Parklands of “Dynamo” park, “Naval Fleet Officers’ House” in the city of Khabarovsk and their ecological state

V I Roslikova¹ and T I Matveenko²

¹ Institute of Water and Ecological Problems of Far Eastern Branch of Russian Academy of Sciences, Khabarovsk
² Federal State Budgetary Educational Institution of Higher Education “Pacific State University”, Khabarovsk

Corresponding author’s e-mail: roslikova@ivep.as.khb.ru
Corresponding author’s ORCID ID: https://orcid.org/0000-0001-5689-5016

Abstract. On the example of the park zones of the city of Khabarovsk (“Dynamo” and "House of officers of the fleet"), a variety of transformation of the soil cover and the formation of new preferred formations were revealed. The specificity of the state of the soil environment of two parks, located in same type of engineering-geological conditions, but different variants of anthropogenic impact, is revealed. The changes in the structure of the profiles depending on the position of the soil in the elementary landscape are considered and their biological activity is characterized. The use of bioindication methods indicates that the most comfortable park areas of the city are also susceptible to contamination with heavy metals. It is proposed to use the characteristics of the basic parameters of the soil cover as a promising approach in improving the environment. This will reveal the ecological situation of the territory and make appropriate decisions to improve its condition.

Key words: transformed soils, pre-soil formations, elementary landscapes, biological efficiency, heavy metals

1. Introduction

Over the last two decades the significant part of soil in fulfilment of important ecological functions ensuring convenience of medium in city ecosystems has been revealed [1, 3, 10]. In relation to such evaluation of soil cover condition in urban terrain, diverse researches directed at its study obtained the special actuality. In Far East the institute of Water and Ecological Problems of Far Eastern Branch of Russian Academy of Sciences has been conducting the research of soil transformation in city ecosystems [7, 8, 10] since 1998. Parklands’ soils are basic components of urban system which makes city ecological conditions comfortable [9]. Due to the significance of this object and the fact it is unstudied within large industrial center of the city of Khabarovsk, the following aim was set: evaluate the condition of transformed soils for two parklands (“Dynamo” and “Naval fleet officers’ house” - “Far Eastern Federal District”) located in various city areas, but in identical engineering and geological conditions, find out the peculiarities of their bio efficiency and ecological state.

Test objects are represented by soils forming in two parks (the parks of “Dynamo” and “Naval fleet officers’ house” – “Far Eastern Federal District”). “Dynamo” park with area of 31 hectares is situated...
in the center of the city of Khabarovsk on wavy and hillside surface consisting of eluvial formations of tufa and sedimentary rock (clay, loam, grus, crushed stone) weathering zone [8]. It is a federally significant natural landmark which has been created in aid of preserving and reinstating disturbed natural complexes and as well as to create an ecologically clean environment. Restoration works have been conducted on this territory several times. After the last restoration, the floodplain of river Plyusninka was turned into city ponds. By resolution (dated Jan. 17, 2008 No. 44) “Dynamo” park along with the ponds was included in the category of designated conservation areas of local significance.

“Naval fleet officers’ house” park with the area of 3.2 hectares is situated in the northern city district in conditions of geological medium identical to “Dynamo” park. It is an independent architectural and landscape object designed for various forms of recreation activities. In April 2020, the city administration approved of the resolution (No. 1210) granting the “Naval fleet officers’ house” park the status of local significance conservation area.

Used Research methods are widely applied in soil science: specific and genetic, morphological, physical and chemical. The basis for methodological prerequisites is substantively genetic classification [5].

Phytotoxicity – the property of contaminated soil to suppress the germination of higher plants’ seeds – was used as a composite indicator for soil contamination. Oat seeds were used in this study. The determination of phytotoxicity effect was conducted via comparing average criteria of feature test for reference and test seeds and oat. Test reaction was determined by the gradation of phytotoxicity effect display [2]. If phyto-effect (ET) is 20% and more than that soils are considered toxic and affect plants negatively.

2. Findings and interpretation
Comparative analysis of morphological and diagnostic features of transformed soils reveals the condition of soil cover of the territory under research. Their analysis gave grounds to pick out the following types of soils.

1. Variously human-disturbed natural soils. Surface-disturbed brown soils have preserved in both parks (profiles 7, 9, 25). General profile: Ad (0–2 cm) – AY/Ad (2–8 cm) – U1 aR (8–20 cm) – U2R aB1(20–32 cm) – U3 aR B2 (32–49 cm) – C (49–65 cm). This group of soils is notable for the integrity of genetic profile. There are local small lenses of the below laying in accumulative horizon. The transition line is clear.

2. Deeply disturbed brown soils (profiles 5, 23). Profile: O (0–0.1 cm) – O/Ad (0.1–1 (1.5 cm) – A1 (1.5–5 (9 cm)) – U1 B1(5 (9–42 cm)) – U1 B2/C (42–68 cm) – C (68–120 cm). Urbanised layer range within 57 cm. It is enriched with sand inclusions, splinters of glass, crushed stone, brick, concrete. In both groups of soils (1, 2) forest cover, sod horizon typical for brown soils gets formed.

3. Urban soil – pre-soil formations (profiles 10, 13). Profile: U1 a3 [AY] (0–0 cm)– U2 a2 (10–48 cm) – C (48–70 cm). Their peculiarity is poor sophistication of accumulative layer; the thickness of urbanised soil is 35–48 cm. Layers of various thickness are enriched with inclusions of different waste.

4. Urban soil, stratified. Profile: O (0–1 cm) – U 1R [A1] – (1–12 cm) – U2 R (12–25 cm) – U3 R [A1] (25–45 m) – C(45–65 cm) is noted for the absence of accumulative layer; moved layers reach thickness of 45 cm.

5. Rudezem. Profile: O–0.1 cm – Ad (0.1–5 cm) – U1R a5(5–55 cm) – U2r(AY). These are synlithogenic pre-soil formations on construction waste, widespread locally on the territory of “Dynamo” park (profile 6, ravine slopes). Their peculiarity is great urbanised thickness (130 cm).

6. Urban soils, pyrogenic (profile 24 “Naval fleet officers’ house” park). Profile: O (0–0.1 cm) – Apir (0,1–8 cm) – U1 [Apir] (8–25 cm) – U2 a2 (25–59 cm) – U3 a3 (59–65 cm). Pyrogenic process (Apir) in it covered the thickness of up to 25 cm. Lower layers are enriched with man-made inclusions in various degree.

7. Peaty and gleyed, urbanised (profile 8. “Dynamo” park). Profile: U1Ad/ATa 0-19 cm) – G U2 a3(19-35 cm). Developed peaty and gleyed grassy accumulative layer is characteristic for it. Lower gleyed layers are enriched with domestic waste. Addressed diagnostic features of soils reveal a complex
transformation of soil cover for “Dynamo” park, unlike for “Naval fleet officers’ house” park. It is conditioned by multiple reinstatement works conducted on the territory of the park. One of peculiar directions of transformation of urbanised landscapes’ soils is a change in their acidity. For soil cover in “Dynamo” park, the main trend of change in this criterion is shifting to neutral and weakly alkaline range. Values within the range of 6.5-7.5 prevail. Differential peculiarity of soil cover in “Naval fleet officers’ house” park is shifting of this criterion to the side of acid reaction pH=3.7-4.9 (table 3). Such criteria of pH are peculiar to brown soils of far eastern soil and climatic area which is not subject to intense human impact. However, in pyrogenic urban soil (profile 24 “Naval fleet officers’ house” park) it is approaching weakly acid reaction pH=6.1, which is conditioned by pyrogenic process which ensured the reduction of brown soils’ acidity. All in all, pH value of soils in the territory under search varies within a wide range – extremely highly acid to neutral values and alkaline reaction. In soils of “Naval fleet officers’ house” park, the reaction of medium is acid (4.7-4.9). The exception is pyrogenic urban soil.

With regard to peculiarities of studied soils and pre-soil formations it is necessary to consider their biological activity which has been evaluated by CO2 emission rate. Focusing on accumulative horizons of transformed soils in “Dynamo” park, it should be noted that the greatest respirometric activity is peculiar to soils which preserved natural features. Besides there is a tendency to its increase in separate horizons of brown soils (table 1). It is conditioned by the presence of organic matter, the genesis of which doesn’t matter (natural or additionally introduced) [3]. Low respirometric activity is a feature of stratified brown soils which is conditioned by the depauperisation of organic component mineral layer (profile 12, 13). In brown soils of “Naval fleet officers’ house” park, it lays within weal values, excluding pyrogenic urban soil. Its respirometric activity reaches medium values, which is triggered by the shift of acidity to weakly acid reaction of medium conditioned by pyrogenic process.

Complex pattern structure of soil influenced the degree of oat germination as well. Feature test by criteria of oat growth for reference \(L_h\) and test \(L_t\) soil samples witnesses, generally, the revelation of inhibition effect (Table 2). In “Dynamo” park only in 2 accumulative horizons (profiles 5, 6 – accordingly (brown soil and rudezem) oat roots length exceeded \(L_h\) only by 3–7 cm. In all the rest there is no growth at all. Their length didn’t reach the value of reference within the limits from 2 to 52 mm. In accordance with the comparative evaluation of soil biological activity scale, it is weak and only in two samples it may be, to some degree, evaluated as normal.

Differential peculiarity of transformed soil formations in “Naval fleet officers’ house” park is sharp increase of oat growth \(L_e\) compared to \(L_h\) by 10–15 cm (table 3). The greatest growth is noted in horizons with more acid reaction (pH =4.7). However as well in pyrogenic urban soil at pH=6.1 in “Naval fleet officers’ house” park the exceed of oat growth reaches 15 mm, which at such pH in pre-soil formations in “Dynamo” park is characterised as negative result. This speaks of general contamination of soil medium in “Dynamo” park.

Considering territorial location of “Dynamo” park in central, more intense city part, let’s address the degree of transformed soils contamination with heavy metals (table). The concentration of moving forms of quicksilver in accumulative horizons exceeds their background content from 0.9 to 5.40 times. The greatest excess of maximum permissible values is typical of stratified brown soils. The biota activity is low in them as well. The concentration of zinc in all profiles exceeds threshold limit value from 1.6 to 6.3 times. The highest values of zinc appeared in peaty and gleyed urbanized soil (profile 8). For zinc, it is also typical to have an excess compared to the background from 1.4 to 9 times, with the greatest part of concentration also in peaty and gleyed urbanised soil (profile 8). The threshold limit value excess range for manganese falls within the limits of 1.1-4.4 times with maximum value in peaty and gleyed urbanised.

Obtained findings show that by all researched transformed soils and pre-soil formations in “Dynamo” park a distinct excess of background content of heavy metals is traced. Significant values are especially noted for quicksilver, zinc and lead. Although their concentration has pattern nature, brown soils which retained natural features are less contaminated, stratified and peaty and gleyed urban soils are more contaminated. *Transient and accumulative and accumulative location of these formations lead to*
perpetual accumulation of heavy metals in them, which reduces biological productivity of soil cover in “Dynamo” park. Despite the fact that both parks are situated in similar lithologic and geomorphological conditions, their ecological state is diverse. Of two researched parks, “Dynamo” parklands soils are the most stressed.

**Table 1. CO₂ emission rate of soil biota in the parkland of “Dynamo” and “Naval fleet officers’ house”**

| Profile No., soil                                      | Depth, cm | Acid volume, ml | Reference, ml | Area of Petri dish | CO₂ emission rate, mg/cm² | Biological activity |
|-------------------------------------------------------|-----------|----------------|---------------|--------------------|----------------------------|---------------------|
| 5. Brown soil, deeply transformed on loam deposits    | 0–2       | 15.9           |               |                    | 18.7                       | High                |
|                                                       | 2–8       | 15.8           |               |                    | 19.7                       |                     |
|                                                       | 8–20      | 17.0           |               | 63.6               | 11.1                       |                     |
|                                                       | 20–32     | 16.5           |               |                    | 14.9                       | Medium              |
|                                                       | 32–49     | 16.5           |               |                    | 14.5                       |                     |
|                                                       | 49–65     | 15.5           |               |                    | 21.2                       | High                |
| 6. Rudezem on deposits of construction waste          | 1–5       | 16.0           |               |                    | 18.9                       |                     |
|                                                       | 5–20      | 16.4           |               |                    | 15.2                       | High                |
|                                                       | 20–36     | 15.3           |               |                    | 22.8                       |                     |
|                                                       | 36–50     | 18.4           | 18.6          |                    | 1.4                        | Extremely weak       |
| 7. Brown soil, surface–transformed on loam            | 0.5–10    | 15.1           |               |                    | 24.2                       | Extremely high       |
|                                                       | 10–30     | 15.0           |               |                    | 24.9                       |                     |
|                                                       | 30–45     | 17.4           |               |                    | 8.2                        | Weak                |
|                                                       | 45–60     | 16.5           |               |                    | 14.5                       | Medium              |
| 9. Brown soil surface–transformed on loam deposits     | 0.5–9     | 15.7           |               |                    | 19.9                       | High                |
|                                                       | 9–20      | 18.6           |               | 63.6               | 0.3                        | Extremely weak       |
|                                                       | 20–45     | 17.3           |               |                    | 9.3                        |                     |
|                                                       | 45–70     | 16.6           |               |                    | 13.8                       | Medium              |
| 10. Urban soil on loam deposits                       | 0–10 (18) | 15.6           |               |                    | 20.9                       | High                |
|                                                       | 10–48     | 17.0           |               |                    | 11.1                       | Medium              |
| 11. Urban soil, stratified                            | 0–12      | 16.6           |               |                    | 13.8                       | Medium              |
|                                                       | 12–25     | 17.4           |               |                    | 8.3                        |                     |
|                                                       | 25–43     | 17.6           |               |                    | 6.9                        | Weak                |
| 12. Urban soil, stratified                            | 0–11      | 18.3           |               |                    | 2.1                        | Extremely weak       |
|                                                       | 11–35     | 17.8           |               |                    | 5.5                        | Weak                |
| 13. Urban soil, gleyed stratified                     | 0–21      | 18.5           | 18.6          |                    | 0.7                        | Extremely weak       |
|                                                       |           |                |               |                    |                            |                     |
| 23. Brown soil, deeply transformed                    | 42–53     | 17.9           | 19.1          | 63.6               | 8.3                        | Weak                |
| 24. Urban soil, pyrogenic                             | 0–5       | 17.2           |               |                    | 13.1                       | Medium              |
|                                                       | 25–59     | 18.4           |               |                    | 4.8                        |                     |
| 25. Brown soil, surface transformed                   | 27–56     | 18.2           |               |                    | 6.2                        | Weak                |
Table 2. Impact of soil extract on the length of oat seeds’ roots in parklands

| Profile No / soil | Depth, cm | pH  | Average root length, mm | Phyto-effect $E_T$, % | Test reaction | Growth of root length $L_T$, mm |
|------------------|----------|-----|-------------------------|----------------------|--------------|-------------------------------|
|                  |          |     | $L_R$                  | $L_T$                |              |                               |
| 5. Brown soil,   | 0–2      | 7.7 | 93                      | 18.6                 | Normal       | +7                            |
| deeply transformed | 8–20     | 7.1 | 70                      | 39.5                 |              | –16                           |
| “Dynamo” park    | 20–32    | 7.0 | 52                      | 48.8                 | Weak phyto–effect | –34                          |
|                  | 32–49    | 6.9 | 44                      |                      |              | –42                           |
|                  | 49–63    | 6.9 | 38                      | 55.8                 | Inadmissible | –52                           |
|                  | 63–81    | 6.3 | 36                      | 58.1                 | Phytotoxicity | –50                           |
| 6. Rudezem on construction waste | 0.1–5 | 6.4 | 87                      | –                   | Normal       | +1                            |
|                  | 5–50     | 6.0 | 70                      | 18.6                 | Weak phyto–effect | –16                          |
|                  | 50–65    | 6.0 | 68                      | 20.9                 |              | –18                           |
|                  | 65–130   | 5.1 | 59                      | 31.4                 | Weak inhibition effect | –27                          |
| 7. Brown soil,   | 0–0.5    | 6.2 | 72                      | 16.3                 | Weak effect  | –11                           |
| surface–         | 0.5–10   | 5.9 | 44                      | 48.8                 | Inadmissible | –42                           |
| transformed      | 10–41    | 6.1 | 36                      | 58.1                 | Medium       | –50                           |
|                  | 45–60    | 6.2 | 45                      | 47.7                 |              | –41                           |
| 9. Brown soil,   | 0.5–9    | 6.4 | 69                      | 19.8                 | Weak phyto–effect | –17                          |
| surface–         | 9–20     | 6.2 | 67                      | 22.1                 | Medium       | –15                           |
| transformed      | 20–45    | 5.2 | 48                      | 44.2                 |              | –38                           |
|                  | 45–70    | 59  | 42                      | 51.1                 |              | –46                           |
| 7,10. Urban soil | 0–10     | 7.0 | 89                      | 96                   | Medium inhibition effect | +4                           |
|                  | 10–48    | 7.1 | 53                      | 38.4                 |              | –33                           |
| 11. Urban soil,  | 1–12     | 6.3 | 54                      | 37.2                 | Medium       | –32                           |
| stratified       | 12–25    | 6.8 | 44                      | 48.8                 | Inhibition effect | –42                          |
|                  | 25–43    | 6.8 | 43                      | 50.0                 |              | –43                           |
| 12. Urban soil,  | 0–12     | 6.9 | 72                      | 16.3                 | Weak phyto–effect | –14                          |
| gleyed stratified | 12–45   | 6.5 | 62                      | 27.9                 | Inhibition effect | –24                          |
| 13. Urban soil,  | 0–21     | 7.1 | 69                      |                      | Weak phyto–effect |                               |
| gleyed           | 21–40    | 7.1 | 86                      | 15.9                 |              | –17                           |
| “Naval fleet officers’ house” park | | | | | |
| 24. Urban soil,  | 0–25     | 6.3 | 96                      |                      |              | +10                           |
| pyrogenic        | 25–59    | 6.1 | 103                     |                      |              | +15                           |
| 25. Brown soil,  | 12–27    | 4.9 | 886                     | 0                    | No negative effects | +13                          |

The analysis of reference materials shows that the soils of parklands are the purest, and they may serve as references [9]. However, presented materials do not confirm this. The example of the abovementioned is “Dynamo” park, where obtained findings disclosed rather high degree of soil cover transformation and its contamination. Main features are medium reaction, approaching neutral and weakly alkaline, increased, compared to the values of reference sites, values of heavy metals contamination. The application of bio-indication approaches also confirms the findings. Such state of “Dynamo” park is caused by its location in the most intense central city part. Besides, the territory under research has been exposed to fundamental reinstatement: sports center construction, “Musical comedy” theater, building of city ponds, and entire territory rearrangement. Such impacts were bound to affect the condition of soils. On the other hand, “Naval fleet officers’ house” park never experienced such
reinstatement. Similar parklands soil contaminations are noted in other regions. For example, in recreational area of historic center of Saint-Petersburg ("Tikhii otdykh" park), soils are contaminated with lead (the concentration exceeds 3-6 threshold limit value), benzo(a)pyrene (the concentration exceeds 4-15 threshold limit value). Exchangeable sodium in surficial horizons reaches critical values (up to 106 mg/100 g), [4]. It is also noted in research papers that park age influences the level of parkland soil contamination.

### Table 3. Moving forms of metals in transformed soils and pre-soil formations of “Dynamo” park

| Soil / Profile No                          | Depth, cm | pH  | Content of heavy metals, mg/kg | Pb | Zn | Cu | Hg | Mn |
|-------------------------------------------|-----------|-----|--------------------------------|----|----|----|----|----|
| 5. Brown soil, deeply transformed         | 0–20      | 7.1e| 9                              | >20| >20| >20| >20| >20|
| 6. Rudezem                                | 0–5       | 6.4 | 7                              |    |    |    |    |    |
| 7. Brown soil, surface-transformed       | 0–10      | 6.0 | 9                              |    |    |    |    |    |
| 8. Peaty and gleyed urbanised            | 19–35     | 6.4 | 54                             |    |    |    |    |    |
| 9. Brown soil, surface-transformed       | 0–9       | 6.4 | 15                             |    |    |    |    |    |
| 10. Urban soil                            | 0–10      | 7.0 | 7                              |    |    |    |    |    |
| 11. Urban soil, stratified                | 1–12      | 6.3 | 8                              |    |    |    |    |    |
| 12. Urban soil, gleyed stratified         | 0–12      | 6.9 | 8                              |    |    |    |    |    |
| 13. Urban soil, gleyed                    | 0–20      | 7.1 | 4                              |    |    |    |    |    |

| Threshold limit value mg/kg               | 6 | 23 | 3 | 0.1 | 100 |
| Hazard class                              | 1 | 1  | 2 | 1   | 2   |

Thus, research conducted showed that even more convenient areas of urbanised landscapes are also exposed to contamination. Findings made it possible to evaluate the specifics of their contamination conditioned by the degree of impact on object. In order to create ecologically comfortable conditions at territories of parklands it is necessary to develop measurement system. It is possible to implement them only on the basis of complete information of the specifics of modern state of medium integral component – soil system. Geomonitoring is a promising approach to use. Its application will allow to give ecological evaluation and on the basis of obtained findings to decide on improving medium of territories under research.

### References

[1] Gerasimova M I, Stroganov M N, Mozharova N V and Prokofieva T V 2003 Anthropogenic soils: genesis, geography, recultivation Smolensk: Oikumena
[2] Golovko E A 1971 On the methods of studying the biological activity of peat soils Proc. Sci. Conf. on the methods of microbiological and biochemical studies of soils pp 68–76
[3] Gorbov S N and Bezuglova O S 2019 Soil cover of the Rostov agglomeration (Rostov-on-Don–Taganrog. Publishing house of S FedU)
[4] Kovyazin V F., Uskov I B and Derzhavin L M 2010 Park ecosystems of St. Petersburg of varying degrees of urbanization and agrochemical properties of their soils Agrochemistry 3 pp 58–66.
[5] Classification and diagnostics of soils in Russia 2004 (Moscow: Soil Institute named after V V Dokuchaeva RAAS)
[6] Kazeev K Sh, Kolesnikov S I, Akimenko Yu V and Dadenko E V 2016 Methods of bio-
diagnostics of terrestrial ecosystems: monograph (Rostov-on-Don: Southern Federal University
Publishing House)

[7] Narbut N A, Antonova L A, Matyushkina L A, Klimina E M and Karavanov K P 2002 Strategy
for the formation of the ecological framework of the urban area (on the example of the city of
Khabarovsk) (Vladivostok-Khabarovsk: FEB RAS)

[8] Podgornaya T I and Roslikova V I 1999 Influence of technogenic geological processes on modern
soil formation in the cities of the Far East (Vladivostok: Dalnauka)

[9] Soil, city, ecology 1997 (Moscow: Fund "For Economic Literacy")

[10] Roslikova V I and Matveenko T I 2018 Urbanized soils of the Amur region (on the example of
the city of Khabarovsk) (Khabarovsk: Pacific State University Publishing House)

[11] Lehmann A and Stahr K 2007 Nature and Significance of Anthropogenic Urban Soils J. Soils and
Sediments 7 pp 247–60 https://doi.org/10.1065/jss2007.06.235