as a veritable industry determined to do its bit to satisfy the tremendous demand for old furniture, paintings, sculptures, goldsmithery, weapons, violins, coins, etc. The forgers have moved with the times here and have refined their techniques to such an extent that in many cases neither the microscope nor the ultraviolet or infrared lamp can manage to expose them. Moreover, the ring of a coin dropped onto a table is no indication of its authenticity any more than the bite-test used in the Wild West on silver dollars.

In many cases, however, help can be obtained from modern analytical techniques, originally developed for solving technical and scientific problems, which make use of the special properties of stable and radioactive atomic nuclei and of the various forms of radiation. The objects under investigation may, for example, be bombarded with elementary particles or irradiated with gamma quanta;

spontaneous and induced nuclear transformations as well as thermoluminescence are used, and in this way information is obtained about the structure, age and material composition.

Structural investigations

The first spectacular exposure of a forger by means of X-rays occurred

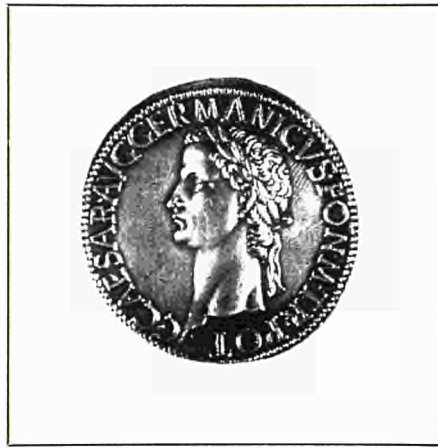
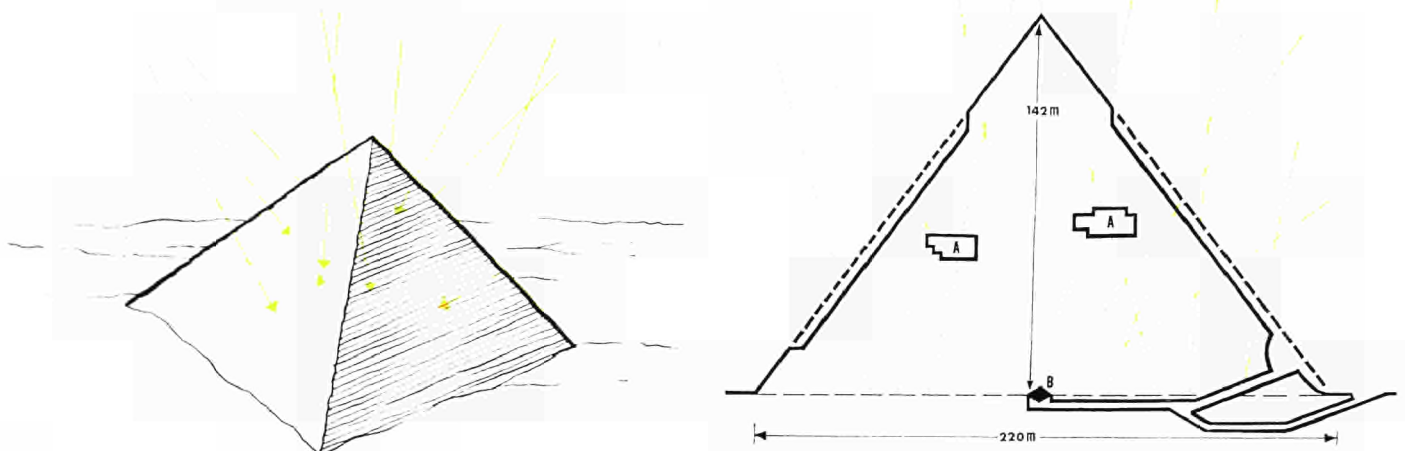


Fig. 1: *Tetradrachmon* from Syracuse, about 400 BC, head of Artemis-Arethusa surrounded by four dolphins. Modern forgery.

Fig. 2: *Imitation of a sesterc* of the Emperor Caligula produced in Padua during the Renaissance.

Fig. 3: *Fantasy coin of the nineteenth century. An attempt at imitating a medieval bracteate from Dortmund (TREMONIENSIS).*

Fig. 4: *The cosmic radiation that penetrates the pyramid is measured by the spark chambers at B. The results are processed by computer to locate the burial chambers, thought to be at A.*



exactly 40 years ago. It was in 1932 that the now famous case took place in Berlin in which the authenticity of 30 Van Gogh paintings was in dispute. The specialists, an international body of illustrious art experts, stuck vehemently to their opposing opinions. It was only in the light of X-ray examination that the pictures were plainly shown to be forgeries, since the structure of the paint layer was harder and more confused than that of genuine Van Goghs.

On the other hand, X-rays were instrumental in clearing up the doubts which had been expressed in the case of the Grünewald Grisailles of Karlsruhe regarding the identity of design and execution. Surprising results were also brought to light when the Pharaoh mummies of the Egyptian Museum in Cairo were X-rayed. For example, it was shown that one of the “queens” was a man and that a “child” embalmed with a queen was in fact a young baboon.

For the examination of the structure of bulky objects, high-energy gamma quanta are required such as those emitted from cobalt-60. These were used on castings such as the Great Buddha at Kamakura and medieval bronze doors, the radiographs providing indications concerning the old manufacturing techniques. Now it is even planned to use cosmic radiation, which is especially penetrating, to radiograph the Chephren pyramid of Gizeh in order to locate (if possible before the ingenious grave-robbers) the secret burial chambers thought to be inside (Fig. 4).

Atoms as a chronometer

For a considerable time now radio-nuclides of suitable half-life have been employed for age determination. With the so-called “geological clocks” such as potassium-40, uranium-238 and rubidium-87 it is possible to estimate the age of rocks and meteorites and even of our planet or our galaxy. Carbon-14 can be employed for dating objects of organic origin anything

between 500 and 70 000 years old, and the age of water and water-containing substances, for example wine, is given by their tritium content. Among these “chronometers”, the radiocarbon clock is of special value in archeology and the history of art, and recently the existing methods have been complemented by others which are specifically suited for the investigation of suspect works of art (1).

The age of oil paintings

The greater the age of metallic lead and lead-containing products, the lower their level of radioactivity. This is due to the fact that radioactive elements (uranium and its daughter products) occur in lead ores, and as these decay a new radioactive lead isotope (Pb^{210}) is continually formed. As soon as the lead is separated from the ore this process stops and the Pb^{210} decays with a half-life of 22 years. For this reason the age of paintings can be determined by measuring the level of activity in lead-containing dyes, especially white lead. This process is not very exact, but does at least make it possible to decide whether a picture was painted before 1800 or since 1900.

In the case of the spectacular Van Meegeren forgery affair in 1945, discussion was still continuing up to a few years ago as to whether the two best pictures sold by him were not perhaps genuine Vermeers. As had happened with the 30 suspect Van Goghs, the experts had not been able to reach agreement, and the results of the X-ray tests, spectral examination and micro-analysis carried out at the time had led to contradictory interpretations. Three years ago examination of the white lead revealed a level of activity such as is only found in twentieth century paintings. Han van Meegeren had skilfully imitated Vermeer’s method of painting on old canvas, using the oils, varnishes and badger-hair brushes customary in the seventeenth century; the only thing he had not thought of was the radio-lead clock.

Moreover, picture forgers are now faced with a new handicap which is to all intents and purposes insurmountable — pollution. As a result of atomic weapon tests and industrial activity (excluding nuclear power stations) the C^{14} content in our atmosphere, and hence also in organic substances such as linseed oil, paper and canvas, has risen to such an extent that it is possible by this means to distinguish without any doubt between pictures painted after 1950 and pictures painted before the war.

Fig. 5: The thermoluminescence clock in its role of detective. The radiation emitted when the ceramic material was heated showed that this was not an Etruscan statue, but a modern forgery.





Fig. 6: Left: Middle section of the fifth century BC Ludovici Throne (Museo delle Terme, Rome) depicting Aphrodite rising from the sea. Right: Middle section of the "Boston Throne" the authenticity of which is disputed. Depicting Eros, the son of Aphrodite, holding a pair of scales.

The thermoluminescence clock

Certain substances have the property of absorbing radiation energy and storing it until they are heated strongly. This phenomenon, which for example is the principle on which thermoluminescence dosimeters are based, can also be used to date fire-clay implements and terracotta statues (Fig. 5). The decisive factor here is the radiation from radioactive materials occurring locally in nature; cosmic radiation has scarcely any effect. The thermoluminescence clock is set to zero when the ceramic substances are fired, as all the radiation energy stored up to that time is dissipated. By means of renewed heating, if the activity of the substance is known, it is possible to calculate its age with a precision of 10 % from the amount of radiation given off. For example, a female terracotta statue supposedly of Etruscan origin was subjected to this process, and to the joy of some archeologists and the annoyance of others the lady proved to be a child of the twentieth century.

X-ray fluorescence and activation analysis

Of the other modern investigation processes only X-ray fluorescence and activation analysis will be mentioned here. As both of these require only very small samples or are completely non-destructive, they are especially suitable for the investigation of works of art.

With the aid of X-ray fluorescence analysis, the least complicated process, one can very quickly obtain a breakdown of the elements present. However, as a result of the small depth of penetration of X-rays in metal objects, only the outermost layer 0.01 - 0.1 mm deep is covered, and in objects of considerable age this layer has a different composition from those further down. In order to exclude this surface effect, the material must therefore be ground down somewhat.

Activation analysis is based on the artificial radioactivity produced by means of irradiation with high-energy particles. The nature and intensity of this radioactivity depends on the method of irradiation and the nuclides present. If suitable exposure times are used, the induced activity decays within a few hours or days to harmless levels.

Oil paintings, for example, were subjected to low activation by thermal neutrons in a nuclear reactor and then placed on a photographic film. From this autoradiographs were obtained which yielded extremely valuable information about the method of painting, the nature of the colours and any additions or falsifications.

The proper field of activation analysis, however, is the determination of the qualitative and quantitative composition of materials by analysing the induced radiation with the aid of the appropriate detectors and counters. This method is so sensitive that even

traces of an element too small to be weighed can be picked up in a complex matrix. Such traces often give indications as to the origin of the materials and also provide clues regarding ancient trade routes. In this way fire-clay articles, glass objects, obsidian arrow-heads, marble samples, etc., have been investigated and localized, so it might now become possible to solve the question of the authenticity of very famous but still disputed marble works or art, such as the "Boston Throne" (Fig. 6).

Since the discovery of this supposed counterpart to the Ludovici Throne under somewhat suspicious circumstances in the year 1894, controversy has raged as to whether it is a classical Greek, Greater Greek or Roman work, or whether it is a skilful nineteenth century fake (2). As stylistic examinations apparently fail to provide a clear-cut answer, investigation by activation analysis might perhaps be able to help.

Analysis of coins

Activation analysis is perfectly suited for the investigation of coins as these can be handled with relative ease in reactors, neutron generators and particle accelerators and can be irradiated in their entirety. In the highly diverse techniques of which details have been published so far, fast and thermal neutrons have been principally used for activation, and to a lesser extent protons, deuterons and photons.

By determining the precious metal content of coin alloys it has been possible in several cases to gain valuable information about former currency conditions and fluctuations. In the case of ancient Greek and medieval Serbian silver coins, indications were obtained regarding the origin of the silver in the coins, and modern counterfeits of old silver coins have been given away by the fact that, owing to improved silver refining, their gold content was much lower than in the genuine articles. (Of course, this technique is no use when the counter-

feiter, like Counsellor Becker, over-stamped old blanks.)

Finally, those hundred masters of the mint who in the year 1124 were horribly mutilated on the orders of King Henry I can now be cleared of the crime of which they were accused, admittedly somewhat late in the day. They had allegedly mixed the minting metal with tin for their own profit, but analysis has shown that the king was in the wrong for the coins proved to be of absolutely full value. (3)

A further example can show in rather greater detail how the united efforts of nuclear technology and

numismatics can help, at least to a modest degree, to throw light on certain historical questions. This concerns the results of investigations which the author conducted together with P. Reimers, of the West German *Institute for Materials Testing*, Berlin, and were reported at the symposium organized by the *Eurisotop Office* on "Nuclear Analysis Techniques in the Production and Industrial Application of Precious Metals" (Brussels, November 1971) (4).

Was Emperor Frederick II a forger?

In the year 1239 Pope Gregory IX excommunicated the Emperor of Rome and King of Sicily, Frederick II of Hohenstaufen, and at the same time accused him amongst other things of

Fig. 7: A medieval mint.



coin forgery. As far as Frederick's Sicilian silver denari are concerned, this charge is by medieval standards not unjustified, for their silver content had fallen from issue to issue and finally they were nothing more than copper coins with a coating of silver, having an intrinsic value scarcely one-tenth of the face value.

But what is the position regarding his gold coins? Frederick II was the first Holy Roman Emperor to have gold coins minted, and these, unlike his denari, were in circulation outside the Kingdom of Sicily also. Fortunately we are in possession of coinage ordinances dating from the thirteenth century. They are the oldest existing documents of this kind and lay down the statutory composition of the gold used for the coins of that time. From these it can be seen that Frederick, in the same way as his Norman predecessors in Sicily, at first minted tarene gold supposed to be 16.3 carat or 68% pure. Gold tarenes weighing 0.4 - 11.0 grams, which exist in every possible gradation of weight, were not counted but weighed.

Besides these, from 1231 Frederick had his famous gold augustales struck in Messina and Brindisi. These are among the finest coins of the Middle Ages, and have a uniform weight of 5.3 g. They were no longer weighed but counted, and according to the coinage ordinances were to be 20.5 carat and to consist of 85.5% gold, 10.9% silver and 3.6% copper, although some contemporary chroniclers gave them only 20 carats.

Coins of tarene and augustale gold continued to be minted in Sicily under Frederick's successors. Charles I of Anjou, however, replaced the augustale in 1266 by his reals, which were officially of the same value, and replaced these in 1278 by 24 carat gold saluti. In the second half of the thirteenth century the major North Italian trading cities began to strike fine gold coins, and then, in the fourteenth century, the authorities north of the Alps who were entitled to issue coinage gradually took over the minting of gold coins.



Fig. 8: Representation of Frederick II of Hohenstaufen at the shrine of Charlemagne in Aachen (1215).

Fig. 9: Augustale (enlarged 2 x) minted by Frederick II from 1231 in Brindisi and Messina. Bust of the Emperor and Hohenstaufen eagle.



The interesting question in this respect is whether the augustales and tarenes were minted in their full value, or did Frederick II, who at the time was held to be the richest prince in Europe, break his own ordinances for fiscal reasons, as is suggested by the Pope and some chroniclers?

Analysis technique

As the gold coins in question are irreplaceable, only an absolutely non-destructive analysis technique could be considered for their investigation. Even a sample of the order of a milligram or local grinding, as described in some publications, was out of the question. Moreover, a method had to be devised which if possible could be used for routine measurements as well.

Preliminary tests showed that the most convenient method, X-ray fluorescence analysis, as expected, was out of the question. Not only with the over 700 year old augustales, reals

and tarenes, but also in only 100 year old modern gold coins, this gave much too high gold values, as in the course of time a considerable impoverishment of the base constituents copper and silver had taken place in the surface layer. This also explains the yellowish gold tinge of old coins such as these, as opposed to the more reddish colour of freshly minted gold coins of identical composition.

We therefore decided to determine the silver and copper content by activation analysis using 14 MeV neutrons. The coins were each irradiated for 40 seconds, and as a result of the (n,2n) reaction the nuclides Ag^{106} and Cu^{62} were formed, both of them positron emitters. Silver and copper were identified on the basis of the 0.511 MeV line, the different half-lives (24 and 9.8 min respectively) being used to separate them. The major uncertainty of the Ag/Cu determination is caused by the self-absorption of the annihilation radiation in the gold coins. This depends on the

Fig. 11: Real (enlarged 2 x) of Charles I minted in Brindisi, Messina and Barletta. Bust of the King and fleur-de-lis arms of Anjou.



Fig. 10: Statue of Charles I of Anjou in the Palazzo dei Conservatori in Rome (thirteenth century).

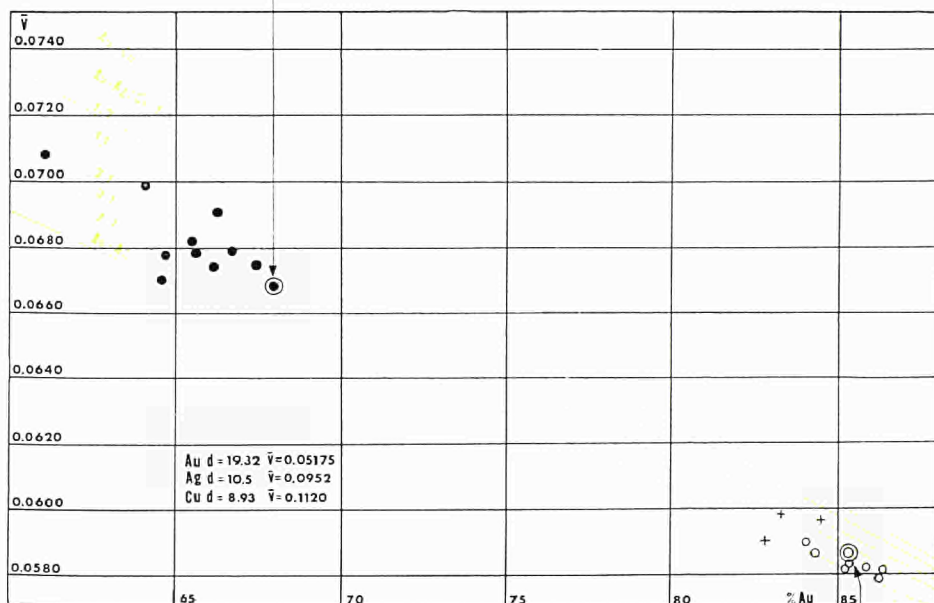
geometry of the samples, is difficult to calculate and in practice is always ascertained experimentally. In the case in question the self-absorption for both elements is the same, as they are divided homogeneously in the coin. Thus as it was possible to establish the Ag/Cu ratio much more exactly than the absolute contents, we used this value. For the accurate determination of the composition of the gold alloys a further measurement was therefore needed.

For this the activation of the gold by fast neutrons would be suitable, resulting in the production of Au^{196m} via the $(n,2n)$ reaction. Unfortunately, however, as only three working days were available for the analysis of the 50 coins, we could not employ this method on account of the long half-lives.

As a second independent measurement a density determination was thus carried out by weighing the coins in air and in a buoyancy liquid, a method in general use since the time of Archimedes. It will be recalled that this great scholar was able to prove by this method that a goldsmith in Syracuse had debased a gold crown made for King Hiero by the addition of silver (one might say the oldest non-destructive analysis of a binary alloy). As our coins are made of gold, silver and copper, it was possible to calculate the composition of the ternary alloy from their density and the Ag/Cu ratio.

for tarenes
16.3 carat

Expected values according to the
medieval coinage ordinances



for augustales and
reals 20.5 carat

Fig. 12:

Position of the augustales (O), reals (+) and tarenes (⊕) investigated by us in a diagram for gold/silver/copper alloys. Abscissa = gold content in %. Ordinate = specific volume of the alloy ($d =$ density, $\bar{v} =$ specific volume).

The highest line represents an alloy of only Au and Cu, the lowest line an alloy of only Au and Ag. The six lines in between represent gold alloys with various Ag/Cu ratios.

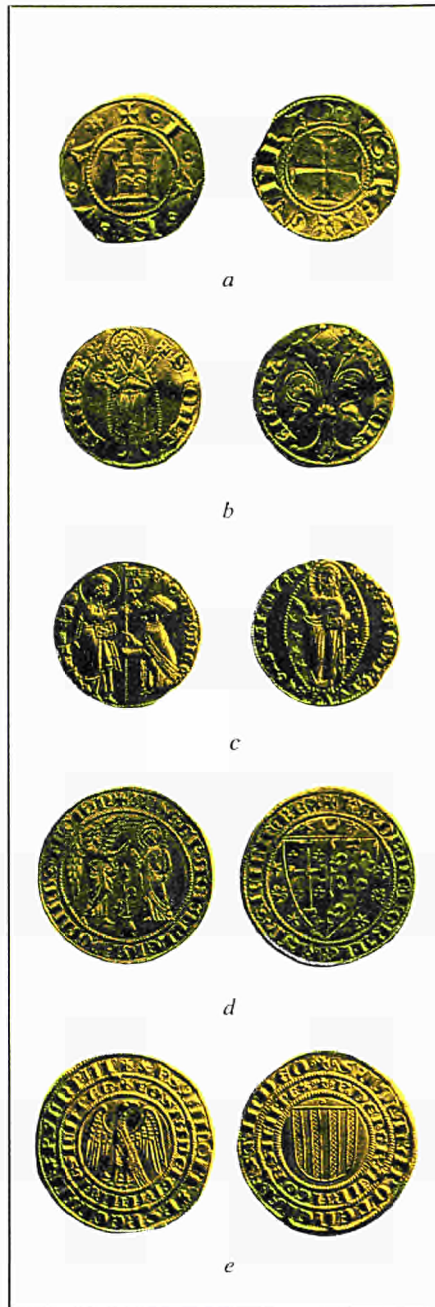


Fig. 13: Italian fine gold coins of the thirteenth century:

- a) Genoa, genovino, from 1250, city gate and cross;
- b) Florence, florin, from 1252, John the Baptist and Florentine lily;
- c) Venice, ducat, from 1284, Christ in the mandorla and the Doge kneeling before St. Mark;
- d) Naples, saluto, from 1278, annunciation, arms of Anjou and Jerusalem;
- e) Messina, pierreal, from 1282, Hohenstaufen eagle and arms of the Aragonese.



Fig. 14: Augustale of Frederick II:
a) genuine coin;
b) thirteenth century forgery (5);
c) modern forgery.

Fig. 15: Gold tarenes of Frederick II:
a) genuine coin;
b) modern forgery.



Results

Our results also embrace work on some Greek, Roman, Byzantine and Arabian gold coinages, but only those which are relevant in this context will be summarized here. The gold tarenes minted in Sicily and the Charles I reals proved on average to be some 0.5 carat poorer in their gold content than was laid down in the ordinances,

whereas the genovini, florins, ducats, saluti and pierreali minted in Genoa, Florence, Venice, Naples and Messina in the thirteenth century do in fact comply with the old coinage ordinances and are made of 24 carat gold.

The most important result for us is the vindication of the augustales. Eight examples of this coin, which today is very rare, were available and it was shown that their gold content is remarkably close to the requirements of the Emperor's coinage ordinances. The individual values only diverge by around 0.25 carat and the average value is exactly the prescribed 20.5 carats or 85.5% gold. The silver and copper contents show more fluctuation, but this is of little importance for the value of the coin.

Pope Gregory IX was therefore well advised, when, in calling Frederick II a *novus monetae falsarius*, he denounced only his silver coins and refrained from comment about the augustales. It may be assumed that the chroniclers who described the augustales as somewhat under value were confusing them with the reals of Charles I, which were sometimes also referred to as "augustales" and are in fact only 20 carats. Furthermore, the usual means of determining the gold content at that time—a touchstone and needle—were naturally not very reliable.

Counterfeits, counterfeits...

In order to recognize the counterfeit augustales and tarenas of medieval origin, no activation analysis is necessary, as they are of crude workmanship and with the passage of time lost their original coating of gold.

The modern augustale and real counterfeits present more of a problem. The examples known to the author are produced by centrifugal casting from good gold; in fact the gold is too good, for our analysis showed that the counterfeiter was badly informed and to his own undoing he employed almost 24 carat instead of 20.5 carat gold.



Fig. 16: Real of Charles I of Anjou:
a) genuine coin;
b) modern forgery.

The trickiest examples might well be the tarenas imitations which have appeared recently. They are skilfully minted and their gold content conforms very closely with the original. But here the combination of X-ray fluorescence and activation analysis offers a new means of bringing the truth to light, for whereas the centuries old genuine tarenas already show the

Fig. 17: Gold tarenas of Charles I:
a) genuine coin;
b) modern forgery.



silver copper impoverishment in the surface layer mentioned above, this effect naturally does not exist in modern imitations.

These examples should suffice to make clear the extent to which modern nuclear techniques already represent a valuable additional aid to clarifying certain matters of historical interest and especially to exposing forgeries of every kind, particularly in those cases in which stylistic analysis still leaves room for doubt. These techniques are not deceived by outward appearances, since they examine the microscopic and nuclear qualities of the materials or else pick up the changes which are the result of the age of the materials and are virtually impossible to forge.

It would be desirable to develop these analysis techniques further; the majority of them are still in the laboratory stage, so that they are also suitable for routine investigations. It would then be possible gradually to detect the forgeries, which in the field of furniture, paintings and coins alone run into thousands, some of them very skilful—provided, of course, that the owners in question would wish to know for certain, and that would be a very risky assumption!

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Remote sensing of atmospheric pollution

Spectroscopic know-how plus new laser techniques may shed new light on a pressing modern problem.

SANTINO SANDRONI

A PARTICULAR ASPECT of pollution control is the detection of noxious substances which industry or any other human activity causes to be emitted into the environment. While pollution by some of these substances is merely a local problem, that due to others affects the earth as a whole; every year some 66 000 000 tons of carbon monoxide are emitted into the atmosphere. Numerous phenomena on a regional or national scale are associated with pollution: reduced visibility over certain big cities (a typical case

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being the familiar "midday murk"), fog formation over large areas, accumulation of toxic gases in areas with unfavourable climatic and meteorological conditions.

The variety of substances which are constantly degrading the environment is such as to defy any real check at present; no country knows what pollutants, or how much of them, its own industry emits. It is hoped that an inventory of types and quantities will soon be available, at least as regards the most toxic substances or those occurring in the largest quantities. The difficulties are due not only to a lack of good will but also to the need for protection of industrial secrets.

The main sources of pollution are discharges from motor vehicles, heating installations and industrial plants. The most immediate solution that might be proposed is the *monitoring of stack emissions*. In practice, this is possible only to an extremely limited extent, since not all emissions are accessible. A better solution might be the remote monitoring (from a land base or aircraft) of the smoke and the air in general above the plant.

Pollution is currently evaluated by taking samples at strategic points (e.g., a square in a city centre or a working environment) and analysing them in the laboratory, or, in some cases, by continuously measuring the pollution at a given point (e.g., continuous determination of sulphur dioxide). Unfortunately, the environment consists of more than one point: carbon monoxide has been measured locally at concentrations of more than 100 ppm in working environments (this being a high level of toxicity for humans), but the average concentration in the atmosphere is estimated at 0.1 ppm. It would be interesting to know the *average concentration* in a given area, say between the Eiffel Tower and Notre Dame, or between two extreme points over a thermal power plant. The average value would show how fit the air was to be breathed!

Remote measurement

As has been said, the pollution at a given point is not always accessible for measurement and is of little significance for the environment. The two most important applications of remote measurement, either from the ground or from an aircraft or space vehicle, are the *monitoring of emissions* and the evaluation of the *average concentration*.

A further interesting item of information that can be ascertained by remote measurement is the “*vertical burden*” of a toxic substance, i.e. the measurement of how much toxic substance is present in the air above us. It is known that aerosols raised from the ground by natural or artificial phenomena (such as soot from stacks, which is responsible for the above-mentioned phenomenon of “*midday murk*”) remain suspended in the air and become more dense in the “*inversion layer*” of the atmosphere, where the temperature gradient, under optimum meteorological conditions at an altitude of about 3 km, is reversed. In this layer the accumulation of particles is such as to create a reflecting “*mirror*” as a result of light radiation from below. Not even gases released from the ground can pass through this barrier. The measurement of the vertical burden of a pollutant is, of course, the measurement of how much of it is present in the column of air between the ground and the inversion layer.

The vertical burden of pollution can also be established from data supplied from an aircraft or satellite; satellites are particularly suitable for the measurement of pollution distributed over the entire globe and thus enable its geographical distribution to be mapped.

Remote measurement, by monitoring from land or air, can also be used for *determining the flow and displacement* of pollutants; there would be no need to take series of samples with balloons or other means. In this way it can be shown to what extent a site is polluted by a given emission a few kilometres away, and the forecasting of dangerous situations can thus be assisted.

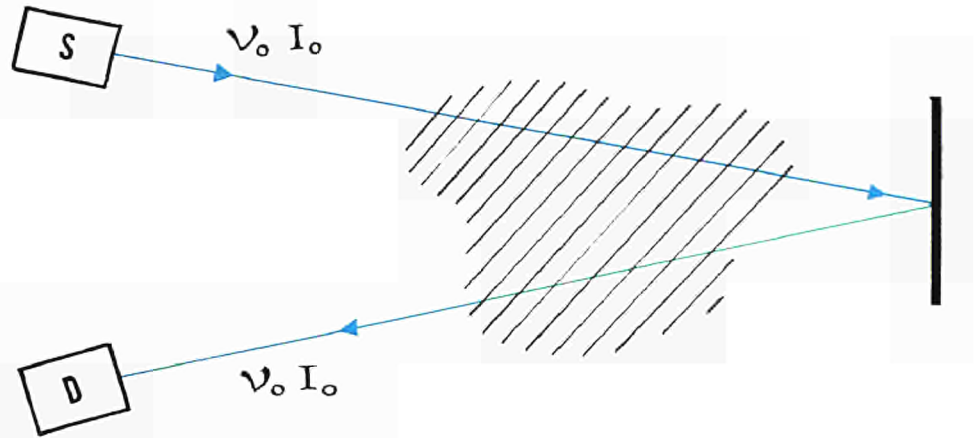
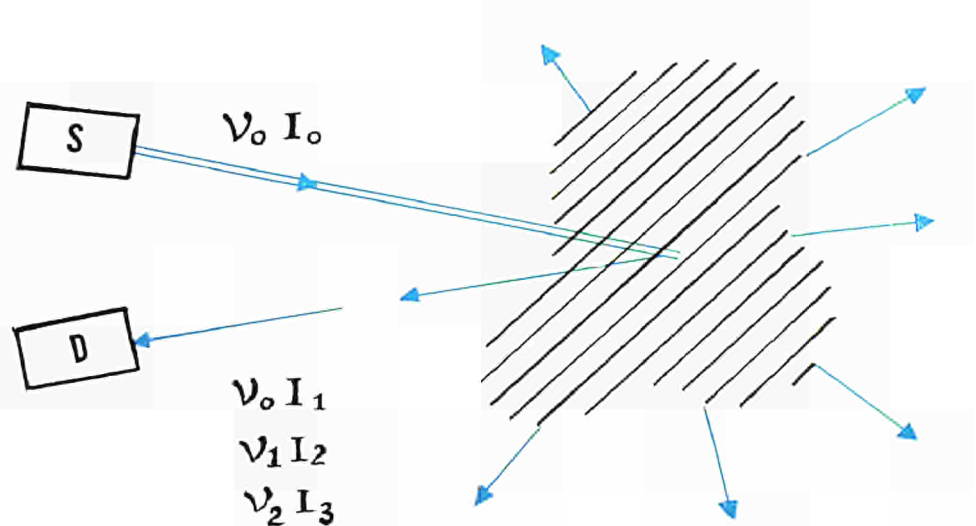


Fig. 1: Diagram of absorption spectroscopy principle. The “specific” source (S), capable of emitting radiation of characteristic frequency for a given pollutant, is of relatively low power and its band width is at least equal to that of the spectral

band of the pollutant. The specific frequency emitted by the source is absorbed by the pollutant and arrives at the detector (D), which measures the reduction in intensity.

Fig. 2: Diagram of scattering spectroscopy. The “non-specific” source (S) (i.e. one capable of emitting monochromatic light of any frequency, provided, of course, that it is not absorbed by the clean atmosphere) is of high power. Bombardment with high-energy radiation excites the molecules, which scatter light throughout the surrounding space. A detector (D), placed for convenience near the source, captures a small fraction of the scattered energy and measures it.

If the return radiation has the same frequency as that emitted by the source (ν_0), the aerosol is measured; if it is different (ν_1, ν_2, ν_3), the various components 1, 2, etc. are measured by Raman scattering of the molecules. In practice, the Raman lines are very weak, and it is therefore relatively simple to measure the aerosol in the atmosphere; it is much more difficult to detect gases.



Pollutant	tons/year
Carbon monoxide (CO)	66 000 000
Nitrogen dioxide (NO ₂)	6 000 000
Hydrocarbons	12 000 000
Sulphur dioxide (SO ₂)	1 000 000
Lead	100 000
Aerosols	1 000 000

Table 1: The quantities of certain pollutants discharged into the atmosphere are shown (2). It should be remembered that every year 142 000 000 tons of pollutants are released into the air, 20% of which comes from industry and wastes, 13% from power plants and 60% from motor vehicle exhausts.

What techniques can be used?

Spectroscopic techniques are the most promising for the remote detection of gas traces. In particular:

1. *Absorption of light* (infra-red, ultra-violet or visible) of a frequency characteristic of the pollutant: the reduction of "specific" intensity is a function of the quantity of pollutant present (Fig. 1).
2. *Elastic or inelastic scattering* (Mie and Raman) by aerosols and certain

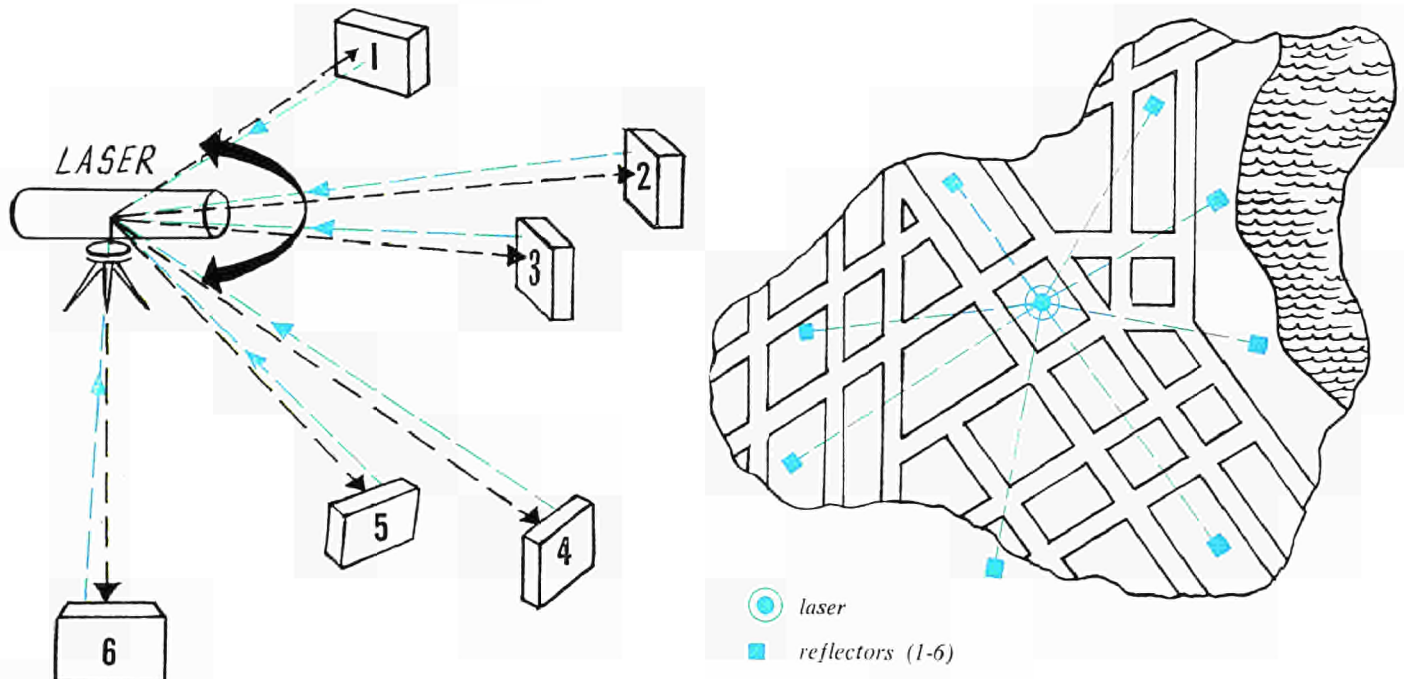
gases; the scattered light intensity is a function of the quantity of pollutant (Fig. 2).

It is, of course, necessary to distinguish between polluted air and clean air, which contains not only oxygen, nitrogen, rare gases, water vapour and carbon dioxide but also methane and ozone at a certain altitude.

The problem of sources: lasers

Since specific substances are to be detected at a distance, powerful light

Fig. 3: It is shown here how it would be possible to carry out an urban inspection. The laser source and detector are mounted as a single central unit. A number of reflectors placed around it return the ray.



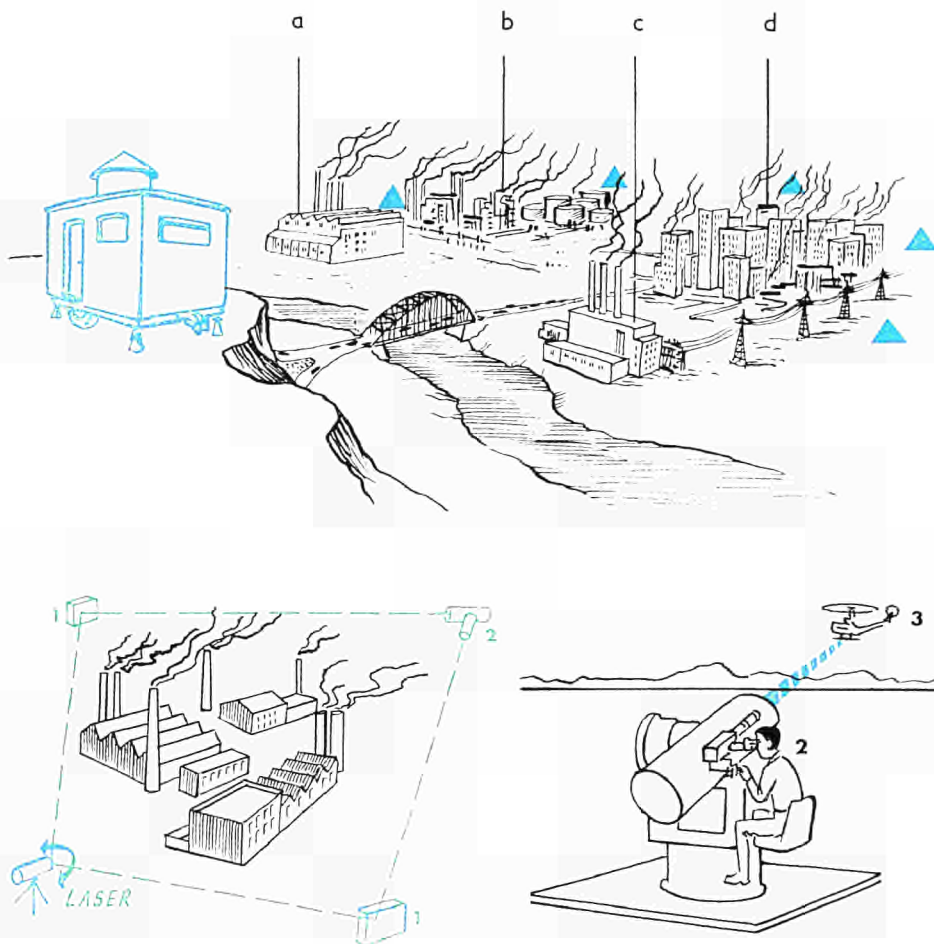


Fig. 4: Various possibilities of inspection on a large scale: the positioning of the reflectors, the optical relay and the laser operator are shown.

- ▲ reflectors
- a. paper mill
- b. refinery
- c. power plant
- d. city
- 1. optical relay
- 2. laser operator
- 3. reflectors

sources for *specific* measurements are necessary.

The only source of considerable power available in nature for measuring absorption is daylight, which offers a wide spectrum from ultra-violet to infra-red. The availability of a natural source is particularly important for measurement from an aircraft or satellite, where both space and the energy required for feeding a source are very limited. Daylight, which is diffused in only two cases (sulphur dioxide and nitrogen dioxide) in the ultra-violet/visible light range of the spectrum, is capable of being rendered selective; in the infra-red zone the use of filters or some other dispersive system (a prism or grating) does not provide sufficient spectral resolution to allow "specific" measurements (the spectral resolution of an IR spectrometer with a prism/grating is about 0.5 cm^{-1} , while the width of a gas band is about 0.01 cm^{-1}).

Lasers constitute valid sources because they are monochromatic, coherent and of sufficient power; they must be "specific" for measurements of absorption and "non-specific" and of high power for scattering.

Figs. 3 and 4 show how the inspection of a city or industrial zone by the absorption method might be carried out with lasers.

The COSPEC analyser

The *COSPEC* analyser developed by *Barringer Research* (Ontario, Canada)

Table 2: Typical concentrations of atmospheric pollutants, expressed in parts per million. The CAMP (Continuous Air Monitoring Project) figures in the third column represent average data worked out by six monitoring stations situated at central points in six large American cities: Washington DC, Chicago, Philadelphia, Denver, St. Louis and Cincinnati.

Pollutant	Concentrations (in ppm)	CAMP mean daily figures (in ppm)
Carbon monoxide	2.0 to 300	32.1
Sulphur dioxide	0.001 to 3.2	0.789
Ozone	0.009 to 1.0	
Aldehydes	0.02 to 2.0	
Ammonia	0.02 to 3.0	
Hydrofluoric acid	0.001 to 0.08	
Nitric oxide	0.02 to 3.5	0.282
Hydrogen sulphide	0.002 to 1.0	
Hydrocarbons		10.0
Nitrogen dioxide		0.132

Fig. 5: COSPEC analyser of Barringer Research (Ontario, Canada).



is a portable spectrometer (Fig. 5) which can be mounted on aircraft and motor vehicles and is designed for the simultaneous determination of SO_2 and NO_2 at the maximum sensitivity of 1 ppb for a distance of 1 km by measurement of ultra-violet absorption (3100 \AA for SO_2) and visible-light absorption (4000 \AA for NO_2) (5). Either daylight or a xenon lamp can be used as a source. The principle of the instrument is as follows: light collected by the telescope is resolved spectroscopically by two gratings and compared with a "mask" which reproduces the spectrum of the pollutant. Measurements are in ppm/m (parts per million per metre of optical path). Typical applications are shown in Fig. 6.

If the instrument is installed on a vehicle driven along a predetermined route, the distribution of SO_2 and NO_2 can be mapped as vertical burdens on regions, industrial emissions can be regularly monitored from a distance of 1 km, average concentrations can be measured, etc. Only these two gases can be detected (Fig. 7).

For other gases, the "specific" absorption lines in the infra-red zone of the spectrum must be used. With the usual infra-red sources it is virtually impossible to isolate the spectral line required by the pollutant; the best resolution obtainable with conventional systems is 0.5 cm^{-1} , whereas the lines of gases are 0.01 cm^{-1} wide. New types of laser, however, even at the experimental stage, can be used to great advantage.



Tunable infra-red lasers

These are a subject of great interest, and not only in the field of pollution. According to the data available so far, it is possible to obtain infra-red radiation of relatively high power and very narrow band width, the frequency of which can be modulated over the entire IR zone of the spectrum.

Lasers with semiconductor diodes (3) are very small crystals ($1.2 \times 0.5 \times 0.3$ mm) of certain ternary alloys (e.g., $Pb_{1-x}Sn_xTe$) containing a p-n junction. Such crystals, at the temperature of liquid helium and fed with currents of a few mA, emit IR light with a band width of less than 10^{-3} cm^{-1} (the vibro-rotational bands with a gas require a resolution of 10^{-2} cm^{-1}); the output frequency depends on the current and on the chemical and stoichiometric composition of the crystal. With a given number of such crystals (very difficult to produce!) the entire IR field can be covered. The power at present is 1 mW in continuous operation, but it is hoped to achieve higher powers.

The spin-flip Raman laser (4) is simpler to make than the above-mentioned one, since it uses a binary

Table 3: Atmospheric pollution detection systems under study.

Gas	<ul style="list-style-type: none"> — UV-IR light absorption 	<ul style="list-style-type: none"> — passive mode — active mode 	<ul style="list-style-type: none"> — sunlight absorption — earth radiation absorption 	<ul style="list-style-type: none"> — correlation mask — dispersive systems
			<ul style="list-style-type: none"> — non-dispersive IR — partially dispersed IR — IR dispersed 	<ul style="list-style-type: none"> — gas, with correlation filter — fluorescent source — with filters — in space prism or grating — in time tunable lasers — in frequency interferometer
	<ul style="list-style-type: none"> — Raman scattering 	<ul style="list-style-type: none"> — Raman Lidar 		<ul style="list-style-type: none"> solid-state, dye laser
Aerosols	<ul style="list-style-type: none"> Mie. Rayleigh Scattering — Lidar 			<ul style="list-style-type: none"> — solid-state or dye laser

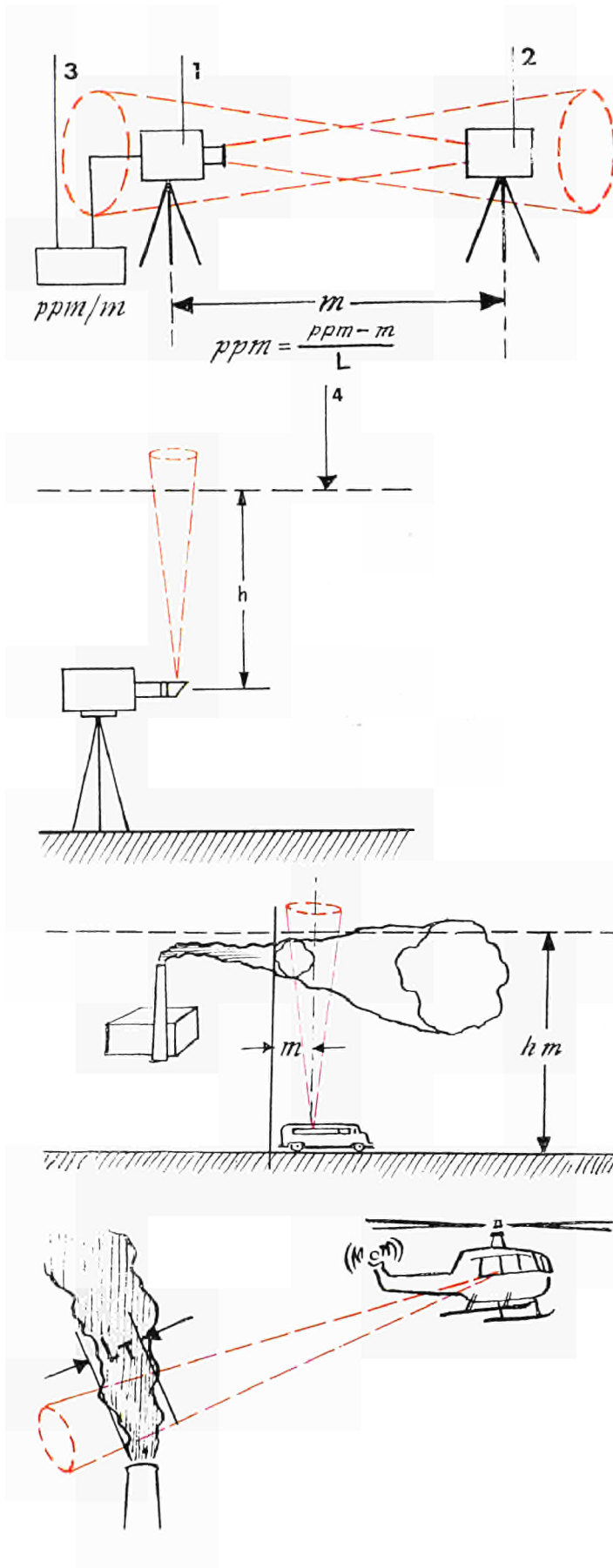


Fig. 6: Applications of the COSPEC analyser illustrated in Fig. 5; measurement of average horizontal concentration (own source), measurement of vertical burden (source: daylight), evaluation of pollution profile from the ground and inspection of a stack from the air by helicopter.

1. sensor
2. light source
3. recorder
4. inversion.

crystal (InSb) to modulate the frequency of a conventional CO_2 (10.6μ) and CO (5.3μ) infra-red laser with a potential scanning range of about 0.8μ . Since the available spectral range is limited, it can be applied only to a limited number of pollutants. The bandwidth is excellent (10^{-2} cm^{-1}) and the power is high (20% of that of the exciting laser).

Diode lasers are very promising; if enough lasers were available to cover the entire infra-red spectrum transmitted by the atmosphere, it would be possible to detect even completely new pollutants.

LIDAR

LIDAR (Light Detection And Ranging) is an optical radar system which measures pollution by light scattering and which was used as a prototype at the NASA establishment in Langley, Virginia, and at the Stanford Research Institute in Menlo Park, Calif. It is the visible-light counterpart of microwave radar. It is capable of locating and measuring aerosols in the atmosphere and of measuring the optical transparency of the atmosphere remotely from a fixed site. The principle is as follows: a high-power ruby or gas laser (100 MW) emits light pulses of short duration (10^{-8} sec. , 20 pulses/sec.) in a specific direction. The cloud (aerosols and, with less effect, gases) absorbs and/or scatters the light in all directions: a small fraction of it reaches the detector fitted to the side of the laser. The intensity of the return signal is an index of the amount of pollutant, and

the time taken by the signal to travel in both directions is an index of the distance. Lidar makes it possible not only to measure the pollution but also to locate the cloud in the atmosphere. It has many uses: the height of smoke, its dilution in the atmosphere and the position of the inversion layer can be measured.

Fig. 8 shows an application of Lidar. Another experiment carried out above the San Francisco peninsula for a period of 24 hours showed that the aerosol layer rises from the earth at dawn, expands during the day, reaching a peak during the hottest hours, contracts again towards evening and descends in this compressed form to the horizon in the early hours of the evening, remaining almost stationary during the night.

Second-generation Lidars

Among the more interesting studies in progress are those on Lidars using dye lasers. In these lasers the possibility is being studied of modulating the frequency of the light emitted and carrying out spectrographic analyses of the light returned. Besides the analysis and location of aerosols, these Lidars will permit determination of the granulometric distribution of aerosols and possibly also fluorescence measurements and the identification and analysis of gaseous pollutants by resonant Raman effect. The few Raman studies carried out with Lidars of the first type led to rather mediocre estimates

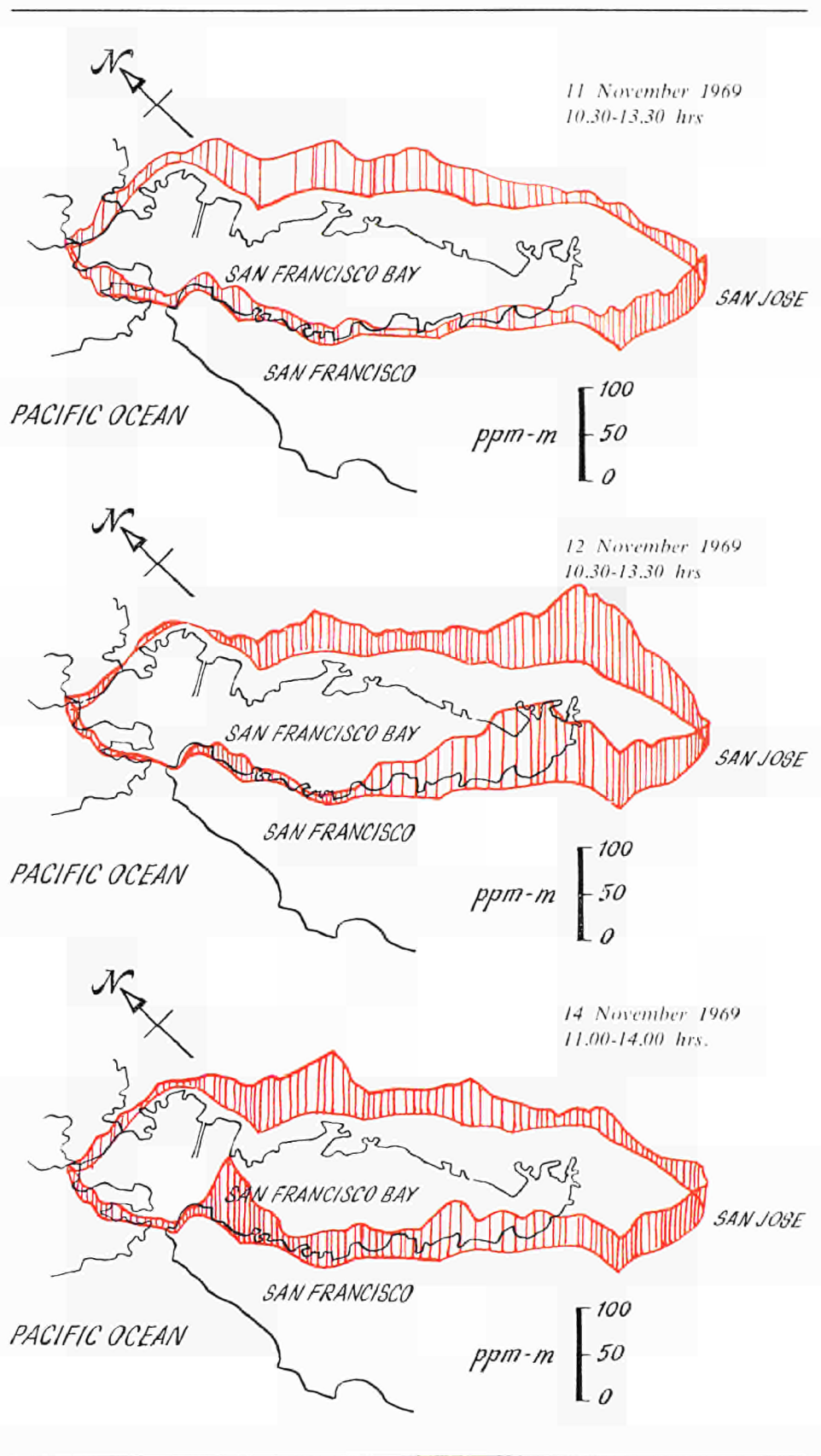
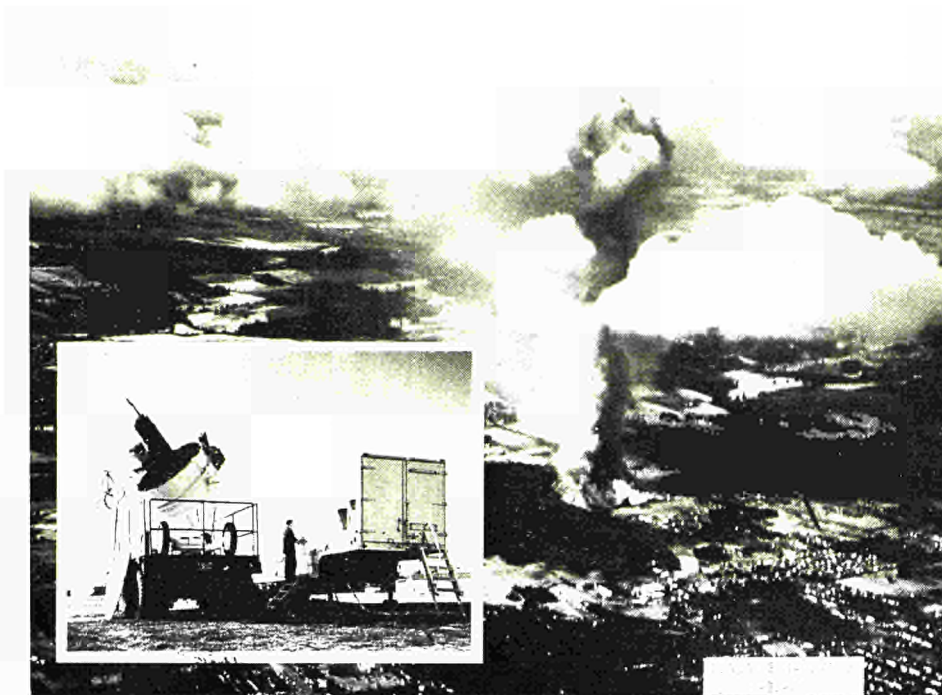


Fig. 7: Trend of the vertical NO₂ burden in ppm/m along approximately 250 km of road at San Francisco Bay during four days of smog. On the first day, the peaks were recorded in the densely populated areas of Oakland and Berkeley; on the second day, when the weather was calm, the smog increased everywhere and only the coastal area was relatively free from it; on the last day, when a breeze was blowing from the Pacific, the smog thickened to the south-east of Santa Clara Valley.

Fig. 8: A case of industrial pollution in the Willamette Valley, Oregon, studied with the NASA Lidar at Langley, Virginia. The smoke rises until it meets the inversion layer and then diffuses laterally in the valley. Accurate measurements were taken of the water vapour/aerosol mixing height and the spatial distribution (data supplied by NASA).



(sensitivity a few tens of ppm, maximum distance 1-2 km) because of the extreme weakness of the Raman signal returned from the scattering medium. The theory is that if it were possible to excite the gas molecule in question by means of radiation of a frequency such as to produce the resonant Raman effect, the return signal would increase by a factor of 10^4 . Studies on molecular scattering and experiments on frequency modulation of dye lasers are necessary in order to confirm the estimates.

Situation in the United States and the Community countries

Even though the resources required are relatively modest, research on the remote detection of pollution is virtually unknown in the Community countries, whereas in the United States considerable efforts are being made: the sponsoring body is the EPA (Environmental Protection Agency), which operates both directly and through contracts with public and private research institutes. Work on the subject is also in progress at NASA: the satellites for the study of terrestrial

resources (ERTS-A, ERTS-B, Skylab), which are to be launched as of 1972, will perform some measurements of pollution, first and foremost measurements of atmospheric turbidity; in the near future the distribution of carbon monoxide over the globe will also be measured.

In the Community countries, Lidars with ruby lasers for the monitoring of dust emission are under study or at the experimental stage. Interest in gases is gradually developing; the possibility of remote measurement of pollution would save both man-power and time and would enable additional information to be obtained.

EUSPA 11-14

References: Ch. GARRIC: *Euro-spectra*, vol. X, No. 3, pp. 81-90, 1971. (2) C.B. LUDWIG, R. BARTH, M. GRIGGS: *NASA Report CR 1380*, 1969. (3) E.D. HINKLEY, P.L. KELLEY: *Science*, vol. 171, p. 635, 1971. (4) L.B. KREUZER, C.K.N. PATEL: *Science*, vol. 173, p. 45, 1971. (5) Data supplied by Barringer Research, Ontario, Canada.

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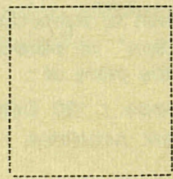
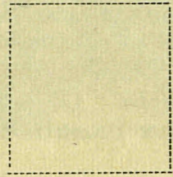
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Just published

- Collection "Research and Development" No. 3 - Public financing of research and development in the Community countries (1967-1971) - Analysis by objectives - Report *EUR 4795 i/n/e*. This analysis is published in French and German in No. 2/1971 of the series "Statistical Studies and Survey" of the Statistical Office of the European Communities.

The present study constitutes the second report of the Statistical Experts

Study Group to the working Group on Scientific and Technical Research Policy of the Medium-Term Economic Policy Committee. Like the first report, of which it is an updated version, this study analyses the R & D appropriations in the central government budgets, broken down according to the objectives specified in a functional Community nomenclature. This nomenclature, in which the R & D activities financed are classified not by the institutions responsible for them but on the basis of homogeneous categories of socio-economic objectives, facilitates international comparisons by reducing, without completely eliminating, the distortion resulting from structural differences between countries considered.

Knowledge of the public appropriations for research at the time the budgets are drawn up makes it possible as a general rule to obtain a better idea of the governments' political intentions. At that stage, however, it is sometimes necessary, especially for the purpose of assigning the data to the various headings in the nomenclature, to employ estimates based on the results of surveys carried out subsequently or on other information. Although appreciable progress has been achieved in this field, these methods of evaluation are still liable to differ from country to country. It must accordingly be emphasized that some of the figures are not entirely reliable, so that caution is necessary in interpreting them.

INTERNATIONAL SYMPOSIUM

"Environmental health aspects of lead"

Amsterdam, October 2-6, 1972

The Commission of the European Communities and the United States Environmental Protection Agency are organizing jointly in Amsterdam, October 2 to 6, 1972, an International Symposium on the "Environmental Health Aspects of Lead".

The aim of the Symposium is to examine the ways through which the recent data supplied by studies on environmental lead can be used to increase the protection of man and his environment.

The programme will cover broadly the following topics:

— *Uptake and metabolism*

of environmental lead by man, including the use of animal experiments aimed at the establishment of human metabolic models.

— *Subclinical effects of lead:*

- Experience gained from lead industrial hygiene and toxicological studies applicable to the better understanding of the biological effects;

- Physiological, morphological and biochemical changes in man in relation with lead uptake;
- Combination effects to lead exposure together with other toxic substances and environmental agents;
- The nature, role and significance of the subclinical effects of lead in establishing lead environmental agents;
- The nature, role and significance of the subclinical effects of lead in establishing lead environmental standards.

— *Epidemiological studies:*

- Identification of susceptible human population groups exposed to environmental lead;
- Current epidemiological studies in relation to the health aspects of environmental lead.

In addition to the above topics, the following themes will be treated briefly and as far as possible by review papers; they are intended to present a more complete picture of environmental lead:

- Sources of man introduced lead into the environment, transfer pathways and abatement technologies,
- Analytical methods and monitoring of environmental lead.

The discussions will be centered mainly on the subclinical effects and on the organization of the protection of man and his environment.

The Symposium is of particular interest for experts in environmental protection and for all those interested in ecological and health aspects of environmental pollution.

Registration:

Participants should register not later than 1 July 1972.

Secretariat:

Direction Protection Sanitaire
(Health Protection Directorate)
Commission of the European
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