UDC 528.44

V. A. Ryabchii,
V. V. Ryabchii, Cand. Sc. (Tech.), Assoc. Prof.,
M. V. Trehub, Cand. Sc. (Tech.),
Yu. Ye. Trehub

State Higher Education Institution "National Mining University", Dnipro, Ukraine, e-mail: nikolaytregub@gmail.com

SUBSTANTIATION OF LAND PARCEL CONFIGURATION IN BUFFER ZONES

В. А. Рябчій,
В. В. Рябчій, канд. техн. наук, доц.,
М. В. Трегуб, канд. техн. наук,
Ю. Є. Трегуб

Державний вищий навчальний заклад „Національний гірничий університет", м. Дніпро, Україна, e-mail: nikolaytregub@gmail.com

ОБҐРУНТУВАННЯ КОНФІГУРАЦІЇ ЗЕМЕЛЬНИХ ДІЛЯНОК ОХОРОННИХ ЗОН

Substantiation of the rational use principles for land of different purpose is a priority of the state policy in Ukraine. Determination of the optimal size and form of land parcels is one of the components of their rational use. According to the regulations of Ukraine, the information about land parcels and restrictions on their use is essential for the national cadastre system. The restrictions of use of land are important for land users and property development. For registration purposes, their location, configuration and size should be clearly identified.

Purpose. The purpose of the publication is to establish the optimal number of angles of rotation of land parcel boundaries in sanitary protection zones, and to determine permissible errors in calculation of their area.

Methodology. The scientific research is based on the use of systematic approach to solving the defined problem: classical geometry methods combined with theoretical and applied foundations of the theory of measurement errors, which are used to process the results of geodetic measurements.

Findings. The research made it possible to carry out preliminary accuracy calculations of the area of land parcels with the configuration of a regular polygon inscribed in a circle. Also, the optimal size of the chord is substantiated, which allows minimizing the values of area errors and the number of angles of rotation of land parcels provided for conversion to the field.

Originality. For the first time, the problem of justification of buffer zone configuration and preliminary evaluation of the accuracy of calculating the areas of land parcels that have the configuration of a regular polygon inscribed in a circle was defined and solved without calculating the coordinates of its vertices.

Practical value. The practical value of the research is in the development of unified approaches to evaluation of the accuracy of calculating the area of land parcels that have configuration of a regular polygon which are intended for the state registration in the state land cadastre.

Keywords: *buffer zone, the configuration of land parcel*

Introduction. The historical process of rights and property development is always combined with different types of restrictions and the rights of third parties. Current trends of land-use and land protection in Ukraine contain very important part – the guarantee of rights by the country. State legal acts of Ukraine set clear standards that define restrictions of land use depending on the hazard type and class of the corresponding object.

According to the Land Code of Ukraine and Law of Ukraine "On land management" [1, 2], the information about restrictions of land use is specified in:

- land management schemes, technical and economic substantiations of land use and protection of administrative and territory units;
- land management projects on the organization and determination of boundaries of the territories of nature reserve fund and other nature protection, health, recreational, historical, cultural, forestry purpose, water fund

and water protection zones, restrictions on the use of land and regime-forming facilities;

- land management projects on the ecological and economic justifications of crop rotation and streamline the lands;

- land management projects on the allocation of land parcels;

- technical land management documentation on the determination of land parcel boundaries;

- general plans of territories;

- detailed plans of territories;

- zoning plans.

The components of land use restrictions are sanitary protection zones which are set around important natural objects of cultural heritage, meteorological stations, along communication lines, power lines, land transport, around industrial facilities.

The structure of the protection zones includes buffer zones and zones of special treatment of land use. Relevant areas are formed to ensure normal operation of facilities, prevent injuries and reduce their negative impact on people and the environment, adjacent land and other natural objects.

It is well known that Ukraine is an agrarian country. Nevertheless, we can observe ramified network of industrial regions, districts and centers distributed in the territory of the country. A buffer zone usually stretches from sources of harm to the boundaries of residential areas, areas of public facilities, buildings and structures, including children, education, health care institutions, institutions of social security, sports facilities, etc., as well as areas of parks, gardens and other green building objects of general use, health and parcels of sports facilities, recreation, gardening societies and other facilities equal to them.

According to the State sanitary rules for planning and housing of settlements approved by the order of Ministry of Health of Ukraine, there are three approaches to determining the size and configuration of buffer zones [3]:

- for companies involved in processes which are sources of air pollution including an unpleasant odor, chemicals and biological factors, buffer zones are set immediately from the sources of organized emissions of air pollutants (through the pipes/mines) or fugitive emissions (through the lights of buildings, smoking and steaming surface of processing plants and other facilities, etc.), as well as the place of unloading raw, industrial products or open warehouses;

- for companies with processes producing noise, ultrasound, vibration, static electricity, electromagnetic and ionizing radiation and other hazards – from buildings, structures and sites where the equipment is installed (units mechanisms), creating these hazards;

- thermal power, industrial and heating plants – from smokestacks and places of storage and preparation of fuel, sources of noise;

- for sanitary installations and installations of municipal purpose, as well as farms and facilities – from the boundary of the object.

The dimensions of buffer zones are set depending on the class and type of industrial hazards, and some are listed in Table 1.

Similar approaches to classification (Table 1) of harm industries exist for the construction industry, wood processing, textile production, processing and animal food, sanitary and other communal facilities.

Unsolved aspects of the problem. Article 111 [1] establishes that the burden of land rights is subject to state registration in the State Register of Rights to Immovable Property, while restrictions in use – in the State Land Cadastre. The question of determination of boundaries of land parcels of buffer zones for single objects of harmful effects is currently acute. Such land parcels should have the circle configuration. The relevant zones are easy to design on the map or plan and calculate their areas; however, it is necessary to determine the boundaries of land parcels on the surface using geodetic methods and appropriate registration. This is important for many reasons, especially to establish efficient and correct use of land designed for allocation near the areas of restrictions. This practice exists in the context of water protection zones.

To perform this study, we will focus on the harmful effects of single objects of harmful effects or objects requiring protection, e. g. smokestacks or water wells. The optimal configuration of land parcel for these objects will be circular.

The determination of boundaries on the surface in the shape of a circle or a square is not appropriate and not rational. Obviously, the configuration should be determined in the form of a regular polygon. And this raises the question: how many angles of rotation should be there, whose mean square error must be identified, and which error of the area of land will be determined?

Analysis of the recent research and publications. The rationale of accuracy of the determination of boundaries of land parcels on the surface for their future use are provided by recognized experts Y. Hubar, L. Perovych, A. Tserklevych, etc. [4–6]. The publications by V. Riabchii and M. Trehub [7, 8] were devoted to the assessment of accuracy of boundary rotation angles of land parcels and their number and systematization of approaches to

Table 1

Dependence of the size of a buffer zone on the class of the industrial enterprise hazard

Class	Type of industry		
	Chemical, m	Metallurgical, machine-building and metal-working, m	For extraction of ores and non-metallic minerals, m
I А	3000	1000	1500
I Б	1000		1000
II	500	500	500
III	300	300	300
IV	100	100	100
V	50	50	50

rational land use. The ecological problems of land-use and air pollution in cities were systematized by [9]. It should be noted that no scientific publication devoted to the study of the issue of accuracy of round land parcels has been found.

The objectives of the article. For the rational design of land protection zones within the restrictions there should be unambiguous methodological approaches to determining the configuration and size. In this regard, the purpose of the publication is to establish the optimal number of land boundary rotation angles of buffer zones, and to determine permissible error of their area.

Presentation of the main research. For further presentation of research results, there should be taken into account the following values (parameters): R – radius of circle; C – circumference; S_{cr} – area of circle; S_{sk} – area of sector; S_{sg} – area of segment; l – length of circle arc; h – length of chord; φ – central angle; a – sagitta.

These values were calculated using formulas that are well known to the reader, but we should summarize them

$$C = 2\pi R;$$

$$S_{cr} = \pi R^2;$$

$$a = R - \sqrt{R^2 - \frac{h^2}{4}} = R\left(1 - \cos\frac{\varphi}{2}\right) = \frac{h}{2}\operatorname{tg}\frac{\varphi}{4};$$

$$h = 2R\sin\frac{\varphi}{2} = 2\sqrt{2aR - a^2};$$

$$l = \frac{2\pi R\varphi}{360};$$

$$S_{sk} = \frac{\pi R^2\varphi}{360};$$

$$S_{sg} = \frac{R^2}{2}\left(\frac{\pi\varphi}{180} - \sin\varphi\right) = \frac{1}{2}\left[lR - h\left(R - a\right)\right].$$

The calculation of above mentioned parameters for the circle of R = 100 m is given in Table 2.

According to [10] "In terms of curved segments, boundaries should be defined depending on the radius of curvature. The next point is coordinated in locations where the tangent passing through the previous point and curve diverge is over 0.25 m". Following these requirements, for R = 100 m, values are listed in the first row in Table 2. The length of the chord is 14.1 m, the central angle φ = 8°06′16.3″, and the number of points that need to be defined is from rounding n = 45. For such a small radius and area S_{cr} = 31415.9 m^2 there are too many points to be defined on the terrain, although the ratio of the segment area and sector area is small.

Of course, the bigger the number of rotation angles is, the smaller the value of the mean square error of land area is. Obviously in such cases it is necessary to set the optimum number of rotation angles and mean square error for land area in the shape of a polygon. To compare parameters at different values of the central angle, the relevant calculations were made and are presented in Table 2.

For example, let us consider a circle of twelve sectors and a corresponding number of vertices in Figure.

The number of rotation angles to denote is n. The number of diagonals to calculate the mean square error of the area is also n.

The formula for calculation of permissible mean square error m_{sd} for the area of regular polygon will be the following

$$m_{sd} = \frac{m_{td}}{\sqrt{8}}\sqrt{\sum_{i=1}^{n} D^2_{(i+1)-(i-1)}},$$

where m_{td} is permissible mean square error of determination of position of rotation angles of land parcel; $D(i+1) - (i-1)$ are polygon diagonals, which in the case of a regular polygon are equal to each other and equal to chord sector with the central angle 2φ, Figure. The number of diagonals will be equal to the number of vertices in polygon n, i. e. we can write the formula

$$m_{sd} = \frac{m_{td}h_{2\varphi}}{\sqrt{8}}\sqrt{n}. \qquad (1)$$

For example, the central angel φ = 30°, then n = 12 and the chord of the sector of 2φ will be the radius – $h_{2\varphi} = R$ = 100 m, Table 2, row 6. According to [10], the recommended maximum length between rotation angles of boundaries of land parcels should be equal to 50–80 m. This length of chord is not presented in calculations in Table 1, but there are similar values when φ = 30°, h = 51.764 m. Considering the value of central

Table 2

Values of inscribed polygon depending on the value of the central angle

№	R, m	C, m	S_{cr}, m^2	φ°′ ″	h, m	a, m	l, m	S_{sk}, m^2	S_{sg}, m^2	n	$\frac{S_{sg}}{S_{sk}}$	ΔS, m^2	K_s, %
1	100	628.319	31415.9	8°06′16.3″	14.133	0.250	14.145	707.2	2.3	44.4	1/300	104	0.3
2				15	26.105	0.856	26.180	1308.9	14.9	24	1/88	358	1.1
3				20	34.730	1.519	34.907	1745.3	35.2	18	1/50	634	2.0
4				30	51.764	3.407	52.360	2617.9	117.9	12	1/22	1416	4.5
5				40	68.404	6.031	69.813	3490.6	276.7	9	1/13	2490	7.9
6				60	100.00	13.397	104.720	5235.9	905.8	6	1/6	5435	17.3

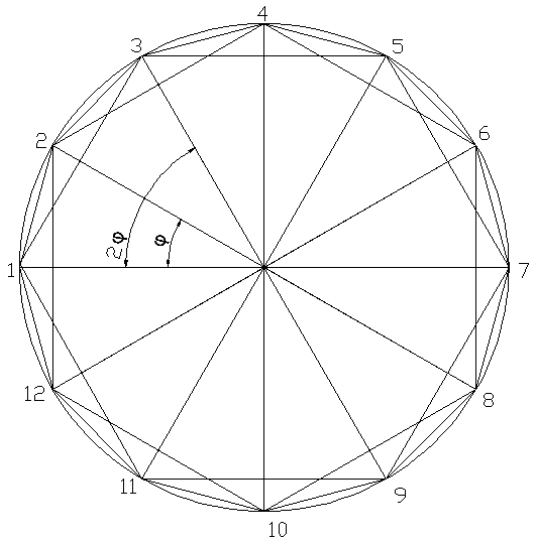

Fig. Arbitrarily inscribed dodecahedron

angel φ = 30° and the chord length, we may accept exactly the same parameters during the process of determination of boundaries for a circle with radius $R = 100$ m. A similar approach can be adopted with land parcels with other radii, only in case the number of sectors (chords) is integer.

The proposed approach to establishing the same values of the diagonals of the polygon will lead to the case when under the same mean square errors, the location of rotation angles on the ground and values of mean square errors areas of land will be minimal. That is, the permissible value of the mean square error of regular dodecahedron area must be calculated using the formula (1). But these values are permissible errors of dodecahedron area with a radius of the described circle $R = 100$ m. The differences between the areas of land parcels of circular and polygonal shapes (ΔS) will equal the area of the segment multiplied by the number of the sectors, m^2.

$$\Delta S = n \cdot S_{sd};$$

$$\Delta S = 12 \cdot 117.994 = 1415.928,$$

which, with regard to the area of the circle with $R = 100$ makes

$$K_s = \frac{n \cdot S_{sd}}{S_{\hat{e}\partial}} = \frac{1415.928}{31415.925} = \frac{1}{22}.$$

The percentage range is $K_s = 4.5$ %.

At the first glance, the value of relative error is large, but let us consider the size of this segment. To simplify, the segment can be considered as two triangles with one common side $a = 3.497$ m, the other ones are 26.105 and 25.882 m. On the land parcels of such sizes, the construction of large industrial and civil buildings is impossible. Let us assume that these values of areas could be neglected. Moreover, this factor can be considered in terms of the length of the curve. As is known, the length of arc is the limit to which the length of the polylines is approaching, with its longest part approaching to zero. Let us calculate the ratio $K_l = h/l$ for the sector of inscribed dodecahedron (Table 2) 51.764 / 52.360 = 0.989. The ratio of the sum of twelve chords to the length of the entire circumference is the same. If converted to percentage, the losses in length will be $\Delta l = 1.1$ %.

The mean square error of area of land parcel using (1) could be calculated for different types of settlements using different permissible mean square errors of determination of position of rotation angles of land parcel. The permissible mean square errors are the following:

- in Kyiv, Sevastopol and cities – regional centers and cities of regional subordination – 0.1 m;
- other cities and settlements – 0.2 m;
- in villages – 0.3 m.

Using the above mentioned conditions the values of permissible mean square error of area will be the following, m^2

$$m_{sd1} = \frac{m_{td1}}{\sqrt{8}} h\sqrt{n} = \frac{0.1*100}{\sqrt{8}}\sqrt{12} = 12.2;$$

$$m_{sd2} = \frac{m_{td2}}{\sqrt{8}} h\sqrt{n} = \frac{0.2*100}{\sqrt{8}}\sqrt{12} = 24.5;$$

$$m_{sd3} = \frac{m_{td3}}{\sqrt{8}} h\sqrt{n} = \frac{0.3*100}{\sqrt{8}}\sqrt{12} = 36.7.$$

During the mathematical processing of geodetic measurements results, different definitions of the importance of systematic error are used. To assess the accuracy by differences of double equal observations, the influence factor is taken as $K = 0.2$. In [7], three criteria of the significance of the impact of coordinate rounding errors depending on the value of the mean square error of area are defined. Such criteria are between 2–5 %, but for the urban territories 2 % is recommended. Similar restrictions can be suggested in this research.

Research conclusions and recommendations for further research.

1. To enhance the visibility, validity and accuracy of land management and planning information, it is necessary to provide the determination and registration of all types of buffer zones.

2. Special attention should be paid to the buffer zones of circle configuration. For single objects, inscribed polygon is suggested as the form of the buffer zones.

3. The research has made it possible to determine the formula of calculation of the permissible mean square error of the area of buffer zones without calculating the coordinates of the polygon rotation angles.

4. It has been defined that the chords (lengths of polygon sides) should be $h = 50–55$ m and the length of the diagonal will be estimated as 100 m. The increase in the length of the polygon will make losses of the circle space significant, and in case of reduction, the number of angles of rotation to be determined will increase, and the reduction of area errors of will not compensate anything.

5. The investigation provided an opportunity to develop a method of calculating the parameters of a polygon inscribed in a circle of the given radius. This approach ensures determining the minimum mean square error of the polygon area.

Further research should be focused on determining the mean square error of angles of rotation of boundaries of buffer zones as a result of their conversion to the field, depending on the radius. The radius of buffer zones could be used according to the State sanitary rules for planning and housing of settlements [3] for different types of industries.

References.

1. Land Code of Ukraine as of 25.10.2001 No. 2768-III., 2001. [online] Available at: <http://kodeksy.com.ua/zemel_nij_kodeks_ukraini.htm> [Accessed 15 September 2016].

2. № 858-IV, 2001. [online] Available at: <http://online.budstandart.com/ua/catalog/doc-page?id_doc=61675> [Accessed 12 September 2016].

3. State sanitary rules for planning and housing of settlements approved by the order of Ministry of Health of Ukraine as of 19.06.1996 No. 173. [online] Available at: <http://dnaop.com/html/2375/doc%D0%94%D0%A1%D0%9F_173-96> [Accessed 4 October 2016].

4. Hubar,Yu., 2011. Calculation of the necessary accuracy of coordinates of boundary markers to assess the land of settlements. *Geodesy, cartography and aerial photography*, 74, pp. 132–135.

5. Tserklevych, A., Deineka, Yu. and Petrov, S., 2012. On an accuracy assessment method for calculation of land area. *Modern achievements of geodetic science and production: Proceedings of West. Geod. Company UAGC*, I(23), pp. 263–267.

6. Perovych, L. M. and Tkachyk, O. I., 2011. Determination of zones of restricted use taking into account the impact of electromagnetic fields of power lines. *Geodesy, cartography and aerial photography*, 74, pp. 108–116.

7. Riabchii, V. A. and Riabchii, V. V., 2003. Influence of rounding errors in angles of rotation for land parcels on the accuracy of their area calculation. *Engineering Geodesy: Sc.-tech. coll*, 49, pp. 193–201.

8. Petrakovska, O. and Tregub, M., 2017. Current State of Industrial Land-Use in Ukraine. In: *Land Ownership and Land Use Development: the Integration of Past, Present, and Future in Spatial Planning and Land Management Policies*, pp. 319–325.

9. Biliaiev, M. M., Rusakova, T. I., Kolesnik, V. Ye. and Pavlichenko, A. V., 2016. The predicted level of atmospheric air pollution in the city area affected by highways. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, 1, pp. 81–87.

10. GUGKK, 1993. *Leading technical matter "Land inventory for settlements (surface methods)",* approved of 02.02.1993, Order No. 6, Kyiv.

Обґрунтування принципів раціонального використання земельних ділянок різного цільового призначення є пріоритетом державної політики в Україні. Однією зі складових їх раціонального використання є визначення оптимальних розмірів і форм земельних ділянок. Відповідно до чинних нормативно-правових актів України, обов'язковому внесенню до державного земельного кадастру підлягають не лише земельні ділянки, але й обмеження у їх використанні. Важливими для землекористувачів і ведення державного земельного кадастру є обмеження у використанні земельних ділянок. Для проведення державної реєстрації необхідно визначити їх місцезнаходження, конфігурацію й розміри.

Мета. Встановлення оптимальної кількості вершин кутів поворотів меж земельних ділянок санітарно-захисних зон і зон санітарної охорони, а також визначення допустимих похибок їх площі.

Методика. Обчислення базується на використанні системного підходу до вирішення поставленої задачі: методів класичної геометрії, поєднаної з теоретичними й прикладними основами теорії похибок вимірювань, що використовуються для оброблення результатів геодезичних вимірювань.

Результати. На підставі проведеного дослідження стало можливим виконувати попередні розрахунки точності обчислення площ земельних ділянок, що мають вигляд багатокутника, вписаного в коло. Також встановлені значення розмірів хорди, що дозволяє отримувати мінімальні значення похибок площ та оптимальну кількість вершин кутів поворотів меж земельних ділянок, які передбачаються для перенесення на місцевість.

Наукова новизна. Уперше поставлена й вирішена задача обґрунтування конфігурації охоронних зон і попереднього оцінювання точності обчислення площ земельних ділянок, що мають форму багатокутника, вписаного в коло, без обчислення координат його вершин.

Практична значимість. Полягає в розробленні єдиних підходів щодо оцінювання точності обчислення площ земельних ділянок, що передбачаються для державної реєстрації в державному земельному кадастрі.

Ключові слова: *санітарно-захисна зона, зона санітарної охорони, конфігурація земельної ділянки*

Обоснование принципов рационального использования земельных участков различного целевого назначения является приоритетом государственной политики в Украине. Одной из составляющих их рационального использования является определение оптимальных размеров и форм земельных участков. В соответствии с действующими нормативно-правовыми актами Украины, обязательному внесению в государственный земельный кадастр подлежат не только земельные участки, но и ограничения в их использовании. Важными для землепользователей и ведения государственного земельного кадастра являются ограничения в использовании земельных участков. Для проведения государственной регистрации необходимо определить их местонахождение, конфигурацию и размеры.

Цель. Установление оптимального количества вершин углов поворотов границ земельных участков санитарно-защитных зон и зон санитарной охраны, а также определение допустимых погрешностей их площади.

Методика. Вычисления базируются на использовании системного подхода к решению поставленной задачи: методов классической геометрии, сопряженной с теоретическими и прикладными основами теории ошибок измерений, используемых для обработки результатов геодезических измерений.

Результаты. На основании проведенного исследования стало возможным выполнять предварительные расчеты точности вычисления площадей земельных участков, которые имеют вид многоугольника, вписанного в окружность. Также установлено значение размеров хорды, которое позволяет получать минимальные значения погрешностей площадей и оптимальное количество вершин углов поворотов границ земельных участков, которые предусматриваются для переноса на местность.

Научная новизна. Впервые поставлена и решена задача обоснования конфигурации охранных зон и предварительной оценки точности вычисления площадей земельных участков, которые имеют вид многоугольника, вписанного в окружность, без вычисления координат его вершин.

Практическая значимость. Состоит в разработке единых подходов к оценке точности вычисления площадей земельных участков, которые предусматриваются для государственной регистрации в государственном земельном кадастре.

Ключевые слова: *санитарно-защитная зона, зона санитарной защиты, конфигурация земельного участка*

Рекомендовано до публікації докт. техн. наук Р. О. Дичковським. Дата надходження рукопису 18.06.16.