Integrated approach to environmental protection in refining, petrochemical and energy complex in the field of environmental legislation

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Introduction

It is easy to state that industrial activity is strictly linked with its surrounding. Direct and indirect influence can be easily noticed on economic, social and environmental levels. Every aspect mentioned above must be considered while decision making process, especially when it comes to the expansion and development of the particular sector. Refining, petrochemical and energy complex is characterised by an extensive and complicated network of interconnections. Its impact on the environment is connected with the operation of the plant as a whole and its products. In recent years, mainly due to technical development, this impact is becoming lower and lower but still a sustainable coexistence of industry and natural environment remains a technical and legislative challenge. Crude oil processing and chemical production involve the impact on all environmental components – air, soil, water and wastes. Since it is difficult not to agree with the slogan that the environment is a common good handed down from generation to generation, and everyone should be responsible for its condition, it is important not only to develop environmental protection technologies, but also to enable operating in a stable and rational regulatory environment.

Main body

Due to growing environmental awareness and increasingly stringent regulations for environmental protection, accurate and proper understanding of the comprehensive impact of production plants on the environment is very important and essential. Legislation in this field tends to focus on individual components of the environment separately. IED Directive as the one of the most important European environmental regulations, in a quantitative manner mainly regulates air emissions. Meanwhile, to be able to accurately assess the impact of industrial production in terms of emissions to air, water and soil protection, water and energy generation (noise, electromagnetic fields), individual approach seems to be insufficient. Therefore, for the integrated refinery and petrochemical complex with its own source of energy, it was proposed an integrated approach to environmental management based on the model of connections between products,, raw materials and energy. It is schematically shown in Figure 1.

The model is based on the assumption that an industrial complex works as a homogeneous thermodynamic machine (Fig. 1) that converts one form of energy into another, in accordance with the law of conservation of mass and energy (including losses). Therefore, regardless of the complexity of the processes inside the machine, the input/output parameters should be balanced. It is easy to note that if non-waste and non-loss processes existed, all introduced mass and energy would have to balance the mass and energy obtained in the form of a product, which is contrary to the basic laws of thermodynamics – there is no device on the overall efficiency of 100%. In order to analyse and understand why some processes are said to be non-waste and zero-carbon, it is necessary to delve into the individual streams interoperable within the plant (thermodynamic machine).

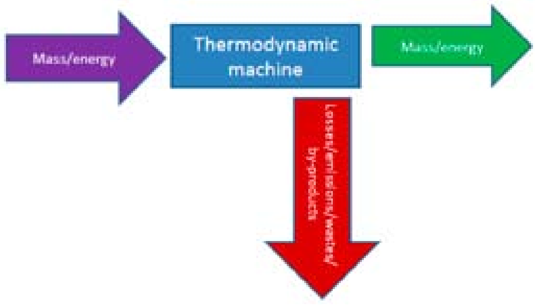

Fig. 1. A simplified model of the industrial complex

To make the analysis as simply as possible it can be assumed that as an input there are three elements. These are mainly crude oil and other raw materials and energy sources, including fuel (e.g. purchased natural gas) and water. Depending on the current needs and the complexity of the plant, particular streams are routed into individual facilities, installations, etc. In the case of refining and petrochemical complex, the most important elements which constitute the essence of physical and chemical processes occurring here, are refining, petrochemical and energy units. With these modules it is possible to process the feedstock in the desirable products – fuels, chemicals and usable energy in the form of electricity and heat. As it was mentioned before, due to the basic principles of thermodynamics, industrial processes are also a source of by-products, undesirable products and wastes. These include gaseous substances and dust emitted to the atmosphere, as well as solids and wastewater components. In brief, it can be assumed that any industry complex consisting only of the above elements could successfully perform their tasks and be operated in accordance with its intended target, if we consider that generating marketable products in acceptable quality is a priority. The refinery, using energy, converts crude oil into fuels and petrochemical raw materials which are feedstock for the petrochemical segment, which produces chemicals as commercial products.

However, a number of other very important aspects of industrial production should not be forgotten. Primarily, economic and environmental aspects can be distinguished. They force plant operators to use a range of auxiliary units, among which a key role is played by wastewater treatment plants, waste incinerators or facilities for flue gas treatment. They allow to meet strict environmental standards, and also they contribute to improving the efficiency of processes, e.g. by industrial water recycling or generating additional energy from calorific wastes. Taking into account additional facilities in the production cycle makes the industrial complex more developed and, in addition, connections and streams between the units become more

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complicated. Nevertheless, as shown in Figure 2, the type of output streams have not changed significantly. Only their sources have shifted from one unit to another.

These considerations featured above allow to conclude that the model of industrial complex shown in Figures 1 and 2 presents the exactly the same. Regardless of how much we extend the thermodynamic machine and how much flows we include, the final result will be similar. Only the distribution of individual products (understood as everything which leaves the machine) will change. It should be always kept in mind when formulating any optimization or pro-environmental issues. Disregarding abovementioned factors and focusing only on the selected production processes results in shifting the risk of adverse effects and side effects to any other activity, which is associated with illusory impression of perfection of such process.

In the model presented in Figure 2, the Refinery, Petrochemical and Power Plant/CCGT modules, through the implementation of flue gas treatment techniques, wastewater treatment plant and calorific waste incineration, seem to be almost non-waste and zero emission. This argument is often used in discussions about the environmental aspects of industrial production by saying that application of appropriate techniques may help to reduce emissions significantly, virtually to zero. However, more detailed view on this problem leads to the conclusion that emissions always occur. Their source is no longer a production unit, but the auxiliary unit or other facility.

Similar risk of too narrow analysis of this problem occurs in the case of limiting to the selected component of the environment. European legislation, through directives, regulations and other guideline documents, focuses mainly on the air protection and emissions abatement. It forces the industry to use the advanced 'end of pipe' flue gas treatment techniques, especially if large amounts of fossil fuels are combusted. Such techniques allow for keeping the emission limits of different pollutants, e.g. SO_2 and NOx, without sudden resignation from conventional energy sources.

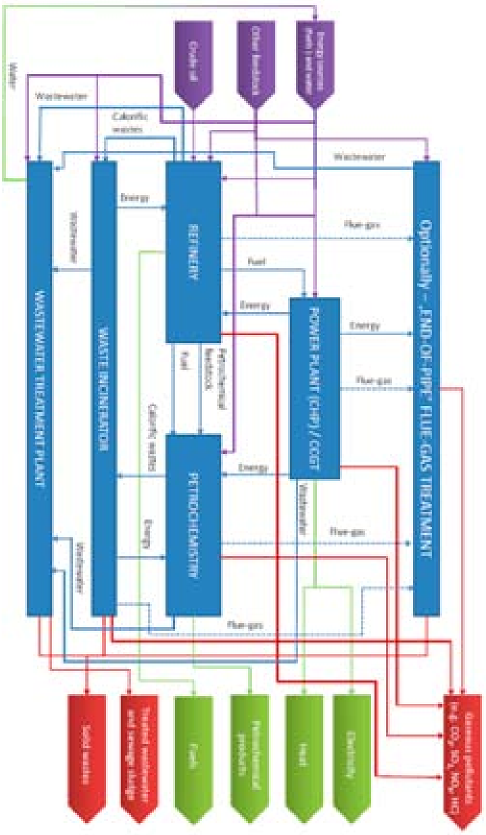

Fig. 2. Model of streams in refining, petrochemical and energy complex

Today's technology development in the case of flue gas desulphurisation allows for even multiple mass reduction of SO_2, using costly, but well-known techniques. Very popular, and possible to apply for both solid and liquid fuels, it is the technology of wet flue gas desulphurisation (FGD) using a slurry of alkaline sorbent, usually limestone or lime. With its help it is easy to reduce SO_2 concentration in flue gas from approx. 4 000 mg/Nm^3 to even below 200 mg/Nm^3. So, what is the risk? Each scrubbed SO_2 molecule gives one molecule of calcium sulphate dihydrate (gypsum). Therefore, a substantial reduction of emission to the atmosphere causes generation of additional solid substance. Admittedly, gypsum produced by this method may be treated as commercial product, but it is expected that in the near future, due to the increasing number of installations equipped with wet FGD, gypsum market will become saturated and problems with its ecological and sustainable disposal may occur.

Summary and conclusions

As a summary, here are the basic conclusions of the analysis within the proposed model:

- Refining, petrochemical and energy production is closely related to the use of natural resources.
- As a result of industrial activities, desirable products and waste/residues of different form and state of aggregation are generated.
- Processes run with plenty of interoperable and intermediate streams which allow for controlling the quantity and quality of desired and undesired products, within the laws of thermodynamics and the conservation of mass.
- The overall balance of input/output, including all streams, should be equilibrated.
- Conducting industrial processes in accordance with the principle of sustainable development depends on such control which allows for manufacturing the desired product as much as possible and manufacturing burdensome and difficult to utilize products as least as possible with minimal energy demand.
- Completely non-waste and zero emissions processes do not exist - such impression arises if the borders of balancing are defined too narrowly.
- Legislation for the environmental protection within the individual components of the environment should take into account mutual and close interdependencies between them.
- When developing and giving opinions on environmental regulations, independently of the analysed component, not only environmental issues are important, but also technological capabilities, local conditions and the laws of thermodynamics and conservation of mass.

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