

PAPER • OPEN ACCESS

Gradient Energetic Criterion of the Surface Water Layer

To cite this article: A Gazhur and E Myasnikova 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **272** 022101

View the [article online](#) for updates and enhancements.

Gradient Energetic Criterion of the Surface Water Layer

A Gazhur¹, E Myasnikova¹

¹Plekhanov Russian University of Economics t affiliation, Moscow, Stremyanny lane, d. 36, 117997, Russia

E-mail: gajour@mail.ru

Abstract. The article is devoted to the methods of analysis of the surface water layer of oceanic, marine and inland water basins. Due to water pollution, the optical properties of the surface layer are changed. The temperature field in the surface layer is locally transformed. This has a serious impact on the maintenance of the current structure. Water quality is changing. The conditions of existence of flora and fauna are changing. The article analyzes the indicators that determine water pollution. Absence of common energetic characteristic of a condition of a surface water layer is specified. It is proposed to estimate the dynamic picture of the heat absorption process. To do this, a gradient energetic criterion is introduced. The numerator of this criterion shows the intensity of the absorbed solar energy flux by the surface layer with a thickness of 1 m. the Denominator is the magnitude of the maximum possible absorption of the radiation flux. This maximal radiation flux is taken to be the value of the solar constant. The absorption of flow is considered to be evenly. This means linear temperature distribution. The depth of absorption to be a certain predetermined depth at which almost the entire stream of solar radiation is absorbed. The gradient criterion for the contaminated surface layer is several times higher than its value for clean water. That is, the gradient criterion captures the rapid overheating of the surface layer of the polluted water basin. This process, in particular, leads to the displacement of water currents. This is due to the fact that the bulk of the moving layer is at the surface. Also gradient criterion shows the danger of this local overheating for living organisms.

1. Introduction

Pollution of water basins, both ocean and marine and inland, continues to increase. This affects the quality of water and the state of flora and fauna. Pollution causes a change in the optical properties of the surface layer. This locally changes the temperature field in it and, in turn, has a serious impact on the maintenance of the current structure. The main volumes of moving water masses are in the surface layer. Optical changes in the layer can cause the formation of a new flow structure. This will cause large-scale changes from such large temperature deformations.

The most dangerous and well-known precedent is the oil spill in the Gulf of Mexico in 2010 on the oil platform Deepwater Horizon of British petroleum (BP). A sharp change in the color of the sea surface caused an increase in absorption capacity. This, accordingly, caused an increase in temperature in the surface layer of water. In addition to the huge environmental damage, there have been changes in the regime of the Gulf stream movement with unpredictable consequences in the future [1,2]. Similar problems only on a smaller scale arise in other water basins. A range of effective tools are used to identify a number of indicators by which water pollution can be measured. These include, first of all, assessments concerning the organoleptic and chemical composition of water [3, 4, 5, 6].



There are also estimates that relate to the quality of water associated with its temperature. Growth of the temperature indicates the possibility of thermal pollution. For example, emissions of the enterprises of water with a temperature in excess of taken away from the pond, disturb the natural balance of the pond. The temperature increases the differentiation of the layers. The concentration of oxygen dissolved in water is reduced. Blue-green algae are growing. The color, water turbidity and transparency (light transmission) of water are also investigated. Transparency is defined as, for example, the height of the water column through which the text can be read on white paper. Such estimates are taken only at a few points of warm water discharge. But the increase in the absorption of radiation from contaminated water occurs throughout the surface of the reservoir. There is no single relative energy characteristic of the state of the surface layer of water. The albedo index is not quite suitable for this role as it relates to the reflected radiation flux [7]). The use of a single relative energy characteristic of the water surface relative to the flow of radiation incident on it is important to create common models of the behavior of the aquatic environment. This characteristic will show the dependence on changes in the optical characteristics of water caused, in particular, by the level of its pollution. This applies to both oceanic and lacustrine water environment. Pollution can raise or reduce the amount of solar energy absorbed.

2. Basic assumptions and equations

A dimensionless criterion is proposed as an indicator of the effect of the absorption of solar radiation by contaminated water. This is a criterion of energy efficiency of the element of water (and earth) surface relative to the flow of solar energy. The energy efficiency criterion is defined as follows [8]:

$$L = Q_{real} / Q_{max} \quad (1)$$

where L is the energy efficiency criterion of the earth's surface element relative to the solar energy flow;

$Q_{max} = 1367 \text{ [W/m}^2\text{]}$ -solar constant (solar flux passing through a surface element of 1 m^2 , located perpendicular to the radiation flux at a distance of one astronomical unit from the center of the Sun (at the entrance to The earth's atmosphere) [9];

Q_{real} -solar radiation flux absorbed by 1 m^2 of the estimated water surface

In turn, the solar radiation flux absorbed by 1 m^2 of the estimated water surface will be determined as follows

$$Real Q = Q_s(A + D) \quad (2)$$

Here, Q_s is the solar flux incident on 1 m^2 of the estimated water surface;

A -the absorption coefficient of the water surface at this point (based on $A + D + R = 1$, R – reflection coefficient);

D is the solar radiation transmittance of the sea surface at a given point.

The value of the energy efficiency criterion of the earth's surface element relative to the solar energy flow will be:

$$L = Q_s (A + D) / Q_{max} \quad (3)$$

The maximum value of the energy efficiency criterion of the earth's surface element relative to the solar energy flow will be flow value equal to the solar constant (practically unattainable):

$$L_{max} = 1 \quad (4)$$

For any area can be defined criterion of energy efficiency. For example, the criterion can be determined from the annual average of pure water radiation. The change in the criterion will take into account the turbidity of water, the presence of a polluting film, the "flowering" of water. It will indicate a deviation from the water purity standard. Gives the quantitative value of the deviation. The energy efficiency criterion for an earth surface element can be used for the sea and ocean surface. This will determine the temperature drop caused by oil films and other waste floating on the surface.

3. Numerical solutions and analysis of the results

Here is an example of a specific application:

- 1) The sea surface is clean ($L_p = L_{pure}$):

$$Q_s = 700 \text{ [Vt/M}^2\text{]};$$

$$(A + D) = 0,95;$$

$$L_p = Q_{real} / Q_{max} = 700(0,95) / 1367 = 0,486$$

This means that the proportion of solar energy absorbed by the clean sea surface is 0.486 per cent of the solar energy before it passes through the atmosphere.

2) Contaminated sea surface ($L_d = L_{dirt}$).

$$Q_s = 700 \text{ [Vt/M}^2\text{]};$$

$$(A + D) = 0,80;$$

$$L_d = Q_{real} / Q_{max} = 700(0,80) / 1367 = 0,41$$

This means that the share of solar energy absorbed by the polluted sea surface is 0.41 of the solar energy flow before it passes through the atmosphere. Similarly, the value of the criterion of energy efficiency of the earth's surface element can be determined depending on the composition of the surface layer, for example:

3) Ground surface (sand) ($L_s = L_{sand}$).

$$Q_s = 700 \text{ [Vt/M}^2\text{]};$$

$$(A + D) = 0,95;$$

$$L_s = Q_{real} / Q_{max} = 700(0,70) / 1367 = 0,358$$

This means that the proportion of solar energy absorbed by the earth's surface (sand) is 0.358 from the flow of solar energy before it passes through the atmosphere [10].

Table 1. The energy efficiency criterion.

Place of determination of the energy efficiency criterion	$L = Q_{real} / Q_{max} = Q_s(A + D) / Q_{max}$
Clean sea surface	0,486
Contaminated sea surface	0,410
Land surface (sand)	0,358

It is also possible to assess the dynamic picture of the heat absorption process, for example, by the ocean surface. To do this, we can introduce a gradient criterion for L_{grad} energy absorption. Gradient energy absorption criterion L_{grad} shows the intensity with which the solar energy flux is absorbed by the surface layer of 1 m thickness, with respect to the absorption of the maximum possible radiation flux $Q_{max} = 1367 \text{ [W/m}^2\text{]}$ (solar constant). We will assume that the temperature distribution in depth is linear.

$$L_{grad} = (Q_{real}/X)/(Q_{max}/X_0) \quad (5)$$

X is the absorption depth of the main energy flow in the real object. As X_0 , we take the depth of 100m- we assume that at this depth the entire q_{max} flow is absorbed. Then the value of the base gradient will be equal to

$$grad_0 = Q_{max}/X_0 = 1367 / 100 = 13,67 \text{ [Vt/M]} \quad (6)$$

1) We are looking for a gradient criterion of energy absorption for a clean sea surface. The depth X at which the whole radiation flux is absorbed is considered to be equal to 80 m. The gradient value at this is equal to

$$grad_p = Q_{real} / x = 700 / 80 = 8,75 \text{ [Vt/M]} \quad (7)$$

The gradient criterion for energy absorption for a clean sea surface is

$$L_{gradp} = (Q_{real} / x) / (Q_{max} / X_0) = 8,75 / 13,67 = 0,64 \quad (8)$$

2) We are looking for a gradient criterion of energy absorption for the polluted sea surface. The depth X at which the entire radiation flux is absorbed is 10 m. The gradient will be equal

$$grad_d = Q_{real} / x = 700 / 10 = 70 \text{ [Vt/M]} \quad (9)$$

A gradient criterion of energy absorption for a contaminated sea surface

$$L_{grad} = (Q_{real}/X)/(Q_{max}/X_0) = 70/13,67 = 5,12 \quad (10)$$

Table 2. The gradient criterion.

Place of definition of the gradient criterion for the energy absorption	$L_{grad} = (Q_{real}/x)/(Q_{max}/X_0)$
Unpolluted sea surface	0,64
Contaminated sea surface	5,12

Thus, the gradient criterion for a contaminated surface is 8 times greater than its value for an unpolluted one. This shows the rapid overheating of the surface layer of the polluted sea. And this is despite the fact that the criterion of energy efficiency of the surface (the level of solar energy absorption) at the contaminated surface is lower ($L_p = 0,486$, $L_d = 0,41$).

For ocean and sea water, the temperature change in the deeper surface layer is also significant. This change can cause water currents to change. Therefore, it is possible to apply a different modification of the energy efficiency criterion of the earth's surface element.

Select the temperature equalization point at the depth (about 100m) and consider the 100-meter "rod" of water with a cross-section area equal to 1m^2 , starting from the surface and ending at a depth of 100m. To solve such a thermal task, can be used the differential equation for a semi-bounded rod with a given temperature at one end (temperature at a depth of 100 m), that is, with Dirichlet boundary conditions and Neumann boundary conditions at the other (surface). But the solution of such a task is more difficult, and how much the result will be more effective is unknown.

4. Conclusion

The introduction of a number of criteria based on a single relative characteristic of the surface relative to the flow of incident solar energy - criteria for the energy efficiency of the earth's surface element – can help to assess the ecological state of the Earth.

5. References

- [1] Kozina O V, Dugin V S 2013 *Climate forcing of ocean currents* (Nizhnevartovsk: Bulletin of the Nizhnevartovsk state University) vol 3 pp 22-31
- [2] Malinin V N 2012 *Gulf stream and climate of Europe* (Saint-Petersburg: Society. Environment. Development) vol 1
- [3] State Standard 27065-85 Water Quality. Terms and definitions
- [4] State Standard 17.1.1.01-77 Use and protection of water. Terms and definitions
- [5] State Standard 2874-82 Drinking water
- [6] Sanitary-epidemiological rules and norms 2.1.4.559-96 Drinking water. Hygienic requirements to water quality of centralized drinking water supply systems. Quality control
- [7] Seager S 2010 *Temperature, Albedos, and Flux Ratios* (Princeton Exoplanet Atmospheres: Physical Processes Princeton University Press) pp 35–38
- [8] Gazhur A 2013 *The systemic criteria assessment basic economic structure: territory, infrastructure, processes, production chains, end-products* (Moscow: Economics of the company) vol 2 no 3-4 pp 35-39
- [9] Makarova E A, Kharitonov A V 1972 *Energy Distribution in The sun spectrum and the solar constant* (Moscow)
- [10] Gazhur A 2017 *The criterion of energy efficiency of the element of the earth's surface relative to the flow of solar energy* (Moscow: Cost-effective and environmentally friendly innovative technologies materials of the Third International scientific and practical conference) pp 258-265