The results obtained in preliminary tests on catalysts in industrial gaseous waste from the Moscow Coke–Gas Factory (MCGF), the Kashirsk Thermoelectric Power Station, and the Cellulose Industry in Krasnoyarsk are presented below. Table 4 gives the composition of the effluent gases from the MCGF.

As a result of the application of the catalyst, hydrogen sulphide, hydrogen cyanide, and nitric oxide are eliminated from the gases (Table 5).

Table 5. Results of tests on new catalytic systems (MCGF).

Source of waste	Ecologically harmful impurity	Catalyst operating conditions		Impurity concentration, mg m^{-1}		Duration of operation before breakthrough	Efficiency of purification, %
		space velocity, h^{-1}	temperature, °C	before purifcation	after purification		
Straight run coke gas	Hydrogen sulphide	300	20	3000	0	312	100.0
Reverse run coke gas	"	470	20	30	0	816	100.0
Straight run coke gas	Hydrogen cyanide, hydrogen	300	20	1000	2.8	1440	99.7
Reverse run coke gas	"	100	20	171	6.0	1440	99.8
	Acetylene	300	200	800	82.7	1440	89.7
	Nitrogen oxides	2000	300	0.21	0.065	1440	69.0
Industrial waste at the MCGF	Ammonia	300	500	1500–78 500	64–28 500	1440	84.0–99.9
Removal of ammonia from aqueous solution by bubbling	"	300	500	134 000	600	1440	96.4
Petrol engine	Nitrogen oxides	12 000	180	1600 ppm	140 ppm	1440	91.0
Stand with UMZ-416 engine	Carbon monoxide	12 000	270	3500 ppm	170 ppm	1440	95.0
Manufacture of viscose	Carbon disulphide	1000	20	1300	50	1	96.1
	"	1000	20	500	9	1	98.2

The advantages of the catalysts described above are as follows:

availability and the possibility of obtaining them directly in the factory, since this requires only a carrier, a hydrocarbon gas, a metal salt, and plant of suitable size and of a relatively simple design;

a lower cost than that of activated charcoal, which makes it possible to organise a large scale industrial production without a large capital expenditure;

the possibility of using spent catalysts, already containing metals, as carriers;

the use of catalysts makes it possible to combine adsorption and catalytic purification processes;

The solution of the problem of the elimination of ecologically harmful impurities from gaseous waste can be reduced (in view of the multifunctional nature of the catalyst) to setting up a balance between oxidative and reductive components. This provides a simple and effective lever for controlling the process, can guarantee the reliability and quality of the purification, and creates conditions for automating the purification processes and the monitoring of the chemical composition of the waste.

The large scale employment of the systems developed requires the creation and organisation of the production of standard apparatus for coating inorganic materials with carbon. At the present time, there exists only laboratory apparatus as well as the plant at the MCGF, which has made it possible to produce one tonne of the catalyst. It is necessary to solve a series of technological problems (in particular, the problem of the additional aerodynamic resistance to the effluent gases) and to develop methods for the regeneration of the catalysts. Furthermore, it is essential to develop apparatus for the rapid analysis of the effluent gases before and after purification, a computer technique, and a module for the automatic control of the purification processes.

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Membrane technology in the resolution of nature conservancy problems

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1. The potential of membrane technology and certain examples

In future membrane technology could provide the basis for resolving a number of ecological problems in many branches of industry and agriculture. Practical experience throughout the world has highlighted examples of how membrane technology may be used on the industrial scale in order to resolve ecological problems.

First of all there is the project in the USA now in its final stages in which the salinity of the Colorado river has been reduced from 1.5 g^{-1} to approximately 0.7 g^{-1} (i.e. in regard to salt content the water has been converted to drinking water). A similar water processing facility is now under construction in the town of Hume (Arizona state) close to the border with Mexico. In this case part of the river discharge will be channelled through the desalination plant where blocks of membrane assemblies for reverse osmosis are located and have an operating efficiency of 400 thousand cubic metres per day. Under these conditions the solvent (water) is forced through the membranes in the presence of a high osmotic pressure (the operating pressure is usually approximately 3–5 MPa) while salts

are retained. The flow of desalinated water will be mixed with the untreated portion of the Colorado river discharge so that the river water in Mexico has an acceptable salt content.

The future possibility of combining complexone (based on organophosphorus compounds) stabilisation (prevention of salt deposition) of water† with membrane treatment of water in circulating water supply systems by means of ultrafiltration, electrodialysis, and reverse osmosis should be considered. This approach would be even more attractive, since in the case of water stabilisation by complexones part of the circulating discharge would inevitably have to be replenished and the organophosphorus compounds would remain outside the water circulating system.

Reverse osmosis installations are also used for generating large volumes of drinking water, and this process is carried out in Saudi Arabia in plants for the distillation of briny waters in which approximately 10^4 m^3 of water are produced each day. There is a clear awareness of the severity of problems associated with water supplies in the USSR especially in Southern regions. Adequately large reserves of brackish water (approximately $3-6$ g l^{-1}) have been located, so that attention may be focused on the supply of water to rural areas which would be ecologically safe as a result of the use of membrane techniques. The success of the respective developments will apparently be determined not only by the availability of high performance membranes (with respect to operating efficiency, selectivity, chemical and thermal output, stability, mechanical properties) but also by the creation of high-capacity membrane devices and by the supply of essential equipment including heavy duty pumps.

It is noteworthy that progress has already been made in the USSR in resolving water supply problems. In Tambov the Rodnik type of electrodialysers fitted with ion-exchange membranes MK-40 and MA-40 and with an operating efficiency of $1-4$ m^3 h^{-1} (a product of the scientific-industrial complex Plastmassy, Scientific Research Institute of Plastics) have been in full-scale production since 1974. These facilities provide a reliable supply of drinking and household water produced from brackish waters of artesian boreholes for more than one million inhabitants of rural localities in Kazakhstan, the land along the Volga, the Ukraine, Kalmykin, and Central Asia.

The main electrodialysis installations for demineralisation of water for the requirements of the Prikumskii plastic factory are currently operating. These facilities (operating efficiency is approximately 50 m^3 h^{-1}) reduce the salt content from $0.75-0.8$ g l^{-1} to 0.1 g l^{-1}. In this case a certain portion of the demineralised water is used in low pressure steam boilers, while the remaining portion of the water after secondary purification by ion-exchange is utilised for the industrial manufacture of ethylene oxide. The significant reduction in the amount of waste waters attained with the aid of this type of water treatment technology has a favourable ecological effect.

Academician A V Fokin‡ has already indicated in an earlier report that losses of mercury in Soviet plants during the production of one tonne of caustic soda (a total quantity of more than 0.5 million tonnes per annum) reaches 600 g, whereas in foreign countries the loss of mercury during the production of caustic soda is more than an order of magnitude lower. Apparently the only answer to this problem would be to convert to the production of caustic soda under clean conditions with the aid of membrane techniques. By adopting such a strategy there would still be many problems to surmount, despite the purchase of perforated carboxyl-containing membranes and electrolysers from the Japanese firm, Asaki Glass. It is noteworthy that the world-wide production of "membrane" caustic reached approximately 4.5 million tonnes per annum in 1988. [1]

In a number of major chemical and petrochemical plants membrane techniques are now being introduced for the extraction of exploitable components from process gas mixtures which, in addition to saving resources, enables harmful gaseous discharges to the atmosphere to be reduced or eliminated. The American firm Monsanto uses membrane assemblies with an operating efficiency of up to 2.8×10^4 m^3 h^{-1} as a result of which up to 9% of the hydrogen not utilised in the chemical transformations can be returned to the manufacturing process and up to 99% of the hydrogen may be concentrated and subsequently utilised for the synthesis of ammonia and methanol and for hydrorefining and hydrogenolysis. A high order of cost savings is being attained in Saudi Arabia where the firm "Chieda" has built an air separation plant for generating high purity oxygen (1200 tonnes per day) and nitrogen (10^4 m^3 h^{-1}) in a petroleum chemistry complex (plants for the production of ethylene, ethylene glycol, and low density polyethylene). In this regard certain achievements in the Soviet Union are noteworthy. Gas separation membranes made of polyvinyltrimethylsilane and gas-separating membrane devices have been developed§. Assemblies, which are commercially available from the scientific-industrial complex "Kriogenmash", are used for the biological purification of waste waters, oxygenation of water for the artificial breeding of fish and other living organisms, for medicinal purposes, and for the generation of a controlled gas phase during the storage of different kinds of agricultural produce and for other purposes. Other examples in which membrane technology may be effectively employed could be given.

2. Resolution of fundamental problems in membrane separation. The basis of the development and extensive exploitation of membrane technology for a wide range of practical purposes

Advances in membrane technology will only be possible as a result of a comprehensive study of a broad range of scientific problems, and the wide experience of many foreign firms supports this view. The main problems will be briefly listed.

1. Problems associated with the production of materials (organic polymers, inorganic material particularly ceramics) for membranes. In this case one has in mind a broad range of problems concerning membrane material science which relate to the selection of conditions for the synthesis and treatment of materials and to the formation of membranes and their modification (volume, surface).[2,3].

† See the paper by M I Kabachnik and N M Dyatlova "Chemical Aspects of a Circulating Water Supply" in the present issue.

‡ See the article by A V Fokin "Protection of the Environment and Chemical Ecology" in the present issue.

§ See the article by N A Plate, V V Teplyakov, V S Khotimskii, and Yu P Yampol'skii "Certain Possibilities with Gas-separating Membranes for the Creation of Ecologically Friendly Plants" in the present issue.

2. Problems associated with the physical chemistry of membrane separation. This group of questions includes attempts to determine the nature of the selectivity of the transport of a given component through the membrane and the determination of the structure of membranes in various three-dimensional scales (beginning with nanometres) and relationships between the structure and functional characteristics of the membranes.[4,5] The mechanisms of transport of ions and molecules within different types of synthetic membranes vary. "Particle size" effects play a major role in microfiltration (particles in the 0.02 μm – 10 μm range are retained) and ultrafiltration (particles typically with a mass of 500 daltons to 0.1 μm in size[5]) processes. However even in the case of ultrafiltration surface force fields, the interaction (Coulomb, dispersion, and "structural"[6]) between particles passing through the membrane pores and the surface of the pore have a significant effect on the efficiency of the separation process. Therefore modification of the surface of the pores (for example by grafting of charged and polar functional groups) may significantly alter the retention effect.

Fields of surface forces are exerted in a particular way in reverse osmosis processes, when under the influence of high osmotic pressures the solvent or individual components of a complex solvent are pressed through the submicropore or subchannel system. In this case the efficiency of the separation (when specifications are met in regard to chemical and mechanical stability of the selective layer in the membranes) is dependent on the topology of paths along which the solvent flows and on the fields of surface forces created by the functional groups within the material used.

In a large proportion of currently available processes for electrodialysis, electrolysis, gas separation, and pervaporation (evaporation through non-porous "diffusion" layers) drift diffusion transport through membranes occurs, so that the effect of membrane separation is determined for various components in the mixtures by the differences in the permeability constants (P) of the material from which the membrane is made. These values are obtained as the product of two factors, a thermodynamic factor (the solubility constant of a component in the given material, the Henry constant) and a kinetic factor (diffusion coefficient, electrical mobility, etc.). In a number of cases the mutual action of the penetrating components have a significant effect, for example on account of the plasticisation of the polymeric matrix, when one of the components dissolves in the latter.

Even at this level of factual description of cross-membrane transport many problems arise which are associated with the need to have an adequate understanding of the technological parameters of the membranes and with the determination of routes for increasing the efficiency of membrane separation, mainly on account of the selection of materials for membranes. The problems increase immeasurably on transition to regimes of intensive mass-transfer through the membrane (high current densities flowing through the membrane, high operating pressures), when the above-mentioned quasi-equilibrium representations are found to be inadequate. Under these conditions the selectivity of the separation may be determined entirely by kinetic factors and may be dependent to a greater extent on the membrane structure in different spatial scales, and on the condition of the membrane surface and the interphase boundaries in the body of the membranes.[4] By gaining an understanding of the nature of the above-mentioned features of the transport process the membrane material and the surface of the membranes can be realistically modified with the objective of obtaining membranes with specified characteristics.

New qualitative relationships and hence new advances in research in the development of new-generation membranes may be elaborated, when barrier membrane structures are used for the separation of mixtures, i.e. ultrathin layers of submicroscopical thickness (10 – 100 nm) made from organic or inorganic materials formed on ultrafiltration and microfiltration supports. In this case the permeability of the membrane layer to a particular type of particle is dependent on the ratio of two spatial scales: the minimal length of a_0, the average distance between centres of localisation of the particle moving in the membrane and also the correlation length, ξ, the characteristic degree of the structural heterogeneity of the barrier layer within the limits of which "coherence" is realised. On scales greater than ξ the system is homogeneous, and therefore the permeability constant P of membranes with a thickness $d \gg \xi$ has the normal meaning. However, when $d < \xi$, the parameter P is not a constant value, since the flow of particles through the membrane under stationary conditions is dependent on the value d according to the non-traditional method (the fractal mode of transport). On account of the difference in the values of the probabilities of the elementary jumps for the various particles, the local heterogeneity of the layer structure is "felt" in different ways by the different types of particles passing through the membrane. Thus the barrier layer may for example consist of a homogeneous system for certain particles, $i (d \gg \xi_i)$, but may constitute a fractal system for other particles, $j (d < \xi_j)$. Thus one might conclude that there is possibly a relationship between the selective permeability of the different types of particles and the thickness of the barrier layers. This may serve as a basis for the targetted search for barrier structures, which are highly permeable and highly selective with respect to specific components and which have different chemical properties and a different three-dimensional structure.

3. Questions concerning the optimisation of separation processes. The advantages of membrane techniques for resolving specific problems concerning the isolation or concentration of the required components from a gas or liquid mixture may be totally realised only when the process as a whole is optimised. In this case combined (integrated) process diagrams may be obtained specifying the use of other process units (distillation, rectification, etc.) in addition to membrane blocks (in general with membrane cascades including recycling[7]).

These complex strategies may be fulfilled by means of mathematical modelling of the processes and the creation of a bank of models for membrane-sorption processes and cross-membrane transport of components in the mixtures. All of the advantages of membrane technology can be exploited only when the process flows, equipment construction, types of membranes, and process arrangements are optimised with the aid of the mathematical models derived.

3. Prospects for the use of membrane technology to resolve ecological problems

Academician I V Petryanov-Sokolov commented on the essential strategic direction for scientific studies against a background of imminent ecological calamities. "There is no process which does not require continual monitoring..." One might anticipate that through the extensive use of membrane separation techniques it should be possible to come close to confirming this principle in real-life situations. Several Soviet developments, which could form the basis of ecologically acceptable processes, are indicated below.

A) The elaboration of basic membrane technology processes for the extraction of utilisation of ammonia from gasous and liquid discharges from chemical and metallurgical plants

In present-day manufacture of ammonia (plants for the synthesis at an output of approximately 450 tonnes of ammonia per annum are used) there are no closed-up material cycles in relation to ammonia. A certain proportion of the circulating gas mixture, the so-called blow-off gases (approximately 7–8 thousand $nm^3\ h^{-1}$) are led out of the synthetic cycle in order to prevent the accumulation of secondary gases above a particular level (approximately 10%) and tank gases are released from the storage tank (approximately 2.5 thousand $nm^3\ h^{-1}$). After the ammonia has been condensed (by cooling to 243–248 K), the ammonia content in the blow-off and storage tank gases is 1.4 and 10.7 vol.%, respectively. The ammonia is either burned in the jets of tube furnaces for natural gas conversion, which leads to further losses of the original raw material and to marked contamination of the environment with oxides of nitrogen¶, or is washed with water with the formation of ammonia water (approximately 3–6 vol.% ammonia) which in many cases is regarded as liquid sewage.

In this regard the close-up of material cycles with respect to ammonia is a key priority from the ecological standpoint (with an unquestionable saving of resources) and could be achieved if highly selective membranes were used for the extraction of ammonia from tank and blow-off gases and also from the ammonia, liquid sewage of the plant.

Ecologically important problems are associated with the operation of gaseous nitration processes which are still used, i.e. the chemico-thermal treatment of steel items, in order to increase their strength, corrosion resistance, and durability by saturation of the surface layer with the nitrogen formed during the thermal dissociation of ammonia, which is present among the operating gases used. An important defect of nitration technology is the partial (approximately 50%) thermal dissociation of ammonia, as a result of which the remaining portion of ammonia is burned with the formation of oxides of nitrogen. There is obviously a need for close-up of the ammonia cycle in this case also, since the annual demand for ammonia is $3-4 \times 10^6\ m^3$ on the premises of the Ministry of Automobile and Agricultural Engineering alone. The need to isolate ammonia from gas mixtures also arises in a number of biotechnology processes.

Membrane technology may be used for the separation of mixtures containing ammonia, in order to surmount this complex of problems. The membrane used for this purpose could be formed from hollow fibre, which has anomalously high permeability and selectivity parameters with respect to ammonia ($P_{NH_3} \approx 5\ m^3/(m^2\ h\ atm.)$, $\alpha = P_{NH_3}/P_{H_2} \approx 10^3$). This type of membrane is under development at present in the Karpov Scientific-Research Institute of Physical Chemistry in collaboration with a number of other organisations, i.e. the Kiev Branch of the All-Union Scientific-Research and Design Institute of Synthetic Fibre, the "Khimvolokno" scientific-industrial complex, the Okhtinsk scientific-industrial complex "Plastopolimer", the State Scientific-Research and Design Institute of the Nitrogen Industry and Products of Organic Synthesis, the Moscow Engineering and Physics Institute, and the Institute of Chemical Physics, Academy of Sciences of the USSR. [8,9] The membranes are based on a perfluorinated sulpho-containing copolymer with a high thermal and chemical stability. Effective methods for modifying the copolymer have been found, adhesive fillers have been developed for gas separation membrane elements, and processes have been designed in which gases are separated in hollow fibre membrane modules using different flow diagram arrangements for organisation of the process. In contrast to known membranes based on polyfluoroethylene resin [10] this membrane is not susceptible to the marked effects of plasticisation and its properties are not altered, when the composition of the ammonia-containing mixture is changed. Trials performed on membranes and gas-separating elements based on these materials have shown that in principle it is possible to surmount the above-mentioned problems on the industrial scale in regard to resource saving and the prevention of harmful wastes from entering the environment.

B) Elaboration of membrane technologies for the extraction and concentration of "acid" components from gas mixtures

In recent years serious ecological problems have arisen in regard to the processing of certain gas-bearing formations mainly in the Orenberg and Astrakhan regions. The main cause of the ecological hazard is the low standard of technology employed for recovery of the gas and also the equipment used which results in the discharge of hydrogen sulphide, sulphur dioxide and carbon dioxide into the atmosphere. Sulphur dioxide is also released into the atmosphere from many industrial plants. Discharge of this gas by thermoelectrical power stations amounts to more than eight million tonnes in the USSR [11] and integrated mining and metallurgical works (Norilsk and others)† discharge several million tonnes. The problems of extraction and concentration of acid gas are especially acute in ferrous metallurgy sites, for example sulphur dioxide in coke chemical plants and carbon dioxide in blast furnaces. Gaseous discharges from motor transport are also known to present a serious hazard to the natural environment.

The release of ecologically harmful components, including acid gases, into the atmosphere has serious consequences. The hazards are mainly acid rain, which is a threat to soil bacteria and causes degradation of the topsoil, and also the greenhouse effect as a result of the release of carbon dioxide.

Apparently it will be possible to eliminate some of these problems in future [12–14] with the aid of membrane technology (it is hoped that in this regard the major successes will be associated with the use of catalytic methods for the recovery of acid gases). Although at present there are essentially no large-scale industrial installations in operation for the entrapment and concentration of the components in aggressive acid gases (sulphur dioxide, hydrogen sulphide, oxides of nitrogen), intensive research in underway in many parts of the world in the search for high-efficiency membranes for acid gases, and line diagrams are in preparation for membrane processes and membrane-sorption and other combined installations.

Of the membranes developed in the USSR for extraction of aggressive acid gases and gas mixtures generated by the various plants, and "Seragel" type membranes are noteworthy. [15] These membranes are highly selective for sulphur dioxide and hydrogen sulphide. In addition membranes for hydrogen sulphide and carbon

¶ Apparently discharges of oxides of nitrogen together with emergency discharges of ammonia in the Shchekin industrial complex "Azot" caused irreparable damage to Tolstoy's farm in Yasnaya Polyana.

† See the article by K I Zamaraev, "Development and Introduction of Catalytic Methods for the Detoxification of Discharges from Industry and Motor Transport" in the present issue.

dioxide which are based on aromatic polyamidoimides obtained from solutions of polymers in N-methylpyrrolidone are of interest.[16]

The American firm Bend Research has designed a membrane, which is highly selective for hydrogen sulphide ($P_{H_2S}/P_{CO_2} \approx 30$) [17] and which consists of a gelatinoid layer containing an alkylpyrrolidone or an alkyl phosphate carried on an asymmetrical cellulose support. In earlier reports[18,19] it has been shown that membranes based on heat-resistant and chemically stable perfluorinated copolymers ("Nafion") are highly efficient in regard to the extraction of acid gases. These copolymers contain sulphonic acid groups with carriers containing amino groups and anion-exchange groups with quaternary ammonium bases. In these cases[18] difficulties are encountered in the determination of specific pathways for the modification of these types of materials and the elaboration of thin-layer (< 50 μm) membrane technology. Thus there would appear to be great potential in the use of hollow fibre modules with membranes based on perfluorinated ionomers for the extraction of acid gas and also for the extraction of ammonia. In these types of materials the gas molecules are transported through a system of submicroscopic canals[4] and the diffusing molecules undergo reversible binding with functional groups or the carriers. In this case certain components may be selectively controlled by altering the moisture content of the membranes.[20] One might suggest that, in addition to the above-mentioned aggressive components (hydrogen sulphide, sulphur dioxide, and ammonia) and carbon dioxide, membranes based on perfluorinated ionomers, which constitute a class of relatively heat resistant and chemically stable polymeric membranes, may (with certain modifications) also be used for the extraction of oxides of nitrogen and carbon monoxide (in the presence of nitrogen) from gas mixtures, for the separation and concentration of certain hydrocarbons, and for drying gases. The above-mentioned studies emphasise the interest in perfluorinated materials containing functional groups as membranes which may be used for the separation of the most aggressive and ecologically harmful components from gaseous media. Apparently in future in addition to hollow fibre membranes flat composite membranes with a selective layer formed from solutions of perfluorinated ionomers will be manufactured (for roll modules).

C) Design of a process of membrane electrolysis in alumina production

A membrane electrolysis process in which the recuperation of alkali is a major component of the technology for the recovery of industrial products in alumina production is being developed by the State Scientific-Research and Design Institute of the Rare Metals Industry, the Institute of Metallurgy and Enrichment, Academy of Sciences of the Kazakh SSR, and alumina plants within the Ministry of Metallurgy of the USSR.

In addition to the question of resource savings the treatment of soda-sulphate mixtures, which are formed during the recovery of sulphide-containing bauxites in a number of aluminium plants in which alkali is completely regenerated (ten–twelve thousand tonnes in terms of 100% caustic on average in each factory), has a very marked ecological impact. Trials with electrolysis using perfluorinated ion-exchange membranes in an installation at an alumina works in the Urals aluminium factory have shown that in principle it is possible to attain almost total regeneration of alkali with the concomitant production of gypsum. Broader objectives have been set for the use of membrane electrolysis for reprocessing carbonate-sulphate, chloride-carbonate, and chloride-sulphate mixtures and also alkaline aluminate solutions.

D) Replacement of ion-exchange cycles by continuous membrane processes in the production of riboxine

A preliminary analysis of the existing technologies for the production of riboxine in plants in which medicinal preparations are manufactured has shown that the use of electrodialysis may significantly reduce losses (reaching almost 50%) of the main product and significantly reduce the ecological hazard presented by the plant on account of the elimination of discharges of water used for the regeneration of ion-exchange columns. The technology of demineralisation by electrodialysis may provide the basis for this and a number of other biotechnological processes.

E) Processes for the treatment of industrial waste waters involving the extraction of valuable components

It is noteworthy that among many plants of this type in existence throughout the world including those in which electrodialysis is employed (see for example Ref. 21) processes are being designed involving the use of impregnated liquid membranes, which contain a solution of a complex-forming agent and an ionophore in an organic solvent, which is injected into the pores of the membrane support. By creating in these systems a counter (antiport) flow of ions of like sign (for example M^{n+} and nH^+) or a unidirectional flow (symport) of ions of opposite sign (M^{n+} and nOH^-) it is possible to achieve a high degree of extraction of the required component (Cu^{2+}, Cr^{3+}, VO_2^{2+}, etc.) from the original solution. In this way copper has been extracted from wash waters in electroplating shops.[22] Porous hollow fibres made from polypropylene have been used as a hydrophobic matrix, the impregnated phase being a solution of di(2-ethylhexyl)-phosphoric acid in n-dodecane. A pH value of 3–5 was maintained in the feeder solution. When sulphuric acid is used in the recipient solution, up to 99% extraction of copper, a toxic component of waste waters, was attained, which corresponded to a residual copper concentration at the normal BOD level. In this case a saturated solution of copper sulphate was obtained in the recipient solution. The demineralised water from which the copper had been removed was returned for use as the wash water and the saturated solution of copper sulphate was used for the periodic adjustment of the composition of the electroplating baths. There is an obvious need to employ this type of technology in industry in the USSR from the standpoint of resource saving and ecology.

One should note two additional general factors.

1. Attainment of ecological objectives is impossible in the absence of any novel techniques and equipment for the continuous monitoring (analytical chemical) of the composition of the environment (atmosphere, reservoirs, land) which permit rapid determinations, and which are reliable and simple to operate. One is essentially concerned with the design and production of a new generation of analytical facilities, i.e. chemical membrane sensors, miniature, highly sensitive devices for the direct, selective, and fully automated determination of chemical compounds in industrial systems and natural specimens. In these devices film (membrane) coatings made from organic and inorganic materials with increased permeability constants with respect to particular environmental components (molecules, ions) are used as barriers separating the environment under analysis from the recording system (semiconducting oxide films, field-effect transistors, etc.). With the aid of these systems it will be possible to monitor rapidly and continuously the chemical composition of liquid and gaseous natural media and industrial discharges down to trace concentrations. Unfortunately studies and developments of this nature are not in

progress in the institutes of the Section of General and Industrial Chemistry, Academy of Sciences of the USSR.

2. As regards solving ecological problems we have no right to procrastinate. It is our duty to our fellow-countrymen and to the world community to exploit to the maximum all available means for construction plants which discharge little or no wastes, in order to reduce the concentration of harmful and toxic components in the environment. This is a very complex problem, which is compounded by the fact that the Soviet authorities at present have no effective mechanisms which help industrial enterprises and factories to become interested in exploiting the achievements of science which are targetted towards the resolution of acute ecological problems. It would seems that, if there are no such mechanisms available, they must be created or at least their creation must be encouraged.

In a present-day assessment of the economic efficiency of technological processes the actual damage which they inflict upon the natural environment (in the mining of exploitable minerals, during the disposal of industrial wastes, at water intakes, etc.) and the expenses which the complete restoration of the environment would demand are not taken into consideration. If in future the objective (by introduction of appropriate laws by the Supreme Soviet of the USSR) will be to take into account this hazard in an adequate manner‡ during the planning of the various technological projects and to weigh the economic advantages against the effects of such projects, the economic advantages of fulfilling many technological plans will be viewed in a completely different light. The need to uphold a way of life with resource-, material- and energy-saving and environmentally acceptable technologies (in particular membrane technology) is undoubtedly becoming a vitally important issue for factories and industrial enterprises. It is precisely this type of revaluation of the technical level of a diverse range of manufacturing processes under Soviet conditions which may open up a route to new technologies.

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‡ In accordance with the currently operating procedures for assessing economical damage inflicted upon the environment, a fine of approximately one rouble must be payed by an industrial plant or establishment for one tonne of salts discharged into an open reservoir.