ECONOMIC APPLICATIONS OF ION EXCHANGES IN WATER PURIFICATION TREATMENT

Daniela GRĂDINARU[1], Ştefania RACOVIŢĂ[2]

e-mail: danyella_gradinaru@yahoo.com

Abstract

Our global economy is at a turning point. The progress in communications and technology has surpassed our imagination, yet we find ourselves facing limited natural resources that may put an end to the economic development and even, to life itself. The green economy replaces slowly, but steady the traditional one. The rules are changing. Competition is moving in a green court and only those who will show a social and ecological responsibility will survive. Water, the resource we depend on, becomes more and more polluted. Time has come to act and join forces from all areas and domains, with the sole purpose to find the best solutions. Ion exchange technology seems to be a reliable option. We believe it is a domain that will develop through future studies and research, and will be successfully implemented in many of the world's companies. The things we witness in this era are alarming, and in finding the suitable solution, we have to rely on research and inter-science collaboration.

Key words: green economy, sustainable development, water pollution, ion exchange

Events and phenomena which characterize the world nowadays are alarming. Natural disasters, climatic changes, ambient disequilibria, and abnormal phenomena, all these raise a question mark: where are we heading towards? What does the future look like and what is to be done to direct it towards the direction we want? What is to be done to reach a sustainable development in the economical-social plan? Slowly, but precisely, the last decades were marked by a social awareness and assumption of responsibility, among actors of the economic market, either consumers, producers, mediators, arbitration or regulation bodies. The natural resources we have profited by over centuries are reducing alarmingly. Until recently, we acted without thinking to return something to the environment, acting on the principle that its natural laws will ensure its equilibrium and everything will be the same, life will continue its normal, accelerated rhythm, characterized by an irrational and unconscious consumption.

It has come the moment to act responsibly, especially economically, and in carrying out major changes in the manner of functioning of economic entities, whose negative impact on the environment must be considerably reduced. This current tendency is part of a reorientation at worldwide level, from the traditional economy towards the green economy. Companies oriented towards the protection of the environment, preoccupied by the reduction of pollution through the activities carried out, which make investments in order to reach this objective, which implement an environment integrated management system,they are those that will characterize the economy of the future. Those that will not align to this "*green*" current will not survive for long on an economic market where the functioning laws are changing.

The economic organizations which make these public efforts ensure themselves a good image before business partners, clients, investors. This image can be integrated to the concept of *goodwill* or *commercial fund*, from a financial-accounting point of view, and as time passes, the rate of this part will increase. Moreover, implementing production technologies which facilitate the consumption of resources and reduce the negative impact on the environment, will be concretized on long term in a reduction of production costs. Under these conditions, the profit rate will increase, allowing them to practice even a price inferior to the competitors', which will increase the market niche, respectively the profitability of activity. Therefore, the solutions through which these objectives are reached are worth of attention. By means of this article, we

[1] Universitatea „Alexandru Ioan Cuza", Iaşi
[2] Institutul de Chimie Macromoleculară „Petru Poni", Iaşi

suggest such a solution. We want to inform the economic organizations of any profile and any type of industry on the negative impact of their activity on the environment, possibilities to reduce this effect, the advantages that the implementation of such a technology will bring not only to the ecological plan, but also to the economical one.

MATERIAL AND METHOD

This article integrated two (economical and chemical) scientific perspectives, on an up-to-date subject and of major importance, not only for the economic community, but for the human society, generally: water pollution. The research we have carried out is based on a theoretical and practical material of the two fields, trying their integration in the purpose of obtaining some viable conclusions and practical recommendations for Romanian economic organizations, which confront water pollution in the production process. The theoretical documentation, the comparative analysis, the non-participative observation, data interpretation, are the methods which guided this research, and led us to the conclusions, results and optimal acting directions, which will be revealed in the paper.

RESULTS AND DISCUSSIONS

Although pollution has accompanied the human society from its very beginnings, it became a subject of great interest, exercising alarming consequences, once with the industrial revolution from the 19th century and with the development of the population, both from a numeric aspect and from a technical-scientific and social one.

The economic space is dominated by the following objective: obtaining maximum advantages with minimum efforts. In order to reach this purpose, there were mobilized natural resources, technologies under continuous development, directing towards a time horizon not very long and not being aware of polluting dangers which accompanied this entire activity. In any productive process, only a part of natural resources are usefully consumed, but a great part is represented by waste, which returns to this form, back in the environment. There is a determination relation between population, production and pollution. Starting with the 16th century, the population has been alarmingly increasing. The needs of food and health have led to a mobilization on the technological plan, to innovation and progress. Definitely, all these are good, and helped the development of the society, but among all these preoccupations were not mentioned those referring to the consequences of pollution, at least not until their effects started to feel in a socio-economic plan. The pollution of the environment can be defined as the contamination of physical and biological components up to the negative affectation of own natural processes of the environment (Terceiro et al., 2009). Pollution has only negative effects, and these are not limited to the level of the living matter, of ecosystems, but also extend to the economy of the planet. It is rather about an influence which acts in both directions: the industrial processes lead to the pollution of nature, and this subsequently has implications of the economic environment, in terms of costs (taxes, reconstruction of installation, implementation of new technologies, according to the effective laws and environmental standards, and so on).

Three main types of pollution of environmental factors are known: air, soil and water pollution. Pollutant factors can be chemical, physical or biological and can originate from natural (volcanic eruptions, fires, floods) or artificial (human-specific activities) sources (Vlad, 2007). Although all types of pollution deserve attention, this article focuses on water pollution. Water, indispensable element for life, is present in all environments (soil, air, water) and appears in all the three aggregation states (liquid, solid, gas). In its circuit, water transports all types of substances, among these being also the harmful ones. Therefore, water represents at the same time a means of spreading pollutants. This would not represent itself a great danger, but, being a good solvent for many solid, liquid and gaseous substances, water composition changes, sometimes irreversibly, threatening not only the existence of flora and fauna, but the human life, too.

Moreover, in its capacity of very good transporting and solving agent, water also takes pollutants from air and soil. It becomes obvious the fact that it is not possible a delimitation of pollutants specific to the aquatic environment, based on water interaction with all these environments, which leads to taking a varied range of pollutants from different sources.

Waste water, eliminated from polluting sources (city, industry, transport, zootechnics, etc.) through the sewerage system, in a natural water course, is called *effluent* (Vlad, 2007). The running water where the effluent reaches is called emissary, and these pollutants, through this system, are taken further. The problem of water pollution must be treated systemically, being aware of the fact that all water sources are interconnected, from atmosphere to the seas, representing the hydrological cycle.

Pollutants which affect water quality are briefly presented as follows (Vlad, 2007):

A. Chemical pollutants:

a) Inorganic chemical substances: plumb, mercury, arsenic, cadmium, nitrates, nitrites, sulphurous and nitrous acids. This situation occurs in the case of mines where raw materials are processed.

b) Organic substances: hydrocarbons (which originate from installations of extraction, transport and processing of oil and derived products); detergents (their harmful effect was considerably reduced through the predominant production of biodegradable detergents); pesticides, herbicides, fungicides, synthetic fertilizers (these can reach water either directly from the producing companies, or subsequently, from the users of these substances in agriculture, zootechnics).

c) Organic and inorganic solid suspensions (cement dust, rests of plants and animals)

A. The biological pollutants represented by biological waste. This situation is mainly encountered in large cities, and the discharged waste can be biodegradable or not.

B. Physical pollution:

a) Radioactive substances – water used in nuclear, atomic-electric centrals, research laboratories, etc.

b) Discharge of hot water – in the case of industries where water is used as a cooling agent or used to obtain vapours.

C. Biological pollution, through different pathogenic microorganisms reaching the water used by hospitals or farms.

It is noticed the overwhelming "contribution" of industrial processes and economic ones, generally speaking, to whom should be also associated corresponding responsibility and actions.

As the effects of water pollution are concerned, first of all, pollutants affect the state of health of population, directly by the consumption of water or indirectly by the consumption of flora and fauna affected in a first phase by the polluting water. Apart from effects in the field of health, the economic effects manifest, too. Different industries require specific types of water, of a certain quality. Water from natural sources does not initially meet these requirements, therefore requiring a treatment, which entails different costs. These costs increase very much when water is already full of different pollutants. Thereafter appear costs with the treatment of waste water.

All these being mentioned, there is no doubt in respect of the importance of fighting water pollution. But this thing is quite difficult to put into practice, being necessary the unison action of every individual, of every organization and nation apart.

In order to fight this poisonous phenomenon, a simultaneous action on three plans is required (Vlad, 2007):

a) The achievement of a legislative framework – to set limits as regards the nature, the concentrations of pollutants allowed, penalties for those who ignore the problematic of pollution. Along time, the European Union has regulated this field through directives. A major step towards an integrated management of water resources in the community space was achieved by Directive 2000/60/EC of the European Parliament and Council, also called *Water Framework Directive*. This directive has introduced an integrated, holistic approach, focussed on the measurements of protection and on a good water management by every European government apart. This way, the underground water, too, became a part of the water integrated management system. The purpose is that until 2015 to be reached a good level of the quantitative and chemical statute of water, including the underground water (Terceiro et al., 2009).

b) Measures of preventing water pollution – prevention is always the desirable way to be followed in the case of a negative phenomenon. In this case, prevention might consist of the implementation of technologies to consume less water, or to totally or partially recycle the waste water.

c) The implementation of a system of procedures and techniques for the treatment of waste/polluted water. These procedures entail certain costs, investments, and this is why they are left apart. But the legislative framework has evolved, establishing limits for the qualitative parameters of water used in the industry and in any human activity, too, limits which must be observed before discharging water back to the nature.

Assessing water quality is essential in order to control the pollution and protection of either ground or underground water (Gray, 2005). Although apparently simple, water quality is a complex variable, influenced by a multitude of factors, and consequently, difficult to measure. Water quality is reported to a specific purpose, to a certain activity for which it will be used, and is determined through a selected set of physical, chemical and biological features. These features, once selected, are compared to the guidelines and numerical and qualitative standards in the field, in order to establish if water can be used for that activity (Terceiro et al., 2009).

At the same time, we have to consider that when we refer to water quality, we have to consider from the very beginning the assumption that water does not exist in its pure state – at least not naturally (it can be reached only by repeated distillation or synthesis from constituent elements: hydrogen and oxygen).

“Natural water purity” refers to maintaining the features of quality of fresh water, taste, smell, contents in ion species (bicarbonates, iodine, flour, etc.), microorganisms within normal, natural limits. More correctly, for the appreciation of fresh water: the term of “water quality” represents the assembly of physical-chemical and biological properties which meet the requirements of their field of use (Vlad, 2007). In most of the cases, water from different natural sources will already contain a series of substances and composites, in quantities and concentrations from the most different ones, being necessary its previous treatment before entering in industrial processes, not taking into consideration different pollutants that the water source might have taken in its course until participating in the given processes. Therefore, water pollution, only from these considerations, briefly presented, is for no doubt a complex problem, which, despite the fact that it was acknowledged quite late in relation to the evolution of the human society, can be efficiently managed and integrated in a quality and control management.

When we deal with waste water, when is water treatment realized, before participating in the industrial processes or afterwards? Of course, there are several techniques, but the generally-known term is purification, which can be: mechanical, biological or chemical. Mechanical purification is achieved in a first stage, and by means of it, solid matters which do not dissolve in water are removed. Biological purification takes place through the introduction of microorganisms which will consume pollutants from water.

Chemical purification takes place when in water there are pollutants that cannot be removed by decantation. The procedure implies the use of certain chemical substances which neutralize pollutants, rendering them inoffensive for the environment, or rendering them in a solid form, in order to be subsequently removed by mechanic procedures (Vlad, 2007).

In choosing the type of purification, there are taken into consideration factors such as: source of pollution, types of pollutants, type of activity, features that water must have, etc.

A chemical purification procedure which has the support on the part of specialists in chemistry, and that we also suggest, as an option which is advantageous from a financial point of view, too, is the one based on ion exchangers.

The ion exchangers are insoluble polyelectrolytes where the ionic groups attached to the polymer matrix offer them the capacity to participate in reversible reactions of ionic exchange and to store ionic species present in solutions. In other words, the ion exchangers can retain different substances (metals, organic composites) when they are passed through water. These substances have a major importance in different fields of economic interest, being successfully used in water treatment: deionization, treatment of effluents, treatment of residual water, treatment of water mixes (Neagu, 2007).

The main features of ion exchangers are the capacity of ionic exchange (retaining ions from water) and their selectivity (can select ions they will retain from the aqueous solution).

The most often encountered strongly basic ion exchangers are anion exchangers which have in the structural unit quaternary atoms of azoth, among which those based on styrene copolymers: divinylbenzene (St:DVB) are used and commercialized prevailingly, the acrylic anion exchangers being also used, in a reduced quantity.

The polymer matrices of St:DVB type present many advantages for the ion exchangers due to the low price (cost) of styrene and the superior physical properties such as: the chemical stability to oxidation, hydrolysis or high temperatures, as well as the reactivity of the aromatic nucleus of styrene, fact which allows to fix the ionogenic groups.

Another example is the one of strongly basic ion exchangers with quaternary groups of ammonium, used for the purification of water used in the energetic, electronic, pharmaceutical, food, chemical, metallurgical industries – which require a high degree of water purity.

Initially, these ion exchangers had restraint applicability, only for the retention of inorganic substances from water. New researches and studies have led to obtaining from reactions of amphoteric ion exchangers which had the capacity to retain the organic substances found in water.

In the process of ground water purification, it can occur the irreversible "poisoning" of anion exchangers, especially of the strongly basic ones, which leads to their degradation and implicitly to the loss of capacity of ionic exchange. This is why was necessary to obtain some anion exchangers with special absorbing properties. Such a category is represented by absorbing resins which have a porous morphological structure with large specific surface, high resistance to abrasion, high chemical stability and high wettability (Neagu, 2007). Some ion exchangers can be regenerated, requiring high consumption of HCl and NaOH; but for a certain type of ion exchangers, a resin known under the name of "snake in cage" polyelectrolyte, regeneration is achieved through a simple wash with water. This property is very advantageous from an economical point of view. The retention of metals in a selective way from aqueous solutions is also advantageous, so that in the mine industry, a great part of them can be recovered from waste water and then valorised.

Mercury, another toxic metal, which is present in high concentrations in waste water in the chemical industry (pesticides, paints), mine and pharmaceutical industries, can be retained in proportion of 81% in the first two hours of contact of waste water with the anion exchanger resins which contain quaternary groups of ammonium.

In industries which use heavy metals, the productive process becomes efficient due to this chemical procedure applied to waste water, by the recovery of metals and their reintroduction to the cycle of production as raw materials, or by valorising them on the market.

We should also mention that these techniques for the chemical treatment of water have a reduced cost of maintenance, through the possibility of regeneration of ion exchangers/resins.

The implementation of such a system in enterprises proves to be advantageous also from a financial point of view – it does not represent only a way to comply with the legal provisions of the European or national community.

On the market there are such systems of waste water treatment, based on ion exchangers, which can be purchased "brand-new". For small enterprises, such an option is justified. But in large companies which use huge quantities of water, in different industrial processes, and which have their own department of chemical engineering, such a system can be implemented by own design. The advantage is that it can be continuously improved and fits better to the needs of the enterprise, being customized, and not only a "serial" product. Another advantage is the permanent assistance and monitoring of functioning from the inside of the organization, the time of reaction being considerably reduced.

The field of water treatment using ion exchangers is in full progress, improvements and innovations taking place continuously. The economic organizations must realize the importance of facilitating this process, which is nothing else than the reduction of production costs, and moreover, the observance of the law and the enforcement of an active environmental policy.

CONCLUSIONS

To conclude, this article presents an ecological solution, but also a financially-efficient one for water pollution, a viable, advantageous and competitive alternative, a reorientation of production processes towards increased efficiency under the conditions of active social and environmental responsibility. This way of thinking is a part of the new management system, which leaves behind the old economic principles and directs towards other purposes, which exceed the capitalist selfishness, integrating a new – *green* – perspective. This is also the way the results will be seen: advantageous for us, here and now, and also for the future generations.

Is the preoccupation for the environment an option or a necessity, a luxury or the only chance of survival for long term? No other type of economic behaviour is responsible or offers the solution of a sustainable and lasting development.

We consider that the efforts, of any type, directed towards the reduction of pollution and of its effects to the minimum, must be a part of the environmental strategy of any organization that respects itself, respects its business partners, but also the natural resources used in its activity.

REFERENCES

Edmunds, W.M., Shand, P., 2008 – *Natural groundwater quality*, Blackwell Publishing, Oxford, United Kingdom

Gray, N.F., 2005 – *Water technology: an introduction for environmental scientists and engineers*, Elsevier Science and Technology Books, Dublin, Ireland

Luca, C., 2000 – *Organic Ion Exchanger*, in Encyclopedia of Separation Science, Wison, Y.D., Adlard, E.R., Cooke, M., Poole, C.F. (Eds.), Academic Press London, UK, vol.7, p.1617-1632

Luca, C., Neagu, V., Vasiliu, S., Bărboiu, V., Drăgan, S.E., 2005 – *Synthetic polybetaines. Synthesis and properties*, Research Singpost, p.117-152

Neagu, V., 2007 – *Polimeri ionici: sinteză şi proprietăţi*, Editura PIM, Iaşi

Samuilă, G.E., Petchescu, N.M., 2009 – *Epurarea apelor uzate*, Editura Politehnica, Timişoara

Tabără, N., Horomnea, E., Mircea, M-C., 2009 – *Contabilitate Internaţională*, Editura Tipo Moldova, Iaşi

Terceiro, P., Ceclan, R., Popa, I., 2009 – *Environmental monitoring of water sources*, Editura Electra, Bucureşti

Ţuţuianu, O., 2011 – *Evaluarea şi raportarea performanţei de mediu. Indicatori de mediu*, Ediţia a III-a, Editura AGIR, Bucureşti

Vlad, C.D., 2007 – *Poluarea, problemă mereu actuală*, Editura PIM, Iaşi.