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INTRODUCTION

Contemporary civilization is characterized by an exceedingly fast development of science and technology. Outstanding achievements in various fields have had as consequences the creation in many countries of large industrial centres with a production satisfying the ever increasing needs of the world population.1/

Although amazing achievements have been obtained in contemporary industry, its rapid development stirs up greater and greater anxiety, because industrial enterprises are a source of negative phenomena menacing man's health or even endangering his life. The phenomena of increasing concern to the specialists are air pollution and surface water pollution, which appear with a particular intensity in the large urban agglomerations where is a significant concentration of industries.

More and more frequently one reads, both in the specialist literature and in newspapers, of cases of environmental pollution that result in considerable social damage. Among the most serious should be mentioned first of all the chronic and acute mass intoxications, the disturbances caused in the physical and psychical state of people living in areas with a high degree of process gas and dust contamination, the loss of strength of humans working and living in such areas, the destruction caused by the noxious materials released in air and water to fauna and flora, and the modification of the ecological equilibrium, which is sometimes irreversible.

It must be also mentioned that air and water pollution brings about not only damages of great social significance but also losses of an economical nature that can be more or less estimated in terms of money. Such losses are increasingly important in the economy of the highly industrialized countries because they cannot be ignored when the consequences caused by the influence of the negative phenomena accompanying the development of the contemporary industry are analysed. To illustrate the magnitude of such losses due to air and water pollution, it is enough to quote some figures from the world literature.

1/ [illegible], vol. 25, No.1 (1972), pp. 93-96.

For instance, on the basis of the investigations carried out in the United Kingdom of Great Britain and Northern Ireland, it was found that the corrosion of the railways due to air pollution is now six times faster than in the early [illegible]. In France, zinc-plated sheet roofs now last about 4-5 years instead of 30 years. In Paris, Venice and many other cities, rapid destruction of the plaster of buildings and historical monuments has been reported. It has been proved that concrete not protected with a coating deteriorates quickly under the influence of sulphur, chlorine, nitrogen, carbon compounds; after only a few months in service, holes can easily be made in the concrete. In Poland, according to a survey made in 1965, it was found that over 250,000 ha of forest had been destroyed because of air pollution. The direct losses due to the decrease in the brush growth and the additional planting expenses were estimated at over 300 million zlotys annually.

The combined effect of several types of noxious materials may lead to the destruction of flora over large areas, to soil erosion and finally to landslides, with inestimable social and economic consequences. Severe air pollution leads to the increase of light absorption in the atmosphere, resulting in an increase of the energy consumed for lighting. It has been calculated that in Leningrad the losses due to the effect represent about 28 per cent of the total energy consumed in the city.

In the case of water pollution, specialists have calculated that about $40 billion would be required to clean up Lake Erie in the United States of America.

The above-mentioned figures representing the losses caused by air and water pollution are only examples and do not give the complete picture of the negative economic consequences accompanying contemporary industrial development. In order to illustrate this more accurately, it is necessary to have data by means of which one may calculate the economic losses produced by environmental pollution as a result of the operation of improperly equipped manufacturing plants. Similar data on air pollution have been established on the basis of the investigations carried out in the United Kingdom and the United States. In the United States, the calculation showed that 1 t of impurities in the air caused losses representing an average of $200 (the losses [illegible] estimated [illegible] agriculture and urban areas without including [illegible] were estimated at $270/t. If it is taken into account that, according to the same calculation, about 145 million tons of different impurities are annually released into the atmosphere in the United States, one may estimate that annually this country records losses up to about $60 billion attributable to air pollution alone. According to the calculations made, in order to provide tolerable life conditions the United States would have to spend for atmosphere protection equipment alone an amount of about $300 billion, i.e., about $10 billion per year from 1970 to 2000. In fact, that was the sum requested for environment protection by the President of the United States in his "State-of-the Union" message in 1970.

Although the examples presented here mostly refer to atmospheric pollution, water pollution is just as serious a problem. It is unnecessary, however, to prolong this introduction; the examples given here are sufficient to show the social and economic losses that may be caused by air and water pollution when plants are not provided with facilities for collecting and destroying the noxious matters they discharge into the environment.

This paper is intended as a concise analysis of the impact of the petrochemical industry on the environment. It identifies the pollutants produced, describes their effects on the environment, specifies the maximum allowable concentrations of these noxious materials, and discusses the treatment methods necessary to keep the petrochemical contribution below those limits. The final chapter gives two concrete, detailed examples of water-pollution control in petrochemical complexes.

It should be emphasized that this paper deals with the reduction of the pollution produced only by petrochemical processing plants and their auxiliaries. That pollution represents only a thousandth of the pollution brought about by the use of the petrochemical products themselves. More attention must be directed towards the reasonable use of these products.

For example, it was pointed out at the United Nations Conference on the Human Environment, held at Stockholm in 1972, that the application of fertilizers and pesticides was not being carried out reasonably and scientifically, leading to the pollution of soil and ground water, the destruction of fauna over large areas and the contamination of surface water. Another example is the unreasonable use of plastic materials. According to the specialists, it is possible that sometime during the period 1980-1985, the production of plastics will become equal to that of steel.[2] If in the case of ferrous and non-ferrous metals a recovery and reuse system has been established in almost all countries, an analogous action in the plastics field is still in its initial stages and this only in some countries (Federal Republic of Germany, Japan, United Kingdom, United States).

Today, there are several manufacturing processes for almost every product. Specialists have to select the process with the least pollution tendency or for which the most effective, not necessarily the most economical, treatment plants can be utilized. If that principle is ignored negative effects with even more serious economic implications may appear later.

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[2] "Trends and concerns in the plastic material industry", *Plastic Materials Review*, No.1/1974, pp. 19-41.

1. THE IMPACT OF THE PETROCHEMICAL INDUSTRY ON THE ENVIRONMENT

One of the industries that contribute the most to environmental pollution is the chemical industry. Among the various branches of that industry, petrochemicals is considered as one of the worst offenders owing to the huge amount of chemicals that pass through the plants, whether they are simple refineries or huge complexes for the cracking and petrochemical processing of the intermediates, and the high toxicity of the products. It is natural that, from the high volume of materials processed or used in processing, some portions that are quite insignificant from the [illegible] standpoint but rather high in absolute value will be lost during the processing either in atmosphere or in the waste waters.

The restrictive measures concerning poisonous discharges in the environment imposed during the last two decades upon industry have led to an increase of investments for environment protection within the chemical and petrochemical industries. The amounts spent by the chemical companies in the United States to reducing pollution were 4.[illegible] per cent of investment in 1970, 8.[illegible] per cent in 1[illegible] and [illegible] per cent in 1[illegible]. For [illegible], all the 137 chemical companies members of the Manufacturing Chemists' Association have reported that they would spend $1.4 billion for this purpose.[1] The average investment cost for environmental protection will increase to 9.[illegible] per cent in Japan, [illegible] per cent in the United States and 6.[illegible] per cent in Sweden.[2] All these financial efforts are meant to continuously reduce the noxious materials released into the air, water and soil.

Air pollution

There is the tendency to consider air pollution as a recent phenomenon. But the problem was already present in the early days of the Industrial Revolution and has since become more and more prominent. As far back as the second half of the 19th century, the problem was severe in London, but the citizens' protests were dissipated in the rush of industrial development.

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[1] Chemical Week, vol. 110, No.21 (May 19[illegible]), pp. 59-64.

[2] Bulletin d'informations Heurtey, No.60 (March 1974), p. 1[illegible].

In the United States, the first law to control air pollution appeared in 1881 in Cincinnati and Chicago.

The effects of pollution on man's health may be serious. Cases of collective intoxication are known, such as that in 1948 at Donora, Pennsylvania, United States, when almost half of the town population (about 14,000 persons) became ill and 20 of them died. But the greatest disaster took place in London in 1952 when mortality increased by 1,600 per cent because of the so-called "killing smog".

Along with acute air pollution, chronic diseases have appeared, such as emphysema, bronchitis, cardiovascular diseases, pulmonary cancer and so on. The quantitative effects of each pollutant are not yet known, but the effect of general intoxication of pollutants is well established.

Extrapolating from a number of recent data, specialists have established approximately that the rate of release of noxious gas and dust in the total atmosphere is up to about [illegible]40 million t/a, of which about 150 million is sulphur dioxide. If the values mentioned above are applied to these values, we may obtain the amount of losses caused by air pollution on a world level - $[illegible]40 - [illegible] billion.

The contribution of the petrochemical industry to these losses is substantial due to the extremely toxic materials that are exhausted in large amounts. Among these are saturated and unsaturated, closed-ring and open-chain, hydrocarbons; monofunctional compounds (alcohols, phenols, ethers, thiols); polyfunctional compounds (aldehydes, ketones); carbon, nitrogen and sulphur oxides; hydrogen sulphide, aerosols; and powders.

The amount of pollution depends strongly on atmospheric conditions. In certain regions and times of year, the winds and the thickness of the atmospheric layer may contribute to the dispersion of large amounts of pollutants; when the atmosphere is stable, much lower quantities of toxic gas accumulate in dangerous concentration. The nature of the terrain also has an effect: places situated in natural basins, at river confluences, on gulfs, or in the shelter of mountains are more exposed to pollution because of the temperature inversions, which stabilize the air, are more prevalent there.

Surface-water pollution

Surface-water pollution represents one of the most important of the effects on the environment caused by the petrochemical industry. Certain groups of pollutants, including inorganic acids, bases and salts, all types of hydrocarbons, organic compounds with one to four functional groups, and various suspensions of dimers, trimers and polymers, are discharged by the large petrochemical units.

If the introduction stressed the destructive action of the [illegible] materials spread into the atmosphere, this subsection will dwell upon the over-all effects of the above-mentioned groups of products on aquatic ecosystems.

The evacuated pollutants, some of which are highly poisonous, strongly affect aquatic life even in quite low concentrations. Thus, hydrogen sulphide, ammonia, free chlorine, phenols, amines, cyanides, unsaturated hydrocarbons in low concentrations may change the organoleptic, physical, chemical and biological characteristics of water, giving it a repugnant taste and odour. The same effects are also given by alcohols, esthers, ketones, aldehydes, organic acids and oil products in low dosage.

The action of these toxic materials on aquatic life is complex. The various organisms populating an aquatic basin and the abiotic medium are compulsorily interdependent. The connexions between them are achieved in various ways, mainly by means of the trophic element, and confer an integrality to the entire biocenosis. The integrality represents the result of the structural and functional differentiation of the species forming the biocenosis, manifesting itself by a more or less advanced mutual adaptation. Its development direction is that of the optimum use of the materials and power resources proper to the given ecosystem.

Pollution of a water basin, i.e., the introduction of certain chemicals, influences the integrality of the respective biocenosis and upsets its equilibrium. Contaminant biodegradable organic substances produce such disturbances rather by their amount than by their nature. Presumably, the aquatic organism's living in the basin are already adapted to the presence of such materials, in the form of dead plants and animals, and are able to degrade and mineralize them. But their large amount effects some biocenotic modifications: an increasing density of the species directly using the organic materials as a nutritive substratum, the appearance of others that can bear the loss of the oxygen consumed in the [illegible] process, and the disappearance of species characterized by an increased requirement of oxygen. Hence, a reorganization of the biocenosis accompanied by the alteration of the integrality is produced. The sequence and rate of displacement and of integrality decrease depend, on one hand, on the kind and concentration of the impurities and, on the other hand, on the sensitivity of the organism species, each vegetable or animal species presenting a certain degree of resistance that enables it to [illegible] a certain toxic material.

With inferior organisms, the toxic materials penetrate through the whole surface of the body. As they differentiate morpho-physiologically, special entry passages are penetrated, for example the digestive system and the breathing apparatus by means of which the toxic materials come into the circulatory system, which in its turn carries them to various organs and tissues. When the toxic materials reach the cell level, they act on the cell metabolism in the various ways according to their chemical composition and depending on the chemical composition of the cell substratum. So, they may influence the permeability of the cell membranes, producing disturbances in the osmoregulator mechanism; act on the enzyme equipment, inhibiting some enzyme activity; or react with certain radicals of the proteinic substances, modifying the physico-chemical composition and the aggregation state of the protoplasm.

Various toxic materials may selectively act upon certain parts of the organism, but, because of the high integrality of the living matter at the organization level of the individual, the action of the toxins on one part also has repercussions on other parts with which it is in a close functional relationship.

The living organism, which is a self-control system, tends to counteract the poisonous action of the toxic materials, i.e., preserve its integrality by means of various mechanisms. The reactions of the organism in this respect vary with the nature of the toxic material, corresponding to the action of the latter.

For instance, fish defend themselves [illegible] action by an abundant secretion of mucus [illegible] the response varies widely. Since they affect [illegible] processes, the main reaction [illegible] and the elimination from the body of the metabolic products. [illegible] modifications of the enzymatic systems may occur, with the tendency [illegible] process the toxic products and to convert them [illegible] conversion of toxic DDT by [illegible] DDE).

A more frequent [illegible] in certain tissues of the body. The heavy metals [illegible] such as [illegible], liver, bones. Some insecticides, [illegible] hydrocarbons, oil hydrocarbons, etc., deposit especially in the fatty [illegible], becoming harmless for a while. Under certain conditions, for example, when the organism is subjected to a starving regime, [illegible] materials [illegible] the circulation, producing an acute intoxication [illegible].

Finally, the toxicity of a material, i.e. the intensity and rapidity with which it acts, depends on two types of factors: those relating to the environment where the organisms are integrated – the external or ecological factors – and those characteristic of the organism upon which the action is performed – the internal factors.

The external or ecological factors influence the toxicity of a material in two ways: by changes in the intensity of the metabolic processes and by modification of the physical and chemical properties of the toxic material. Generally, it is difficult to separate these two categories of effects because they usually appear at the same time.

The main external factors influencing the action of some toxic material may be the following: the interaction between the toxic materials, the environment temperature, the amount of oxygen dissolved in the water, the CO_2 content, pH, the mineral salt content, light, turbidity.

Soil and ground-water pollution

The toxic products that may pollute the soil and, by leaching, also the ground-water layers are practically the same as those encountered in surface-water pollution. Their presence on the soil at undesired places and in the ground-water layer is due to the following main causes:

(c) [illegible] sewage lines due to [illegible] mechanical impact [illegible] corrosive sewage areas of some waters that can corrode [illegible] the sewage lines are made;

(d) [illegible] the soil or in inadequate dumps of some wastes [illegible] partial leaching of the products into the ground-water layer [illegible] wastes or the increase of [illegible];

(e) [illegible] or after a process failure and water [illegible] the refuse spouts.

Finally, [illegible] all the [illegible] may lead to the soil contamination of the inside or around the area of the plants with direct consequences on the ground-water layer.

Because of the low flow rate of ground water, it does not purify itself as readily as the surface water, and therefore the effect has a more persistent character. [illegible], these layers are used both for the water supply in areas that are short of surface water and for the water supply in the industrial units. Therefore, the effects of the aquatic layer contamination will have direct consequences, both social and economic. Also, it is necessary to keep in mind that there is a continuous communication between the ground-water layers and the surface waters, so that pollution of the ground-water layer will sooner or later lead to pollution of the surface water with which it communicates.

Noise

The main sources of noise in petrochemical complexes are the pump and compressor units and the high-pressure thermal equipment in the nitrogenous fertilizer plants. There is nothing unique in this aspect of pollution by petrochemical industry. A brief discussion of the salient points is given in chapter IX.

II. ALLOWABLE POLLUTANT LEVELS

At the outset, it should be stated that the establishment of maximum allowable levels (limit values) for pollutants within a given country is a matter of regulation and depends on the country's environment protection policy. For border regions and bodies of water shared by several countries, regulations are established by joint commissions taking into account the principal international standards. Therefore, the limit values for air and water pollutants given here can only be considered as suggestions. It is recommended, however, that countries that have not yet legislated maximum allowable levels consult the pertinent ASTM Standards of the United States, the GOST Standards of the Union of Soviet Socialist Republics, the British Standards of the United Kingdom and the International Standards of the of the International Standards Office.

Air pollutants

Annex I is a table giving the limit values established in the United States and the Union of Soviet Socialist Republics for some [illegible] noxious materials that can be air pollutants.

The United States limit values were established by the American Conference of Government Industrial Hygienists (ACGIH)[5] and are characterized as follows:

(a) They are experimental values obtained in industrial practice and in experiments conducted on animals;

(b) They are valid for momentary contaminations;

(c) The determination methods differ from one material to the other. For certain materials, the limit is determined on the basis of subjective considerations, for others, it is based on observations characterized by short or long term interruptions. Hence, these values do not have the same significance for all the materials, and no distinction can be made between dangerous and non-dangerous materials;

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[5] "Threshold Limit Values for 1972" (Cincinnati, ACGIH).

(d) The threshold limit value is defined as the concentration to which workers can be exposed daily without unfavourable consequences. They are average values for a working schedule of seven to eight hours a day, five days a week.

A limit value marked with the letter P in column 5 is the threshold limit of the concentration. A concentration of this magnitude does not present any danger, but if it is exceeded for 15 minutes, the following may occur:

Intolerable irritation
Chronic or irreversible modification of the tissues
Inhibition of self-preservation reflexes
Reduction of working efficiency

The following relation between the units will help in interpreting the table (a temperature of 25°C and pressure of 760 Torr is assumed): concentration (mg/m^3) = concentration (ppm) x molecular weight/24.45.

The Soviet limit values were established by Public Health Ministry Standard No. 245-71 of [illegible] November 1971 and are enforced by the State Sanitary Inspector. They are defined as the concentrations at which no occupational disease occurs during an ordinary eight-hour working day.

In both the United States and Union of Soviet Socialist Republics standards, certain materials (marked by an "x" in columns 5 and 7 of the table) are said to have "striking toxicity", i.e., they cause intoxication not only via the respiratory and alimentary systems but also through the skin.

Surface-water pollutants

Some countries use several categories of standards when they establish the limits for surface water pollutants. For example, in Romania surface-water supplies are divided into three categories according to end use as follows:

Category I

Drinking

Industrial units

Animal breeding units

Food and other industries requiring drinking water

Certain irrigated agricultural crops
Salmonoidic fish culture
Swimming pools and basins

Category II

Fish culture except salmonoids
Breeding and development of native fish in natural bodies of water
Certain industrial units
Urban and recreational use

Category III

Irrigation
Industrial processes

Annex II is a table giving the quality standards for the waters in these three categories. The data are according to Romanian Standard No. 4706/1966.

Besides quality standards for surface water, there are also quality standards for effluents. These may be established separately for each industry (e.g., oil processing, petrochemical, fertilizer, dyestuff, sugar) or for certain sections of a body of water on which industrial units are located, e.g., a case of a river, the upstream and downstream contribution from other manufacturing plants, is taken into account when imposing specific quality indexes on a given industrial unit.

In establishing these indexes, the amount of pollution from upstream, the surface-water flow, the self-purification capability of the river, the downstream requirements and other limitations are taken into account. That is why the limitations imposed in some cases may be more severe than those stipulated in the regulations concerning the quality of the water supply.

As these quality standards differ when the same river passes from one country to another, it is difficult to make recommendations in this field. Such data are given in the literature, but without any comment on the factors determining the establishment of the limit values.

On the other hand, there are cases when the local values [illegible] for the [illegible] waste water [illegible] stipulated [illegible] on water quality. [illegible] water-courses with [illegible] (with high pumping power), where the self-purification process takes place satisfactorily and where the industrial density in certain areas is very low, meaning that the distance between two waste-water [illegible], whether industrial or urban, is relatively high, say more than 50 km.

The condition that must be met for each pollutant if the waste water containing it is to be discharged into the river at n different locations without preliminary treatment is:

$$\sum_{i=1}^{n} q_i C_i < Q_{uz} C_{ad}$$

where

$q_i (i=1, \ldots, n)$ = Average rate of discharge of waste water at location (in l/s or m^3/h)

$C_i (i=1, \ldots, n)$ Average concentration of the pollutant in the waste water discharged at location (in mg/l or g/m^3)

Q_{uz} = Average waste-water flow rate in the river (in l/s or m^3/h)

C_{ad} = Maximum permissible average concentration of pollutant in the river (in mg/l or g/m^3)

Note that the contribution of pollutant to the effluent, the product $Q_{uz} C_{ad}$ above, has the dimensions of a rate (mg/s or g/h).

Soil and ground-water pollutants

The specialized literature has very little data on contaminants discharged onto the soil. Practically speaking, the maximum allowable concentrations of various materials and groups of materials depend on the flora and fauna surrounding the plant. Usually, these limits are established by agricultural experts and silviculturists.

For ground water, the maximum allowable concentrations of pollutants in most countries are the limit values corresponding to category I of surface water.

Noise

In almost every country, the maximum allowable level of the "pollutant" noise has been set in the range 90-100 dB. (See chapter IX).

[illegible]
[illegible]

A [illegible]

[illegible]

The principal sources of air pollutants from [illegible] are the combustion processes used to supply power for the manufacturing processes and the manufacturing processes themselves. The main pollutants are carbon monoxide, sulphur oxides, hydrogen sulphide and hydrocarbons.

Carbon monoxide appears as a result of incomplete oxidation reactions in either manufacturing or combustion processes. Its negative effects are due to its combination with the haemoglobin in the blood of mammals, producing highly stable carboxyhaemoglobin. The consequences are cardiovascular and pulmonary diseases, anaemia and alterations of thyroid [illegible]. Studies show that breathing air containing as little as 1 ppm carbon monoxide is harmful to mental activity.

Sulphur oxides appear as a result of the complete oxidation of hydrocarbons contaminated with sulphur compounds. If the sulphur content of the crude oil to be processed is above certain limits, the oil is desulphurized. Nevertheless, the sulphur that remains in the feedstock, or is present in the fuel the plant uses will still appear in the waste gas in the form of sulphur dioxide or trioxide.

Sulphur oxides irritate the upper respiratory tract and, together with any solid pollutant particles that get into the lungs, are quite harmful. In the presence of oxygen and moisture, sulphur trioxide and sulphuric acid are formed in the alveoli. An annual average concentration of only 0.04 ppm physically overworks the individual, and in the presence of a concentration

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[1] See also P. Gilles, "La Pétrochimie et la chimie face aux problèmes de l'environnement après la Conférence de Stockholm", paper presented at the International Conference on Environmental Engineering Problems in Industrialized and Developing Countries, New York, September 1973 (sponsored by World Federation of Engineering Organizations, London).

[illegible] atmosphere, mortality due to bronchitis and [illegible] significantly. Besides having these effects on people, [illegible] are the main cause of the corrosion of machinery and [illegible] of industrial areas and populated centres.

The [illegible] effect of sulphur oxides is enhanced by a high content of [illegible] in air, especially carbon dust, which facilitates the [illegible] sulphur dioxide and trioxide, which in combination with water [illegible] and sulphuric acid, respectively. That explains why the [illegible] sulphur oxides and dust content is virtually, [illegible] destroyed. In such areas one can see a great deal of [illegible] and high incidence of occupational diseases. Also, in these areas, [illegible] equipment and buildings have to be replaced from twice to three times as often as in other areas.

Hydrogen sulphide is a by-product of hydrorefining and desulphurization. It is a toxic gas, acting especially on the nervous system. In concentrations [illegible] in air for long periods, it may cause death. It has the same effect on warm-blooded animals. Because of its strong and specific odor, people cannot work well in places polluted by it.

Hydrocarbons escape into the air during decantation and handling of various types of finished, intermediate and raw products, mostly through leaks in the processing and transport equipment. Generally speaking, these pollutants are less toxic than those mentioned above. The danger from them arises from the fact that they are a major factor in photochemical fog formation. This recently discovered phenomenon[1] contains photochemical oxidants that directly affect health. At a concentration of 0.1 ppm, eye irritations occur and at 0.05-0.06 ppm concentrations, the frequency of asthma crises is increased. The adverse effects of these products is being studied, the existing data being insufficient to draw detailed conclusions about them.

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[1] Annual Report of the Council for Environmental Quality presented to the Congress of the United States, August 1970.

Among the economic effects of these contaminants an important one is that the air inlets of oxygen-manufacturing plants in hydrocarbon-polluted areas must be situated a great distance away in non-polluted regions to avoid the danger of explosion.

Nitrogenous fertilizer plant.

The main contaminants appearing during nitrogenous fertilizer production are carbon oxides, nitrogen oxides, ammonia, sulphur oxides in case the methane gas contains sulphur compounds (mercaptans), and dusts, e.g., ammonium nitrate dust.

The nitrogen oxides appear in high concentrations only in the production of nitric acid by ammonia oxidation. The noxious effects of the nitrogen oxides are due partly to nitrous and nitric acid formation in the atmosphere in the presence of moisture, and partly to their role, in sunlight, as initiators of chain reactions involving gaseous hydrocarbons which produce a range of secondary pollutants called photochemical oxidants. These oxidants, together with the solid and liquid particles in the air, form the so-called "smog" and cause irritation of the mucous membranes and the respiratory tract.

The pollutants from the photochemical oxidant family also include ozone (an unstable, toxic form of oxygen), nitrates, peroxides, aldehydes, acrolein etc.

Concerning the toxic effects of nitrogen oxides on man, fauna and flora, little is known aside from their contribution to smog formation. One fact is that small amounts increase a person's susceptibility to Asiatic influenza.

The carbon oxides appear in very high quantities in synthesis gas production, in the methane gas cracking unit.

Ammonia appears in all the steps of the nitrogenous fertilizer production (nitric acid, ammonium nitrate and urea preparation). It is an irritant to mucous membranes and the respiratory tract. If sufficient quantities are breathed for a long time, it produces maladies of the digestive and respiratory systems. It may also produce eutrophication effects on the flora.

[illegible]. [illegible] have [illegible].

A [illegible] with possible serious [illegible]. A[illegible] near the electrical [illegible] power outages.

[illegible]

The [illegible] other [illegible] xylene, [illegible] cyan[illegible]), [illegible] of [illegible] chem[illegible].

Of these [illegible], the most dange[illegible] are the highly toxic [illegible] which [illegible]. When present at concentrations as low as 10 ppm ([illegible]) and [illegible] (acrylonitrile) over long periods, they may cause paralysis. At higher concentrations, these compounds cause death even after only a short exposure. They have a similar effect on animals and birds.

Chlorinated products, the benzene-toluene-xylene (BTX) fraction, [illegible] and aldehydes are [illegible] nerve poisons, but are more tolerable and take longer to act. Their effects are usually detected and treated in time.

One of the main negative effects of the entire above-mentioned contaminant group is the tendency to form photochemical oxidants. The danger is even greater when there are nitrogenous fertilizer plants in the neighbourhood or on the same site.

Auxiliary plants

For technical and economic reasons, petrochemical complexes include, besides the basic plants, auxiliary plants for upgrading existing raw materials or for supplying the additional feedstock required for monomer production.

Examples are plants used for the production of carbon black, [illegible] of pesticides and chlorine. The contaminants released by these plants are carbon black [illegible] chlorine [illegible] leakage.

Carbon black, by itself, is a pollutant only from the [illegible] aesthetic point of view. However, in the presence of sulphur and nitrogen oxides it facilitates, because of its high absorptivity, many [illegible] and corrosive actions of these oxides, contributing at the same time to smog formation.

Pesticides, of course, are intended for the controlled and selective destruction of undesirable plant and insect species. They may be dangerous to other life when allowed to escape into the air [illegible] in an uncontrolled manner. It should be pointed out that some of these products have a cumulative effect and they may cause illness either by direct contact with the product or by ingestion of food contaminated by it (DDT is a well-known example).

[illegible] PETROCHEMICAL [illegible] EFFECTS

[illegible] contain several toxic materials. [illegible] varies according to their [illegible] (synergism), greater than [illegible] (synergism) or lower (antagonism).

The [illegible] surface water, such as its temperature, [illegible], amount of [illegible] effect on the action of [illegible] and fauna.

[illegible] of aquatic organisms according to van't Hoff's [illegible] 10°C, within certain limits [illegible] metabolic rate and with it the rate of [illegible]. Temperature also affects the physical [illegible] water, gas solubility, electrolytic d[illegible]

Dissolved oxygen [illegible] influences the metabolic processes of aquatic organisms and [illegible] with some toxic materials. For example, the action of a toxic ma[illegible] more severe in water with a low dissolved-oxygen content, resulting in a decrease in the fish survival time, or in other words an [illegible] in toxicity. The explanation is that many noxious materials act primarily on the breathing apparatus, reducing its efficiency. In oxygen-poor water, the [illegible] processed by the organism is consequently reduced, resulting in a lowered chance for survival.

A high concentration of dissolved oxygen in the water, on the other hand, accelerates the oxidation of any oxidable noxious material present, leading to detoxification of the environment and a prolongation of organism survival time.

In the case of oxygen-saturated water, the response time of the organism to the noxious material is inversely proportional to its oxygen consumption, namely the intensity of its breathing. Thus, the trout, which consumes oxygen at a high rate, responds more quickly to the toxic action of a material; therefore, it is more sensitive than, for example, the crucian, carp and tench, which do not need so much oxygen.

The carbon dioxide content directly influences the respiration of aquatic organisms. Large amounts of carbon dioxide in water containing noxious materials, generally accelerate intoxication. High CO_2 concentrations in water make it more difficult for the CO_2 produced in respiration to diffuse through the branchial membranes, leading to its accumulation in the body. This accumulation causes the blood pH to decrease with serious effects on the state of the organism. Also, the higher the carbon dioxide concentration in blood, the more difficult the combination of haemoglobin with dissolved oxygen. Therefore, the presence of large amounts of CO_2 increases the minimum limit of the oxygen concentration.

The carbon dioxide content may also indirectly influence the noxious effect of some impurities by its effect upon environmental factors, especially the pH. It is known that the toxicity of a material may depend upon its dissociation rate in water and this is determined by the pH. For example, ammonia is more toxic in water with high pH (alkaline), where it largely retains its identity as NH_3, than in water with low pH (acid), where it reacts to form the ammonium ion NH_4^+, which is less toxic than NH_3.

The cyanides and sulfides, on the other hand, are more toxic in an acid medium than in an alkaline one. Fish may tolerate a concentration of cyanides combined with nickel which is 1,000 times higher at pH 8 than at pH 5. A decrease of 0.3 in pH in a nickel sulphate solution leads to a ten-fold increase of toxicity.

The mineral content of water greatly influences the toxicity of noxious materials. Generally, the toxicity is lower in hard water than in soft water. The decrease in toxicity is due primarily to chemical reactions that result in the precipitation of some non-toxic salts and secondarily to alterations in cell-membrane permeability.

Light has a direct action on some noxious materials. Some cyanides are decomposed by light with the release of highly toxic cyanide ions. The action of light may also create toxic materials from some tars.

The toxicity of some materials is much decreased in highly turbid water owing to their being adsorbed on the suspended particles.

Petroleum refineries

Effluents from oil refineries contain mainly the following contaminant products or groups of products: mineral acids, sodium hydroxide, sulphides, phenols and hydrocarbons.

Mineral acids may appear in the waste water either from the manufacturing processes or from the waste water treatment. They may have a direct destructive effect on flora and fauna or an indirect effect by alteration of pH.

Sodium hydroxide results from the desulphurization processes employed in refineries. It is a corrosive poison that directly affects fish bronchia and aquatic flora.

Sulphides are potential reducing agents and have high toxicity even in small concentrations. At pH 8, 3-4 mg/l sulphide represents the lethal dose for most species of fish. The toxicity increases with decreasing pH, e.g., at pH 7 the lethal dose for fish is 1 mg/l (see footnote on page 25). The sulphides are quite toxic for the microfauna that serves as fish food; it is practically destroyed at sulphide concentrations of 10 mg/l.

Phenols are not always present in the waste water from the refineries, but in some cases they can attain very high concentrations. The phenols are usually carried off by hydrocarbons during cycle failures or jet overflows. The phenol concentration is variable depending on the origin of the crude oil and the characteristics of the final products. The main negative consequences they have on water are the following:

(a) They are very toxic for fish and microfauna. At 1-2 mg/l concentration, the micro-organisms are destroyed; at 5-10 mg/l, the salmonoids are destroyed; and at 10-15 mg/l, the cyprinids are destroyed;

(b) At 0.1 mg/l concentration, the flesh of food fish is no longer edible;

(c) The phenol presence is quite troublesome in the treated water used for drinking water supplies because in combination with chlorine or hypochlorite (both used instead of ozone as oxidants for organic materials) they give chlorophenol, which is perceptible even in concentrations as low as 1 μg/l.

Hydrocarbons appear in the waste water from the manufacturing processes by being carried off by rainwater from the industrial platforms or accidentally. Their toxic and destructive action on fauna and flora is evidenced in these ways:

(a) A decrease of biodegradability, which can lead to increased accumulation that hampers vital exchanges and impedes the development of fauna and flora;

(b) The carcinogenic effect of some hydrocarbons, which by degradation release benzopyrenes;

(c) Cumulative phenomena caused by chain concentration in food;

(d) A decrease of oxygen exchange between air and water because of a continuous film formed on the water surface;

(e) High toxicity for aquatic organisms. The harmfulness varies depending on the constituents, e.g., for benzene and toluene the limit is established between 10 and 90 ppm and for naphthenes and anthraquinone hydrocarbons, the limits are as low as 4-5 ppm. The paraffin hydrocarbons are less noxious but they create biological derangements (fauna migrations); similar phenomena are experienced with the olefin hydrocarbons. The hydrocarbon fractions with molecular (sulphur, metal compounds etc.) have a toxicity comparable to the aromatics.

Nitrogenous fertilizer plants

The effluents from nitrogenous fertilizer plants contain nitrogen compounds such as: nitric acid (HNO_3), ammonium hydroxide (NH_4OH), ammonium nitrate (NH_4NO_3) and urea ($CO(NH_2)_2$) coming from the nitric acid, ammonia, ammonium nitrate and urea plants, respectively.

The main effect of all these products is that by dissociation they release nitrate (NO_3^-), ammonium (NH_4^+) ions and CO_2, which lead to the eutrophication of bodies of water. Ammonia attacks the breathing systems of fish, more or less severely, depending on pH and temperature. An NH_3 concentration of up to 0.025 mg/l is tolerable by fish. The table gives the total ammonia + ammonium-ion ($NH_3 + NH_4^+$) concentration that yields an NH_3 concentration of 0.025 mg/l as a function of temperature and pH.

[illegible]) required to yield an NH_3
[illegible] mg/l

Temp. in °C.	pH					
	[illegible]	[illegible]	[illegible]	8.[illegible]	[illegible].0	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.088
10	[illegible]	[illegible]	[illegible]	[illegible].4[illegible]	0.16	0.068
15	[illegible]	[illegible]	[illegible]	[illegible]	0.12	0.054
20	[illegible]	[illegible]	0.[illegible]	0.[illegible]	0.088	0.04[illegible]
25	4.[illegible]	[illegible]	0.4	0.17	0.06[illegible]	0.039
30	3.1	1.0	0.3[illegible]	0.1[illegible]	0.05[illegible]	0.035

Much larger quantities of the noxious materials mentioned above may appear in surface water because of incorrect methods of soil fertilizer application. [illegible] products, nitrogenous fertilizers may be carried off by rain water into the rivers. An excessive concentration of nitrates in drinking water may cause methemoglobinemia and cyanosis in children.

Plants [illegible] and other primary petrochemical products

The principal pollutants discharged in waste water by these plants are mineral acids, phenols, cyano compounds, hydrocarbons, various chlorinated products, ketones, aldehydes, heavy-metal ions, suspensions of various kinds, detergents and heat. Since the effects of the mineral acids, phenols, hydrocarbons and heat have already been discussed, this section will be limited to brief discussion of the other contaminants.

The cyano compounds, such as acrylonitrile, hydrocyanic acid, cyanogen chloride and sodium cyanide, come from plants manufacturing acrylonitrile from propylene and ammonia and plants adjacent to them. These products have a high toxicity in water, not only for aquatic fauna but also for any terrestrial fauna exposed to the water. At 50 µg/l concentration they cause the death of trout in a few days, and a concentration of 0.1 mg/l is the lethal dose for about half of the fish species. This concentration also leads to biological derangements of the aquatic environment. Toxicity increases with decreasing pH and is quite persistent.

The chlorinated products come from the vinyl chloride plants and their satellite units in petrochemical complexes. In general, the products are non-biodegradable or have a long biodegradation time. They are highly toxic and directly affect the fauna and the aquatic biological equilibrium. At the same time they impart unpleasant odours to the water even in low concentrations, thus making the water unsuitable for various purposes. At higher concentrations, they cause trouble in water softening units.

The heavy-metal ions result either from the water used to purge the cooling systems or from processes in which they have been used as reaction catalysts. These ions act mainly as inhibitors of biological treatment and as poisons to fish. They also act together synergetically or additively. For example, equal quantities of copper and zinc ions in water more than doubles the toxic action on trout and roach, whereas the combination of cadmium and zinc produces only an additive toxic action on the same species. Chromium and nickel ions also act additively.

The suspensions mentioned above consist of waste matter coming from the chemical washing of plants and their platforms and polymers having a low polymerization rate that have been carelessly discharged from equipment.

Among the undesirable properties of these suspensions are the following:

(a) They become an impediment to the development of bottom flora;

(b) They produce fermentation during which noxious materials are released;

(c) They cause asphyxiation of fish due to noxious materials released either by fermentation or by contact with water;

(d) They increase turbidity;

(e) They impede the breathing of fish by causing deposits on the bronchia and other parts of the respiratory system.

The detergents appear in waste water as a result of industrial platform washing. Their toxic action may be direct, by their mere presence, or indirect, by creating a film on the water surface that traps suspensions and hydrocarbons. The consequences are the following:[8]

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[8] "Techniques pétrolières et pétrochimiques modernes, leurs effets sur la production d'eaux résiduelles", paper presented by the French Government at a seminar in Warsaw, September 1973.

(a) [illegible] of the reoxygenation capability of the river, due to the surfactant film;

(b) Destruction of aquatic herbs at 2.5 mg/l concentration;

(c) [illegible] concentrations above [illegible] mg/l;

(d) Increased maintenance costs due to necessity of more frequent [illegible] etc.

Auxiliary plants

As in the discussion of air pollution from auxiliary plants (see above), the discussion here will be limited to the contaminants originating in the production of carbon black, pesticides and chlorine by electrolysis.

In the residual water from these processes may be found carbon black, oil products, [illegible] chlorinated hydrocarbons, mercury or mercury salts, sodium chloride and sodium hydroxide.

Carbon black [illegible] form has effects on flora and fauna that are similar to those of suspensions, with the difference that it does not ferment. If the carbon black is not wettable (has a very high specific surface), the noxious effect in surface waters is similar to that of detergent foam. Because of these effects, neither form of carbon black should be used in a biological treatment plant, although the material is actually not toxic.

The mercury and mercury salts come from the electrolytic cells used in chlorine production, which have mercury cathodes. They are highly toxic for aquatic flora and fauna. The mercury finds its way into the flesh of fish [illegible] of whatever animal eats it. As with other heavy metals, mercury poisoning is cumulative. Where fish consumption is high, mass diseases may occur in chronic or acute form.

Although sodium chloride is not toxic, its presence at concentrations of 50–100 mg/l in surface water makes it unfit for uses such as agricultural irrigation, water supply of steam boilers (by reducing the ion-exchange capacity of demineralization equipment), drinking and recreational purposes.

V. SOIL AND GROUND-WATER POLLUTION BY PETROCHEMICAL INDUSTRIES

As already outlined, contamination of soil and ground water may arise from inadequate waste pits, cracked sewers, discharges of plant washing water or rain water, or from all these three causes together.

On the average, the petrochemical industry does not produce as much waste as industries such as soda ash, phosphorous fertilizer and NPK fertilizer manufacturing. Nevertheless, there are significant amounts of such wastes as polymers, acid tars, slops and sludges from the purification units. These wastes, excepting the polymers, should be pelletized when possible and stored in specially arranged places when their recovery is not economical, because their toxicity and high moisture content (93-94 per cent) may contaminate the ground-water layer or may constitute a public danger. Indeed, such wastes are better destroyed because of that danger. Soil polluted with acid tars takes a very long time to recover and should be taken out of the agricultural cycle in the meantime.

VI. METHODS OF AIR-POLLUTION CONTROL

Most petrochemical activities release into the air some pollutants that, as we have seen, represent the end of a manufacturing process. Depending on the processes and the type of equipments used, these pollutants are quite different; but they may be divided into two large groups according to their physical nature: (a) solid particles and (b) gases and vapours.9/

Particles in air or, more generally speaking, in gas, appear in the form of dusts that settle spontaneously or aerosols that do not, depending on the size of the particles. These particles arise mainly from combustion furnaces but are also released into the air in the process of storing and handling products. Those up to 10 µm in diameter are most numerous; they can be as small as 0.01 µm.

It is generally agreed that there are only two ways to fight industrial air pollution efficiently. The first is to prevent the escape of waste gas at the source and the second, to treat and purify it. Nevertheless, the release of gas from tall stacks is one of the most frequent methods of disposal used today. Although the author does not consider that this so-called "protection" is effective, some data related to stack-height calculation will be presented for practical reasons.

After an analysis of various calculation methods, the Centre Interprofessionnel Technique d'Etudes de la Pollution Atmosphérique (CITEPA) selected the following method as the simplest.10/ For SO_2 emissions, the stack-height formula is

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9/ Industrie et techniques, No. 229 (10 mai 1973).

10/ "Calculs de la hauteur des cheminées en France", paper presented at the May-June 1974 session of the Agence pour la Coopération Technique Industrielle et Economique (ACTIM) by M.M. Detrif and Bousoaren of CITEPA.

$$hp = \sqrt{\frac{340\,q}{C_M}\sqrt{\frac{R}{\Delta T}}}$$

where hp = stack height in metres

T = the temperature difference between the gas from combustion and the outside air in °C

R = exhausted gas flow rate in m^3/h

C_M = SO_2 concentration limit at soil level in mg/m^3

q = SO_2 flow rate in kg/h

This relation is theoretically valid for any pollutant gas if the appropriate concentration limit at soil level C_M for the given gas is used.

For dust, the stack height formula is

$$hp = \sqrt{\frac{680\,q}{C_M}\sqrt{\frac{R}{n\,\Delta T}}}$$

where

hp = stack height in metres

T = the temperature difference between the gas from combustion and the outside air in °C

R = exhausted gas flow rate in m^3/h

C_M = dust concentration limit at soil level in mg/m^3

q = dust flow rate in kg/h

n = number of stacks

The coefficient 680 = 2 x 340 takes into account the settlement effect of the dust particles.

The [illegible] [illegible] methods presented here were checked in the Soviet Union over [illegible] [illegible] during the construction of the stacks for seven thermal power stations, with the heights ranging from 40 to 150 m.

It is [illegible] to find a calculation method for the chimney height that will be perfectly valid under all meteorological conditions and over the whole [illegible]. However, the method suggested by CITEPA gives correct results in cases of ordinary atmosphere diffusion, namely in 95-97 per cent of all cases. In extraordinary cases (significant temperature inversion, unusual wind regime) a more stringent calculation is necessary.

Solid-particle separation

By now, the means to prevent particle or dust emissions are quite well known and efficient. They may be classified according to their operating principles as follows:

Mechanical separation by gravity or inertia
Hydraulic separation by bubbling or spraying
Filtration by bag or layered medium
Electrostatic precipitation

The mechanical dust separators acting by gravity are the simplest. They consist of a settling chamber having a large volume through which the purged gas passes with low velocity so that dust may settle by gravity. However, they have drawbacks: large volume, low gas velocity and inability to separate dust particles smaller than 50-100 µm.

Inertia dust separators are manufactured in a great variety of types from simple baffle separators to cyclones and multicyclones. The efficiency of the latter is very high. For example, the use of multicyclone batteries in a nitrogenous fertilizer plant can result in the following separation yields:

Particle size (µm)	Yield (%)
2.5	68
5	85
10	95
25	99

The over-all yields, depending on the dust granulometry, are in the range 94-98.5 per cent. The maximum capacity of the cyclones used in this application is 25,000 m^3/h at a pressure drop of 100-150 mm water gauge. Hydraulic dust separators use a liquid (usually water) to capture the dust and separate it from the gas. The efficiency of the equipment depends on the effectiveness of particle moistening, the velocity of the water particle in spraying, the gas particle velocity, water dispersion, and the diameter and number of the spraying nozzles.

There are various types having high efficiency depending on the nature of the dust: bubbling, spraying, venturi tube. The last type may have a high operating cost because an additional sludge treatment is required. All three types and the electrostatic dust separator are used for gas containing carbon-black in suspension.

Filtration separators use different filtering mediums depending on the suspension to be filtered. Here, too, there are a variety of types. The filtering layer may be cleaned manually or automatically by shaking and air blasting in a counter-current. Special attention must be given to the filtering material, which should be mechanically strong and resistant to chemical reagents and high temperatures.

Electrostatic precipitators (electrofilters) are based on the corona effect and consist of electrode rows through which the gas-containing dust is blown. The dust adheres to the collecting electrode and is eliminated. To increase the efficiency, some types of electrofilters operate with water mist. The equipment has a very high yield and efficiency, but they also have the disadvantage of a relatively high energy consumption.

Gas and vapour separation

While aerosol and dust removal is carried out rather easily by means of the equipment described above, waste gas and vapour treatment must resort to complex technical processes, since they have to deal with a continuous range of concentration of pollutants having quite different chemical properties. Four groups of air pollutants may be established: sulphur compounds, hydrocarbon vapours, nitrogen oxides, other polluting gases.

C. [illegible]

[illegible]

In [illegible] saturation [illegible] washing with [illegible], ammonia [illegible], calcium hydroxide [illegible]) [illegible] sulphite or diluted sulphuric [illegible], [illegible] appear in the recovery solutions.

Another wet process [illegible] the catalytic oxidation of SO_2 [illegible] and fixation of the latter [illegible] with water. This process is called "Sulphacid" and may be carried out in one or two steps depending on the reactor type. The end product of this process, impure sulphuric acid, is more interesting from the economical standpoint than the salts that can be recovered from the first process.

The drawback of both processes is that they release gas saturated with water into the atmosphere. They do have the advantage, however, of achieving a high retention yield - above 90 per cent - using simple, robust equipment.[11]

There are three important dry processes. The first involves the passage of SO_2 and SO_3 gas over waste products such as lime and dolomite. In this way, SO_3 is completely removed, but SO_2 is only partially removed. Another disadvantage is that the salts that are formed represent solid wastes from which sulphur cannot be recovered.

The second dry process consists of two steps: first, a catalytic oxidation of SO_2 to SO_3, and then fixation of SO_3 on metal oxides. By a further treatment, sulphur may be recovered in the form of SO_2, sulphates or even elementary sulphur.

The third dry process may be applied at sites where H_2S is present. In this case, a catalytic reduction of SO_2 and H_2S at about 150°C takes place: $2SO_2 + H_2S \longrightarrow 3S + H_2O + 35$ kcal. This process is called "Sulfeen" and is used in several countries, e.g., Canada and France.

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[11] R. Joffre, "SO_2 removal from waste gas in the chemical industry", *Rev. Nuisance d'environnement* (October 197[illegible]).

The tre[illegible] of [illegible] catalytic [illegible] the pre[illegible]. The [illegible] gas is [illegible] catalyst bed [illegible] amount of [illegible]. The following reactions [illegible]:

$$4NH_3 + 6NO \longrightarrow 5N_2 + 6H_2O + \Delta$$

$$8NH_3 + 6NO_2 \longrightarrow 7N_2 + 12H_2O + \Delta$$

To a less extent, the following reaction [illegible]:

$$4NH_3 + 3O_2 \longrightarrow 2N_2 + 6H_2O + \Delta$$

The pr[illegible] 200°C; the [illegible] below [illegible]. [illegible] pressure, no conditions are imposed, so that the [illegible] may be applied [illegible] any nitric acid plants.

The catalyst, which is under the licence [illegible], is not mentioned in literature. The only characteristic [illegible] is that it is in pellet form. The amount of catalyst [illegible] the reactor must be such that the gas flow rate is at least 10,000 m[illegible] per hour [illegible] metre of catalyst. Under these conditions, the concentration of nitrogen oxides can be reduced to [illegible] ppm, irrespective of their initial concentration in the waste gas.

For each reacted 1,000 ppm nitrogen oxide, the temperature increases by 14°C. For instance, if the initial nitrogen oxide content is 3,000 ppm, the gas will be 42° hotter after the reaction.

Approximately 1.5 moles of NH_3 are required to eliminate 1 mole NO_x from the gas mixture; for 1000 Nm^3/h waste gas having 1000 ppm (NO_x) content, the rate consumption of NH_3 is thus about 1.15 kg/h. The ammonia used must be gaseous, somewhat super-heated and supplied at a pressure at least 3 kgf/cm^2 higher than the waste-gas pressure. Additional power must be provided for the evaporation and super-heating facilities.

In [illegible] heated to about [illegible]0°C, and the ammonia is proper[illegible] reaction. At the outlet, the gas is [illegible], [illegible], and then exhausted to atmosphere.

A[illegible] nitrogen oxides consists of mixing the waste [illegible] and [illegible] them over a specific catalyst. [illegible] $_1$ [illegible]ture is in the range of 400-[illegible]. The volume ratio is in the f[illegible] : [illegible] between 1:1 and 1:[illegible]. The red[illegible] the first mixture and 80-94 per cent for the [illegible] waste gas containing [illegible],000-[illegible],500 ppm NO_x, two [illegible] the concentration down to 50 ppm.

The [illegible]: the waste [illegible] heated and mixed with C_1-C_4 hydrocarbons [illegible]. The mixture is introduced into the r[illegible], [illegible] finally into a recovery oven to obtain steam, [illegible] turbine. Afterwards, the gas is released [illegible].

The cost of such [illegible] to [illegible] per cent of the total investment for the nitric acid plant.

Generally, [illegible] take the most efficient measures for oxide absorption [illegible] and apply the catalytic reduction method only afterwards.

The purification of gas containing the carbon oxides is applied only to the gas exhausted from the manufacturing plants. It is not a destruction but a separation and recovery of these gases, which in the cases of nitrogenous fertilizer plants or partial methane-oxidation plants, are present in very high concentration and considerable volumes. The recommended method is a separation of these gases by washing them with a hydroxide solution, which converts carbon dioxide into carbonate; the carbon monoxide that remains may be dried and used in other processes (e.g. methanol manufacture).

In the case of thermal power plants existing on the site, carbon oxide pollution can be prevented by releasing the gases into the atmosphere at a suitable height.

The key to the control of pollution caused by other products, such as ammonia, hydrocarton vapours and cyanide vapours is to make sure that no leakage appears during the transportation and handling of such products. For such cases, there are no special procedures, the only efficient measure to prevent pollution being the proper and continuous supervision and maintenance of equipment and plants.

VII. METHODS OF CONTROLLING SURFACE-WATER POLLUTION

For the treatment of the noxious materials discharged in water by petrochemical plants, any of the treatment procedures known today may be applied. Since even a brief discussion of these processes would require a large volume, only the classical methods and the most efficient processes will be described here, starting from the most general to the most specific treatment methods.

Mechanical-chemical treatment

All waste waters discharged from the petrochemical plants are subjected to a mechanical and chemical treatment. This type of treatment consists of several distinct steps: separation of large pieces of solid matter, homogenization, neutralization, flocculation and settling.

Large pieces of matter are separated at the inlet to the mechanical-chemical plant by means of metal grills, the material caught by the grill being automatically removed.

Homogenization takes place in rectangular or circular tanks in which the effluents discharged from different processes are stirred and homogenized by means of scraping bridges in preparation for chemical treatment. If material accumulates at the surface or bottom of the homogenization unit, it is removed by the scraping bridge and sent for further treatment.

Neutralization of water at pH 8.5 is carried out with 96 per cent sulphuric acid or sulphuric acid discarded in other processes. Acidic water is neutralized with caustic soda lye or milk of lime when acid recovery is not possible. It is better to use dolomite lime because it produces less slurry and is cheaper than caustic soda or caustic soda lye. The introduction of the neutralizing reagents is controlled on the basis of pH measurements taken with a pH-meter. To carry out a more complete reaction between the neutralizer and neutralizant during the neutralization process, it is desirable to stir the reactants in the medium by air bubbling.

The neutralized water is passed through a unit where a flocculating agent such as ferrous sulphate or aluminium sulphate is added. In certain cases flocculation auxiliaries are also added to increase reagent action. To achieve an intimate mixture between the reactants and increase the reaction yield, air bubbling is carried out in this step also.

Settling takes place in circular or rectangular tanks. The aim is the deposition of the suspensions and of the insoluble salts formed during the neutralization process. When this step is completed, the waste water may be discharged into the water course if it meets all the conditions imposed, or it may be transferred to a higher treatment.

Activated-sludge (biological) treatment

An activated-sludge treatment is used to reduce the organic content of the effluent by digesting these compounds with the help of the micro-organisms existing in the activated sludge and by oxidizing the products with oxygen. Oxygen is diffused throughout the aeration tank by air bubbling (through stainless steel or plastic tubes) or by means of turbines, the oxidation in this case taking place in the atmosphere at the interface between the air and the water particles. Both processes provide the maximum use of the entire volume of the aeration tank achieving at the same time a homogeneous distribution of the micro-organisms and oxygen in the water. The oxygen is necessary not only for the oxidation process but also to keep the aerobian micro-organisms alive and multiplying. Nutritive agents containing phosphorus and nitrogen may also be added to maintain optimum life conditions.

The biodegradation (biological degradation) time depends on the biodegradability of the products and on their concentration, and it may range from 2 to 10 hours.

The waters together with the sludge from this step are transferred to settling tanks. Some of the sludge that settles is returned to the aeration tank to replace what was used there, and the excess is sent to a sludge-treatment unit. The treated water may be subjected to an additional flocculation and settling process or filtered through a sand filter and discharged into the water course.

The advantages of this method are that high-quality effluents can be obtained on small surfaces, without pressure losses and with reasonable power consumption.

The drawbacks of the process are high maintenance and operation costs, difficulties in dehydrating the sludge, high sensitivity of the micro-organisms to the action of high concentrations of noxious materials, difficult recovery if the bacteria cultures are affected by the noxious materials (heavy-metal ions, chlorinated products etc.) or by shock loadings, the necessity of careful control of the returned sludge volume and concentration etc.

Sludge treatment

If a high volume of wet sludge having a high content of organic materials is obtained in waste-water treatment, some measures have to be taken for its treatment and storage. The following are the most common methods being applied:

(a) Anaerobic digestion in heated, closed tanks provided with devices to maintain the optimum alkalinity conditions. This system receives the sludge from primary settling (after the mechanical-chemical treatment) and secondary settling (biological treatment). The digested sludge passes to dehydration and storage;

(b) Anaerobic digestion preliminary to the other treatment stages, known as a "pre-digestion" process, which is efficient especially in waste waters having a high biological oxygen demand (BOD) or chemical oxygen demand (COD). Use of this method allows a decrease in the size of the treatment units, especially the settling tank and the biological stages;

(c) Dehydration of the wet crude sludge by physical or thermal destruction in thickeners, in vacuum filters, by spray drying, by centrifugation or by other processes.

When anaerobic digestion is applied, it is necessary to operate with two vessels, the first being used for digestion and the second for the storage and collection of the gas formed. Usually, the first vessel is fitted with stirring devices to provide an intimate contact between the sludge being digested and the newly introduced sludge. A diminution of organic material decomposition is thus achieved, and more gas and [illegible] medium conditions are attained in the digestion unit.

The heating of the contents is achieved by coils mounted on the [illegible] surface of the reactor or by vertical coil assemblies suspended from the vessel cover. In this case, the sludge that is directed by the streams formed by stirring will flow and come into contact with the hot coils. There are also cases when the sludge is heated from the outside of the vessel, using as a heating medium the liquid that has overflown and is being recycled. The hot water used is obtained in boilers or heat-exchangers located in the manufacturing flow between the two digestion units.

From experience it has been found that a process similar to human metabolism and requiring a certain temperature and alkalinity takes place in the digestion tanks. The result is the production of methane gas with a low content of hydrogen sulphide that is suitable for combustion. In order to achieve a digestion without odours leading to the production of useful gas, it is necessary to increase the temperature of the digester content to 32-25°C and to use a reagent to adjust the pH to 7.

Since the digestion tanks are large, sometimes 30 m in diameter and 8 m high, a significant quantity of heat is required. This heat can be obtained from the combustion of the gas resulting from the sludge digestion.

After vacuum filtration, centrifugation etc., the sludge is dehydrated and sent to the incinerator(which may be vertical with superposed hearths, tubular like a cement oven, in a fluid bed with inner ceramics or sand, or some other construction) fueled by methane, residual gas or heavy oil.

Dialysis and electrodialysis

Dialysis is the separation of substances in solution by means of their unequal diffusion through a semipermeable membrane. Electrodialysis, or dialysis in the presence of an electrical field, is particularly well suited for the separation of the ionic components from a solution. The [illegible] d, [illegible] membranes with [illegible] between, [illegible] alternately follow. One membrane permeable [illegible] and [illegible]; the other, with [illegible]. As in an electrolytic cell, the anode attracts [illegible] and the cathode, positive ions. The cell is built in such a way that the ions attracted to and penetrating the anode and cathode [illegible] return to the solution passing between the membranes. Thus, the solution subjected to electrodialysis becomes highly purified.

[illegible] very costly because of an energy consumption of [illegible] kWh/m. Moreover, the process requires an effective removal [illegible] dialysed [illegible] that could [illegible] the membranes. [illegible] different series of membranes must be used, depending on the kinds of salt to be removed.

Reverse Osmosis

Reverse osmosis is a kind of filtration by membrane sometimes called "superfiltration" or "hyperfiltration". It differs from dialysis in that high pressure is used to force the liquid through a semi-permeable membrane, leaving behind the solid suspensions or the dissolved salts. In normal osmosis, the flow is the other way: pure water passes from the less concentrated solution through the membrane into the more concentrated solution. When pressure is applied to the more concentrated solution, the water passes in the reverse direction; thus the name, reverse osmosis.

Originally, the method was used for desalting sea water. Now, it is used in industry to remove sulphuric acid and hydrogen chloride from their aqueous solutions. The process is relatively expensive but is the best solution for treating water on which severe restrictions apply or that should have a high purity for recycling.

In some plants, the system removes, in one step, solid suspensions, bacteria and viruses from the effluent. After this process, the BOD of the effluent is 5-10 mg/l. The results are comparable to those of biological treatment, but the cost of the plant using a filtering membrane is lower than the cost of a classical treatment plant, where the purpose is to obtain high purity water.

The membranes used are cellulose acetate strips, which are not easily blocked by suspensions and allow flow rates of 400-1,000 l/day/m² filtering surface at pressures below 40 kg/cm². The plant is compact and occupies little space; it can even be installed inside the building. Each cubic meter of plant provides a filtering surface of 150-300 m².

The process described has given satisfactory results in the treatment of waste water from chemical and pharmaceutical industries and has also been successfully applied in the treatment of water containing large amounts of organic impurities.

Chlorine, hypochlorite and ozone oxidation

In some cases, the process waste waters may still be heavily loaded with organic matter even though they have been subjected to mechanical-chemical and biological treatment, so that they do not meet the standards for discharge into a public water course. A finishing step using strong oxidants such as chlorine, hypochlorite or ozone is carried out. This oxidation process is also applied to water containing cyanides and phenol. Usually ozone is used in this case because it oxidizes cyanide ion into cyanate ion, which is about 1,000 times less toxic and hydrolyses to CO_2 and NH_3. In the case of phenol, ozone is used in the finishing step in order to avoid the chlorophenol that would be formed in the oxidation by chlorine or hypochlorite. It is known that chlorophenols give an unpleasant taste to drinking water when present in concentrations as low as 0.015 ppm.

In some countries, ozone is used in treating the waste water from refineries and coke ovens (such water is similar to the water coming from petrochemical plants). Phenols, as well as mercaptans and other sulphur compounds, disappear after being in contact with ozone for only 3 min. After 15 min of contact, an organic material content of 30-50 mg/l is reduced to 10 mg/l. The ozone consumption in this case is 1.5-2.7 mg/mg contaminant.

In making the ozone if oxygen is used as raw material instead of air, twice as much ozone is produced for the same consumption. Either raw material must be dried at $-60^{\circ}C$ and fed into the ozonizer at a temperature below [illegible]°C. It is recommended that 99.5 per cent pure oxygen be used.

The most practical ozone/contaminant ratios are the following: 1.[illegible]-[illegible] for phenol and 1.[illegible] for cyanide ion. In treating refinery waste water, the goal in the tertiary treatment is to obtain a final effluent with maximum phenol content of 3 ppm.

The over-all energy consumption of the process is about 20 kWH per kg of ozone.

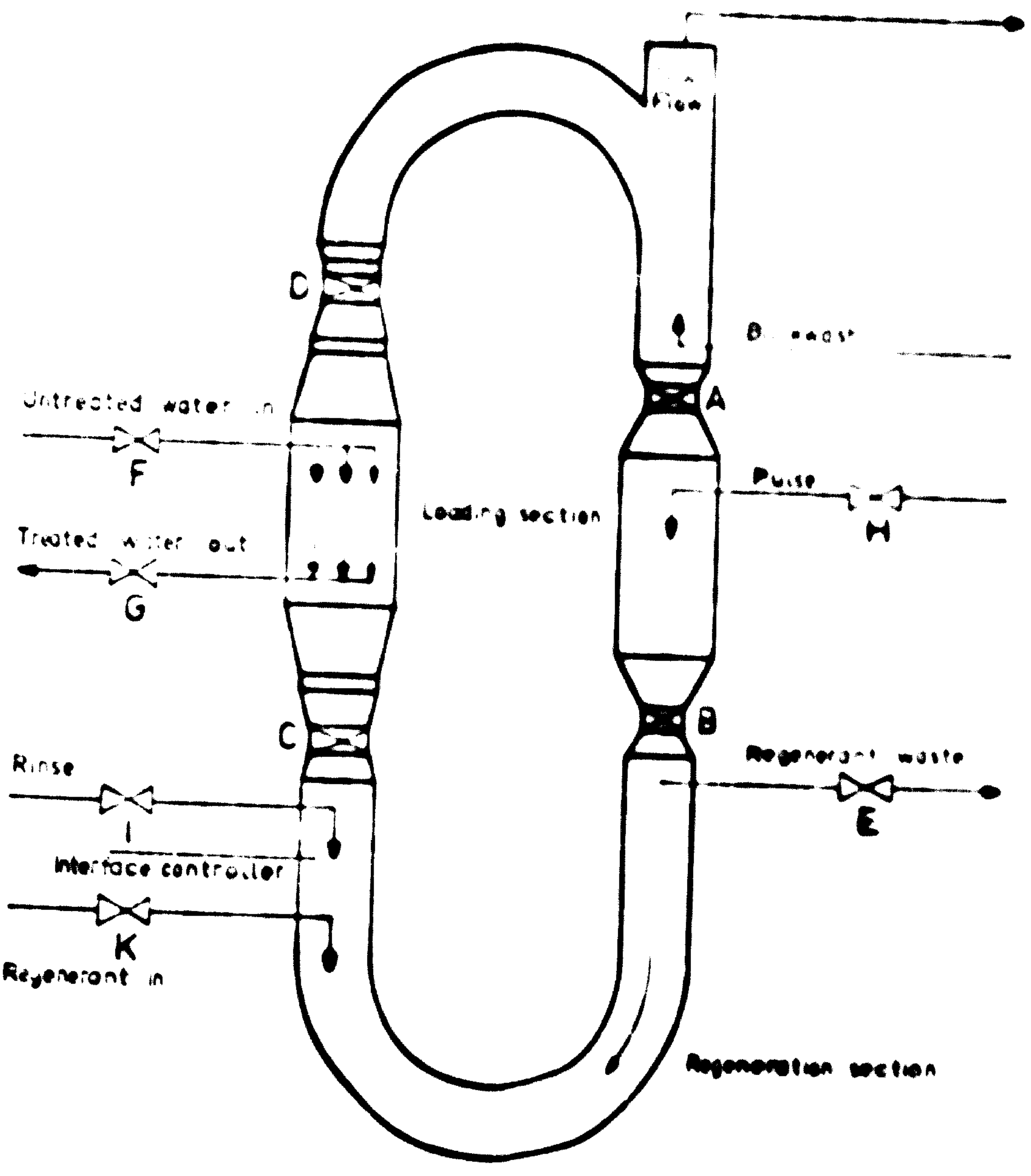
Treatment of water containing nitrate and ammonium ions

Formerly, it was believed sufficient to neutralize water containing nitrate and ammonium ions with lime or acids, but experience proved the process to be inefficient because of hydrolysis. Several other treatment and destruction processes have been developed, among which are stripping and ion exchange.

Stripping of waste water containing these contaminants is carried out with low-pressure steam in ordinary towers after a preliminary alkalization of the effluent. Ammonia is extracted at the top and returned to the process or utilized as a fertilizer (ammonia water), and the acidic water from the still is neutralized.

Ion-exchange adsorption was once an expensive batch process. Now, a continuous process is available, using a reactor similar to that shown in Figure I. The process has four distinct stages. In the first stage, the ion-exchange resin is put in contact with the ion that must be adsorbed. When the resin is saturated, admission of effluent is stopped and the resin is passed to the following section where it is washed. In the third stage, regeneration of the resin is carried out with the recovery of the adsorbed ion in the form of ammonium nitrate, and after this the resin is transferred to the fourth stage for washing loosening before return to the first stage of the process. Any resin lost in the process is replaced in the last stage.

FIG. 1. [illegible]



Valve positions during cycles:

Run cycle: valves A, E, F, G, I, K open; valves B, C, D, H closed

Pulse cycle: valves B, C, D, H open; valves A, E, F, G, I, K closed [illegible] way, all [illegible] take place in the same equipment, [illegible] separately from [illegible]. [illegible] the water for the admission of [illegible] water, [illegible] and the [illegible] water.

[illegible] there for [illegible] and for other purposes. In [illegible] was [illegible].

M[illegible]

[illegible] waters [illegible] mineral acids and [illegible] in the mechanical-chemical treatment [illegible]. When the discharged salt concentration exceeds the [illegible] needed to dilute this water or to treat it [illegible].

Phenols

[illegible] phenolic waters gives satisfactory results. [illegible] together with other effluents or separately, [illegible] a simplified process called "oxidation ditch" may be used.

This [illegible] alternative of the activated sludge method: It depends not only upon mechanical aeration and stirring of the effluent to maintain [illegible] in the ditch and to ensure contact between the waste liquid and the introduced oxygen. This is achieved by an impeller spraying the water on the ditch surface. By this method it is possible to accomplish complete mixing and to lengthen the aeration period for a long-term oxidation (usually longer than 24 h). Sufficient oxygen is provided for the stabilization or destruction of the phenolic product. The volume of an oxidation ditch should be 5 m^3 for 1 kg BOD per day. A liquid layer thickness of 0.90–1.5 m is recommended. The ditch may be in the form of a ring or a single or double ellipse but must form a closed cycle. The median strip must be wide enough so that the ends of the ditch should not be too acute. To handle 40 kg BOD per day, the median strip should be 5 m wide.

Besides the ditch, there is also a mechanical-chemical water treatment at the inlet and a settling of the water discharged from the ditch. Part of the sludge from the settling tank is returned to the ditch and the excess is deposited in drying beds or treated by one of the processes described above under "Sludge treatment".

Phenolic waters may also be incinerated. This method may be applied to effluents with very low flow rates and very high phenol concentrations or to phenolic waters. The process is expensive because of the high fuel consumption.

The incinerators are vertical kilns that have four, six or eight burners at the bottom arranged on the furnace circumference and a central burner. The effluent to be incinerated is sprayed through two to four nozzles onto the flames of the burners. The burning regime is controlled by thermocouples and may be automatically adjusted.

Cyanides

As was previously pointed out, ozone is preferred to chlorine or chlorine compounds as a reagent for destroying cyanides. The cost of a plant using ozone is higher, but the operation is cheaper. In literature one finds mention of a consumption of 2 kg ozone per 1 kg cyanide, at a cost of about $1, as compared to other plants where 8 kg chlorine are used for 1 kg cyanide at a cost of about $1.70.[12] Hypochlorite is not suitable for high cyanide concentrations and volumes because it is not much cheaper and requires complex equipment for operation and handling. Also, hypochlorite decomposes easily and becomes useless. The cost of ozonization plants decreases considerably if they are operated continuously or are not overdimensioned.

As with phenolic waters, when the effluent containing cyanides has a low flow rate and high concentrations, incineration may be adopted as a treatment method.

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[12] Edmund B. Besselievre, The treatment of industrial wastes (New York, McGraw-Hill, 1970).

Hydrocarbons

Removal of hydrocarbons from the effluent is achieved with high yields ([illegible]) by [illegible] oil-[illegible] processes. For this purpose, the waters are [illegible] in homogenization tanks.

In place of [illegible] hydrocarbons may appear in "shocks" (high-volume surges), [illegible] tanks are installed ahead of the homogenization tanks to absorb [illegible]. After homogenization, the waste water is subjected [illegible] process in settling tanks. The most common types of settling tanks are, the type standardized by the American Petroleum Institute (API), the parallel-plate interseparator (PPI) and the corrugated-plate interseparator (CPI).

The API tank is of a size calculated to provide a slow velocity of liquid passage through the tank and a uniform distribution of the liquid jet. Its construction enables the oil and hydrocarbon particles to form a thin layer on the surface while the heavy materials fall to the bottom. A [illegible] scraper shoves the hydrocarbons into a hole and the heavy materials into a tank. The most important factors in the yield of the API tank are circulation velocity, time required for the oil to separate from the water, suspension settling rate, water temperature, density and diameter of the oil drops, quantity and composition of the suspended matter, presence of sulphur and detergents, pH and geometry of the tank.

The PPI tank is a conventional tank divided into longitudinal channels by some parallel plates. In this way, the separation capacity is increased because the maximum height that an oil drop must rise before reaching the surface is reduced. This separator also has the advantage that it diminishes turbulence and favours gravitational separation. The process is less expensive than the one described previously.

The CPI tank is like the PPI tank, except that its plates are corrugated rather than flat. This fact leads to two interesting phenomena: sliding of the sediments downwards in the circulation sense and regrouping of the oil particles upwards in the counter current. This device provides a slight improvement by increasing the hydrodynamic quality and creating counter currents between the water to be treated and the hydrocarbons, thus favouring coalescence.

This new equipment, when used in the refineries, [illegible] water hydrocarbon concentrations in the range 5–9 [illegible], whereas [illegible] hundreds [illegible] per litre of hydrocarbons [illegible]. Therefore, after this treatment, if the water [illegible] products, it may be discharged directly into water courses.[13]

Other mechanical-physical processes for removing hydrocarbons are settling aided by active flocculation and floating.

Settling aided by active flocculation separates the [illegible] of a large part of the suspended matter and hydrocarbons [illegible]. This treatment is doubled by a chemical treatment of sulphurous waters being dealt with. Desulphurization by chemical precipitation when the sulphide or mercaptan content is below 100 mg/l is carried out efficiently by utilizing classical coagulant reagents such as iron or aluminium salts. At the same time, if hydrocarbons are present, it is necessary to increase their weight by adding lime and diminishing the settling rate. In this case, floating is desirable.

Air floating and electrofloating is carried out only after the addition of an agent to the liquid to be flocculated, so that the microbubbles that collect around the hydrocarbons and suspended matter may carry them to the water surface to be removed by a scraper. The microbubbles are produced either by the release of pressure on an effluent saturated with air at a pressure of 4-5 bars (air floating) or by the release of oxygen and hydrogen bubbles from the surfaces of immersed electrodes (electrofloating). The flow rate of liquid in the floats is higher than that used in settling tanks and varies from 3 to 6 m/h depending on the nature of the water, the degree of treatment and the concentration of the floating agent. It is important that the distribution of the microbubbles be as uniform as possible and the hydraulic concentration be controlled. In air-floating, the lime consumption varies between 20 and 50 l/m^3 water, the flow of process water representing 20–40 per cent of the treated water flow.

13/ "Techniques pétrolières et pétrochimiques modernes, leurs effets sur la production d'eaux résiduelles" - conference presented by the French Government at a seminar in Warsaw, September 1973.

(R[illegible] be used for [illegible] water). A 70 per cent decrease [illegible] suspended matters and a [illegible] per cent decrease of the [illegible] attained.

[illegible] effluent, the hydrocarbons that remain after the [illegible] be destroyed in the biological treatment [illegible] treatment with oxidizing agents and filtering layers.

[illegible]

The [illegible] mentioned in chapter IV are preliminarily tested in the lab[illegible] biodegradability, on which the possibility of eliminating [illegible] treatment depends. At the same time the toxicity [illegible] is checked.

Irrespective of the test results, waters containing organic materials are subjected to mechanical-chemical treatment. If they are biodegradable, the effluent [illegible] biological step, otherwise, they are subjected to reverse [illegible] electrodialysis or oxidation. If the materials are not biodegradable, effluent separation is attempted and a low flow rate is maintained [illegible] with a high concentration to prepare the effluent for incineration.

Heavy-metal ions

As was mentioned before, zinc, chromium, copper, manganese, nickel, cobalt and vanadium ions are strong inhibitors of the biological treatment process. Therefore, the treatment of water containing these elements is carried out quite separately from that of other water in chemical plants. This treatment process is relatively simple and is based on the precipitation of these ions by adding a dilute sodium hydroxide solution (10 per cent) simultaneously with a flocculating agent (ferrous sulphate) and stirring the solution vigorously. After the reactions take place, the hydroxides are separated, removed by filtration through a press filter and deposited in the dump. The water is discharged into the storm sewer. It must be pointed out that not all the metal hydroxides precipitate at pH 6-7; chromium, copper and manganese precipitate at pH 7-8 and nickel at pH 7.5-8.

Mercury salts

The treatment of water containing mercury salts is also carried out separately. In this case, the mercury is precipitated with calcium hydroxide and carbon disulphide; after filtration, the water is discharged separately into the storm sewer. The carbon disulphide is regenerated by distillation, and the mercury is recovered and returned to the process. The wastes are put into sealed containers and deposited in specially arranged places (surge tanks reinforced with concrete).

Carbon black

The removal of carbon black from waste water is effected by mechanical-physical processes. Dry carbon black (high specific surface) is retained in the settling tanks, where it rises to the surface with the light hydrocarbons and other light suspensions, collected and incinerated. Wettable carbon black is found on the bottom of the settling tank and is discharged with the sludge to the sludge thickeners and fermenters.

When the amount of carbon black is quite large (e.g., in partial oxidation methane plants), the water is separately treated, the carbon black being separated according to the above-mentioned principles and incinerated after it has been dehydrated by filtration and compression. If the settling process does not give satisfactory results because of the presence of petroleum products, the air floating process is recommended.

VIII. METHODS OF CONTROLLING SOIL AND GROUND-WATER POLLUTION

To many people, the term "waste deposits" still connotes large areas chaotically covered with various domestic and industrial wastes. In fact specialists in this subject have worked out a series of principles for the salubrious and organized deposition of wastes.

To define the deposition area, data on the following items are necessary:

Geological structure of the land
Characteristics of the ground-water layers
Ultimate disposition of the waste

For the first two items, it is necessary to carry out some drillings and detailed analyses. The former requirement for a low soil permeability in the deposit area is no longer so important because of modern techniques (insulation with reinforced sheets or bitumen, draining systems etc.).

The organized deposit is accomplished with industrial equipment within a well defined perimeter and under continuous supervision, in order to avoid the scattering of the waste. The soil water is continuously examined and analyzed to detect any exfiltrations from the deposit. The organized deposit may also include provision for reclamation of the land after the deposit is broken up. Depending on the structure of the soil, the area may be used for agriculture or recreation.

Construction of waste pits

Waste deposits are usually located on non-fertile areas around the industrial chemical works and, if possible, where impermeable loess or marl layers exist at the surface or slightly below. In this case, the bottom of the storage pit need not be impermeabilized. The marginal dikes are made impermeable shields of impermeable gel. On slopes, impermeabilization is effected with stabilized clay protected with sand.

In case the [illegible] is permeable or the [illegible], mobile layer [illegible], asphalt layers made with [illegible] bitumen [illegible] reinforced with glass fibre are used to insulate the deposit. For less severe conditions, only the polyethylene sheets could be used [illegible] with the waste verify that they will be adequate. For extremely toxic wastes, concrete-reinforced pits are recommended.

Discharging of wastes at the deposits is done by overhead cranes with grab buckets or conveyor belts. In the case of large deposits, access roads must be built.

Determination of ground-water movement

It is necessary to determine the hazard of ground-water pollution by the noxious materials that may eventually exfiltrate through the impermeable storage pit system into the ground-water system. A radiometric method has been developed[14] for the establishment of the direction and rate of flow of water underground. Its principal advantage is that it does not disturb the natural conditions of the water flow at the given place and during the tests. One starts from the hypothesis that a water volume marked with radio-nuclides has the same dynamic parameters as a non-marked water volume. For determining the velocity vector, it is necessary and sufficient to determine at any moment the position of the centre of gravity of the radio-nuclide cloud.

The radioactive Br^{82} solution is introduced in the area by a vibratory pile driver. The tracing of the movement of the radio-nuclide cloud through the investigated porous medium is done by detecting sounders on the circumference of a circle centred on the injection point and with a radius dependent on the supposed water velocity. The detection of the centre of gravity of the radioactive tracer is done by sliding a Geiger-Müller radiation counter inside the detecting sounder and recording its counting rate at different distances.

It is possible to determine the flow direction by tracing the centre of gravity of the radioactive tracer. The radio-nuclide cloud carried off

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[14] "Radiometric method for the determination of velocity, flowing direction and course of the ground waters", Romania Patent No. 47.215-1965.

by the underground water will come close to the detecting sounder located in the direction of the movement. The counting rate of this sounder will reach a maximum when the centre of gravity passes through that point. The horizontal component of the flow direction is given by the straight line joining the launching point with the location point of the detecting sounder registering the maximum activity. The vertical component, i.e. the depth of the centre of gravity, is obtained from an analysis of the counting rate variation with depth in the same sounder. Measurements [illegible] may be extended to greater distances by extracting the detecting sounder and replacing it further along the projected path of flow.

The flow rate is determined by direct division of the distance covered between the moment of launching and the moment of detection of the maximum radioactivity by the time interval between those moments. However, there is a difference between the tracer speed and the actual water flow rate, caused by the interaction phenomena between the radio-nuclide and the porous medium that was penetrated.

Analysing these phenomena (adsorption and absorption, ionic exchange, diffusion etc.), many researchers have concluded that the difference between the tracer and water speeds, if not adjusted for, may lead to relative errors as high as 50 per cent, especially for low water flow rates.

Applying a differential equation for the rate of change of tracer concentration in a porous medium derived by Inoue and Kaufmann[15] to the case of cation exchange, Vermeulen and Hierster[16] arrived at this relation:

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[15] Y. Inoue and W. Kaufmann, Health Physics (1953).

[16] T. Vermeulen and N.K. Hierster, Industrial and Engineering Chemistry (1952), p. 636.

$$\frac{V^a}{V^t} = \frac{1}{1 + \frac{q\,p}{C^o\,P}}$$

where V^a = water speed

V^t = tracer speed

q = ion exchange capacity of the medium

p - density of the medium

C^o = initial concentration of the tracer

P = porosity of the medium

The method and calculations have received practical application in Romania, where it has been found to give very accurate results.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

The [illegible] that noise not [illegible] the plant, [illegible] near [illegible].

Noise [illegible] in almost every [illegible] at a level [illegible] dB higher [illegible].

A [illegible] International Organization [illegible] of May [illegible] for fluctuating levels.

Once the limit values for noise are decided, it is necessary to establish the permissible exposure time of the individual, considering that at 50 dB intellectual work begins to be disturbed and at 70 dB it is very difficult to continue such work.

Depending on noise limit and exposure time, the [illegible] night and the [illegible].

To simplify the calculation of noise pollution [illegible] plant, one may assume that all the noise sources in the plant are brought together at a single point called the phonic polluting centre. This approximation is valid for average plants with blocks of houses below [illegible] in size and the observation point being [illegible] away.

If L_{pA} is the maximum permissible acoustic pressure level (established by standards), at point A located at a distance d_A from the phonic polluting centre, the maximum pressure that should be produced at the phonic polluting centre IMA is

$$\mathrm{IMA} = L_{pA} + 10 \log \pi\, d_A^2$$

This relation is based on the assumption of propagation by spherical waves in a calm and isotropic atmosphere. It does not take atmospheric absorption into account, which is proportional to distance and depends on frequency. There is also a wind effect that modifies the shape of the wave surface. This phenomenon leads to an increase in loudness at observation points situated in the wind direction and a decrease at observation points in the opposite direction. To correct for this in cases of an almost constant prevailing wind, albeit imperfectly, one may introduce a correction independent of frequency of ±5 dB at 400 m and ±10 dB at 1000 m. For plants in construction, the screening effect of the buildings should also be considered.

When there are several sources of noise, it is also advisable to classify the sources principal frequencies of the sounds they produce: low frequency (≤ 350 Hz), average frequency ($350 \leq f \leq 1{,}700$ Hz) and high frequency ($\geq 1{,}700$ Hz).

X. TWO ACTUAL EXAMPLES OF [illegible] CONTROL IN PETROCHEMICAL COMPLEXES

This [illegible] two [illegible] examples of petrochemical [illegible], [illegible] Italy, that have a range of [illegible] balanced unit, say, a [illegible].

First [illegible]: [illegible]

Basic data

The [illegible] plant within the complex process the acetylene obtained by methane pyrolysis [illegible] for the production of vinyl acetate and polyvinyl acetate (PVA).

The nitrogen [illegible] fertilizer plants release ammonia and ammonium salts, nitric acid, and products containing arsenic with an effluent flow rate of 250 m³/h.

The methane pyrolysis and PVA plants release organic materials at the rate of 0.8 t/h, [illegible], carbon black, ammonia and hydrocarbons. The effluent has a flow rate of about 1,000 m³/h and a BOD of 1,500 kg/h.

The conditions imposed on the effluents discharged into the river are as follows:

BOD	max. 10 mg/l
COD	max. 150 mg/l
Ammonia	max. 0.3 mg/l
Hydrocarbons	max. 0.1 mg/l

pH 6.5 - 9.0

Ammonia and [illegible]

Ion exchange treatment

The effluents that contain [illegible] ammonia [illegible] (condensate water [illegible]) [illegible] nitrate and [illegible] to remove nitrate and chloride ion, which are then [illegible] resin with ammonia solution. The remaining [illegible] solution is passed to a three-step vacuum [illegible] concentration (to about [illegible] per cent), the ammonium nitrate [illegible] ferred to the ammonium nitrate plant [illegible] process operations.

The acid or alkaline waste water [illegible] exchange resin are sent to an ordinary neutralisation plant and [illegible] discharged into the river.

Stripping treatment

Simultaneously with the first process, the effluents with [illegible] ammonia content and high flow rates that appear continuously [illegible] continuously in the fertilizer plants are stripped [illegible] alkaline with sodium hydroxide in excess to completely release the ammonia. The process takes place at 100° C with steam in the distillation tower. The ammonia and water vapours are condensed in the form of ammonia water having a concentration of 15-20 per cent ammonia. This ammonia water is reused within the same complex in other manufacturing processes and in the biological treatment.

Arsenic

From the carbon dioxide washing towers in the ammonia plant, the following waters with arsenic content are obtained: continuous condensate, rain and washwater from the platforms, waste water resulting from accidental [illegible] a precautionary unit [illegible] of these types [illegible] with [illegible] per cent lime [illegible], [illegible] which the arsenic is later [illegible].

[illegible]

[illegible] and carbon black are [illegible] the methane [illegible] plant and are gravitationally guided [illegible], which [illegible] preliminary treatment station.

[illegible], [illegible] settling unit consisting of [illegible]. The size of the unit is such [illegible].

[illegible] collecting tank from which [illegible]. The hydrocarbons dis[illegible] from which they are [illegible]. The waste water, when determined by analysis to be sufficiently free of ammonia and hydrocarbons, may be sent either to the biological treatment station or used in the transportation of the sludge towards the ash dump.

A large amount of carbon black and coke is separated from the cooling water in the lower part of the pyrolysis furnace and sent to a rotary filtering unit. The filtrate is discharged into the storm sewer and the moist carbon black and coke residue on the filter is incinerated in rotary ovens.

Ammonia and higher acetylenes from the methane pyrolysis

Since the effluent discharged from the acetylene plant contains both ammonia and the higher homologues of acetylene, such waste waters are incinerated in a fluid-bed furnace with two combustion sections. For the incineration two furnaces are provided and they operate alternately.

In the lower section, which is shaped like a truncated cone and has a fluid-bed consisting of refractory lumps or gravel, the water is evaporated and the residue burned, incompletely or completely depending on the quantity of primary air introduced. The temperature is in the range 800-1100° C.

In the upper section, complete burning takes place in the presence of secondary air introduced tangential through two holes, 180° apart. The temperature is about 800° C.

The methane-gas burner that initially produces a temperature of at least 800° C and maintains it during the waste incineration is placed in the lower part of the evaporation-burning area.

Pollutants from polymer production

Pre-treatment

The pre-treatment of the waste water from monomer and polyvinyl acetate production consists of a polymer suspension separation and a pH adjustment of the discharged water with calcium hydroxide. The polymer suspension, settled in a local settling tank, is extracted and deposited separately in an appropriate storage pit. The water is then given a mechanical-chemical treatment.

Mechanical-chemical treatment

The water first passes over a screen where the coarse material is separated out and mechanically removed. Further on, the water passes into a sand-clearing basin. The separated sand is discharged in batches by a mammoth pump. The water is treated with calcium hydroxide and directed to the primary settling tanks. These are fitted with hydro-elevators for recycling the sludge and scraping bridges removing it. They also have collecting systems for the hydrocarbons that happen to appear after local treatment and separate out in this stage. The lime-milk suspension is fed by pumps controlled by a pH-meter. The sludge that was separated in the settling tank is removed by gravity to the pumping station and then to the ash dump.

The resulting effluent, wh[illegible] pH of 1, is collected in a retaining pit system and the pH [illegible] with sulphuric acid under agitation by air bubbling. The [illegible] of the calcium sulphate formed takes place in a settling tank w[illegible] bridge. The sludge is sent to [illegible] dump.

The treatment yield of the [illegible] per cent of the organic contamination. For special [illegible]), either step may be substituted by the other.

Homogenization, the next step, [illegible] provided for both steady and irregular flows (e.g. rain [illegible] and consists of two tanks operating alternately or in [illegible]. The tanks have aeration turbines mounted on floats in order to [illegible] variation. The homogenized water is passed to a second [illegible] and then to the biological treatment station.

Biological treatment

Nutrients containing phosphorus and nitrogen are added and the water and activated-sludge mixture is aerated by [illegible] turbines provided with suction tubes. Of the total volume of the tanks (41,500 m^3), 75 per cent is for the biological treatment and [illegible] per cent for activated-sludge regeneration. With an over-all oxygen [illegible] rate of 2,200 kg/h, a BOD of 0.665 kg/m^3/day can be handled.

The phosphorus and nitrogen required for the nutrition of the micro-organisms are given in the form of sodium phosphate and ammonia water, respectively. The proportioning of the nutrients is carried out automatically depending on loading and flow rates. The yield of the biological treatment is 90 per cent of the input BOD.

Secondary settling

The water and activated sludge mixture is gravitationally guided to the secondary settling, accomplished in circular settling tanks equipped with scraper bridges. The separated water is passed to the third step - a mechanical-chemical treatment.

The separated activated sludge is collected by a [illegible] tube system mounted on the scraping bridge and is directed to a central metallic tank from which it is recycled to the aeration tank by means of vertical pumps. The sludge excess is removed by gravity to the pumping station and deposited in the ash dump.

Tertiary mechanical-chemical treatment

In order to assure a high degree of treatment, a final flocculation-settling step is provided. The equipment consists of the necessary reaction vessels and two tertiary settling tanks. The treated water is drained through a flow-metered channel to the treated-water collector, and the chemical sludge formed is discharged gravitationally to the pumps and further on to the ash dump.

Corrosion problems

Corrosion problems appear in these plants, especially at the ammonium-ion recovery unit, where special acid-resisting steel must be used. In the monomer and polymer plants, the effluent settling tanks and catchment basins are lined with acid-resisting bricks and the fittings, joints, pipes and pumps are manufactured of special acid-resisting steel. In the mechanical-chemical and biological treatment, the tanks are protected by an epoxy-resin coating.

The influent conduits for the industrial waste water are made of glass-fibre reinforced polyester, and the reagent preparation, proportioning, feeding and transportation equipment is manufactured out of special steel.

Process control

The entire waste water treatment process is controlled from a central control room where all the data is recorded by instruments. Depending on this data, the plant may be operated automatically or not by remote control.

Second example: A petrochemical complex consisting of monomer production and processing plants and an oil refinery

The second example analysed is a petrochemical platform consisting of a refinery, pyrolysis plant, plants for the separation of monomers and production of polymers, polyethylene, polypropylene, polystyrene, complementary plants for the manufacturing of other products (acrylonitrile, ethylene oxide, glycols), and a carbon-black plant.

Basic data

The main contaminants that may be found in the waste water are the following:

Inorganics: sodium hydroxide, sodium sulphide, sodium carbonate, calcium chloride, sulphuric acid, titanium dioxide

Organics: benzene, ethylbenzene, diethylamine, ethylene glycol, ethyl alcohol, methanol, N-methylpyrolidene, cyanogen chloride, hydrocyanic acid, gluconates, dichlorhydrin, triethanolamine, acrylonitrile, oils, polymer suspensions

The average hourly discharge of the effluent is 1400 m^3 and the BOD load is 13,000 kg/day.

The limit values imposed on discharges into the river are the following:

BOD	10 mg/l
COD	150 mg/l
sulphides and hydrogen sulphide	0
phenol	0.02 mg/l
mercaptan	0.5 mg/l
oils	0.3 mg/l
pH	6.5-8.5

On the basis of these data, the following sequence of treatments was adopted for the treatment of the waste water discharged from this petrochemical complex:

Primary (mechanical-chemical) treatment
Secondary (biological) treatment, in two steps
Tertiary finishing treatment (physical-chemical)
Sludge treatment

The treatments comprise the following operations:

Primary treatment

Homogenisation
Neutralization
Oil separation
Flocculation and primary settling

Secondary treatment

Aeration 1
Sludge regeneration
Secondary settling 1
Aeration 2
Secondary settling 2

Tertiary treatment

Secondary flocculation - tertiary settling
Filtration through sand

Sludge treatment

Thickening
Filtration
Incineration

Description of the treatment operations (see Figure II)

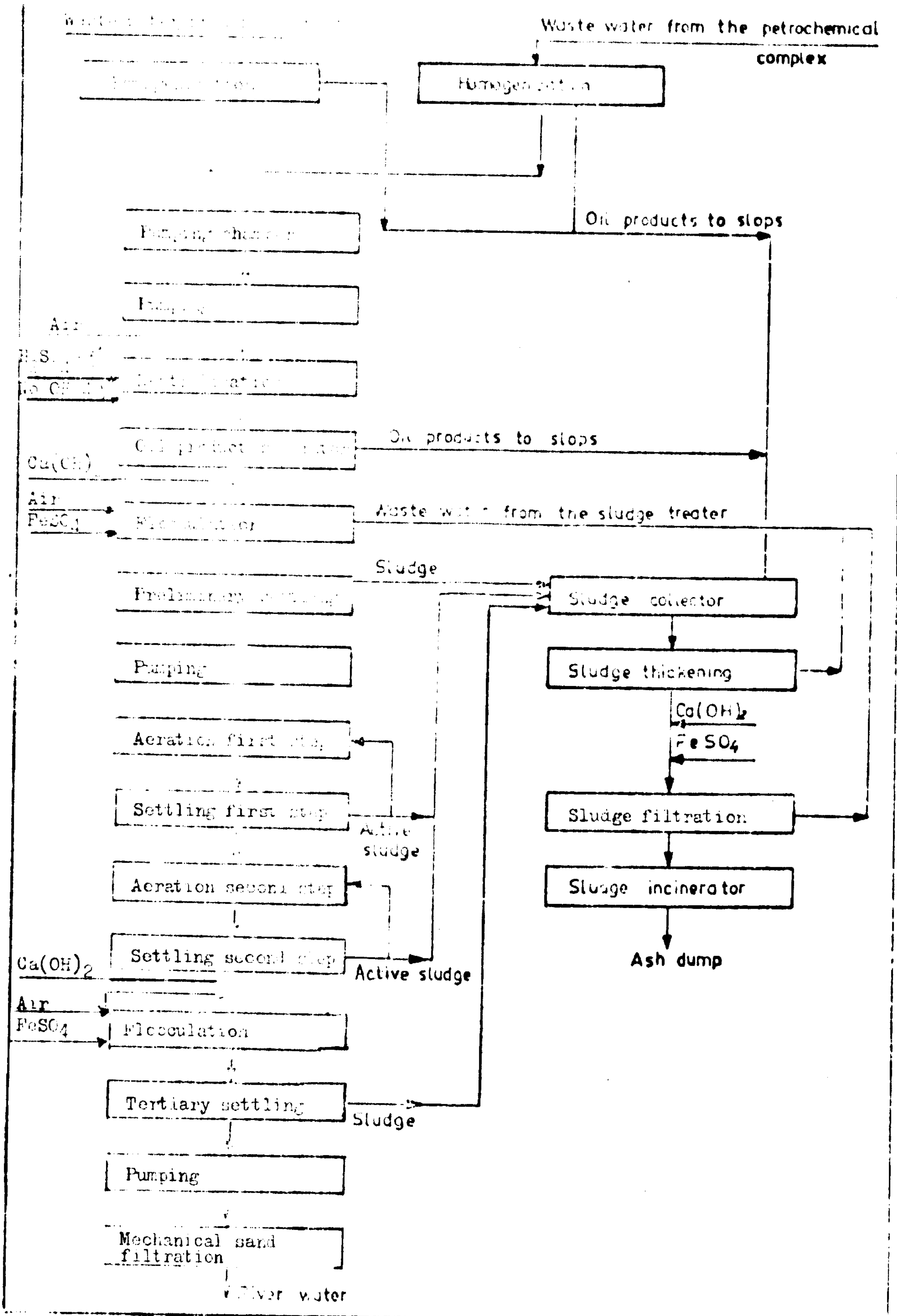
Primary treatment

Homogenization of the waste water from the refinery and from the petrochemical complex takes place separately. This first stage also includes a primary separation of the oil products, which are directed towards the slop separators. The homogenization tanks are circular in shape, have a scraping bridge and are calculated for a homogenization time of 4-4.5 h. The homogenized effluents are discharged through two pipes to a single pumping chamber. Their flow rate is automatically maintained constant.

Since in this case the two homogenization tanks discharge at a lower level than the neutralization unit, it is necessary to use pumps - in this case helical pumps to convey their discharges to neutralization unit. If the ground permits, situations like that should be avoided to save the expense of pumping.

Neutralization takes place in a rectangular tank by adding sufficient 96 per cent sulphuric acid or 40 per cent sodium hydroxide to make the water pH at the outlet 6.5-7.0. The tank contents are stirred by air blasting. Average neutralization time is 10 minutes.

FIGURE [illegible]. [illegible] FLOWCHART FOR [illegible] OF WASTE WATER [illegible] A PETROCHEMICAL COMPLEX ([illegible] OIL REFINERY)



The neutralization reagents are automatically delivered from their storage tanks by proportioning pumps according to the indications given by the pH-meter.

The neutralized water then passes into a circular oil product separator, 2.5 m in diameter, made of reinforced concrete and provided with a scraping bridge to collect the oils into a hole on the periphery, from which they are gravitationally discharged to the final oil product separator - slops.

The separated water flows through several slits made in the separator wall and into the flocculator. At the discharge points, lime milk is automatically fed into the water by proportioning pumps to bring the pH up to 10.5; the residence time is about 50 minutes.

Flocculation and primary settling is achieved in a circular tank, concentric with the oil product separator and divided into sections, where the process operations described below take place. The inner diameter is 2.5 m, the outer diameter, 30 m.

In the first circular section, the orthokinetic step of the flocculation is effected under fast stirring with an amount of ferrous sulphate automatically determined by the flow rate. Then, the water passes into the second concentric section where the perikinetic step under a slow stirring takes place and the flocs are formed. The flocculation time is 10 minutes.

After flocculation the waters pass through a flattening and quieting device into the primary settling tank, which is concentric to the petroleum product separator and flocculator, and come out through a collecting drain into a surge tank. Inside diameter is 30 m, outside diameter 45 m. An extension of the scraping bridge of the petroleum product separator works simultaneously in the primary settling tank, collecting the sludge into a central hole. The settling time is 100-110 minutes.

The collected sludge is passed to the sludge thickener by vertical pumps. In this primary treatment, a decrease of 4 per cent in the initial BOD and 20 per cent of the initial COD is obtained.

Secondary treatment

In the [illegible] treatment, the organic load is decreased [illegible] micro-organisms. Since the water is highly [illegible], the [illegible] treatment consists of two aeration-settling steps.

Aeration 1. The water is pumped by vertical pumps from the primary settling [illegible] distribution system of the aeration tank, a rectangular [illegible] divided into six compartments, into which the water [illegible] distribution system. The aeration is accomplished [illegible], [illegible] in diameter.

The nutrients, [illegible] fed into the pump suction tank, consist of phosphorus in the form of [illegible] phosphate and nitrogen in the form of ammonia, to a concentration of 1 per cent phosphorus and 5 per cent nitrogen depending on the eliminated BOD. This step has 70 per cent yield for a total [illegible] about 1,400 m², total volume about 5,800 m³, sludge concentration [illegible], specific oxygenation 2 kg O_2/kWh, and overall consumption rate of oxygen about 1,[illegible]00 kg/day. The aerated waters come out through a constant-level device and fall freely into the first set of secondary settling tanks.

Sludge from the secondary settling tank is recycled into the aeration tank by a helical pump and regenerated by aeration with the turbines, the sludge being divided among the aeration compartments by discharge chutes.

Secondary settling 1. The biologically treated water with about 4 kg/m³ activated sludge is [illegible] introduced into two secondary settling tanks, 30 m in diameter, fitted with scraping bridges and fast sludge drains. The settling time is about 2 h and 15 minutes. The water is drained through a peripheric refuse spout into a surge tank, from which they are guided towards the second aeration tank.

The sludge is collected by the scraping bridge into a central tank where it falls freely into a surge and is sent as recycled sludge back to aeration 1 or as excess sludge to the thickener.

Aeration 2. The water from secondary settling [illegible] are distributed to the eight chambers of aeration 2 through discharge chutes.

As in aeration 1, aeration is by turbines, and sludge is recycled by helical pumps from secondary settling 2. After an aeration time of 4 h, the yield is about 90 per cent. The over-all surface of the compartments is 1,7[illegible] m^2, total volume 7,000 m^3, sludge concentration [illegible] kg/m^3, specific oxygenation [illegible] kg [illegible]/kWh, and over-all consumption rate of oxygen 1,300 kg/day.

The aerated waters pass through a constant-level device and fall freely into secondary settling tank 2.

Secondary settling 2. The biologically treated water, containing 3 kg/m^3 activated sludge, axially enters a circular tank, 45 m in diameter, for secondary settling 2, also fitted with a scraping bridge and a fast sludge drain. The settling time is 3 h and 30 minutes.

From a peripheral refuse spout, the water is guided through a surge tank towards the tertiary settling tank. Within the surge tank, the water is alkalized with lime milk to pH 9.

The sludge from settling tank 2 is gravitationally drained into a surge tank, from which it is distributed as recycled sludge to aeration 2 by pumps or gravity and as sludge in excess to the sludge thickener.

Tertiary treatment

Secondary flocculation - tertiary settling. The alkaline water from secondary settling 2 enters a surge tank next to the tertiary settling tank, where the orthokinetic stage of flocculation with ferrous sulphate under fast air stirring takes place. The water, mixed with the reagent, axially enters the circular tertiary settling tank, 12 m in diameter, where the perikinetic stage of flocculation takes place (duration 12 minutes). The air required for vigorous water stirring and oxidation of divalent iron to trivalent iron is provided by an air blast mounted on the scraping bridge.

From this section, the waters pass through a flattening and quieting device in the settling tank proper, 35 m in diameter, where the sludge is scraped into a concentric hole and drained hydrostatically towards the sludge thickener. The settling time is 90 minutes.

[illegible] pass into [illegible] to the [illegible].

[illegible]. [illegible] water from [illegible] of contamina- [illegible] river.

[illegible] wells, the water is collected in the [illegible], from which it is discharged into the river. The [illegible] m² and the filtration rate is about [illegible]

[illegible] the washing of the sand [illegible] pumped from [illegible] returned to the treatment cycle after the washing. [illegible] for the aeration is provided by three air blasts installed [illegible] platform.

Sludge treatment

The [illegible] of sludge to be processed is about [illegible],700 m³/day. It comes from the [illegible] of the primary, secondary (aeration) and tertiary treatments. There are three distinct operations involved in sludge treatment: thickening, filtration and incineration.

Thickening. The sludge enters the thickener by gravity after it has been collected in a surge tank from the above-mentioned sources.

After a long settling of about [illegible] h in a parallelepiped thickener having a volume of about [illegible],000 m³, the sludge reaches 4 per cent concentration and is collected in a central hole by means of a scraping bridge, the water being returned to the primary step of the treatment cycle.

Filtration. Further on, the sludge is pumped to the filtration unit, where, after addition of 15 parts of lime milk and 20 parts of ferrous sulphate to 100 parts dry sludge, it is filtered through six rotary filters having a total surface of 240 m², and attains a concentration of 20 per cent. The filtrate joins the water from the thickening step for recycling.

Incineration. The sludge paste from filtration is passed to a methane-fueled rotary incinerator having a capacity of 7 t/h. The ash obtained (at the rate of about 30 t/day) is deposited in a special waste dump.

Process control

Control of the process is provided by automatic measurement and recording of control parameters throughout the operation, automatic control of the process steps and supervision and intervention by the operator from a central control panel.

Corrosion problems

To prevent corrosion due to acids in the waste water and the added reagents (e.g. ferrous sulphate and sulphuric acid), the parts of the plant subject to such effects must be protected as follows:

(a) Epoxy-resin coatings should be applied to the entire primary treatment stage;

(b) Acid-resistant brick lining should be provided for the primary reagent dissolving unit, the reagent preparation and feeding unit, the ferrous sulphate tanks and the process channels;

(c) The stirring devices in the ferrous sulphate tanks must be constructed of stainless steel.

Annex I

LIMIT VALUES FOR NOXIOUS MATERIALS IN THE ATMOSPHERE

No.	Noxious material	USA		USSR	
		ppm	mg/m³	a/	mg/m³
1	2	3	4	5	6
1.	Acetopropyl acetate	-	-		5
2.	Amyl acetate	-	-		100
3.	Amyl acetate (n)	100	525		-
4.	Amyl acetate (sec)	125	650		-
5.	Bromacetopropyl acetate	-	-		0,5
6.	Butyl acetate	-	-		200
7.	Butyl acetate (n)	150	710		-
8.	Butyl acetate (sec)	200	950		-
9.	Butyl acetate (tert)	200	950		-
10.	Chloroacetopropyl acetate	-	-		2
11.	Ethyl acetate	400	1400		200
12.	Ethylglycol acetate	100	540	x	-
13.	Hexyl acetate (sec)	50	300		-
14.	Isoamyl acetate	100	525		-
15.	Isobutyl acetate	150	700		-
16.	Isopropyl acetate	250	950		-
17.	Methyl acetate	200	610		100
18.	Methylglycol acetate	25	120	x	-

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a/ Letters in this column give additional information about the noxious aterials or their United States limit values, as follows:

x = Striking toxicity
P = Threshold value
C = Carcinogenic
CE = Carcinogenic experimental

b/ The letter x in this column means that in the USSR standards, the material is said to have striking toxicity.

1	2	3	4	5	6	7
19.	Propyl acetate (n)	200	540		-	
20.	Propyl acetate	-	-		200	
21.	Vinyl acetate	10	[illegible]		10	
22.	Acetonanil					
23.	2,2,4 Trimethyl-1,2 dihydroquinoleine					
24.	Acetone	1000	2400		200	
25.	Acetone cyanohydrin	-	-		0.9	x
26.	Acetonitrile	40	70		10	
27.	Acetophenone	-	-		5	x
28.	Isopropyl acetoxycarbamate (n)	-	-		2	
29.	2-Acetylaminofluorene	-	-	xCE	-	
30.	Acetic acid	10	25		5	
31.	Acrylic acid	-	-		5	
32.	Amino-oenantic acid	-	-		8	
33.	Aminopelargonic acid	-	-		8	
34.	Boric acid	-	-		10	
35.	Hydrobromic acid	3	10		-	
36.	Butyric acid	-	-		10	
37.	Caproic acid	-	-		5	
38.	Hydrochloric acid	5	7	P	5	
39.	4-Chlorobenzophenon-2-carboxylic acid	-	-		1	
40.	Chloropelargonic acid	-	-		5	
41.	Chloropropionic acid	-	-		5	
42.	Hydrocyanic acid	10	11	x	0.3	x
43.	Hydrofluoric acid	3	2		0.5	
44.	Formic acid	5	9		-	
45.	Methacrylic acid	-	-		10	
46.	Nitric acid	2	5		-	
47.	Oxalic acid	-	1		-	

1	2	3	4	5	6	
[illegible]	[illegible] acid	-	-		2	
[illegible]	[illegible]	-	1		-	
[illegible]	[illegible]	-	0.1	x	-	
51.	[illegible]	-	1		1	
52.	[illegible] acid	-	-		0.1	
53.	Thioglycolic acid	-	-		0.1	x
54.	Trichloracetic acid	-	-		2	
[illegible]	[illegible] acid	-	-		5	
56.	Acroleine	0.1	0.25		0.7	
57.	Acrylamide	-	0.3	x	-	
58.	Butyl acrilate	-	-		10	
59.	Ethyl acrilate	25	100	x	-	
60.	Methyl acrilate	10	35	x	20	
61.	Acrylonitrile	20	45	x	0.5	x
62.	Piperazidine adipat	-	-		5	
63.	Adipodinitrile	-	-		20	
64.	Acetopropylic alcohol	-	-		10	
65.	Allylic alcohol	2	5	x	2	
66.	Amylic alcohol	-	-		10	
67.	Butyl alcohol	100	300		10	
68.	Butyl alcohol (sec)	150	450		-	
69.	Butyl alcohol (tert)	100	300		-	
70.	2-Chloroethyl alcohol					
71.	Ethylene chlorohydrin					
72.	Crotonic alcohol	-	-		2	
73.	Decyl alcohol (n)	-	-		10	
74.	1,3-dichlorisopropylic alcohol					
75.	Dichlorohydrin					
76.	Ethyl alcohol	1000	1900		1000	

1	2	3	4	5	6	7
77.	Furfuryl alcohol	50	200		-	
78.	Heptylic alcohol (n)	-	-		10	
79.	Hexyl alcohol (n)	-	-		10	
80.	Isoamyl alcohol	100	360		-	
81.	Isobutyl alcohol	100	300		-	
82.	Isooctyl alcohol	-	-		50	
83.	Isopropyl alcohol	400	980		-	
84.	Methylamylic alcohol	25	100	x	-	
85.	Methanol	200	260		5	x
86.	Nonylalcohol (n)	-	-		10	
87.	Octafluoramylic alcohol	-	-		20	
88.	Octylalcohol (n)	-	-		10	
89.	Propargyl alcohol	1	-	x	1	
90.	Propyl alcohol	200	500		10	
91.	Tetrafluorpropylic alcohol	-	-		20	
92.	Trifluorbutyl alcohol	-	-		20	
93.	Trifluorethyl alcohol	-	-		10	
94.	Unsaturated alcohols from the fatty alcohol series (allyl, crotonic)	-	-		2	
95.	Acetic aldehyde	200	300		5	
96.	Butyraldehyde	-	-		5	
97.	Chloroacetic aldehyde	1	3	P	-	
98.	Crotonic aldehyde	2	6		0.5	
99.	2-ethylhexaldehyde	-	-		3	
100.	Formaldehyde	2	3	P	0.5	
101.	Furfuryl aldehyde	5	20	x	10	
102.	Isobuthyl aldehyde	-	-		5	
103.	Propionic aldehyde	-	-		5	
104.	Aldrin	-	0.25	x	0.01	x

1	2	3	4	5	6	7
105.	Aluminium (oxide)					
106.	Alundum, corundum					
107.	Ammonium chrome alum					
108.	Chrome (ammonium sulphate)					
109.	Alundum	-	10		-	
11o.	Starch	-	10		-	
111.	Primary aliphatic amines (C_7-C_9)	-	-		1	
112.	Secondary aliphatic amines (C_{15}-C_{19})	-	-		1	
113.	Alpha-aminoanthraquinone	-	-		5	
114.	4-Aminodiphenyl	-	-	xC	-	
115.	2-Aminoethanol					
116.	Ethanolamine					
117.	5-Amino-8-oxy-3,7-dibrom-1,4-naphtoquinonimine	-	-		1	
118.	Aminoplastics (powders for moulding)	-	-		6	
119.	2-Aminopyridine	0.5	2		-	
120.	Aminopyrimidine					
121.	2-Methyl-4-amino-5-etoxy-methylpyrimidine					
122.	Amino alpha-trifluortoluene		-		0.5	
123.	Ammonia	50	35		20	
124.	Ammonium (sulphamate)					
125.	Ammonium sulphamate					
126.	Anabasine (sulphate)	-	-		0.1	
127.	Acetic anhydride	5	20		-	
128.	Arsenious anhydride					
129.	Arsenic (arsenious anhydride)					
130.	Arsenic anhydride					
131.	Arsenic (arsenic anhydride)					
132.	Boric anhydride					

1	2	3	4	5	6	7
133.	Boron (oxide)					
134.	Butyl anhydride	-	-		1	
135.	Carbonic anhydride	5000	9000		-	
136.	Chromic anhydride					
137.	Chrome (oxide hexavalent)					
138.	Maleic anhydride	0.25	1		1	
139.	Methacrylic anhydride	-	-		1	
140.	Phthalic anhydride	2	12		1	
141.	Phosphoric anhydride					
142.	Phosphorus (pentoxide)					
143.	Selenious anhydride					
144.	Selenium(dioxide)					
145.	Sulphurous anhydride					
146.	Sulphur (dioxide)					
147.	Sulphuric anhydride					
148.	Sulphur (trioxide)					
149.	Aniline	5	19	x	0.1	x
150.	Anisidine (p)	-	-		1	x
151.	9,10-Anthraquinone	-	-		5	
152.	Anisidine (o- and p-)	-	0.5	x	-	
153.	Stibium and compounds (Sb)	-	0.5		-	
154.	Metallic stibium (under powder form)	-	-		0.5	
155.	Stibium (fluorides and chlorides III and IV expressed as Sb)	-	-		0.3	
156.	Stibium hydride					
157.	Hydrogen stibiate					
158.	Stibium (oxides and sulphides III powders, expressed in Sb)					
159.	Stibium (oxides and sulphides IV powders, expressed in Sb)					
160.	Oxygenated water - Hydrogen peroxide					

1	3	4	5	6	
161. Silver (metal and soluble compounds)	-	0.01		-	
162. Arsenic and its compounds (expressed as As, except hydrogen arsenide)	-	0.5		-	
163. Arsenic (arsenious and arsenic anhydrides)	-			0.3	
164. Arsine Arseniated hydrogen					
165. Nitrogen (nitric oxide)	25	30		-	
166. Nitrogen (peroxide)	5	9	F	-	
167. Nitrogen (oxides) expressed as NO_2	-	-		5	
168. Nitrogen (trifluoride)	10	29		-	
169. Isopropyl nitrate	-	-		5	
170. Propyl nitrate (n)	25	110		-	
171. Isopropyl nitrate	-	-		1	x
172. Barium (soluble compounds)	-	0.5		-	
173. Benzene	25	80	Px	5	x
174. Benzidine and salts	-	-	C	-	
175. Fuel gasoline(bitumen, cracking,etc. expressed in C)	-	-	100		
176. Solvent gasoline (expressed in C)	-	-	300		
177. Benzoquinone (p-)	0.1	0.4		0.05	
178. Berilium	-	0.002		-	
179. Berilium and compounds (Be)	-	-		0.001	
180. Boron (oxide)	-	10		5	
181. Boron (tribromide)	1	10		-	
182. Boron (trifluoride)	1	3	P	1	
183. Bromine	0.1	0.7			
184. Bromine (pentafluoride)	0.1	0.7		-	
185. Brombenzene	-	-		3	
186. Bromchloromethane	200	1050		-	
187. 1,3-Bromchloropropane	-	-		3	

1	2	3	4	5	6	7
188.	Bromethane	200	390		5	
189.	Bromethylene	250	1100		-	
190.	Bromoform					
191.	Tribromomethane					
192.	Bromomethane	-	-		1	
193.	Bromtrifluorethane	1000	6100		-	
194.	Ethyl bromide					
195.	Bromethane					
196.	Ethylene bromide					
197.	1,2 Dibromethane					
198.	Methyl bromide					
199.	Bromomethane					
200.	Vinyl bromide					
201.	Bromethylene					
202.	1,3-Butadiene	1000	2200		100	
203.	2-Butanone					
204.	Methylethylketone					
205.	2-Butene	-	-		100	
206.	2-Butoxyethanol Butylglycol					
207.	Butylamine	5	15	Px	10	
208.	Butylglycol	50	240	x	-	
209.	Butylmercaptan	0.5	1.5		-	
210.	2-Butylthiobenzothiazole	-	-		10	
211.	Butyltoluene (p-tert)	10	60		-	
212.	1,4 Butendiol	-	-		1	
213.	Methyl butyrate	-	-		5	
214.	Cadmium (oxide) (vapours in Cd)	-	0.1	P	0.1	

1	2	3	4	5	6	7
215.	Cadmium (metallic powders and soluble salts)	-	0.2		-	
216.	Cadmium (stearate expressed in Cd)	-	-		0.1	
217.	Calcite	-	10		-	
218.	Calcium (arseniate)	-	1		-	
219.	Calcium (carbonate)	-	10		-	
220.	Calcium (oxide)	-	5		-	
221.	Calcium (sulphate)					
222.	Gypsum and plaster for modelling					
223.	Chlorinated camphene	-	0.5	x	-	
224.	Camphor	-	-		3	
225.	Camphor (synthetic)	2	12		-	
226.	Caprolactame	-	-		10	
227.	Carbaryl	-	5		1	
228.	Cyclohexylamine carbonate	-	-		10	
229.	Celullose (paper fibre)	-	10		-	
230.	Ketene	0.5	0.9		-	
231.	Chlordan	-	0.5	x	0.01	x
232.	Chlorine	1	3		1	
233.	Chlorine (dioxide)	0.1	0.3		0.1	
234.	Chlorine (trifluoride)	0.1	0.4	P	-	
235.	Methyl chloroacetate	-	-		5	
236.	Alpha-chloracetophenone	0.05	0.3		-	
237.	Chloraniline (m-)	-	-		0.05	x
238.	Chloraniline (p-)	-	-		0.3	x
239.	Chlorobenzene (mono)	75	350		50	x
240.	Chlorobenzal malononitrile (o-)	0.05	0.4	x	-	
241.	2-Chloro-4,6-bis(diethylamino)-1,3,5 triazine	-	-		2	
242.	2-Chloro-1,3-butadiene	25	90	x	2	

1	2	3	4	5	6	7
243.	Isopropyl chlorocarbonate	-	-		0.1	
244.	Chlorocyclohexane	-	-		50	
245.	1-Chloro-2,3-epoxypropane					
246.	Epichlorhydrin					
247.	Chlorethane	1000	2600		50	
248.	Chlorethylene	200	770		30	
249.	Chlorphenizone	-	-		2	
250.	Chloroform					
	Trichloromethane					
251.	Chloromethane	100	210		5	
252.	5-Chloromethyl-1-furan-carboxylate butyl	-	-		0.5	
253.	Chloroacetophenone					
254.	Chloromethyltrichlorosilan	-	-		1	
255.	Chloronitrobenzene (p-)	-	1	x	-	
256.	Chloronitrobenzene and derivatives	-	-		1	x
257.	1-Chloro-1-nitropropane	20	100		-	
258.	Chlorophenol (p-)	-	-		1	x
259.	3-Chlorophenylcarbamate isopropyl (n)	-	-		2	
260.	Chloropicrin	0.1	0.7		-	
261.	Chloroprene					
	2-Chloro-1,3-butadiene					
262.	3-Chloropropene	1	3		-	
263.	Chlorostyrene	-	-		50	
264.	2-Chlorethyl chlorosulphamate	-	-		0.3	x
265,	Chloroteno (chlorinated dycycle compounds)	-	-		0.2	
266.	Diethyl chlorothiophosphate	-	-		1	
267.	Dimethyl chlorothiophosphate	-	-		0.5	
268.	Alpha-chlorotoluene	1	5		0.5	

1	2	3	4	5	6	7
269.	Chlorotrifluoropropane	-	-		1.	x
270.	Acryloil chloride	-	-		0.3	
271.	Allyl chloride					
272.	3-Chloropropene					
273.	Ammonium chloride (fume)	-	10		-	
274.	Benzenyl chloride					
275.	Alpha-trichlorotoluene					
276.	Benzoyl chloride	-	-		5	
277.	Benzyl chloride					
278.	Alpha-chlorotoluene					
279.	Benzal chloride					
280.	Alpha-dichlorotoluene					
281.	Cyan chloride	-	-		0.1	
282.	5-etoxy-phenyl-1,2-thiazotiamine chloride	-	-		0.2	
283.	Ethyl chloride					
284.	Chloroethane					
285.	Ethylene chloride					
286.	1,2-Dichloroethane					
287.	Ethyliden chloride					
288.	1,1-Dichloroethane					
289.	Isobutylene chloride					
290.	1,2-Dichloro-2-methylpropane					
291.	Methacryloyl chloride	-	-		0.3	
292.	Methyl chloride					
293.	Chloromethane					
294.	Methylene chloride					
295.	Dichloromethane					
296.	Phenacyl chloride					
297.	Alpha-chloracetophenone					

1	2	3	4	5	6	7
298.	Polyvinyl chloride	-	-		6	
299.	Propylene chloride					
300.	1,2-Dichloropropane					
301.	Trichloroacetyl chloride	-	-		0.1	
302.	Vinyl chloride					
303.	Chlorethylene					
304.	Tertiary butyl chromate (expressed in CrO_3)	-	0.1	Px	-	
305.	Cyclohexylamine chromate	-	-		2	x
306.	Chromates and dichromates expressed in CrO_3	-	-		0.01	
307.	Chromium (metal and insoluble salts)	-	1		-	
308.	Chromium (some insoluble salts)	-	0.1	C	-	
309.	Chromium (Cr III hexahydrated chloride expressed in CrO_3)	-	-		0.01	
310.	Chromium (hexavalent oxide) and chromates (expressed in CrO_3)	-	0.1		-	
311.	Chromium (hexavalent oxide)	-	-		0.01	
312.	Chromium (soluble chromous and chromic salts in Cr)	-	0.5		-	
313.	Chromium (sulphate and ammonium sulphate) in CrO_3	-	-		0.02	
314.	1-methyl-4-diethyl-carbomoyl-piperazine citrate	-	-		5	
315.	Cobalt (vapours and powder)	-	0.1		-	
316.	Cobalt and oxide	-	-		0.5	
317.	Cobalt (dicobalt-orthocarbonyl)	-	-		0.01	
318.	Cobalt hydrocarbonyl and its decomposition products (in CO)	-	-		0.01	
319.	Colophony (decomposition products of the welding bars, expressed in formaldehyde)	-	0.1		-	
320.	Corundum (Al_2O_3)	-	10		-	
321.	Cumaphene	-	0.1		-	

1	2	3	4	5	6	7
322.	Cresols (all isomers)	5	22	x	-	
323.	Copper	-	-		1	
324.	Copper (vapours)	-	0.1		-	
325.	Copper (powder and mist)	-	1		-	
326.	Copper (trichlorophenate)	-	-		0.1	
327.	Cumene	50	245	x	50	
328.	Free cyanamide	-	-		0.5	x
329.	Allyl cyanate	-	-		0.3	x
330.	Methyl 2-cyanacrylate	2	8		-	
331.	Cyanogen	10	-		-	
332.	Cyanides (expressed in CN)	-	5	x	-	
333.	Cyanides (expressed in HCN)	-	-		0.3	x
334.	Benzyl cyanide					
335.	Phenylacetonitrile					
336.	Vinyl cyanide					
337.	Acrylonitrile					
338.	Cyclohexane	300	1050		80	
339.	Cyclohexanol	50	200		-	
340.	Cyclohexanone	50	200		10	
341.	Cyclohexanone-oxime	-	-		10	
342.	Cyclohexene	300	1015		-	
343.	Cyclohexylamine	-	-		1	
344.	Cyclopentadiene	75	200		5	
345.	2,4-D	-	10		-	
346.	2,4-D (butyl-ester)	-	-		0.5	
347.	2,4-D (alpha-chloro-crotylic ester)	-	-		1	
348.	2,4-D (octyl ester)	-	-		1	
349.	2,4 (ammonium salt)	-	-		1	
350.	DDT					

1	2	3	4	5	6	7
351.	Zeidan					
352.	Decatoran	0.05	0.3	x	-	
353.	Decaline	-	-		100	
354.	Demeton (mixture of O and S)	-	0.1	x	0.02	x
355.	Demeton-methyl (mixture of O and S)	-	0.5	x	0.1	x
356.	Ethyleneglycon diacetate	-	-		50	
357.	Diacetonalcohol	50	240		-	
358.	1,2 Diaminoethane	10	25		2	
359.	Diazonone	-	0.1	x	-	
360.	Diazomethane	0.2	0.4		-	
361.	Diborane	0.1	0.1		-	
362.	Dibromchlorotrifluorethane	-	-		50	
363.	Dibromdofluormethane	100	860		-	
364.	1,2 Dibromethane	25	190	x	-	
365.	Di bromomethane	-	-		10	
366.	1,2-Dibromopropane	-	-		5	
367.	Dibutylaminoethanol (2-N-)	2	14	x	-	
368.	Dichloroacetylene	0.1	0.4	P	-	
369.	3,4-Dichloroaniline	-	-		0.5	
370.	Dichloromethylbenzene	-	-		1	
371.	Dichloromethylnaphathalene	-	-		0.5	
372.	3,3-Chloromethyloxacyclobutane	-	-		0.5	
373.	Dichloromethylxylene	-	-		1	
374.	Dichlorobenzene (o-)	50	300	P	-	
375.	Dichlorobenzene (p-)	75	450		-	
376.	Dichlorobenzene	-	-		20	x
377.	3,3-Dichlorobenzidine	-	-	xCK	-	
378.	1,3-Dichloro-2-butene	-	-		-	1
379.	Dichlorodufluoromethane	1000	4950		-	

1	3	4	5	6	
380. 1,3-[illegible]-dimethylhydantoin	-	0.2		-	
381 1,1-[illegible]	100	400		-	
382. 1,2-[illegible]	50	200			
383. Dichl[illegible]	-	-		10	x
384. 1,1-[illegible]ene	-	-		50	
385. 1,2-[illegible]	200	790		-	
386. Dichl[illegible]ene	1000	4200		-	
387. Dichl[illegible]	-	-		5	
388. 1,2-Dic[illegible]butane	-	-		20	
389. 1,3-Di[illegible]ylene	-	-		0.5	
390. 3,5-Di[illegible]ylene (synthetic [illegible])	-	-		0.3	
391. Dichlo[illegible]	500	1740		50	
392. Dichloromethylketone					
393. 1,1,3-Trichloroacetone					
394. 1,2-Dichloro-2-methyl-propane	-	-		0.3	
395. 2,3-Dichloro-1,4-naphtaquinone	-	-		0.5	
396. 3,4-Dichloronitrobenzene	-	-		1	x
397. 1,1-Dichloro-1-nitroethane	10	60	P	-	
398. Dichloroctafluorcyclohexane	-	-		1	
399. Dichlorophenyltrichlorosylane	-	-		1	
400. 1,2-Dichloropropane	75	350		10	
401. 1,3-Dichlorpropylene	-	-		5	
402. 2,3-Dichloropropylene	-	-		3	
403. Dichlorostyrene	-	-		50	
404. Dichlortetrafluorethane	1000	7000		-	
405. Alpha-dichlorotoluene	-	-		0.5	
406. Alpha-Alpha'-dichloroxylene					
407. Di(chloromethyl)benzene					

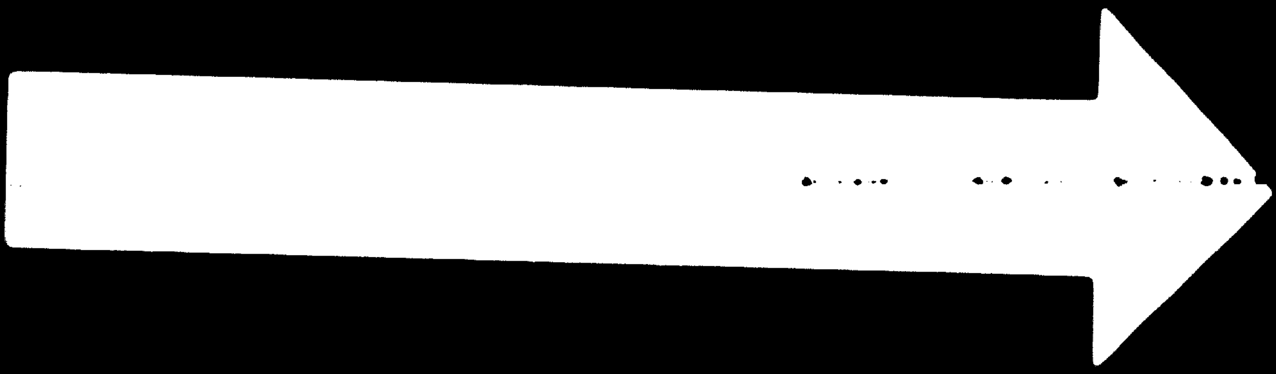
1	2	3	4	5	6	7
408.	Acetylene dichloride					
409.	1,2-Dichloro-ethylene					
410.	Dicumylmethane	-	-		5	x
411.	Dicyclopentadiene	-	-		1	x
412.	Dieldrine	-	0.25	x	0.01	x
413.	Diethylamine	25	75		30	
414.	Diethylaminoethanol	10	50	x	5	
415.	Beta-Diethylaminoethylmercaptan	-	-		1	x
416.	Diethylbenzene	-	-		10	
417.	Diethylenetriamine	1	4	x	-	
418.	Diethyletanolamine					
419.	Diethylamino-ethanol					
420.	Dihydrate perfluoracetone	-	-		2	x
421.	Diisobutylketone	50	290		-	
422.	4,4'-Diisocyanate diphenylmethane	0.02	0.2	P	-	
423.	Hexamethylene diisocyanate	-	-		0.05	x
424.	Toluylene 2,4-diisocyanate	0.02	0.14	P	-	
425.	Toluylene diisocyanate	-	-		0.5	
426.	Diisopropylamine	5	20	x	5	
427.	Diisopropylbenzene	-	-		50	x
428.	Dimetoxymethane					
429.	Methylal					
430.	Dimethylacetamide	10	35	x	-	
431.	Dimethylamine	10	18		1	
432.	4-Dimethylaminoazobenzene	-	-	CE	-	
433.	3-Dimethylamino-2-chloro-phenotiazine (10-chlorohydrate)	-	-		0.3	x
434.	Dimethylaminoethanol	-	-		5	
435.	Dimethylaniline (n)	5	25	x	0.2	x

1	2	3	4	5	6	7
436.	Dimethylbenzylamine	-	-		5	
437.	Dimethylketone					
	Acetone					
438.	Dimethyl[illegible]ne	-	-		10	
439.	Dimethylethanolamine					
440.	Dimethylaminoethanol					
441.	Dimethylformamide	10	30	x	10	
442.	1,1-Dimethylhydrazine	0.5	1	x	-	
443.	Dinitrobenzene (all isomers)	-	1	x	-	
444.	Dinitrobenzene	-	-		1	x
445.	Dinitrobutylphenol (sec)	-	-		0.05	x
446.	Dinitrocresole (o-)	-	0.2	x	0.05	x
447.	4,6-Dinitro-2-isopropylphenol	-	-		0.05	
448.	Dinitrophenol	-	-		0.05	
449.	Dinitrothiocyanobenzene	-	-		2	x
450.	Dinitrotoluene	-	1.5	x	1	x
451.	1,4-Dioxane	100	360	x	-	
452.	Dioxane	-	-		10	
453.	1,3-Dioxolane	-	-		50	x
454.	Diphenylamine	-	10		-	
455.	Diphenylolpropane	-	-		5	
456.	Dipropylamine (n-)	-	-		2	
457.	Allyl and propyl disulphide	2	12		-	
458.	Dithiometon	-	-		0.1	x
459.	Divinyl					
460.	1,3 Butadiene					
461.	Dodecylmercaptan (tert)	-	-		5	
462.	Emery	-	10		-	
463.	Endosulphane	-	0.1	x	0.1	x

1	2	3	4	5	6	7
464.	Endrin	-	0.1	x	-	
465.	Epychlorohydryne	5	19	x	1	
466.	EPN	-	0.5	x	-	
467.	2,3-Epoxy-1-propanol					
	Glycidol					
468.	EPTC	-	-		2	
469.	Tin (dioxide)	-	10		-	
470.	Tin (inorganic compounds)	-	2		-	
471.	Tin (organic compounds)	-	0.1	x	-	
472.	Ethanolamine	3	6		-	
473.	Ether					
474.	Oxide					
475.	Beta- ethoxipropionitrile	-	-		50	
476.	Ethylamine	10	18		-	
477.	Ethylamylketone (sec)	25	130		-	
478.	Ethylbenzene	100	435		-	
479.	Ethylbutylketone	50	230		-	
480.	Ethylenechlorohydrine	5	16	x	0.5	x
481.	Ethylene cyanhydrine	-	-		10	
482.	Ethylene diamine					
483.	1,2 Diaminoethane					
484.	Ethylene imine	0.5	1	xCE	0.02	x
485.	Ethylglycol	200	740	x	-	
486.	2-Ethylhexenal					
487.	2-Ethyl-hexenoic aldehyde					
488.	Ethylmercaptan	0.5	1		1	
489.	Ethylmorpholine (n-)	20	94	x	5	
490.	Ethyltoluene	-	-		50	
491.	Ethoxy aniline	-	-		0.2	x

1		2	3	4	5	6
492.	[illegible] ([illegible])	-	-		0.5	
493.	[illegible]	5	[illegible]	[illegible]	5	x
494.	[illegible]	-	-		6	
495.	[illegible]	-	[illegible]	x	-	
496.	[illegible]	-			0.15	
497.	[illegible]	-	-		0.3	x
498.	[illegible] (n)	-	-		2	
499.	[illegible] (-)	-	0.1	[illegible]	-	
500.	Phen[illegible]	5	[illegible]	x	-	
501.	[illegible]yldichlorsilane	-	-		1	
502.	Iro[illegible] (Vapours)	-	10		-	
503.	Iron ([illegible] red oxide)	-	10		-	
504.	Iron (soluble salts in Fe)	-	1		-	
505.	Iron pentacarbonyl	0.01	0.08		-	
506.	Ferbam	-	10		-	
507.	Ferrovanadium (powder)	-	1		-	
508.	Ferrovanadium	-	-		1	
509.	Fluorine	0.1	0.2		-	
510.	Fluorides (expressed in F)	-	2.5		-	
511.	Fluorides (expressed in HF)	-	-		1	
512.	Benzenyl fluoride					
513.	Alpha-trifluortoluene					
514.	Benzenyl-m-nitro fluoride					
515.	Alpha-trifluor-m-nitrotoluene					
516.	Fluorzirconate	-	-		1	
517.	Formalglycol					
518.	1,3 Dioxalane					
519.	Formamide	-	-		3	
520.	Ethyl formiate	100	300		-	

1	2	3	4	5	6	7
521.	Methyl formiate	100	250		-	
522.	Formalin					
523.	Formaldehyde					
524.	Phosgene	0.1	0.4		0.5	
525.	Dibutyl phosphate	1	5		-	
526.	Phenyl and diphenyl phosphate (2-ethyl-hexyl)	-	-		1	
527.	Tributyl phosphate	-	5		0.5	x
528.	Tricresyl phosphate (o-)	-	0.1		-	
529.	Tricresyl phosphate (containing less 3 % ortho-isomers)	-	-		0.5	x
530.	tricresyl phosphate (containing more than 3% ortho-isomers)	-	-		0.1	x
531.	Triphenyl phosphate	-	3		-	
532.	Trixylenyl phosphate	-	-		1.5	x
533.	Phosphine					
534.	Hydrogen phosphide					
535.	Yellow phosphorus	-	0.1		0.03	
536.	Phosphorus (pentachloride)	-	1		-	
537.	Phorphorus (pentasulphide)	-	1		-	
538.	Phosphorus (pentoxide)	-	-		1	
539.	Phosphorus (trichloride)	0.5	3		-	
540.	Dibutyl phthalate	-	5		0.5	
541.	Dimethyl phthalate	-	5		-	
542.	Dioctyl phthalate (sec)	-	5		-	
543.	Furan	-	-		0.5	
544.	Butyl 2-furancarboxilate	-	-		0.5	
545.	Furfural					
546.	Furfurylic aldehyde					
547.	Germanium (oxide)	-	-		2	



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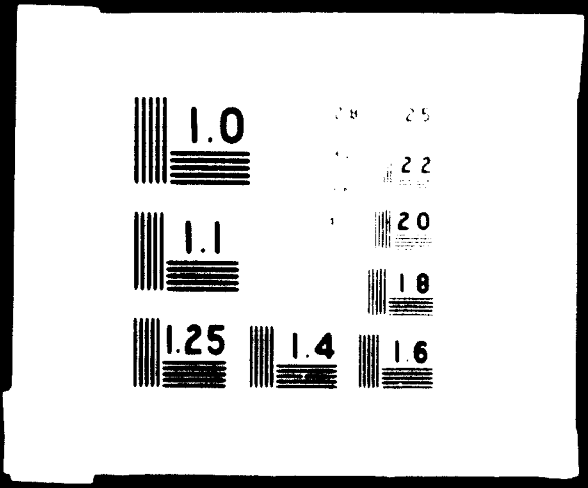

1	2	3	4	5	6	7
548.	Germanium (tetrachloride) expressed in Ge)	-	-		1	
549.	Glycerine	-	10		-	
550.	Glycidol	50	150		-	
551.	Graphite (synthetic)	-	10		-	
552.	Gypsum	-	10		-	
553.	Haphnium	-	0.5		-	
554.	HCH	-	-		0.1	x
555.	Gamma-HCH	-	0.5		0.05	x
556.	Heptachlor	-	0.5	x	0.01	x
557.	Heptane (n)	500	2000		-	
558.	Hexachloracetone	-	-		0.5	
559.	Hexachlorobenzene	-	-		0.9	x
560.	Hexachlorocyclopentadiene	-	-		0.01	x
561.	Hexachlorethane	1	10	x	-	
562.	Hexachloronaphthalene	-	0.2	x	-	
563.	Hexafluoropropylene	-	-		5	
564.	Hexamethylenediemine	-	-		1	
565.	Hexamethylenimine	-	-		0.5	
566.	Hexamethylenethiocarbamate S-ethyl (N,N-)					
567.	Molinate					
568.	Hexane	500	1800		-	
569.	Hexogone	-	1.5	x	1	
570.	Hexone					
571.	Methylisobutylketone					
572.	Hydrazine	1	1.3	x	-	
573.	Hydrazine, hydrate and derivatives	-	-		0.1	x
574.	Saturated aliphatic hydrocarbons C_1-C_{10} (expressed in C)	-	-		300	

1	2	3	4	5	6	7
575.	Hydrogen stibiate	0.1	0.5		-	
576.	Hydrogen arseniate	0.05	0.2	0.3		x
577.	Hydrogen phosphide	0.3	0.4		0.1	
578.	Hydrogen selenide	0.05	0.2		-	
579.	Hydrogen sulphide	10	15		10	x
580.	Hydrogen sulphide in mixture with hydrocarbons C_1-C_5	-	-		3	
581.	Cumene hydroperoxide	-	-		1	
582.	Hydroquinone	-	2		-	
583.	Hydroxydiphenilamine (p-)	-	-		0.5	
584.	Beta-hydroxyethylmercaptan	-	-		1	x
585.	Beta-hydroxypropionitrile					
586.	Ethylenecyanhydrine					
587.	Indene	10	45		-	
588.	Indium and its compounds (expressed in In)	-	0.1		-	
589.	Iodine	0.1	1	P	1	
590.	Iodomethane	5	28	x	-	
591.	Methyl iodine					
592.	Iodomethane					
593.	Isobutylene	-	-		100	
594.	Methyl isobutirate	-	-		10	x
595.	Chlorophenyl isocyanate (m- and p-)	-	-		0.5	
596.	3,4-dichloro-phenyl isocyanate	-	-		0.5	
597.	Methyl isocyanate	0.02	0.05	x	0.05	
598.	Isopropene	-	-		40	
599.	Isopropylamine	5	12		1	
600.	Isopropylaminodiphenyl-amine	-	-		2	
601.	Isopropylbenzene					
602.	Cumene					

1	2	3	4	5	6	7
603.	Methyl thiocyanate	-	-		0.1	x
604.	Methyl isovalerianate	-	-		5	x
605.	Kaolin	-	10		-	
606.	Ligroin (expressed in C)	-	-		300	
607.	Lithium (hydride)	-	0.025		-	
608.	Magnezite	-	10		-	
609.	Magnesium (carbonate)					
610.	Magnezite					
611.	Magnesium (oxide) vapours	-	10		-	
612.	Malathion	-	10	x	0.5	x
613.	Manganese and its compounds (expressed in Mn)	-	5	P	-	
614.	Manganese	-	-		0.3	
615.	Manganese cyclopentadienyl-tricarbonyl	-	-		0.1	
616.	Manganese methylcyclopentadienyltricarbonyl (expressed in Mn)	0.1	0.2	x	-	
617.	Plastic materials with fluorine-4	-	-		10	
618.	MDI					
619.	Diphenylmethane diisocyanate					
620.	Mercury (alkilate compounds)	-	0.01	x	-	
621.	Mercury (all compounds except alkilate compounds)	-	0.05		-	
622.	Mercury	-	-		0.01	
623.	Mercury (mercury chloride)	-	-		0.1	
624.	Mercurethyl (chloride)	-	-		0.005	x
625.	Mercurethyl (phosphate)	-	-		0.005	x
626.	Diethyl-aminoethyl methacrylate	-	-		800	
627.	Methyl methacrylate	100	410		-	
628.	Metoxychlor	-	10		-	
629.	Metoxyphenol (m-)					

1	2	3	4	5	6	7
630.	Methyl oxide and m-hydroxyphenyl					
631.	Methylacetylene					
632.	Propine					
633.	Methylal	1000	3100		-	
634.	Methylamine	10	12		1	
635.	2-Methyl-4-amino-5-ethoxy-methylpyrimidine	-	-		1	
636.	Methylamylketone (n-)	100	465		-	
637.	Methylaniline	2	9	x	-	
638.	2-Methyl-1,3-butadiene					
639.	Isoprene					
640.	Methylbutylketone	100	410		-	
641.	Methylchlorophorm					
642.	1,1,1-Trichloroethane					
643.	Methylcyclohexane	500	2000		50	
644.	Methylcyclohexanol	100	470		-	
645.	Methylcyclohexanone (o-)	100	460	x	-	
646.	Methyldihydropyran	-	-		5	x
647.	Methyldipropyleneglycol	100	600	x	-	
648.	Methylethylketone	200	590		200	
649.	2-Methyl-5-ethylpyridine	-	-		2	x
650.	Methyl-fluorphenyl-dichlorosylan	-	-		1	
651.	2-Methylfuran					
652.	Sylvan					
653.	Methylglycol	25	80	x	-	
654.	Methylhexylketone	-	-		200	
655.	Methylhydrazine	0.2	0.35	xP	-	
656.	Methylisoamylketone	100	475		-	
657.	Methylisobutylcarbynol					
658.	Methylamylic alcohol					

1	2	3	4	5	6	7
659.	Methylisobutylketone	100	410		-	
660.	Methylmercaptan	0.5	1		-	
661.	Methylmorpholine (N-)	-	-		5	
662.	1-Methylnaphthalene	-	-		20	
663.	2-Methylnaphthalene	-	-		20	
664.	Methylphenylketone					
665.	Acetophenone					
666.	Methylpropylketone	200	700		200	
667.	Methylpropylenglycol	100	360		-	
668.	Methylpyrrolidone	-	-		800	
669.	Alpha-methylstyrene	100	480	P	5	
670.	Methylthiophen (isomers)	-	-		20	
671.	Methylurethane-benzole-sulpho-hydrazine	-	-		0.05	
672.	Methylvinylketone	-	-		0.1	
673.	5-Methyl-5-vinylpyridine	-	-		2	
674.	6-Methyl-2-vinylpyridine	-	-		0.5	
675.	Molybdenum (insoluble compounds)	-	10		6	
676.	Molybdenum (soluble compounds)	-	5		-	
677.	Molybdenum (soluble compounds under the form of condensation aerosols)	-	-		2	
678.	Molybdenum (soluble compounds under the form of powders)	-	-		4	
679.	Morpholine	20	70	x	0.5	x
680.	Naphthalene	10	50		20	
681.	Chlorinated naphthalene (higher)	-	-		0.5	x
682.	Alpha-naphthoquinone	-	-		0.1	
683.	Beta-naphthylamine	-	-	C	-	
684.	Nickel (metal and soluble compounds expressed in Ni)	-	1		-	
685.	Nickel (oxide and sulphide expressed in Ni)	-	-		0.5	

1	2	3	4	5	6	7
686.	Nickel (salts under the form of aerosols expressed in Ni)	-	-		0.005	
687.	Nickel carbonyl	0.001	0.007	C	0.0005	
688.	Nicotine	-	0.5	x	-	
689.	Nicotine (sulphate)	-	-		0.1	
690.	Nitroaniline (o-)	-	-		0.5	x
691.	Nitroaniline (p-)	1	6	x	0.1	x
692.	Nitroanisol (p-)	-	-		3	
693.	Nitrobenzene	1	5	x	3	x
694.	Nitrobutane	-	-		30	
695.	Nitrochlorbenzene					
696.	Chloronitrobenzene					
697.	Nitrocyclohexane	-	-		1	
698.	4-Nitrodiphenyl	-	-	C	-	
699.	Nitroethane	100	310		30	
700.	Nitroform					
701.	Trinitromethane					
702.	Nitroglycerine	0.2	2	x	-	
703.	Nitromethane	100	250		30	
704.	1-Nitropropane	25	90		30	
705.	2-Nitropropane	25	90		30	
706.	Nitrosodimethylaniline (N-)	-	-	xCE	-	
707.	Nitrotoluene	5	30	x	-	
708.	Nitrotrichloromethane					
709.	Chloropicrine					
710.	Nitroxylene	-	-		5	x
711.	Octachloronaphthalene	-	0.1	x	-	
712.	Octane	400	1900		-	
713.	Osmium (tetraoxide)	-	0.002		-	

1	2	3	4	5	6	7
714.	2-Oxohexamethylenimine					
715.	Caprolactame					
716.	Oxycarbamate	-	-		0.5	
717.	Allyl and glucidil oxide	10	45	P	-	
718.	Butyl and glucidil oxide	50	270		-	
719.	Carbon oxide	50	55		20	
720.	2,2'-dichlorodiethyl oxide	10	90	Px	2	x
721.	Diethyl oxide	400	1200		300	
722.	Diglicidil oxide	0.5	2.8	P	-	
723.	Diphenyl oxide (vapours)	1	7		-	
724.	Diphenyl/biphenyl oxide (vapours)	1	7		-	
725.	Diphenyl chlorate oxide	-	0.5		0.5	-
726.	Ethylene oxide	50	90		1	
727.	Isopropyl and glicidil oxide	50	240		-	
728.	Mesityl oxide	25	100		1	x
729.	Methyl and m-hydroxyphenyl oxide	-	-		0.5	x
730.	Methyl and chloromethyl oxide	-	-		0.5	
731.	Phenyl and gliycidil oxide	10	60		-	
732.	Propylene oxide	100	240		1	x
733.	Oxygene (difluoride)	-	-		20	
734.	Ozone	0.05	0.1		-	
735.	Paraformaledhyde					
736.	polyformaldehyde					
737.	Parathion	-	0.1	x	0.05	x
738.	Parathion-methyl	-	0.2	x	0.1	x
739.	Parathion-methyl-ethyl	-	-		0.03	x
740.	Pentaboran	0.005	0.01		-	
741.	Pentachloracetone	-	-		0.5	
742.	Pentachloronaphthalene	-	0.5	x	-	

1	2	3	4	5	6	7
743.	Pentachlornitrobenzene	-	-		0.5	
744.	Pentachlorophenol	-	0.5	x	0.1	x
745.	Pentachlorphenol (Na salt)					
746.	Sodium (pentachlorphenate)					
747.	Pentane	500	1500		-	
748.	Butyl peracetate (tert)	-	-		0.1	
749.	Butyl perbenzoate (tert)	-	-		1	
750.	Perchlorodimethylketone					
751.	Hexachloroacetone					
752.	Perchloroethylene	100	670		10	
753.	Perchloromethylmercaptan	0.1	0.8		1	
754.	Perchloryl (fluoride)	3	14		-	
755.	Diethyl perfluoradipate	-	-		0.1	
756.	Perfluoradiponitrile	-	-		0.1	
757.	Perfluorodimethylketone					
758.	Hexafluoracetone					
759.	Diethyl perfluorglutarat	-	-		0.1	
760.	Perfluorglutarodinitrile	-	-		0.05	
761.	Perfluoroizobutilene	-	-		0.1	
762.	Dibenzoyl peroxide	-	5		-	
763.	Tertiary dibutyl peroxide	-	-		100	
764.	Hydrogen peroxide	1	1.4		-	
765.	Petroleum (bitumen) (vapours)	-	5		-	
766.	Petroleum (gasoline)					
767.	Naphtha, fuel gaosline					
768.	Petroleum (liquid gas)	1000	1800		-	
769.	Picoline (isomer mixture)	-	-		5	
770.	Chlorinated pipen					
771.	Polychlorpipen					

1	2	3	4	5	6	7
772.	Piperidine	-	-		0.2	x
773.	Pivalone	-	0.1		-	
774,	Platinum (soluble salts in Pt)	-	0.002		-	
775.	Lead and its inorganic compounds	-	-		0.01	
776.	Lead (arseniate)	-	0.15		-	
777.	Lead tetraethyl	-	0.100	x	0.005	x
778.	Lead tetramethyl	-	0.150	x	-	
779.	Polychloropinen	-	-		0.2	x
780.	High density polyethylene	-	-		10	
781.	Polyformaldehyde	-	-		5	
782.	Polypropylene (unstabilized)	-	-		10	
783.	Potassium (butyl xantogenate)	-	-		10	
784.	Potassium (hydroxide)					
	Caustic alkali					
785.	Propadiene/propin (mixture)	1000	1800		-	
786.	Propanyl	-	-		0.1	
787.	Propazine (10-3(dimethylamino-propyl) phenothiazincchlorhydrate	-	-		5	
788.	Beta-propiolactone	-	-	CE	-	
789.	Methyl propionate	-	-		10	x
790.	Propyl propionate	-	-		70	
791.	Propylamine (N-)	-	-		5	
792.	Propylenimine	2	5	x	-	
793.	Propine	1000	1650		-	
794.	Propine/propadiene (mixture)	1000	1800		-	
795.	Pseudobutilene					
796.	2-Butene					
797.	Rhodium (vapours and metallic powders)	-	0.1		-	
798.	Rhodium (soluble salts)	-	0.001		-	

1	2	3	4	5	6	7
799.	Selenium amorphous	-	-		2	x
800.	Selenium (dioxide)	-	-		0.1	
801.	Selenium (compounds expressed in Se except hydrogen selenide)	-	0.2		-	
802.	Selenium (hexafluoride	0.05	0.4		-	
803.	Ethyl silicate	100	850		20	
804.	Methyl silicate	5	30	P	-	
805.	Silicon (carbide)	-	10		-	
806.	Sodium (cis-beta-chloroacrylate)	-	-		2	
807.	Sodium (2-(2,4-dichlorphenoxy) ethylsulphate)	-	-		0.5	
808.	Sodium (fluoracetate)	-	10		-	
809.	Sodium (hydroxide)	-	2		-	
810.	Sodium (pentachlorphenate)	-	-		0.1	x
811.	Sodium (thiocyanate) technical	-	-		50	
812.	Naphtha solvent (expressed in C)	-	-		100	
813.	Glass (fibre 5 - 7 diametre)	-	10		-	
814.	Stibine					
815.	Hydrogen antimonide					
816.	Streptomycin	-	-		0.1	
817.	Stricnine	-	0.15		-	
818.	Styrene	100	420		5	
819.	Styrene and alpha-methyl styrene (copolymer)	-	-		5	
820.	Sulphur (dioxide)	5	13		10	
821.	Sulphur (hexafluoride)	1000	6000		-	
822.	Sulphur (monochloride)	1	6		-	
823.	Sulphur (pentafluoride)	0.025	0.25		-	
824.	Sulphur (trioxide)	-	-		1	
825.	Ammonium sulphamate	-	10		10	

1	2	3	4	5	6	7
826.	Sulphamide	-	-		1	
827.	Dimethyl sulphate	1	5	x	-	
828.	Carbon sulphide	20	60	x	10	
829.	Dimethyl sulphide	-	-		50	x
830.	Ethylene sulphide	-	-		0.1	x
831.	Sulphuryl (fluoride)	5	20		-	
832.	Sylvane	-	-		1	
833.	2,4,5-T	-	10		-	
834.	Tantalum	-	5		-	
835.	Tantalum and oxides	-	-		10	
836.	Tellurium	-	0.1		0.01	
837.	Tellurium (hexafluoride)	0.02	0.2		-	
838.	TEPP	-	0.05	x	-	
839.	Turpentine	100	560		300	
840.	Dimethyl terephthalate	-	-		0.1	
841.	1,1,2,2-Tetrabromethane	1	14		-	
842.	Tetrabromethane	-	-		1	
843.	Acetylene tetrabromide					
844.	1,1,2,-Tetrabromethane					
845.	1,1,2,-Tetrachloro-2,2-difluorethane	500	4170		-	
846.	1,1,2,-Tetrachloro-1,2-difluorethane	500	4170		-	
847.	1,1,2,-Tetrachlorethane	5	25	x	-	
848.	Tetrachloroethane	-	-		5	x
849.	Tetrachlorethylene					
850.	Perchlorethylene					
851.	Tetrachloroheptane	-	-		1	
852.	Tetrachlorhexatriene	-	-		0.3	x
853.	Tetrachloromethane	10	65	x	20	x

1	2	3	4	5	6	7
854.	Tetrachlorononane	-	-		1	
855.	Tetrachloronaphthalene	-	2	x	-	
856.	Tetrachloropentane	-	-		1	
857.	Tetrachloropropane	-	-		1	
858.	Acetylene tetrachloride					
859.	1,1,2,2-Tetrachloroethane					
860.	Carbon tetrachloride					
861.	Tetrachloromethane					
862.	Tetrahydrofuran	200	590		100	
863.	Tetraline	-	-		100	
864.	Tetranitromethane	1	3		0.3	
865.	Thallium (Soluble compounds in Tl)	-	0.1	x	-	
866.	Thallium (bromide and iodine)	-	-		0.01	
867.	Thiodiphenylamine					
868.	Phenothiazine					
869.	Thiofuran	-	-		20	
870.	O,O'-dimethyl and O-ethoxycarbonylmethyl thiophosphate	-	-		1	x
871.	O-methyl, O-ethyl and O-trichlorophenyl thiophosphate	-	-		0.3	x
872.	Tyram	-	5		0.5	
873.	Thorium	-	-		0.05	
874.	Titanium (dioxide)	-	10		-	
875.	Titanium and dioxide	-	-		10	
876.	Titanium (tetrachloride)	-	-		1	
877.	Toluene	-	-		50	
878.	Toluydine (o-)	5	22		-	
879.	Toluydine	-	-		3	x
880.	Toluene diamine	-	-		2	x
881.	Toxaphen					
882.	Chlorinated camphene					

1	2	3	4	5	6	7
883.	Tribromomethane	0.5	5	x	5	
884.	1,1,3-Trichloroacetone	-	-		0.3	
885.	Trichlorobenzene	-	-		10	
886.	Trichlorodiethylketone					
887.	1,1,3-Trichloroacetone					
888.	1,1, Trichlorethane	350	1900		20	
889.	1,1,2-Trichlorethane	10	45	x	-	
890.	Trichloroethylene	100	535		10	
891.	Trichlorofluormethane	1000	5600		-	
892.	Trichloromethane	50	240	P	-	
893.	Trichloromethylmercaptan					
894.	Perchloromethyl-mercaptan					
895.	Trichloronaphthalene	-	5	x	1	x
896.	Trichlorophenol (Cu salt)					
897.	Cu (Cu trichlorophenate)					
898.	1,2,3,Trichloropropane	50	300		-	
899.	Trichloropropane	-	-		2	
900.	Trichloropropylene	-	-		3	
901.	Trichlorosylane	-	-		1	
902.	Trichlorothiophenol (trichlorthiophenol disulphide and paraffin mixture)	-	-		5	
903.	Trichlortoluene	-	-		0.2	
904.	Trichlorotriazone					
905.	Cyan chloride					
906.	1,1,2-Trichloro-1,2,2,-trifluorethane	1000	7600		-	
907.	Triethylamine	25	100		10	
908.	Triethoxysylan	-	-		1	
909.	Trifluorethylamine	-	-		100	
910.	2-Trifluormethyl-10-/3-4-methyl-1-piperidinyl)propyl/phenothiazine dichlorohydrate	-	-		0.01	

1	2	3	4	5	6	7
911.	Alpha-trifluor-m-nitrotoluene	-	-		1	
912.	Trifluorpropylamine	-	-		5	
913.	Alpha-trifluortoluene	-	-		100	
914.	Trimethylamine	-	-		5	
915.	Trimethylbenzene	25	120		-	
916.	2,2,4-Trimethyl-1,2-dihydro-quinoleine	-	-		1	
917.	Trimethylene trinitramine					
918.	Hexogen					
919.	Trimethylolpropane	-	-		50	
920.	Trinitromethane	-	-		0.5	
921.	2,4,6,-Trinitrophenyl-methyl-nitramine					
922.	Tetryl					
923.	Trinitrotoluene	-	1.5	x	1	x
924.	Tripropylamine	-	-		2	
925.	Trithiophosphate S,S,S-tributyl	-	-		0.2	
926.	Tungsten (insoluble compounds expressed in W)	-			-	
927.	Tungsten and carbides	-	-		6	
928.	Tungsten (soluble compounds expressed in W)	-	1		-	
929.	Natural uranium and soluble and insoluble compounds expressed in U)	-	0.2		-	
930.	Uranium (insoluble compounds)	-	-		0.075	
931.	Uranium (soluble compounds)	-	-		0.015	
932.	Methyl valerianate	-	-		1	x
933.	Vanadium (pentoxide)(vapours)	-	0.05	P	-	
934.	Vanadium (pentoxide)(powders)	-	0.5		-	
935.	Vanadium (trioxide and pentoxide) (powder)	-	-		0.5	
936.	Vanadium (powder)	-	-		4	

1	2	3	4	5	6	7
937.	Vinylacetylene	-	-		20	
938.	2-Vinylpyridine	-	-		0.5	
939.	Vinyltoluene	100	480		50	
940.	White-spirit	200	1150		-	
941.	White-spirit (expressed in C)	-	-		300	
942.	Xylene	100	435		50	
943.	Xylidine	5	25	x	3	x
944.	Yttrium	-	1		-	
945.	Zinc (chloride) vapours	-	1		-	
946.	Zinc (oxide) vapours	-	5		-	
947.	Zinc (oxide)	-	-		6	
948. 949. 950.	Zirconylfluoride Zinc pentachlorothiophenate Fluorzirconate	-	-		2	
951.	Zirconium (compounds in Zn)	-	5		-	
952.	Zirconium and its insoluble compounds (silicates, dioxide and carbide)	-	-		6	
953.	Zirconium (nitrate)	-	-		4	

Annex II

QUALITY STANDARDS FOR SURFACE-WATER SUPPLIES IN ROMANIA

No.	Characteristic	Category[a] I	II	III
1	2	3	4	5
1.	Ammonium (NH_4), mg/dm^3 max.	1	3	10
2.	Ammonia (NH_3), mg/dm^3 max.	0.1	0.3	0.5
3.	Silver (Ag), mg/dm^3 max.	0.01	0.01	0.01
4.	Arsenic (As), mg/dm^3 max.	0.05	0.2	0.5
5.	Nitrates (NO_3), mg/dm^3 max.	10	30	no standard
6.	Nitrates (NO_2), mg/dm^3 max.	1	3	"
7.	Barium (Ba), mg/dm^3 max.	1	4	4
8.	Benzene, mg/dm^3	0.1	0.1	0.1
9.	Free CO_2, mg/dm^3	50	50	50
10.	Cadmium (Cd), mg/dm^3	0.005	0.03	0.2
11.	Calcium (Ca), mg/dm^3	150	200	300
12.	Cyanides (CN), mg/dm^3	0.01	0.2	0.2
13.	Free waste chlorine (Cl_2), mg/dm^3	0.005	0.005	0.005
14.	Chlorides (Cl), mg/dm^3	250	400	400
15.	Cobalt (Co), mg/dm^3	1	5	5
16.	Hydrogen ion concentration, pH	6.5-8.5	6.5-8.5	6.5-9.0
17.	Chromium trivalent (Cr), mg/dm^3	0.5	0.5	0.5
18.	Chromium hexavalent (Cr), mg/dm^3	0.05	0.05	0.1
19.	Copper (Cu), mg/dm^3	0.1	0.1	3
20.	Active anion detergents, mg/dm^3	0.5	1	3

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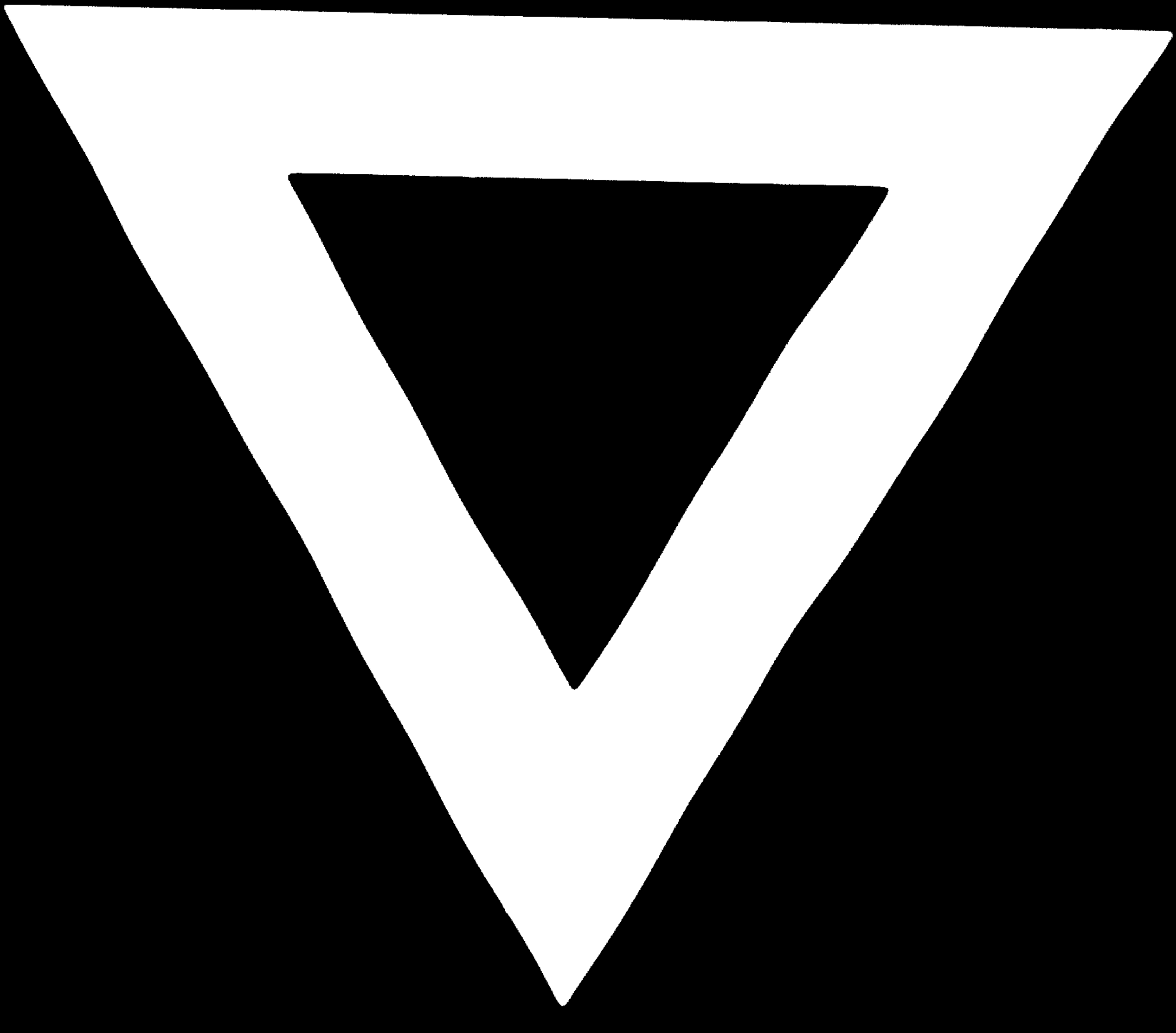
[a] See text (Chapter II) for explanation of categories.

1	2	3	4	5
21.	Phenols carried off by water vapours, mg/dm³	0.001	0.02	0.05
22.	Total ionic iron (Fe), mg/dm³	0.3	1	1
23.	Fluorine (F), mg/dm³	0.5	1	1
24.	Phosphorus (P), mg/dm³	0.1	0.1	0.1
25.	Hydrazine, mg/dm³	0.5	0.5	0.5
26.	Hydrogen sulphide and sulphides (H_2S), mg/dm³	none		0.1
27.	Magnesium (Mg), mg/dm³	50	100	200
28.	Manganese (Mn), mg/dm³	0.1	0.3	0.8
29.	Mercury (Hg), mg/dm³	0.005	0.01	0.02
30.	Naphthalene, mg/dm³	0.1	0.1	0.1
31.	Nickel (Ni), mg/dm³	0.1	0.1	0.1
32.	Oxygen dissolved in water (O_2), mg/dm³ min.	6	5	4
33.	Lead (Pb), mg/dm³	0.05	0.1	0.1
34.	Fix waste, mg/dm³	750	1000	1200
35.	Selenium (Se), mg/dm³	0.01	0.01	0.01
36.	Sodium (Na), mg/dm³	100	200	200
37.	Mercaptanic sulphur, mg/dm³	0.5	0.5	0.5
38.	Sulphates (SO_4), mg/dm³	200	400	400
39.	Carbon sulphide, mg/dm³	1	1	1
40.	Organic materials			
	a) Biological oxygen consumption (BOC_5), mg/dm³	5	7	12
	b) Chemical oxygen consumption (COC), mg/dm³			
	- COC (Mn)	10	15	25
	- COC (Cr)-with K-dichromate	10	20	30

1	2	3	4	5
41.	Tannin and lignin, mg/dm^3	10	10	15
42.	Toluene, mg/dm^3	0.1	0.1	0.1
43.	Oil products, mg/dm^3	0.1	0.1	0.1
44.	Zinc (Zn), mg/dm^3	0.01,	0.1	0.1
45.	Physical and organoleptic characteristics Radioactivity Ci/cm^3			
	- overall alpha	1.10^{-9}	1.10^{-9}	1.10^{-9}
	- overall beta	50.10^{-9}	50.10^{-9}	50.10^{-9}
46.	Colour	colourless	no standard	
47.	Smell	without smell		
48.	Bacteriologic charactoristics Coli bacillus/dm^3 max.	100,000	no standard	



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