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United Nations Industrial Development Organization

REPORT OF THE EXPERT GROUP MEETING
ON THE STUDY OF SYNTHETIC VERSUS NATURAL PRODUCTS

Vienna, 16 - 20 September 1974

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REPORT OF THE EXPERT GROUP MEETING
ON THE STUDY OF SYNTHETIC VERSUS NATURAL PRODUCTS

Pilot project on the rubber industry and its impact on the environment

Corrigendum

The title of document ID/WG.188/3 should read as above.

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CONTENTS

EXPLANATORY NOTE

Within the context of this report, "environment" is taken to mean any physical surroundings affecting the health and welfare of humans and other organisms that are in some way modified by the presence of rubber industry or by the use and disposal of its products. The impact of the rubber industry upon that environment has been studied from the standpoint of its effect upon the public (e.g. air pollution, water pollution, land contamination and noise) and upon the worker within the industry (e.g. exposure to toxic materials and noise). Such effects are usually assessed from an economic standpoint, but they can also have important social and political consequences.

Each production unit, whether it is a plant or a plantation, will have its own environmental problems depending upon the procedures used, the materials handled and its location. This study can only identify those problems that have a common occurrence and are generally recognized. The magnitude of the problem depends upon the inherent potential risk, the control measures taken and the vulnerability of the particular environment.

For the purpose of this study, the synthetic rubber (SR) manufacturing industry has been restricted to the major large-volume general-purpose types, namely styrene butadiene copolymer (SBR), polybutadiene (BR) and polyisoprene (IR). The specialty rubbers, such as butyl or neoprene, which in total comprise roughly 14 per cent of the total rubber requirements have not been considered, but their exclusion does not appear to have any effect upon the conclusions reached. Also for the purpose of this study, the SR manufacturing industry has been taken to include not only the polymerization plants but also the plants required to produce the monomer feed stocks, namely, butadiene, styrene and isoprene, and the study has not gone further into the manufacture of the raw materials that go into the production of these monomers The natural rubber (NR) producing industry is taken to include the growing operations as well as the processing plants required to recover the dry rubber from the latex.

The following abbreviations are used:

BR	-	polybutadiene rubber
IR	-	polyisoprene rubber
NR	-	natural rubber
SBR	-	styrene butadiene rubber
SR	-	synthetic rubber
IISRP	-	International Institute of Synthetic Rubber Producers
IRSG	-	International Rubber Study Group

INTRODUCTION

The increasing damage caused to the environment in the process of industrial development has been the source of grave concern to people of thought and vision in many parts of the world, and cries of alarm have recently come from many quarters. In 1972, the Stockholm Conference on the Human Environment led to the creation of a new United Nations body, the United Nations Environment Programme (UNEP) to take action on the recommendations of the conference. UNEP formed a plan of action, grouping the recommendations in separate areas, and decided that UNIDO, in full partnership with UNEP, should form an integrated programme in industry covering trade, economics and transfer of technology, the central theme being to encourage industrial development of countries without destruction of their environment. Admittedly, the real problem in developing countries today is not one of pollution but of improving their standard of living by industrial development, but looking ahead to the future, it is essential that these countries do not make the mistakes made by the industrially advanced countries in the process of their development.

One of the joint UNIDO/UNEP projects (UNEP 0402-73-005, UNIDO EP/INT/73-005) entitled "Study on synthetic versus natural products: pilot project on the rubber industry", was set up to study the interactions of technological, economic and environmental factors in the rubber industry and the extent to which environmental considerations should influence the choice between natural and synthetic rubber production, the technique of product manufacture and the disposal or recycling of wastes. As a pilot project it is intended to give guidance to similar future studies on other natural and synthetic products.

A preparatory meeting was held in April 1974, when experts from the various branches of the rubber industry made recommendations regarding the basic outline for the study, identified the sources of various inputs and data needed for the study and the contributions that other agencies and international organizations could provide for the elaboration of the study. In accordance with the recommendations, consultants were engaged to make detailed studies on specific aspects of the subject. Those studies were examined in the Expert Group Meeting convened in Vienna 16-20 September 1974. This report gives a summary of the discussions, the conclusions reached and the recommendations of the meeting.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. From an environmental point of view, the advantages of NR production are:

   (a) It is less destructive of non-renewable resources;

   (b) Its high manpower requirement creates employment in developing countries;

   (c) Cultivation of large areas with rubber trees has a purifying effect on the air;

   (d) It avoids the ill effects of the deforestation that usually results from industrialization.

2. The aqueous waste released to the environment appears to have higher concentrations of contaminants in the case of NR production, as treatment facilities are not usually installed, whereas most SR manufacturing plants have two-stage treatment equipment. There is a need for more information on the nature and quantity of water effluent from natural rubber production and for research on economically feasible methods of treatment. It is apparent, however, that the NR treatment problem is much simpler than that for SR.

3. From a social or political standpoint, the limitation on the growth of NR production may well be the availability of suitable land and capital, when compared with other uses of that land for food production or that capital for industrialization.

4. From an economic standpoint, NR can be produced in efficient plantations as cheaply or cheaper than SR; this relative advantage will increase as petroleum prices increase and as NR agronomic practices improve and become more widespread.

5. Even with NR production increasing faster than in the past and even with the growth of total rubber requirements slowing somewhat due to the advent of smaller cars, radial tires, etc., there will still be a need for a significant increase in SR production in the future.

6. In choosing the type of SR for which new facilities will be built in the future, consideration should be given to processes that consume the least amount of non-renewable resources.

7. Regulations to control pollution from the rubber production and rubber fabrication industries will become more prevalent and more severe; however, the cost of satisfactory pollution control will not seriously increase the cost of rubber products manufacture.

8. There is no significant difference between NR and SR with regard to pollution in the products manufacturing operation.

9. An ideal opportunity for greater conservation of resources lies in making better use of scrap rubber products, such as by retreading or reclaiming.

Recommendations

Working Group 1: Raw rubber production

1. NR clearly represents the greater conservation of non-renewable resources since the raw materials used are all renewable. Looking at the world requirement of rubber for the future it is obvious that the area under NR cultivation should be substantially increased and higher yields obtained from existing areas. Transfer of knowledge on the technique of getting increased yields is of prime importance.

2. Appropriate international agencies should explore the possibilities for increased cultivation, taking into account the effects such cultivation will have on food production.

3. Organizations like the FAO and the World Bank, while intensifying their activities on getting higher yields from existing areas of cultivation, should also give serious consideration to problems of supply, price and marketing.

4. Research is going on regarding utilization of by-products like rubber wood, rubber seed and serum, but greater emphasis should be given to this from the point of view of the environment.

Working Group 2: Rubber products manufacture

Product manufacture

1. It is recommended that the health of workers and the working environment be monitored to ensure that healthy conditions are maintained.

2. New chemicals to be used in the rubber products manufacturing industry should be more vigorously tested for health hazards.

3. It is recommended that UNIDO inform all Governments of the necessity of adopting appropriate standards such as the US Food and Drug Administration Regulations and the West German Regulations relating to the use of rubber products in contact with food processing, food products and pharmaceutical packaging. Efforts should be made within the UN organizations to co-ordinate and transmit world information on this aspect of the potential health hazards of these uses of rubber products.

4. New factories should be sited away from residential areas to reduce the impact of work and normal industrial air pollution. Good plant design in the pollution mitigating equipment as well as good in-plant housekeeping practices should be encouraged.

Disposal of discarded products

1. Discarded products, particularly tires, are a cause of environmental problems, and the method of disposal by reclaim, pyrolysis or incineration should be decided after the economic aspects have been looked into.

2. There is a lack of statistics and information on present world-wide production and future requirements of reclaimed rubber. UNIDO should collect these data and make projections.

3. The current method of making reclaim causes environmental pollution. Since future demand for rubber is likely to increase, UNIDO should encourage research and investment into the improvement of the quality and efficiency of rubber reclaim manufacture in an endeavour to reduce waste disposal problems. Owing to increased petroleum prices and other factors, a greater future value of reclaim rubber can be expected.

4. UNIDO should encourage studies on the costs and most efficient methods of collecting, transporting and storing discarded rubber products. Specifically, the concept of national storage of scrap rubber should be considered as a means of developing storehouses of future raw materials for recycling. Various incentives such as government regulations and subsidies should be studied.

Working Group 3: Pollution control policy

1. As part of an over-all international programme, it is recommended that action be taken to promote precautionary labelling for transport and use of chemical products employed in the rubber industry and for the possible need for international agreement on prohibition of certain chemicals that have been found to present health or other environmental risks.

2. It is recommended that some form of enabling environmental legislation be enacted in all countries. Each country will then be free to select detailed enactments to choose an appropriate level of enforcement, taking into account existing legislation and codes. Such legislation should cover the rubber industry, which is not considered a major offender.

3. Information should be obtained on the relationship between pollution level and damage sustained by risk-of-damage assessment relative to the economic viability, in order to form a basis for establishing international environmental criteria applicable to the rubber industry. Once such relationships are established and agreed, individual countries are free to select standards appropriate to their situation. (An example of such an approach has been given by the International Standards Organization in "Assessment of occupational noise exposure for hearing conservation purposes", R1999.1971.)

4. A central information source on environment should be established which would provide information to all countries. The service would gather information from expert organizations in the various fields of industry. Any international referral system should contain a section on rubber.

5. The reports submitted by the consultants represent only a general survey of the environmental problem. A detailed in-depth study of the environmental impact of the rubber industry in one or two limited geographical areas should be undertaken by experts.

6. Although a comparison of environmental hazards in natural and synthetic rubber production has been made, it should be amplified by a single, specially selected multi-professional team working closely with the two industries to carry out detailed case studies in the two industries.

7. Global effects should be studied by the same team when the results of work done by other agencies are known.

8. It is desirable that cost/benefit studies be made, concentrating on raw rubber production. A specific example, such as the location of a synthetic rubber plant in a developing country, should be selected for analysis.

9. In the early stages of planning a new plant, an environmental survey should be made to assess the possible impact of the plant on the environment.

I. ORGANIZATION OF THE MEETING

The meeting, which opened on the morning of 16 September, was attended by nine participants and observers, including six experts from Egypt, France, India, Malaysia, Sri Lanka and the United Kingdom of Great Britain and Northern Ireland in the fields of research and development of natural rubber production, synthetic rubber production, and product manufacture from both types of rubber. A representative from FAO and one from UNCTAD also attended the meeting. Besides members of the UNIDO secretariat, a team of four consultants, specialists in different fields of the rubber industry, attended the meeting to present papers and take part in the discussions.

Mr. M.F. El-Fehy of Egypt was elected Chairman, Mr. O.S. Peiris of Sri Lanka Vice-Chairman, and Mr. A.V. Abraham, UNIDO consultant, Rapporteur.

The meeting opened with a statement from the Officer in Charge of the Industrial Technology Division of UNIDO, welcoming the participants and tracing the history of the meeting from the Stockholm Conference, to the time when this project on the rubber industry started as the first UNIDO/UNEP joint venture in the field of environment. The speaker explained the scope of the study as the technical and industrial aspects of the ecological-economic evaluation of synthetic versus natural rubber and cited other fields in which similar studies are being carried out. He also mentioned a very successful meeting held in Helsinki recently on pollution to the environment from fertilizer and captive acid plants. Mr. Verghese also gave a short account of the activities of UNIDO from its inception in 1967, its interest in the field of rubber and the meetings held in Vienna in March 1972 on the future trends in and competition between natural and synthetic rubber and in Snagov, Romania, in June 1973 on the development of the synthetic rubber industry. In conclusion, he said he was pleased that representatives from other United Nations organizations were present; their co-operation was a source of encouragement to UNIDO in this venture.

The Chief of the General Industrial Techniques Section of UNIDO then addressed the meeting. He spoke of the work his section was carrying out in close liaison with UNEP. He traced the history of such activities to the Stockholm meeting, which had initiated a planned programme for UNEP in the field of environment protection. The main concept in the UNIDO/UNEP joint programme was that under no circumstances should industrial development be stopped for the sake of environment, but that environmental consequences would be assessed as an important factor at the design stage of decision making. He emphasized the advantages of having a mixture of industries in a complex so that waste products from one industry could be used as raw material for, or to neutralize the waste of another industry, thereby reducing the costs of pollution control. He also told the meeting of the impact studies, being done by his section particularly on iron and steel, cement, chemicals and textile industries.

The Speaker pointed out that the purpose of the meeting was to assess the relative merits of producing and using natural and synthetic rubbers in terms of environmental impact. He suggested that recommendations on an action plan should be made after consideration of four major areas of concern: economics, technology, ecology and trade.

Economics

(a) The economic costs/benefits of each type of production, including the costs and benefits derived from social and environmental externalities;

(b) The pattern of supply, particularly the degree of concentration of production within a geographical area in terms of over-reliance on a commodity from a single area by the user, and the risk of disruption of industries which such concentration carries. What measures can be taken to introduce stability of supply?

(c) The pattern of demand, including future projections for each type of rubber.

Technology

(a) Agriculture - What are the implications for producer countries, especially developing countries, of intensifying NR production, bearing in mind the labour-intensive character of growing rubber? What alternatives are available for using land with a good potential for growing rubber?

(b) Synthesis - What are the implications of expanding SR production, bearing in mind the capital-intensive nature of the processing of SR and the relatively high costs of the raw materials.

Ecology

What are the effects of NR and SR production centres on the eco-systems in which they are situated?

Trade

(a) What could be the likely effects on trade if either NR or SR production became completely dominant?

(b) What would be the likely effects on the NR producing countries if either NR or SR production became dominant?

(c) Is a quota system desirable? What measures would be required to ensure a reasonable degree of competition in world rubber markets if such a system were evolved?

Mr. A. Dumitrescu of UNIDO, who was Officer in Charge of the Meeting, spoke of the progress made in collecting the relevant data and information in co-operation with a group of consultants, whose papers would be presented at the meeting. He thanked the participants from Egypt, India, Malaysia and Sri Lanka for having provided UNIDO with substantial contributions consisting of data and information on the impact of the rubber industries on the environment in their countries. Mr. Dumitrescu suggested to the participants that they form themselves into working groups by areas of specialization after the presentation of the consultants' and country papers.

Mr. Dumitrescu invited the participants to view a 12-minute sound film in colour on the production of the Standard Malaysian Rubber, which had been provided through the courtesy of the Malaysian Rubber Fund Board.

The representative from FAO made a brief statement pointing out the interest of FAO in NR and its competitive position. She saw the future of NR as very bright: a recent study on the impact of the energy crisis indicated that its competitive position had received a special boost. The speaker indicated the future trends in prices of SR, using late 1972, when crude oil was selling at $1.85 per barrel CIF Rotterdam, as a base and assuming that the 1980 crude oil price would be somewhat higher than the current price. SBR was then likely to rise 160-180 per cent, BR 200 per cent, and IR 200-300 per cent. She used IRSG projections for 1980, since the FAO projection, which they were doing in conjunction with the World Bank, would not be ready until the end of 1974 or mid-1975. In any case, the results of the cost comparison showed the future for NR was very bright and producing countries would do well to give priority to measures which would bring substantial increase in production by 1985. FAO would be in a position to make any sort of reasonable estimate only when they had the opportunity to see such plans on a country-by-country basis.

The UNCTAD representative drew the attention of the meeting to the UNCTAD/UNEP project on pollution control costs and effects on the competitiveness of natural and synthetic products, of which NR and SR were one pair. He said he would provide UNIDO with this cost data when available, probably by mid-1975. He mentioned that the UNCTAD/UNEP project started from a basis of government regulations as distinct from the UNIDO basis of an industrial matrix where pollutants from one industry are used as raw materials by other industries. The project would measure pollution control costs in crude petroleum refining, organic chemicals and synthetics manufacturing. These costs would be passed on as price increases with effects on competitiveness of the natural and synthetic products, which would form the second part of the study.

He also spoke of UNCTAD work in market access and pricing policy and mentioned a possible study of commodity policies for rubber which might be undertaken in 1975. Calling attention to the scope of the UNIDO/UNEP project, he stated that the meeting ought to decide on the crucial problems and policy recommendations to the rubber industry and to Governments.

After presentation and discussion of the papers in plenary sessions, the Meeting was divided into three working groups on: (1) raw rubber manufacture; (2) product manufacture and recycling of used products; (3) pollution control policy, as follows:

(1) Raw rubber manufacture: B. Agostini-Bennet, Group Leader
J.H. Dunn
E.T. Marshall
C.K.N. Nair
O.S. Peries
P.O. Thomas

(2) Product manufacture and recycling of used products: M. Fathy El-Feky, Group Leader
J. Carmichael
P. Kuzmany
A. Rücker
B. Whittaker

(3) Pollution control policy: Chin Peng Sung, Group Leader
M. Betts
D.P. Elliott
R.J. Sherwood

The groups met separately, considered the consultants' papers and came with their conclusions and recommendations to the plenary session for general discussion. This was followed by further group discussions, and the final recommendations were presented, discussed, amended and approved at the final plenary session. Chapters II, III, IV and V of this report are based on the ideas presented in the papers, as modified by the Meeting after discussing them.

II. RAW RUBBER PRODUCTION

A. Background

1. World rubber requirements

Prior to the Second World War, natural rubber (NR) was the sole source of raw material for a healthily growing rubber goods manufacturing industry. The supply disruptions of the war resulted in the creation of an "instant" synthetic rubber (SR) industry. After the war, NR quickly regained its pre-war production level and then proceeded to grow at an annual rate of 3-4 per cent. This rate was not sufficient for the huge appetite of the rubber goods industry, and SR production grew rapidly to fill the gap. By 1973, SR was supplying 67 per cent of the world requirement for raw rubber, which totalled 10.4 million tons including estimates for Eastern Europe and China. NR consumption amounted to 3.4 million tons, triple the pre-war consumption of NR.

The International Rubber Study Group (IRSG) predicts that the annual growth rate of total rubber consumption between now and 1980 will slow to 4.7 per cent compared with the 6.9 per cent rate that has prevailed for the past ten years. This expected decrease is primarily due to the anticipated effect of high oil prices upon automotive design and driving habits. In any case, the total world requirements in 1980 should be in the 15 to 17 million ton range, with NR supplying one third, or 5 to 6 million tons. Projecting the slower growth rate to 1990 would give a total world requirement of 23 to 25 million tons. If conditions are favourable, NR could then be supplying as much as 40 per cent of this, or 9 to 10 million tons. The difference of 14 to 15 million tons to be filled by SR still represents an appreciable increase over the current level of about 7 million tons.

2. <u>Resource utilization</u>

An analysis of the material and energy requirements of the various raw rubbers discloses that NR is basically derived from a renewable resource, namely, tree latex, while the synthetics are almost totally dependent upon a non-renewable resource, namely, fossil hydrocarbons. Reliance of NR on non-renewable resources is relatively little, consisting primarily of fossil hydrocarbons used for the production of fertilizer and for the energy required in the processing factories, plus small amounts of non-renewable chemicals used for growth stimulation, latex preservation and coagulation.

The major raw materials for the synthetic rubbers, on the other hand, are derived almost totally from non-renewable petroleum. While some of the soap required in styrene-butadiene rubber (SBR) production might be considered largely renewable, many of the other organic and inorganic chemicals required for initiating, controlling and stopping the polymerization reaction, coagulating the latex, inhibiting the product against oxidation, etc., are basically made from non-renewable resources. A resource balance shows that about 3.5 tons of crude oil or its equivalent is required for the production of each ton of the cheapest SR, namely oil-extended SBR (1712 type). Of this amount of crude oil equivalent, about 42 per cent is required as raw material and 58 per cent for producing the energy for driving motors, heating stills and driers, etc. A large portion of the latter requirement for energy production could be satisfied by using coal or atomic energy for the generation of steam and power, rather than oil.

The other major synthetics, non-oil-extended SBR, BR (polybutadiene) and IR (polyisoprene) require somewhat more non-renewable resources than oil-extended SBR, but there is no one SR which has a really major advantage in its conservation of resources, despite the availability of some alternative technologies. An exception to this would involve the fermentation of agricultural products such as grain or molasses to produce the raw materials for making butadiene or isoprene. In general, agricultural products having an alternative use as food cannot be converted to chemical raw materials on an economical basis when compared with the petrochemical route. IR tends to use more resources than other synthetic rubbers because of the basic complexity of its raw material, isoprene. This tendency, when considered along with the fact that IR possesses no single technical advantage over NR, leads to the conclusion that, from an environmental standpoint, IR is the least desirable of the major synthetics.

As opposed to SR, NR requires only around 0.3 ton of crude oil equivalent, although more may be required as fertilizer application and other agronomic practices are optimized and become more widespread.

Two other important differences between NR and the synthetics are in land utilization and labour requirements. Whereas 100,000 tons of SR can be easily produced annually on 40 hectares of unproductive land with an employment of about 300, the same amount of NR would require at least 40,000 hectares of high-yielding trees worked by about 100,000. In those countries where suitable land and labour are available, social and political conditions would add weight to purely techno-economic considerations in judging the desirability of increasing the production and use of NR.

Another route to optimizing the utilization of resources in the rubber industry lies in making the best use of any by-products. No significant by-products from the manufacture of SR are wasted, with the possible exception of sulphur in the flue gases. The principal by-products of NR production are latex serum, tree seeds and tree wood. The serum appears to be useful as a growth medium for micro-organisms and as a fertilizer. Further uses may be found for its individual constituents. The seeds produce an unsaturated oil suitable for paint manufacture and a meal suitable for animal feed. Wood from over-age trees is proving to have excellent properties for the manufacture of furniture and paper.

3. Costs of production

Economic costs

An accurate comparison of the costs of producing NR and SR is difficult because of the proprietary nature of such cost information. What is more, recent prices have not been representative of the prices that would be required to attract new investment for expansion, owing to the current turmoil in the chemical and petroleum industries. From the information available, however, it does appear that, insofar as costs are concerned, NR and SR were highly competitive in the period immediately preceeding the energy crisis. The increase in oil prices that took place in 1973 has clearly given a boost to NR by increasing considerably the costs of producing SR while having only a small effect upon NR. A further factor favouring NR is that the prospects for obtaining increased economies in the production of SR are small, whereas those for NR are extremely large through the use of higher-yielding varieties of trees, better agronomic practices, and chemical yield stimulation. The principal barrier to achieving significant decreases in NR costs and major increases in NR supply would appear to be the difficulties encountered in transferring the results of these agricultural practices to large areas currently under cultivation, and particularly to the smallholders.

External costs and benefits

For a complete comparison, considerations should also be given to external costs and benefits, which are not normally included in a purely financial appraisal. These can be physical, such as the loss of visual enjoyment by the neighbours of new industrial plant; pecuniary, such as the increase in value of a local business that will enjoy increased trade; or social, such as the beneficial effects of increased employment in the plant area. A comprehensive cost/benefit analysis of the environmental externalities resulting from the expansion of either NR or SR production would be desirable, but it would involve an expensive study.

4. Choice of rubber

The foregoing indicates that:

(a) NR can be produced as cheaply as SR and may have a significant cost advantage in the future due to rising petroleum prices and greatly improved agronomic practices;

(b) NR is considerably less destructive of non-renewable resources than any SR;

(c) NR can, from a technical standpoint, supply at least 40 per cent of world rubber needs.

It would appear desirable, therefore, to encourage the maximum use of NR. Given sufficient priority and assistance, a doubling of NR production between 1980 and 1990 appears possible. Whether this would require existing agricultural land and whether the required cheap labour would be available are questions to be considered. The remaining world needs would need to be filled by additional SR production and by the recycling of rubber products.

B. Impact on the environment

A direct comparison of the environmental impact of SR and NR at the production stage is difficult. NR production is a typical agricultural operation, while SR manufacture is a typical highly industrialized operation. NR production takes place in widely dispersed areas in developing countries of the tropics, whereas SR manufacture is a highly concentrated operation carried out primarily in developed countries, where a much higher priority must be given to adverse environmental effects and to long-term health effects. In any case, each individual installation has its own problems due to particular circumstances, and these problems often defy generalization.

1. Air pollution

In the case of both NR and SR, the largest source of potential air pollutants derives from the materials used to supply the energy needed to operate the processes involved. The requirements of SR for steam, power and fuel gas are more than ten times greater than for NR. Such energy needs are usually derived from petroleum, which is burned under carefully controlled conditions to produce a minimum of carbon monoxide, nitrogen oxides, fly ash etc. The quantities of these materials discharged from an efficient heating plant are not environmentally significant. The main potential pollutant is sulphur dioxide, the quantity of which is directly related to the sulphur content of the fuel used. In many industrialized areas, the use of low sulphur fuels is mandatory. In any case, stack heights are usually high enough to eliminate any local problem. It should be noted that the energy requirements for both NR and SR can be supplied from sources other than petroleum: coal, hydroelectricity, atomic energy etc. If high-sulphur feedstocks, whether coal or oil, are used in the future, sulphur removal and recovery equipment may be required. The sale of the sulphur recovered may largely pay the cost of the removal operation.

The SR plants have an added air-pollution potential in the form of the hydrocarbons lost by leakage or by emergency release. Low-molecular-weight hydrocarbons such as butadiene are gases at atmospheric temperature and pressure, so they are generally handled as liquids under pressure. Care is taken to avoid leakage around pump shafts, valve stems etc. for economy and safety, as well as pollution avoidance. In well-run plants, losses are reduced to very low levels.

Both NR and SR plants can have odour problems; SR, from some of the liquid polymers formed inadvertently in pipelines, tanks etc. or from the regeneration of catalysts in the raw material plants; NR, from the possible putrefaction of the organic materials in the serum remaining after coagulation. Both of these problems can be handled satisfactorily by the use of good operating practices.

2. Water pollution

The principal physical environmental impact in the production of both NR and SR occurs in the area of water pollution. Both NR and SR require the use of considerable quantities of water (an important industrial resource), and both produce a large quantity of contaminated water for disposal. Except in the smallest-scale of production some method of water treatment to improve the effluent quality will be required. The extent to which this is necessary depends at the process and upon the scale of production the processes used, and the quantity of water produced. At the receiving end, it depends upon the nature and quantity of the receiving water on the uses to which the receiving water is put, and on other ecological considerations, such as the value the community places upon amenity or conservation aspects. Acceptable limits for the discharge of waste products to surface water can only be developed in relationship to the local conditions, taking into account the factors mentioned above.

For NR, the principal source of potential water contamination is the discharge of the serum remaining after coagulation and removal of the rubber content of the tree latex, along with the water used for subsequent washing and cleaning of the coagulated crumb. The original tree latex is an aqueous dispersion containing roughly 30 per cent of NR hydrocarbon plus significant amounts of "non-rubber" materials, such as proteins, lipids, quebracitol, inorganic salts etc. Some of these non-rubber materials end up in the NR itself as part of the recovery process, but most are contained in the effluent serum. The NR effluent also contains most of the chemicals used as preservatives (e.g., ammonia) and coagulants (e.g., formic acid). Research is proceeding on some promising leads to make use of the non-rubber constituents as culture media, fertilizers, etc. In the meantime, the Rubber Research Institute of Malaysia has shown that an anaerobic-stabilization treatment system will effectively reduce the high oxygen demand of the NR effluents to acceptable levels at a very nominal cost, about 3 per cent of the investment in a rubber processing factory.

In the case of SR, potential water contaminants derive principally from the large number of organic and inorganic chemicals used in the manufacturing process as catalysts, diluents, reaction modifiers, oxidation inhibitors, extraction and absorption agents, coagulants, neutralizers, emulsifiers, and so forth. A large portion of some of these chemicals, such as the soap emulsifiers and the oxidation inhibitors in the SBR latex, end up in the SR product itself. A few of the catalysts, such as that used for ethyl benzene dehydrogenation, are solid, and are disposed of as land fill or recycled to the catalyst manufacturer, but the bulk of the chemicals end up in the water effluent, along with any spills of oil, latex etc.

For successful water treatment it is necessary to segregate the various effluent streams (i.e rain run-off, process water, cooling water), treat each in an optimal fashion before releasing it to a common discharge, and monitor each operation carefully. The extent of the treatment will depend not only upon the scale and nature of the manufacturing process, but also upon the nature of the waters to which the effluent is released. Experience has shown that the SR effluents can be treated satisfactorily at a nominal cost. In the United States of America, the Environmental Protection Agency (EPA) made a survey in 1973 of almost all SR plants. The results showed that satisfactory water treatment using the "best available technology" (which meets standards stricter than those in force today) would increase SR prices up to 1.5 per cent, depending upon the product and the equipment already in place. A calculation shows that even if the total pollution control cost in an SR plant amounts to 10 per cent of the total investment (a very generous estimate), it would add only about 0.5 cent per pound to the selling price. The EPA study points out that existing SR plants in the United States already contain all or most of the pollution control equipment expected to be required. It therefore concludes that new pollution control measures will not have an adverse effect on the growth of the SR industry.

The EPA study of the SR industry in the United States and a somewhat similar study of NR production in Malaysia lead to the conclusion that the possible potential discharge of raw aqueous waste from NR production is somewhat greater than that for comparable SR operations, when measured by the conventional water criteria of chemical and biological oxygen demands (COD and BOD), although the potential discharge of suspended solids is less for NR. The amount of such waste currently released to the environment, as measured by all three criteria, are higher for NR production, since NR treatment facilities are not usually installed, whereas most SR plants already have fairly elaborate treatment equipment. It is obvious, however, that such comparisons do not give a complete picture of the environmental problem. The latter can only be evaluated by studying each installation and its impact on its own environment. It is also apparent that the NR treatment problem is much simpler than that for SR, as witnessed by the fact that, in the future, activated carbon filters will be required in the United States as a final clean-up step on the discharges of the SR plants to inland waters and perhaps to community treatment plants.

3. Land contamination and noise

The greatest source of possible land contamination from NR cultivation arises from fungicides, herbicides and insecticides sprayed on the trees. Care must be taken that soil drainage and wind effects do not cause damage to neighbouring land and crops. Regular spraying may also build up concentration in the NR plantation soil, which might preclude the subsequent use of such land for growing feedstuffs.

NR and particularly SR producers will need to resort to dumping of solid wastes. Solids and sludges from waste-water treatment plants are amenable to disposal by incineration in specially designed systems for smoke-free combustion. Solids that are non-toxic can be disposed of as land-fill, preferably within the plant boundary.

Noise can be a problem, particularly in the SR raw material plants, where compressors, pumps, furnace burners etc. are involved. Standards are available for evaluating these noise effects, and methods for reducing the problem are known.

A possible source of hazard of particular concern in the developing countries is the reuse of chemical transport containers. Precautions must be taken to prevent indiscriminate reuse of these containers before they have been thoroughly cleaned.

3. The working environment

The environment for NR workers would appear to be relatively safe. Potential dangers consist mainly of possible exposure to the toxic hazards of fungicides, herbicides, etc. sprayed on the NR trees and to some of the chemicals, such as ammonia and various acids, used in the tapping and coagulating operations. It is not known whether epidemiological or environmental surveys have been undertaken to quantify the possible environmental risks; they appear to be needed. Measurements of the working environment should be made to assess exposure, and routine monitoring programmes should be instituted where found to be necessary.

The chief hazard encountered by SR workers probably occurs at the time of an accidental upset in the operations. Since most of the materials handled are flammable, fire and explosion hazards require careful assessment and control. There may also be, particularly at times of upset, undue exposure to the chemicals used in the operations, with consequent damaging effects. Noise-induced hearing loss is a potential health hazard particularly in the SR raw material plants; noise exposures need to be measured and, if necessary, noise controls introduced.

III. RUBBER PRODUCTS MANUFACTURE

A. Background

Despite the great differences between the technologies for producing NR and for producing the major SR's, once the polymers are available as finished products, the subsequent technologies for converting them to finished rubber products are essentially identical. The raw rubber, NR or SR, or a blend of the two, is mixed with sulphur (the vulcanizing agent) and with various accelerators, activators, and inhibitors. Other likely ingredients are fillers (particularly carbon black) and processing aids, such as oil, wax and reclaim.

The final compound is shaped into the desired finished form (frequently after being applied to fabrics, wire, etc.) and then heated to vulcanize it to a permanently elastic finished product.

The transport uses of rubber dominate the industry as shown by the following breakdown of current world rubber consumption:

	(Percentage by weight)
Tires and inner tubes	60
Industrial rubber products	23
Foot-wear	5
Latex products	6
Other consumer products	6

Tires and tire products account for 65 per cent of the total rubber consumed in the United States, while the percentage is considerably less than 60 per cent in the developing countries, where the number of passenger cars per capita is considerably smaller.

In any consideration of the future of the rubber industry, it is important to realize that in developing countries with low per capita incomes the consumption of rubber increases three or four times faster than the GNP, because of the urgent need to develop motorized transport. Thus a small increase in the GNP of the developing countries can result in a significant increase in their rubber needs. The increase in the consumption of rubber in the developed countries tends to grow at about the same rate as the GNP, since the transport needs of these countries have been more fully satisfied. There is a great disparity in the rubber needs of the various nations: in 1971, the United States consumed 13.2 kg per capita while India consumed only 0.2 kg per capita. Industries manufacturing rubber products therefore tend to be concentrated in the developed countries, although they may vary widely in size, in the type of products they make, and in the sophistication and modernity of the equipment employed.

B. Impact on the Environment

In rubber product manufacture, environmental problems seldom arise from the rubber itself, but rather from the additives used and processing practices followed. The industry has its share of occupational health hazards due to the diversity and often uncertain toxicity of the products handled compounded by the large amount of human contact in the processes. The chemical environment of the product plants has been the subject of the most active investigation, as the toxicity of a number of the additives used in the processes has led to ill effects.

Some exposure of workers to potentially hazardous chemicals occurs in all process plants. While process improvement and engineering control may minimize this, it cannot eliminate it. Accordingly, occupational exposures should be subject to environmental monitoring and workers should be subject to regular biochemical and medical examination.

Intensive screening of chemical additives is now undertaken in a number of countries. In some countries, approval must be given before new materials are introduced.

Occupational dermatitis is probably the most widespread occupational disease in the rubber processing industries. Combatting it calls for the introduction of improved controls, based on reduction of skin contact, and improved personal hygiene supported by adequate washing facilities that are well maintained.

Rubber product manufacture does not generally result in unusual or unmanageable problems of air, water or noise pollution, provided good operating practices are followed. Environmental problems in the processing plants are usually of a specific nature, related to a particular process, product or location. They are often solved by the resident plant engineer without outside help.

The handling of carbon black has a high potential for creating a nuisance in the neighbourhood. This is recognised in modern plants, and air pollution is successfully controlled. Problems in the process industry have been enormously improved by the availability of carbon black incorporated in master batches. Careful control of particle size in manufacture reduces contamination, and bulk handling of the powder enables stricter confinement to be attained.

As shown earlier, latex products account for about 6 per cent of all rubber consumption. The latex used has been concentrated from that originally produced by the trees or by the SBR emulsion process; however, appropriate measures must be taken, as in the case of NR and SBR coagulation operations, to treat the resulting serum so that waste water pollution does not occur.

The use of rubber products creates some environmental problems. The most widely recognized is skin sensitization and dermatitis (arising from the additives employed rather than the rubber). Less widely recognized is the need to control the formulation of rubber used in food or drink packaging to prevent the leaking of toxic substances into edible products. All countries should adopt strict national controls, such as those active in the United States and in the Federal Republic of Germany, relating to the use of rubber products in contact with food processing, food products, pharmaceutical packaging, etc.

IV. DISPOSAL OF DISCARDED PRODUCTS

The ultimate disposition of rubber products may present some environmental problems, particularly aesthetic ones, but it may also present some opportunities for the conservation of resources.

Only a small fraction of the total rubber product volume is lost by abrasion, as in the case of the tire tread. Even so, recent studies made on the effects of tire wear on the environment have produced no evidence of potential hazard, though more definitive studies appear to be required. It is interesting to note, from an environmental standpoint, that for each kilogram of rubber worn off a tire the vehicle consumes roughly 500 kilograms of petroleum fuel, the waste from which probably pollutes the environment to a far greater extent than the rubber particles.

Most rubber products end up in waste disposal systems. There are three major ways that discarded rubber products can be handled:

Reusing them

Reclaiming material and energy from them

Dumping them.

Reuse of a discarded rubber product in a manner closely following its original use represents the best way to conserve resources, and it should be encouraged. The best example of this is in the retreading of worn tire carcasses to permit their reuse as tires. Wider use of this technique may automatically occur as new tires become more expensive. A major problem with retreading is the achievement of high-quality workmanship in the thousands of small local retreading establishments so that highway safety and reliability are not impaired. The establishment of official quality standards may become necessary.

The use of discarded tires to establish artificial reefs that will improve recreational and commercial fishing is a proven example of useful reuse. Other examples are boat and jetty fenders, sandal soles and floor mats.

The reclamation of vulcanizable rubber from discarded rubber products is a well-established industry. Unfortunately, reclaimed rubber derived from either NR or SR products is not an acceptable substitute for either NR or SR. Instead, it has found a valuable but limited market as a compounding ingredient to aid processability in the manufacture of certain rubber products. The procedure for reclaiming rubber (collecting, grinding, removing fibres and metals, digesting with hot strong chemicals or high pressure steam, masticating and packaging) is expensive and high in energy-consumption. Thus while reclaimed rubber has found a small place for itself in the rubber manufacturing picture, it is not likely to become a major factor in reducing the consumption of non-renewable resources by the rubber industry unless new technology is discovered. More research in this area would appear to be very desirable.

Pyrolysis, the breaking down of organic material by heating in the absence of oxygen, is another possible method for recovering some of the value contained in scrap rubber products. The pyrolysis products consist of fuel gas, liquid oils and a solid residue (mostly carbon), all of which have at least fuel value, if better uses cannot be found. Another possibility being studied involves the mixing of 10 per cent of ground scrap rubber into the oils used to manufacture carbon black.

A disposal method already in considerable use and likely to find increasing application is incineration with recovery of energy and possibly of some raw materials. This technique has required the development of specialized incinerators, with afterburners controlled by smoke detectors in the exhaust stack to give smoke-free combustion. It has been found to be an attractive method, particularly in areas where it is associated with reclaim or tire-making operations, so that the cost of collecting used scrap can be minimized and there is a ready use for the heat generated.

As the least attractive route, controlled dumping of scrap rubber products can be resorted to. Scrap rubber is an unobjectionable land fill except under construction sites. It should not be stored in the open, because of the fire hazard, and such shapes as scrap tires should be reduced to small pieces to compact the fill. A controlled programme for disposing of scrap rubber in central locations, such as old mines or quarries, should be studied, since such accumulations could then represent a storehouse of an important resource for possible future use. A major problem is to find an economical system for collecting, sorting and compacting the scrap, since this has usually been a major debit to the economics of any scheme for handling scrap rubber.

Problems of pollution are minimal when controlled dumping is resorted to. As the processing of the scrap rubber becomes more drastic, however, problems of odour, noise and health increase progressively. Retreading can be carried out without major difficulties, but reclaiming, pyrolysis and incineration all require careful planning and control to eliminate objectionable features.

The search for the most economically and environmentally attractive method of scrap rubber disposal should be carried out at the regional or national level. To date, few such studies have been made.

V. POLLUTION CONTROL POLICY

The establishment of international criteria applicable to the rubber industry would be highly desirable. Such criteria, however, should be based upon risk-of-damage assessments, and, unfortunately, information concerning such relationships between pollution levels and damage sustained are currently unavailable. Once such relationships are established and agreed upon, individual countries or areas are free to select standards appropriate to their situation.

What is needed is better environmental information on the rubber industry and a system for making it more accessible. This should start with a comprehensive review of current sources of information, drawing on expert organizations such as the Rubber Research Institute of Malaysia, Rubber and Plastics Research Assn., etc. Hopefully, this effort would develop into an on-going interchange service providing pertinent up-to-date information to all interested parties.

Another need is for some form of general enabling legislation in each country to cover environmental effects. This general legislation would enable specific regulations to be set up when and where they prove to be necessary to correct environmental problems (e.g. the banning of the use of certain carcinogenic substances). These specific regulations would not ordinarily be universally applied, since the assessment of risk-of-damage is different from country to country.

It should still be kept in mind that, even with the enactment of pollution control regulations, each plant and each process has its own individual pollution problems and that it is the responsibility of prudent management to make each plant an asset to its community and to its workers. For this reason, it is essential that environmental surveys be made before a new plant is built or an old plant expanded. Such surveys assure that environmental factors are given full weight in the original decision-making process and they provide a baseline measurement of existing conditions against which subsequent changes can be judged. It is also advantageous in the case of a process plant to appoint a senior executive as the co-ordinator (usually on a part-time basis) of policies and studies on environmental affairs, to assure that this area receives proper attention.

Annex

AGENDA OF THE MEETING, INCLUDING TITLES OF PAPERS PRESENTED

Monday, 16 September 1974

Registration	
Opening message to the meeting	M.C. Verghese, Officer in Charge, Industrial Technology Division
Election of Chairman, Vice-Chairman and Rapporteur	
Aims and purpose of the meeting	A. Anderson Chief, General Industrial Techniques Section, Industrial Technology Division
Organizational aspects of the meeting	A. Dumitrescu, Officer in Charge of the meeting, Fertilizers, Pesticides and Petrochemicals Section, Industrial Technology Division
Adoption of the Agenda	
A study of the environmental impact of the rubber industry with particular reference to raw rubber manufacture	E.T. Marshall, UNIDO consultant
Ecological aspects of the environmental impact of the rubber industry	R.J. Sherwood, UNIDO consultant
Environmental impact of the rubber industry with particular reference to product manufacture and reuse of discarded products	B. Whittaker, UNIDO consultant
A study on the economic aspects of the tyre industry and its impact on environment	A. Rücker, UNIDO consultant
Studies on effluents from NR production in Malaysia	P.S. Chin, Malaysia

Tuesday, 17 September 1974

Statement on behalf of FAO	B. Agostini-Bennet, FAO
Economics of pollution control policy	D.P. Elliott, UNCTAD
Some aspects of the environmental effects of the rubber industry in Egypt	M.F. El-Feky, Egypt

Objectives and composition of the Working Groups:

- Working Group 1: Raw rubber production
- Working Group 2: Rubber products manufacture
- Working Group 3: Pollution control policy

Wednesday, 18 September 1974

Preparation of reports by the three working groups

Presentation and discussions on the reports prepared by the three working groups

Thursday, 19 September 1974

Preparation of recommendations and conclusions by each of the three working groups

Discussions on the final reports, recommendations and conclusions prepared by the working groups

Friday, 20 September 1974

Approval of recommendations, conclusions and of contents of final report

Closing of the meeting

75.04.09