WALIA journal 32(1): 29-33, 2016
Available online at www.Waliaj.com
ISSN 1026-3861

Methodic Aspects of Soils Contamination Assessment of the Almaty Region, the Republic of Kazakhstan

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Abstract: Sewage water irrigation is a complex measure directed on after purification of sewages, increase of soil fertility, obtaining of stable resources and improvement the ecology of the region. Utilization of sewages sludge and its usage as organic-mineral fertilizer is thought to be an urgent problem of the cities. The received results of the research will allow to make a conclusion about economic security and economic reasonability of using city sewage waters for irrigation of forage, technical and forest cultures, a number of problems is solved at the same time: the need of storage and utilization of sewage waters sludge is excluded, as sewage waters can be used for soil irrigation and sludge can be used as fertility.

Key words: *Utilization; Translocation; Feed crops; Heavy metals; Concentration; Soil*

1. Introduction

It is established that household drains, sewage waters of the food industry (sugar, starch, waterproofing) and livestock complexes sewages can be used for irrigation. For optimum solution the issues of agricultural use of sewage waters and water objects protection from contamination we suggest considering sewage waters allocation as a system of measures like a complex of actions for cleaning, usage, and also regulated disposal of sewages for the purpose of providing protection of water sources from pollution (Seitkaziyev et al., 2005).

Sludge is formed as a result of household sewage cleaning. One of the ways of sewage sludge utilization is its use as an organic and mineral fertilizer, at the same time a number of problems is also solved: the need of sewage storage is excluded and fertility of soils increases. Sewage sludge use is possible under stipulation that contamination of the soil with harmful substances will not occur. The basis of danger assessment of soils contamination used for cultivation agricultural plants is the Trans locational indicator of harmfulness which is the most important indicator at reasoning the maximum permissible concentration (MPC) of chemicals in the soil. It is caused by the facts that:

- On average 70% of harmful chemicals come to the human body with plant- origin food;
- The level of translocation is defined by the level of accumulation of toxic matters in food affecting its quality.

The present difference of admissible levels of chemicals content on various indicators of harmfulness (Mustafayev et al., 1992; Seitkaziyev et al., 2011), and basic provisions of differential assessment of contaminated soils danger degree also allow giving recommendations about practical use of the contaminated territories. To determine the volume and height of sludge which is admissible to use as fertilizer at recultivation of grey desert and meadow soils?

2. Research methods

Proceeding from even mixture of sludge with the soil fertile layer the equation of material balance has the following form (Seitkaziyev et al., 2013):

$$C_b \cdot M + C_{sl} \cdot m = C_{mix} \cdot (M + m), \qquad (1)$$

Where C_b is background concentration of the i substance, soil mg/kg; M –mass of the soil fertile layer, t; C_{sl}-concentration of the i substance in the sludge, soil mg/kg; m – mass of the sludge, kg; C_{mix}-concentration of the i

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substance in the soil after its mixing with the sludge, soil mg/kg;

In order to use the sludge as fertilizers, the following main condition is necessary to observe:

$C_{mix}<MPC$ (2)

Where MPC is the maximum permissible concentration of the i substance, soil mg/kg.

The volume of *W* (m^3) and the mass of M (t) of the fertile layer of the soil on the site is determined by the formulas:

$W=H\times S$, (3

$M=W\times rp$, (4)

Where

H – capacity of the soil layer, m;

S – square of the recultivation object, m^2;

d_{sl} – density of the soil, t/m^3.

The mass of the sludge *m* which is subject to placement on the site is defined from the equation of the material balance: $m=M\ (C_{mix}-C_b)/C_{sl}-C_{mix}$, (5)

The volume of the sludge *V* aimed for utilization on the site is m^3:

$V=m/d_{sl}$, (6)

Where doc – density of the sludge, t/m^3

The height of the sludge will be equal, m:

$H=V/S$, (7)

3. Results of the researches

In the solution of the problems of water resources contamination of the Ili-Balkhash pool the big role is assigned to development of their purposeful use in agricultural fields of irrigation in modern social and economic conditions. This problem caused the necessity of carrying out researches on purposeful and efficient use of sewage waters of Almaty city in production of feed crops, obtaining environmentally friendly production directed on increase of soils fertility, providing high efficiency of agricultural fields of irrigation.

The purpose of the research is using water and sludge of sewage waters of Almaty city as fertilizer and irrigation for feed crops and assessment the quality of water, soil as well as grown agricultural production.

The object of the research is water, sludge of sewage waters of Almaty city, feed crops, soils and ground waters. For assessment the quality of soils, ground water and biochemical structure of plants in laboratory environments N, P, K were defined, and also heavy metals like Zn, Cu, Fe, Ca, Cr, Pb and others were established in compliance with State Standard, State Standard instructions, methods of technical control of the work of treatment facilities of State Standard 18963-73. The sludge formed at cleaning household sewage waters contains copper in concentration C_{sl} =12.5 g/m^3. The sludge density d_{sl} is equal 1,2 t/m^3. The soil layer of the site is presented by grey desert and meadow soils of loamy mechanical structure with capacity H = 0,2 m and density d_{sl} =1,45 t/m^3. The background concentration of copper in the soil according to the sanitary and epidemiologic service (SES) C_b = 0.3 mg/kg of the soil. The area of the experimental site is 0.5 hectares (Seitkaziyev et al., 2002, Estayev, 2005).

The volume and mass of the fertile layer of the soil on the site with the square of S = 0,5 hectares (5000 sq.m) will be:

$W = H\times S = 0{,}2 \times 5000 = 1000$ m^3;

$M = W\times d_{sl} = 1000\times 1{,}45 = 1450$ t.

In order to use the sludge of sewage waters as fertilizers the concentration of copper in the soil after mixing it with the sludge should not exceed MPC.

C_{mix} = MPC Cu = 3,0 mg/kg of the soil.

For calculation the mass of the sludge the sewage sludge concentration needs to be converted from g/m^3 to mg/kg of soil:

$C_{sl} = C_{sl}\ /d_{sl} = 12{,}5/1{,}2 = 10{,}42$ g/t = 10,42 mg/kg of soil;

The mass of the sludge *m* which is assigned to place on the site is equal to:

$m = M\ (C_{mix} - C_b)/C_{sl} - C_{mix} = 1450\ (3 - 0{,}3)\ /\ 10{,}42 - 3 = 527{,}6$ t;

$V = m/d_{sl} = 527.6/1.2 = 439.7$ m^3;

At the same time the height of the sludge will be equal to, m:

$h = V/S = 439.7\ /\ 5000 = 0.088$ m.

It is necessary to define the volume and height of the sludge for all contaminating elements containing in the sludge and to choose such volume of V and height of h at, which contamination of the soil will not happen. The data are provided in the table form (Table 1).

The results of hygienic researches of the contaminated soils allow to estimate the degree of danger of contamination by harmful substances on the level of their possible impact on the systems “soil – plant”, “soils – microorganisms, biological activity”, “soils – ground waters”, “ soil – atmospheric air” and directly on human’s health. From hygienic position the danger of soil contamination is defined by the level of its possible negative affect on contact environments, foodstuff and directly on people as well as on biological activity of the soil and processes of it is self-cleaning. MPC of chemicals in the soil is the main criterion of hygienic assessment of danger of soils contamination by harmful substances.

For assessment danger of soil contamination the selection of chemicals – indicators of contamination is carried out considering:

- The specifics of contamination sources defining the complex of chemical elements participating in contamination the soils of the studied region;

- Priority of ccontaminants according to the MPC list of chemicals in the soil and their danger classes;
- Nature of land use.

Table 1: Volume and height of the sludge for all contaminating elements (H = 0.2 m)

Contaminating elements	Density of the sludge D_{sl}, t/m³	Square S, hectare	Mass of the fertile layer of the soil, M, t	Content in the sludg, C_{sl}, mg/kg	Background content C, mg/kg	Concentration of the *i* substance, C_{mix}, mg/kg	Mass of the sludge m, kg	Volume of the sludg, V, m³	Height sludge, m
Copper	1,2	0,5	1450	10,42	0,3	3	527,6	439,7	0,088
Fluorine	1,2	0,5	1450	6,7	0,1	1	228,9	190,8	0,038
Manganese	1,2	0,5	1450	13,3	0,5	2	192,5	160,4	0,032
Phosphorus	1,2	0,5	1450	12,5	3	5	386,7	322,2	0,064
Nitrate	1,2	0,5	1450	2,75	1,5	2	966,7	805,5	0,161
Plumbum	1,2	0,5	1450	0,028	0,015	0,010	725	604,2	0,120
Suspended matter	1,2	0,5	1450	0,6	0,30	0,35	241,7	201,4	0,040
Source:Seitkaziyev, Jetimov (2013)									

If there is no opportunity to consider the whole complex of the chemicals contaminating the soil, the assessment is carried out on the most toxic substances, which belong to the highest class of danger.

If there is no danger class of chemicals priority for the soils of the studied area in documentation, the class of danger J can be determined under the following formula:

$J = \lg A \cdot S / a\, M\, (MPC) = \lg 64 \cdot 1{,}535 / 58{,}5 \cdot (0{,}575) \cdot 0{,}01 = 2{,}46,$ (8)

Where A – atomic weight of the corresponding element; S – solubility in water of the chemical compound, mg/l; M –molecular mass of the chemical compound where this element enters; a - arithmetic mean from six MPC chemicals in different foodstuff (meat, fish, fruit, milk, bread, vegetables). Thus, the studied soils belong to little dangerous (3 class of danger) at the index value from 0.1 to 2.5. At assessment soils contamination danger by chemicals the following concepts should be considered:

- Contamination danger is the more, the higher actual levels of the content of controlled substances in the soil in comparison with MPC;
- Contamination danger is the more, the higher danger class of controlled substances;
- Buffer capacity of the soil affecting the mobility of chemical elements that defines their impact on the contacting environments.

The assessment of the level of soils chemical contamination as indicators of adverse effect on health of the population is carried out on the indicators developed at associated geochemical and geo hygienic researches of the cities environment. Such indicators are thought to be the coefficient of chemical concentration (Kc) which is defined by relation its real contents in the soil (C) to the background one (C_b):

$Kc = C/C_b,$ (9)

Under the formula (9) we find the coefficients of contaminants concentration:

$K_{c.F} = 10{,}42/0{,}3 = 34{,}7$; $K_{c.Mg.} = 6{,}7/0{,}1 = 67$; $K_{c.P.} = 13.3/0.5 = 26.6$

Total indicator of contamination Z_c equal to the sum of chemical elements concentration coefficients:

$$Z_c = \sum_i^n K_{ci} - (n-1), \quad (10)$$

Where n is the number of summable elements.

Under the formula (10) the total indicator of contamination is equal to:

$Z_c = (34.7 + 67 + 26.6) - (3-1) = 126.3$

The soils of the experimental site are contaminated by fluorine, manganese and phosphorus, whose content of mobile forms estimates 126.3. On the basis of table 1, the soil should be referred to the category of "dangerous" contamination as the level of fluorine, manganese and phosphorus content exceeds the admissible levels of these elements content according to all indicators of harmfulness: Tran's locational, migratory, water and general sanitary. Such soil can be used only for technical cultures or completely excluded from agricultural use.

The assessment of danger of soils contamination by the complex of metals on Z_c indicator that reflects differentiation of urban-industrial environment contamination both by metals and other more widespread ingredients (dust, carbon oxide, nitrogen oxides) is carried out under the estimation scale provided in Table 2 (Seitkaziyev and Jetimov, 2013). Gradations of the estimation scale are developed on the basis of study indicators of health level of the population living in the territory with various levels of soils contamination. Microelements of heavy metals were analyzed in sewage waters at the water separator, Sorbulak and the dead-end channel under 16 ingredients. Comparison of the received values (Seitkaziyev et al., 2013), with MPC criteria show that sewage waters of the store on all spectrums of microelements are suitable for irrigation and at the same time they will not cause negative ecological consequences. During researches in 2010-2013 from 16 ingredients arsenic, molybdenum, titan and mercury were not found in the sewage waters of Sorbulak. Such elements as nickel were found in 5 samples, cadmium - in 3, cobalt in 1 sample with their content within much lower than MPC levels. Other ingredients which are often met in sewage waters are presented in Table 2.

Heavy metals from water, soils through the trophic chain come to plants, and then they are consumed by animals and a human. Therefore any vital process in the organism of plants, animal cannot be carried out without water participation, and any its cell cannot exist without water environment (Jetimov, 2014).

Table 2: Microelements content in the grown production at sewage water irrigation

Culture	Year	Microelements, mg/kg of the dry substance							
		Zn	Fe	Cd	Cu	Cr	Ni	Pb	Co
Corn	2010	13,45	-	0,06	1,10	-	-	0,40	-
	2011	8,49	40,90	0,15	2,18	0,55	0,61	0,21	0,29
	2013	8,35	30,25	0,04	0,11	0,11	1,20	0,86	0,24
Sunflower	2010	13,10	-	0,23	12,97	-	-	4,80	-
	2011	16,39	57,50	0,25	10,66	0,89	1,91	3,35	0,64
	2013	16,69	40,52	0,06	13,46	0,98	1,57	2,11	0,52
Sudan grass	2010	12,60	-	0,26	2,13	-	-	0,90	-
	2011	15,94	51,20	0,14	2,87	0,80	0,82	0,22	0,50
	2013	7,94	25,44	0,06	0,64	0,87	0,49	0,91	0,08
Lucerne	2011	7,00	29,01	0,09	5,02	0,79	1,08	1,17	0,49
	2013	8,07	30,56	0,08	5,61	0,87	1,19	1,86	0,50
Source: Seitkaziyev, Jetimov (2013)									

4. Discussion

To determine the volume and height of sludge which are admissible to use as fertilizer at saline soils recultivation. Provision of plants with good-quality water is one of the conditions of successful development of agricultural production, and also the process of after purification of sewages on agricultural fields of irrigation (AFI) should replace the technologies suffering in after purification of separate ingredients, as a rule they are expensive and ineffective.

Thus, sewage waters irrigation is thought to be the complex measure directed on sewages after purification, soils fertility increase, receiving of stable resources and improvement the ecology of the region. The received results allow making a conclusion about economic security and economic feasibility of city sewage waters use for irrigation forage, technical and forest cultures in the south and south-east of Kazakhstan.

The process of soil after purification is more efficient in the conditions of warm climate, light soils, deep bedding of ground waters and high specific weight in crop rotation of long-term herbs. These factors allow increasing the loads of sewage waters of agricultural fields of irrigation (AFI).

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