RT&A, Special Issue № 4 (70)
Volume 17, November 2022

OPTIMAL POLLUTION CONTROL ENVIRONMENT

Alexander Chupin, Alexander Priymenko, Alexey Ukhanov

•

RUDN University, Russia
Chupin-al@rudn.ru
information@rudn.ru

Abstract

In this article, pollution is defined as the stock or flow of physical substances that diminish one's ability to enjoy life. In this definition, pollution includes a wide range of phenomena. The authors identify the following elements of pollution: natural waste, pollution of air and water pollution, depletion of soil from excessive use, radiation, intensive use of natural resources, exceeding the rate of their renewal. The authors have identified a fundamental similarity between tasks that at first glance appear to be different. The structure of control theory enables us to apply its apparatus to simple models of production and consumption. Optimal pollution control may require reducing some consumption, limiting the use of some production processes, and perhaps even limiting population growth. Pollution problems are problems of processes that change over time; this fact The problems of pollution are time-varying processes; this fact emphasizes the need to apply a dynamic control theory approach.

Keywords: risks, environmental, mathematics, dust pollution

I. Introduction

Everyone wants to live in a safe and comfortable place with clean air, food and water, but modern megacities cannot be called that. The abundance of industrial facilities, densely populated and increasing number of vehicles every year leads to a deplorable state of ecological situation around large cities. The problem of atmospheric air pollution has only become more acute over the past ten years, but the situation began to change in 2017 [1], which was the year of ecology in Russia. This year, a lot of attention was paid to the legislative aspect in terms of the Federal Law "On Environmental Protection". Thus, the changes state that from 2018 to 2022, industrial facilities that pollute the environment to a significant extent, must install specialized means of measuring emissions of pollutants into the atmosphere, with automatic transfer of information to the state environmental monitoring fund.

Before turning to the formal model, let us point out three crucial differences related to the effect of pollutants from an economic point of view. First, it is essential whether the pollutant has the main effect on production, on consumption, or perhaps on both at the same time. The pollutant is clearly part of the utility function with negative marginal utility. At the same time, its presence may have a detrimental effect on production. However, in many cases, which will be studied below, pollutants have positive marginal productivity. Second, we must distinguish what exactly has an effect-the stock of pollutant or its flow. Often the pollutant acts in both roles at the same time [1, 2]. For example, the flow of DDT has a positive marginal capacity for agricultural production, and its stock has negative marginal utility [3, 4, 5]. This is a typical example of pollutant. The stock is harmful either because of its direct effecton consumption, or because it harms production; whereas flow is useful-either because it itself has positive marginal productivity, or because it is an undesirable byproduct, the removal of which requires the expenditure of resources. Pollutants of this kind are in their nature are the opposite of the capital stock. The stock of the latter has positive marginal productivity, and the flow has negative marginal utility (since as capital accumulation reduces consumption in the present). It seems to us that the basic problem of pollution, that the presence of pollution reduces the ability of humans to enjoy life, is the problem of stockpile management. However, if pollutants have a very high rate of natural purification, then the concept of stockpile loses its meaning. In some cases of this kind, the value of the stock becomes proportional to the size of the flow, and it is quite natural then to consider the management problem as a flow management problem. Noise as a pollutant is a limiting case of such a situation, although it is more convenient to consider an air pollution problem as a about a flow. The stressed distinction between stock and flow is directly related to our third - traditional in control theory - distinction between state variables and control variables [6, 7]. We believe that the only acceptable characteristic of stock is that it can never be viewed as a a tool (i.e., a control variable). It follows that tradition can be called a tool, and a variable that is functionally related to it [8]. To contaminate the social problem, it is important to stress that we are often unable to exercise direct control over unwanted products [9, 10, 11]. Planning becomes an urgent necessity. Ignoring the problem or exaggerating it leads to a huge waste of resources [12, 13, 14].

II. Method of determination based on the choice of pollution control model

We have studied optimal equilibria and approximate trajectories in two similar models in which we want to control pollution stocks. These models differ in the structures of the production functions and in the way, pollution is controlled. The target function for both models is the same. It is defined in terms of society as a whole, but it can equally be defined in terms of the individual. To avoid difficulties in estimating the structure of the objective function, we will assume that the supply of labor does not change over time.

The welfare of society at any point in time is a function of the flow of consumption c and the stock of pollution P. The time-independent utility function can be denoted by

$$u(c, P). \quad (1)$$

The first argument gives a positive contribution, the second negative, i.e., $u_c > 0$, $u_P < 0$ and the second derivatives of the of the utility function are negative: $u_{cc} < 0$, $u_{pp} < 0$.

It is assumed that $u_c = \infty$ at $c = 0$. Indifference curves have a simple form. Neither consumption nor reduction (in the most ordinary sense) is reducible to one another.

Utility flow is estimated taking into account the subjective rate of discounting r. The total welfare W, which corresponds to any particular trajectory $c(t)$ and $P(t)$. Thus, the total welfare has the form:

$$W = \int_0^\infty u(c, P)e^{-rt}dt. \quad (2)$$

Model I. Pollution control through processes cleanup. The two factors of production in Model I are labor and production inputs. This model has one additional feature: output can be used not only for capital accumulation and for consumption, but also for pollution control. It assumes that the useful cleanup costs are used to deal with a wide range of pollutants. For example, many types of controls on of water pollution are perfectly consistent with Model I.

It is assumed that the production function satisfies the usual concavity conditions. Since labor is fixed, this means that output z is an increasing concave function of the fixed capital K, i.e.

$$y = f(K), \quad (3)$$

where $f' > 0, f'' < 0$. Fixed capital decreases at a fixed rate a.

In this model, the pollutant is not used in production as a useful product. It is assumed that its flow is a byproduct of production and is proportional to it; the products of production and the pollutant are related to each other. Under this scheme fit: whey in a dairy plant, waste of plants that pack meat, organic residues from paper production, etc.

The product-pollutant relationships in co-production allow us to measure pollution in the same units as the main product. Naturally, the necessary refinements are made in the choice of the utility function. Our unit selection technique is equivalent, for example, to measuring the amount of wool in pounds of its corresponding lamb. Fortunately, empirical observations show that the stock of pollutants dwindles naturally. The purification rate b is assumed to be non-negative. (In situations such as bacterial contamination, b can also be negative).

Model II. Pollution control by choice of production process. We now describe a pollution model in which the pollutant stock is part of a utility function with a negative marginal productivity, and the stream has a positive marginal productivity. The insecticide DDT is a good concrete example of the dual role of pollutants of this type. For simplicity, let's assume that a pollutant soon appears, then it can dwindle naturally. To avoid irrelevant complications, assume that labor is the only scarce production factor. So, the management task in this model is to choose of the production process - this choice is manifested in between the sector producing the commodities and the sector producing the goods consumption, and the sector producing pollutants.

The target function is the same as before. For simplicity, we will assume that consumption and pollution are included in the utility function separately, i.e.

$$u(c, P) = g(c) - h(P), \quad (4)$$

where $g'(0) = +\infty$, $g' \geq 0$, $g'' < 0$, $h'(0) = 0$, $h' \geq 0$, $h'' > 0$.

The supply of labor L, the only factor of production, is fixed. Part of them is used in the production of pollutants. We will assume that $j'(L_1) > 0, j''(L_1) < 0$ and $0 \leq L_1 \leq L$.

The rest of the labor force $\mathrm{L} - \mathrm{L}_1$ is used in the production of consumer goods. The pollutant, being an intermediate product, serves as the second argument of the production function in the production of consumer goods. This function, therefore, has the form:

$$c = F(L - L_1, j(L_1)). \quad (5)$$

Necessary conditions of optimality. Convert the expression by discarding e^{-rt}

$$H = g(f(L_1) - h(P) + \pi(j(L_1) - bP + q(L - L_1) + sL_1. \quad (6)$$

Here q and s are time-dependent non-negative multipliers corresponding to the constraints on L_1. It is clear that it is inefficient to use more than $\tilde{L}$ labor to produce the pollutant because the pollution has a non-positive productivity. Hence, $L_1 < \tilde{L}$ and $\mathrm{q} = 0$.

An interesting aspect of the problem is that the multiplier s can be positive.

III. Results

The two models we have considered lead to completely different conclusions. This distinction suggests that there are no general rules for solving pollution problems and that there is no single, sufficiently well-defined model that would lead to important conclusions without further its details. Nevertheless, we believe that it is possible to generalize our models so that they will encompass pollution problems, which stand in the spirit of the following assumptions (tab. 1).

Consider the problem of river pollution. If a plant is engaged in to treat its wastewater, it thus chooses a more expensive manufacturing process. Reducing the flow of pollution is achieved at the cost of reducing productivity: one must use Model II. On the other hand, if pollutants are still discharged, but there is a purification of the water river, say by means of the aeration process, then the logical structure in this situation is the same as in model I.

A good illustration for the upper right-hand corner of the table is the paper industry. In this industry, the production process can be chosen in various in different ways; the less organic residue is discarded in an individual process, the higher the unit price produced. Model II can be used in this or some other situation where it is necessary to choose production process under the assumption that the process with the greater productivity yields more byproducts pollutants.

Table 1: *Pollution problems*

		Controlling the flow of contamination is carried out with the help of	
		processes cleaning	choosing production process
Contaminants are included in the models	as a byproduct product of production	Model I	-
	as intermediate product production	-	Model II

The field of application of the models considered is broader than the field of purely production processes. For example, the "producers" beverage producers are paid more by consumers if they use production processes in which bottles are not returned (the price goes up for convenience), but processes where bottles can be returned produce less pollution.

The gain from not throwing bottles away, is low, but the disposal of discarded bottles is expensive and sometimes too expensive. Thus, applying to these cases is justified. A prohibition on throwing away bottles may also be appropriate for aesthetic considerations. Another example is transportation "corks"; they can be seen as a by-product of transportation.

Further research should weaken the three assumptions in our models. (1) The pollution control sector capital must be used. (2) Technical progress, especially in the abatement sector, where progress can and should occur in the near future. (3) Labor must be considered as an endogenous value in order to establish the relationship between population growth population and pollution and to illustrate the possible need for some means of regulating population.

IV. Discussion

If the pronounced social and political concerns reflect suboptimal situations, our society is currently operating at pollution levels well above the optimal equilibrium. There seems to have been too much emphasis on building capital assets and maintaining high levels of consumption. The sheer number of factors external to the economy affecting the free market leads to sub-optimal outcomes. Therefore, some form of centralized coordination is necessary to remedy this situation. Such coordination can be accomplished either by policy directives, or by the sale of pollution rights, or perhaps by methods of direct control. Our models show that, generally speaking, no application of drastic measures. In many cases, the significant danger is a drastic response. In fact what is needed is a controlled movement toward optimal trajectory. Unfortunately, a policy of gradual changes in behavior is sometimes impossible due to of the current political environment. Prohibition may be feasible where gradual change would require a bloated administrative apparatus. Radical measures or absence of any measures may be the best of all those measures that can be implemented. The role of economists in real life is not only to identify optimal trajectories, as we have done, but also to suggest practical ways in which by which these trajectories can be approached. But this is precisely is an area in which our contribution is, as usual, very small.

References

[1] Li, Z., Chen, Y., Meng, F., Shao, Q., Heal, M. R., Ren, F., Xu, W. (2022). Integrating life cycle assessment and a farmer survey of management practices to study environmental impacts of peach production in Beijing, China. *Environmental Science and Pollution Research*, 29(38), 57190-57203. doi:10.1007/s11356-022-19780-0

[2] Li, Y., Xiao, G., Li, F., Chen, C., Chen, C., Li, R., . . . Zhang, M. (2022). Response surface analysis (RSA) optimization of temperature-resistant gel foam fabrication and performance evaluation. *Colloids and Surfaces A: Physicochemical and Engineering Aspects,* 655. doi:10.1016/j.colsurfa.2022.130260

[3] Liu, C., Bao, Q., & Nie, W. (2022). The influence of ventilation parameters on dust pollution in a tunnel's environment using the CFD method. *Journal of Wind Engineering and Industrial Aerodynamics,* 230 doi:10.1016/j.jweia.2022.105173

[4] Nie, W., Guo, L., Liu, Q., Hua, Y., Xue, Q., & Sun, N. (2022). Study on the coupling pollution law of dust and gas and determination of the optimal purification position of air duct during tunnel excavation. *Powder Technology,* 411 doi:10.1016/j.powtec.2022.117843

[5] Sun, C., Yi, X., Ma, T., Cai, W., & Wang, W. (2022). Evaluating the optimal air pollution reduction rate: Evidence from the transmission mechanism of air pollution effects on public subjective well-being. *Energy Policy*, 161 doi:10.1016/j.enpol.2021.112706

[6] Alharbi, O. A., & Rangel-Buitrago, N. (2022). Scenery evaluation as a tool for the determination of visual pollution in coastal environments: The rabigh coastline, kingdom of saudi arabia as a study case. *Marine Pollution Bulletin*, 181 doi:10.1016/j.marpolbul.2022.113861

[7] Buribayev, Y., Khamzina, Z., Suteeva, C., Yermukanov, Y., Turlykhankyzy, K., & Kuttygalieva, A. (2021). Analysis of the possibilities for improving the environmental legislation of kazakhstan. *Fronteiras*, 10(3), 78-88. doi:10.21664/2238-8869.2021v10i3. p 78-88

[8] Chen, X., Zhu, Y., & Shen, J. (2020). Input-output dynamic model for optimal environmental pollution control. *Applied Mathematical Modelling*, 83, 301-321.

[9] Flaksman, A. S., Mozgovoy, A. I., Lopatkin, D. S., Dikikh, V. A., Shamsov, I. S., Romanova, J. A., . . . Bovtrikova, E. V. (2021). Prospects for the development of alternative energy sources in the world energy. Paper presented at the IOP Conference Series: Earth and Environmental Science, 723(5) doi:10.1088/1755-1315/723/5/052040.

[10] Liu, X., Wang, Y., & Li, M. (2021). Theory, method and technological application of territorial spatial development suitability evaluation. *Journal of Geo-Information Science*, 23(12), 2097-2110. doi:10.12082/dqxxkx.2021.210037

[11] Luo, L., Sun, H., Gai, C., & Liu, Z. (2021). Application of synchrotron radiation-based spectroscopic techniques in pollution control and utilization of organic solid waste. *Chinese Journal of Environmental Engineering*, 15(12), 3830-3843. doi:10.12030/j.cjee.202109148

[12] Lutoshkin, R. V., Morkovkin, D. E., & Sadriddinov, M. I. (2020). II international scientific and practical conference "actual problems of the energy complex: Mining, production, transmission, processing and environmental protection". IOP Conference Series: Materials Science and Engineering, 976(1) doi:10.1088/1757-899X/976/1/011001

[13] Prenner, S., Allesch, A., Staudner, M., Rexeis, M., Schwingshackl, M., Huber-Humer, M., & Part, F. (2021). Static modelling of the material flows of micro- and nanoplastic particles caused by the use of vehicle tyres. Environmental Pollution, 290 doi:10.1016/j.envpol.2021.118102

[14] Shamraeva, V. V., Kalinin, V. M., Morkovkin, D. E., Koryakov, A. G., Zakharova, M. V., & Perfilyev, A. A. (2022). Mathematical model of optimization of repair activities of power equipment. Paper presented at the IOP Conference Series: Earth and Environmental Science, 990(1) doi:10.1088/1755-1315/990/1/012042.