What positive effect on the Nature / Environment should be achieved in the course of implementation of the NGR in production of General Rubber Goods and Tires.

Is it possible to say something about decreasing of CO_2 emissions?

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Positive ecological effect from NGR technology application lies in significant decreasing of demand in virgin raw materials during the process of manufacturing of Tires and General Rubber goods, which entails also huge power consumption and greenhouse gas emissions decreasing, as well as emissions of thousands of tons of toxic matters to the atmosphere, soil and waters.

Temperature of gas, emitted by the chemical plants, does not differ from ambient temperature, which results in accumulating of the toxic matters close to the sources of emissions. Besides the polluting emissions to atmosphere, chemical plants discharge various hazardous matters to the waters. These waste waters contain hazardous organic matters, mineral acids of different concentration, soluble salts and alkali e. t. c.

Furthermore, decreases the total volume of End-of-life Tires (ELT) storage, because NGR is manufactured from the Rubber crumb, obtained in the result of their recycling. The hazardous impact of ELT landfills on the environment is also eliminating.

To determine the positive ecological effect of the NGR production it is necessary to perform the quantitative assessment of hazardous emissions and industrial wastes from production of Rubber compounds' components, which would be substituted by NGR, and to compare the obtained data with assessment of hazardous emissions and industrial wastes from production of NGR.

1. Assessment of hazardous emissions and industrial wastes from production of Rubber compounds' components, which would be substituted by NGR.

1.1. Assessments of hazardous emissions from the production of flexible polymers suffer with lack of precision due to the missed or not taken into account sources, or due to compilation of average coefficient of pollution, obtained from the data sources of the other countries or regions with characteristics, which differ from those of the country of assessment, where the said coefficient is applied. Absolute value of emissions depends on many factors: type and level of solution, applied at the enterprise, kind of raw materials, climate of region, logistics, power supply, kind of packaging and many others.

1.2. Generally accepted and integral quantitative index in the assessment of emissions is the coefficient **CO^2-eqv./t of product.** All greenhouse gases are recalculating into equivalent of CO_2. **CO_2-eqv./t** which is a conditional, integral quantitative index, characterizing the greenhouse effect, originating due to the emissions of any contaminating matters to the atmosphere, equivalent to the quantity of CO_2 .

1.3. **Carbon Footprint** — integrity of all gases emissions, produced, directly or indirectly, by the human, entity, enterprise, production facility, city, state. In the present calculation (which, nevertheless, makes no pretention to research work) the rough estimation of emissions **CO_{2_mass} /ton of product** was elaborated, leaving out of account the emissions of other gases to the atmosphere. Calculation of **CO_2-eqv. /t of product** in the industry – subject of separate comprehensive investigations.

1.4. In the present calculation, the comparative assessment of gas emissions from the production of NGR and emissions from production of the components of Rubber compounds, substituted by NGR is performed, basing on production capacity of the enterprise 10 000 t/year , for example, with the aim of determining the ecological effect of the production of NGR.

2. The main (till 75%) components, which could be substituted in the Rubber compounds by NGR, are: **Natural Rubber, Synthetic Rubbers and Carbon Black**. Quantity of replaceable components - $Q_{r.c.}$ is equal to quantity of NGR, added to the new rubber compounds, which could be differ in different compounds (new mix - $Q_{n.m.}$):

$$Q_{r.c.} = 10 \div 70\%\ Q_{n.m}$$

2.1. **Natural Rubber (NR)** (using as an example the NR production in Thailand, world leader of production):

2.1.1. Hundreds of thousands of the tropical forests are cutting off for plantations of Hevea trees. Ecological balance of the regions is getting broken. Using of big quantities of fertilizers deteriorates the soils and ground waters.

The lack of advanced methods of felled plantations liquidation leads to using of new areas for new plantations, thus deteriorating the environment. Abandoned plantations are not recultivated.

Harvesting of Latex starts when the tree has not yet reached age of seven years. As a result, manufacturers get only 25 - 60% of Latex, and rubber trees already felled in age of eleven.

The main sources of greenhouse gas emissions from cultivation of rubber trees:

- Conversion of tropical forests to the rubber plantations.
- Manufacturing on the plantations of primary products of processing of Latex: Concentrated Latex, STR 20 (Block Rubber) and RSS (Ribbed Smoked Sheets [High quality Rubber]).
- Emissions in the course of the management of plantations.
- Production of LPG, used in the rubber mills.
- Production of Diesel fuel, used in the rubber mills.
- Production of Electric power, necessary in production of primary products.
- Production of Ammonia for treatment of Latex (against coagulation).
- Production and using of nitrogen and phosphate fertilizers in growing of geveys.
- Biomass burning (~100 kg/t RSS) as a fuel for drying and smoking of Rubber sheets.

2.1.2. Quantity of greenhouse gas emissions depends on the age of plantations. For relatively young plantation, planted less than 20 years ago at the place of the forest, the soils conversion is the most important source of greenhouse gas derived from the production of Rubber.

2.1.3. Total volume of greenhouse emissions at the yield of 5.64 tons of raw Latex from 1 ha per year for plantations on the lands cultivated for more than 60 years (usual practice at the most plantations in Thailand) amounts 0.54, 0.70, and 0.64 tons CO_2-eqv./t of product: Concentrated Latex, STR 20 and RSS correspondingly. The emissions generally connected with using of energy sources and fertilizers.

2.1.4. On the lands, used rather less than 20 years (the last trend in the Thailand Rubber industry), emissions are significantly higher due to the losses of carbon by the soils, caused by the conversion of the land:

13, 13, and 21 ton of CO_2-eqv. per ton of Concentrated Latex, STR 20 and RSS correspondingly.

Source: The emissions associated with the production of concentrated latex, STR 20, and RSS

2.1.5. Data for calculating of emissions $\mathbf{CO_{2\text{-mass}}}$. per ton of manufactured Natural Rubber we obtain from Table 2 (p.3.2.):

$$\mathbf{Q_{n.r.} = 1{,}63\ kg\ CO_2 / kg.}$$

2.2. Synthetic Rubber.

2.2.1. Production of Synthetic Rubber, even at the present level of technological solutions, makes a significant adverse contribution to the formation of technogenic impact on the environment and global climate, due to the high vapour and gas release into the environment, high water and energy consumption per unit of output.

For example: In the process of production of one ton of Synthetic Rubber about 37 kilo of pollutants - Butadiene, Styrene, Lonitril, Solvents, Toluene, Acetone, Isoprene (not considered in the calculations) are emitted to the atmosphere.

Negative impact on the environment has also high water consumption in the production of Synthetic Rubber. In the available sources, for obvious reasons, specified a variety of water consumption for roduction. The following is a calculation based on one of such sources:

Tab.1 Calculation of Waterprint effect of the replaceable Synthetic rubber to NGR in the rubber industry

Design parameter	Unit	Synthetic rubber
Water consumption for to make:		
1 lbs of Synthetic Rubber*	gal/ lbs	55,0
1 kilogram of Synthetic Rubber**	l/ kg	551,2
1 tonne of Synthetic Rubber	ton/ ton	551,2
Passenger Tire (weight SR in traditional tire composition***)	%	27%
Replaceable NGR components volume******	%	30%
Weight SR in 10 000 tonns of NGR components	tons	2 700
Waterprint	ton/year	**1 488 240**

* How Many Gallons of Water Does it Take to Make . . .
** 55 Gallon (UK)/Pound to Liter/Kilogram Conversion
*** "Anatomy of a Tire"
**** For calculation the average value of $Q_{r.c.}$

2.2.2. The calculation shows that production of 10 000 tons of NGR/year, at the replacement of 30% of Synthetic Rubber in the new tire mixes, provides savings for the industry of **446 472t** in production of car tires, and 231 504 t of water per year – for truck tires.

2.2.3. Data for computation of $\mathbf{CO_{2\text{-}mass}}$. emissions per ton of manufactured Synthetic Rubber we obtain from Table 2 (p.3.2.)

$$\mathbf{Q_{s.r.} = 4{,}02} \text{ kg } CO_2 / \text{kg.}$$

2.3. **Carbon Black.**

2.3.1. «The production of new Carbon Black using fuel oils is estimated to generate an approximately 1 kg of CO_2 per kilogram of Carbon Black produced. To produce 1 Ton of Virgin Carbon Black requires 2 Ton of Heavy Oil and produces 10 Tons of CO_2 (including fuel acquisition). In contrast, our Carbon Black is derived from recovering it from scrap tires and waste rubber products which already contains ASTM Carbon Blacks and by doing so, we offset large volumes of emissions and recover this valuable resources, greatly reduce Carbon footprint and landfill, as compared to tire burning or dumping these tires».

2.3.2. «Emissions of CO2 from carbon black production may be estimated by applying the process and feedstock-specific emission factors to the carbon black production activity data. Separate emission factors are provided in Table 3.23 for the furnace black process, thermal black process, and acetylene black process and their associated feed stocks, and separate emission factors are provided for primary feedstock and secondary feedstock. The emission factors are based on the assumption that process emissions are subjected to a thermal treatment process. A range of values for primary and secondary carbon black feedstock is included in (**Tab.2.**) of the draft Integrated Pollution Prevention and Control (IPPC) Reference Document for Best Available Techniques in the Large Volume Inorganic Chemicals (LVIC) Solid and Others Industry (European IPPC Bureau, June 2005; referred to in this chapter as the Draft IPPC LVIC BAT Document.) The CO2 emission factors in Table 3.23 are based on the average of the range of values. Primary and secondary feedstock consumption is converted to carbon consumption using average values for carbon black feedstock carbon content. The CO_2 emission factors are calculated from the carbon input to the process (primary and secondary feed stocks) and carbon output (carbon black) from the process, using an average value for carbon black carbon content».

(Source: European IPPC Bureau, 2005 (Draft IPPC LVIC BAT Document, Table 4.11 data)

Tab.2. CO_2 emission factors for plants in Europe.

Process Configuration	Primary feedstock	Secondary feedstock	Total feedstock
	kg CO_2/tonne carbon black produced		
Furnace black process (default process) **($Q_{c.p.}$)**	1960	660	2620
Thermal black process	4590	660	5250
Acetylene black process	120	660	780

Source: IPCC, 2006.

2.3.3. In the calculation of Average Quantitative Index for this type of emission (**Furnace black process**) we accept:

$$Q_{c.p.} = 2620 \text{ kg } CO_2 / \text{ton}.$$

3. Specific emissions - CO_2 (kg CO_2 / kg) **emission in the production of tire mixes components, substituted by NGR:**

3.1. Emission ΣQ_{CO_2} is the amount of **CO_2** (kg CO_2 / kg) emissions of the production of Natural, Synthetic Rubber and Carbon Black included in the tire compounds.

$$\Sigma Q_{CO_2} = Q_{n.r.} + Q_{s.r.} + Q_{c.p.}$$

3.2. **Data for calculation of Emissions** (**Table .3 and p.2.3.3.):**

Tab.3 INVENTORY OF CARBON & ENERGY (ICE) SUMMARY

Materials	Embodied Energy & Carbon Data		Comments
	EE - MJ/kg	EC - kgCO2/Kg	EE = Embodied Energy, EC = Embodied Carbon
Rubber			
General	101.70	3.18	41.1 MJ/kg Feedstock Energy (Included). Assumes that natural rubber accounts for 35% of market. Difficult to estimate carbon emissions.
Synthetic rubber **($Q_{s.r.}$)**	120.00	4.02	42 MJ/kg Feedstock Energy (Included). Difficult to estimate carbon emissions.
Natural latex rubber **($Q_{n.r.}$)**	67.60	1.63	39.43 MJ/kg Feedstock Energy (Included). Feedstock from the production of carbon black. Difficult to estimate carbon emissions.

Source: Inventory of carbon & energy (ICE) / Version 1.6a p.13

3.3. **Calculation of Emissions** (Table 4).

Tab.4 Calculation of CO_{2_mass} emissions reduction effect of the NGR in the rubber industry					
Parameter	**Unit**	**Replaceable NGR material**			**Summary**
		Natural rubber	**Synthetic rubber**	**Carbon black**	
Footprint CO_{2_mass} for to make:					
1 tonne of Rubber mix components	CO_2 ton/ ton	1,63 *	4,02 *	2,62 **	**8,27**
10 000 tonns of Rubber mix components	CO_2 ton/year	16 300	40 200	26 200	**82 700**

* Inventory of carbon & energy (ICE) Version 1.6a p.13

** Greenhouse gas efficiency of industrial in EU

3.4. CO_2 Emission amounts to: **ΣQCO_2 = 52 700 ton/year**

4. Calculation of CO_2 Emissions from production of NGR.

4.1. **The Method of manufacturing of NGR** is not accompanied by any significant polluting emissions or wastewaters for the following reasons:

4.1.1. Production of NGR is waste-free. Input materials for 100% develop into the final product composition.

4.1.2. Production process goes on under the temperature not more than $80C^0$.

4.1.3. The water in the course of production is used only for cooling/heating of processing equipment (Closed circuit system) and household needs of the factory staff.

4.1.4. Evaporation in the premises from the transportation of Rubber Crumb in the open state (in the mills and in the hoppers), are cleaned by the aspirating filters of intraplant ventilation as well as outside at the releasing to atmosphere.

4.1.5. Using electric forklifts in technological routes exclude the exhaust gases emissions. Gas emissions from charging of electric forklifts' batteries are quite insignificant.

4.2. **Negative impact from production of NGR** to the environment results in the high Electric Power consumption of the processing equipment (Emissions of **CO_2** kg/ kWt from Electric Power production at the Power stations).

4.3. Total quantity of these emissions from the Electric Power production, consumed by the enterprise with production capacity **10 000** tons of NGR per year (**QE_{CO2}**), could be calculated by the formula:

$QE_{CO2} = N_{el} * q = 11\ 404,008 * 1,06 = 12\ 088$ ton / year,

where:

N_{el} = 11 404, 008 MWt/year – Yearly Electric Power consumption (taking into account the simultaneous use of equipment ratio) for production of 10 000 tons of NGR.

q = 1,06 - Emission Factor (EF) – index of the intensity of emissions per unit of production. Value of EF is approximate. Determining the exact value cannot be universal, because the emissions intensity depends entirely on the method of production of energy, types of energy sources, up to the geography of power enterprises, the level of their technical equipment.

In the present calculation the average maximum value EF is accepted from different sources.

For example: Dynamics of development of carbon emission factors in manufacturing of electrical energy in Ukraine (Динамика развития коэффициентов выбросов углерода при производстве электрической энергии в Украине) / Tab.4-1 / p.4-4 / or https://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-annex-ru.pdf / p.113).

4.3.1. In the first example, (Pic. is the meaning of the integrated values **EF = 1,052 ÷ 1,063 ton / MWt*h,** for the National Energy System (Ukraine):

Table 5. Rates of CO_2 emissions for Ukraine per year

[t CO_2/MWt-hour]		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
UKRAINE	RD	1.052	1.055	1.063	1.063	1.058	1.059	1.059	1.059	1.043	1.026	1.022	0.941

4.3.2. In the second example, is given the value **EF = 0,765 ton / MWt*h,** for specific Power Plant, operating with the fossil fuel. (Example for presentation). In the calculation we based on the maximum known value.

5. Determination of Environmental Impact in terms of CO2 emissions from the production of NGR:

5.1. Environmental Impact is demonstrated in difference between emissions of CO_2 at the manufacturing of production using NGR (**QE_{CO2}**), and aggregate emissions from the enterprises (**ΣQCO_2**), producing the components, which substitute this product in composition of new Rubber mixes for tires manufacturing.

$$\Delta CO_2 = \Sigma QCO_2 - QE_{CO2} = 52\,700 - 12\,088 = 40\,612 \text{ t/year}$$

Conclusions

As shown by the comparative calculation of only one of the factors of harmful impact (CO2 emissions) on the environment, the positive environmental effect of NGR technology is obvious. It helps to significantly reduce greenhouse gas emissions, water consumption and waste waters. On this basis, the NGR can be classified as environmentally friendly, sustainable material.

Notes:

- The above calculations only present the approximate data to give the idea of environmental impact of NGR solution and Multiplicative effect.
- The above calculations do not pretend on status of precise scientific research and strict economic analysis because performance of such investigations and developments requires the bigger scope of information, and are physically and time spending.
- By request, such researches and developments (Benchmarking assessment of Greenhouse gas emissions of CO_{2_eqv}, with the specific reference on the branch in Germany) could be performed under the separate agreement.
- The Method of calculation is non-conventional, but in the author's opinion allows considering the present calculations as the answer on the matter in question.
- The present calculation contains the materials held widely available. References to the sources are given in the text.

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