Biogeosystem Technique

Journal is being issued since 2014.
E-ISSN 2413-7316
2022. 9(1). Issued 2 times a year

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Postal Address: 1717 N Street NW, Suite 1, Washington, District of Columbia 20036

Website: https://bgt.cherkasgu.press
E-mail: kalinitch@mail.ru

Founder and Editor: Cherkas Global University

Release date 25.06.2022
Format 21 × 29,7/4.

Headset Georgia.

Order № B-21.

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Biogeosystem Technique

2022

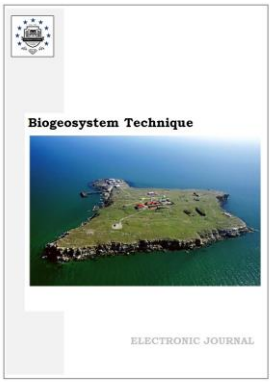
Is. 1

CONTENTS

Articles

Published in the USA
Biogeosystem Technique
Issued since 2014.
E-ISSN: 2413-7316
2022. 9(1): 3-14

DOI: 10.13187/bgt.2022.1.3
https://bgt.cherkasgu.press



Articles

Diagnostics of the Content of Petroleum Products and Heavy Metals in Light Chestnut Soils

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Paper Review Summary:
Received: 2022, July 04
Received in revised form: 2022, July 15
Acceptance: 2022, July 19

Abstract

The article presents the diagnosis of contamination of light chestnut soils of Volzhsky, Volgograd region with petroleum products and heavy metals using various bioindicators: earthworms of the genus *Lumbricus rubbellus* and fungus of the genus *Botryitis cinerea*. The following indicators of bioindication of soil pollution were identified: the survival rate of the earthworms *Lumbricus rubbellus*, the total microbial number of light chestnut and the mycelium mass of the fungus of the genus *Botrytis cinerea*. In clay and sandy light chestnut soils that are contaminated with oil and petroleum products, the mortality of earthworms of the genus *Lumbricus rubellus* was noted on day 7. After 7 days, the spores of the *Botrytis cinerea* fungus began to grow on the control and light chestnut sandy soil of gas station number 3, and after 14 days – on other soils. The survival rate of earthworms depends on the quality of petroleum products and does not depend on the granulometric composition of soils. The largest total microbial number of light chestnut soil, estimated by the Botrytis cinerea fungus, is observed in the sandy soil of gas station number 3 (133333 CFU/cm^3 of water soil extract), and the smallest – in the clay soil of gas station number 1 (6773 CFU/cm^3 of water soil extract).

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Keywords: light chestnut clay and sandy soil, bioindication, petroleum products, heavy metals, earthworms of the genus *Lumbricus rubbellus* and fungus of the genus *Botrytis cinerea*.

1. Introduction

The change in the physical properties of soils under the influence of oil and petroleum products pollution is characterized by the aggregation of soil particles, the water properties and air regime of soils deteriorate (Hewelke et al., 2018, Adams et al., 2008, Błońska et al., 2016, DeBano, 2000, Dekker, Jungerius, 1990, Gordon et al., 2018, Marín-Garcíaetal., 2016, VanDeSteene, Verplancke, 2007, Ferguson et al., 2003, Eckert-Tilotta et al., 1993).

Changes in the chemical properties of the soil during contamination with oil and petroleum products are characterized by the following parameters: the content of organic carbon increases; the soil solution is alkalinized (Okolelova, Egorova, 2020, Okolelova et al., 2015, Xi et al., 2021, Robichaud, 2019).

The composition of oil and petroleum products includes naphthenic-aromatic polycyclic, dicyclic and monocyclic hydrocarbons, cycloparaffins, paraffins. Representatives of these classes of compounds are contained in any soil, regardless of its type, in the form of non-specific organic compounds, in humic and fulvic acid molecules. Therefore, it is impossible to establish the maximum permissible concentrations for petroleum products. A similar opinion is shared by other authors (Vorobeychik, 2011, Sukhanosova et al., 2009).

The duration of the adaptation period in soils contaminated with petroleum products varies greatly in different climatic conditions and also depends on the concentration of oil in soils (Wesselink et al., 2009).

Studies by many authors have proved the influence of oil and petroleum products on the growth and development of plants (Gamm, Maslova, 2012, Pashayan et al., 2021, Adesina, Adelasoye, 2014, Ammosova, Golev, 1998, Holt, 1987, Klamerus-Iwan et al., 2015, Langer et al., 2010, Walker et al., 1987).

To date, there are many works devoted to various methods and methods of cleaning soils and waters from oil and petroleum products pollution (Rogozina et al., 2010; Guslavsky, Kanarskaya, 2011, Szarlip et al., 2014, Muratova et al., 2012, Schoefs et al., 2004, Vasilyeva et al., 2021).

Earthworms of the genus *Lumbricus rubbellus* are special representatives of soil–dwelling animals (Figure 1), swallowing soil and passing it through themselves (Prokhorov, 2004).

Fig. 1. Earthworms *Lumbricus rubbellus* in their natural habitat

The most optimal conditions for the active life of earthworms: pH = 5.5-8.7 (they prefer a neutral soil environment); temperature – 10.6 ° C; humidity – 70-85 %). Such a range of humidity is close to the water content in the body of the worm, while their development worsens soil moisture below 30-35%, and soil moisture equal to 22% is fatal for them. The acidity of the medium also affects the vital activity of worms: if it is below pH = 5 or above pH = 9, then all worms die within a week. A salt concentration of more than 0.5 % is fatal for them. The presence of earthworms increases the concentration of microorganisms producing vitamin B in the soil. This contributes to an increase in organic matter (Gimadeev, Shchipovskikh, 2000, Prokhorov, 2004).

Previously, we studied the condition of soils contaminated with oil and petroleum products using earthworms of the genus *Lumbricus rubellus* as a test organism. As a result of these experimental studies, an inverse relationship was established between the quality of fuels and lubricants (automobile gasoline AI-92, AI-95 and locomotive diesel fuel) and the survival rate of worms. The behavioral reaction of earthworms of the genus *Lumbricus rubellus* when polluted with AI-92 and AI-95 gasoline is manifested in the form of twisting worms into a ball, and when polluted with locomotive diesel fuel – in burying worms in the soil (Zaikina et al., 2016, Okolelova, Zaikina, 2017).

We have also conducted research on detoxification of oil-contaminated soils using chitosan.

Chitosan is a natural sorbent, one of the important features of which is the possibility of biodegradation and decomposition under the action of enzymes (Kokorina et al., 2012).

The fungus of the genus *Botrytis cinerea* was chosen as a culture for determining the biodiagnostic indicators for assessing soil contamination with heavy metals and petroleum products due to the fact that it occurs on various plants and can affect the soil, and it also has a good ability to grow in laboratory conditions (Zaikina et al., 2018, The world of plants, 1991, Fernández-Acero et al., 2010, Hoeberichts et al., 2003, Lin Zhang et al., 2008, Staats et al., 2005).

Botrytis cinerea is a phytopathogenic fungus infecting a number of agricultural crops (tomatoes, strawberries, grapes, etc.), which has been adopted as a model system in molecular phytopathology. It is the causative agent of gray rot on plants, which develops in the conidial and sclerotic stages. Gray plaque on the affected berries and other parts of the plant is a manifestation of the conidial stage of sporulation. The sclerotic stage is expressed by the formation of irregular sclerotia, black in color, 2-5 mm in diameter on berries, leaves and other parts of plants under unfavorable conditions (depletion of the nutrient substrate, high or low temperatures, drought) (Hoeberichts et al., 2003, Lin Zhang et. al., 2008, Staats et al., 2005).

The strain of Botrytis cinerea culture was provided by the Laboratory of Mycology and Phytopathology of the All-Russian Research Institute of Plant Protection (FGBNU VISR). Fungi of the genus Botrytis cinerea in laboratory (A-D) and natural conditions (E) are shown in Figure 2.

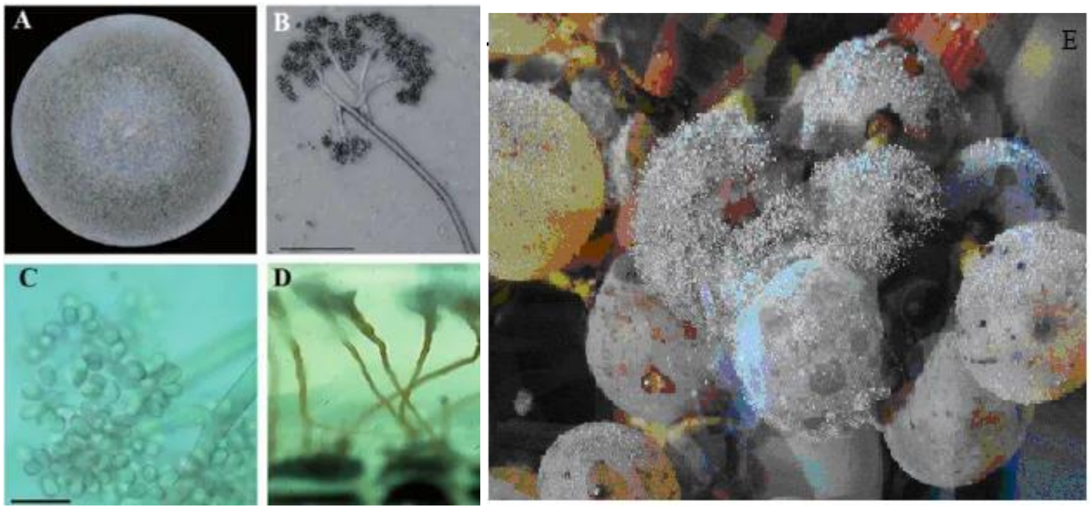

Fig. 2. Fungi of the genus *Botrytis cinerea* in laboratory (A-D) and natural conditions (E)

2. Materials and methods

The objects of the study are located in Volzhsky of Volgograd region. These are light chestnut sandy (gas station No. 3) and clay (gas station No. 1) soils. Sampling and preparation of soils for analysis was carried out according to GOST 17.4.3.01-2017 (GOST 17.4.3.01-2017, 2018).

Determination of pollutants in soils

The gross forms of Cu, Ni, Zn were determined by the X-ray fluorescence method on the device "Spectroscan MAX-GV" according to GOST 33850-2016 (GOST 33850-2016, 2019) they are presented as the sum of HM_{Σ}. The analysis of water–soluble forms of chemical elements was carried out: Cu and Ni – on the device "Spectrophotometer UNICO 2100" by photometric method, Zn - on the liquid analyzer "Fluorat-02-3M" by fluorimetric method. The content of petroleum products (PP) in the soil and water extract was determined on the device "Concentration meter KN-2M". The concentration of organic carbon (humus) was determined by the I. V. Tyurin method in the modification of the TSINAO on the SF-14 spectrophotometer with an error of 0.26-0.55 % according to GOST 26213-91. The data were obtained earlier and are shown in Table 1 and Table 2.

Experimental studies to determine diagnostic indicators of soil pollution using earthworms of the genus *Lumbricus rubellus*

The test organism was the earthworms of the genus Lumbricus rubellus, since this species is sensitive to petroleum products and heavy metals, typical of zonal soils of the Volgograd region, and allows you to quickly determine the presence of petroleum products and heavy metals.

The model experiment with light chestnut sandy soil from the village of Bereslavka in the Gorodishchensky district of Volgograd was carried out three times in plastic cuvettes with a volume of 500 ml, into which 400 g of soil, 30 ml of distilled water, 1 or 10 ml of AI-92 and AI-95 gasoline, locomotive diesel fuel were introduced (2 variants of the experiment) and then 10 earthworms were brought to the surface in each cuvette with contaminated soil and their behavioral reactions and survival (mortality) were monitored (Kozlov, 2003, Fomin G.S., Fomin A.G., 2011).

To assess the effect of petroleum products on the behavior and survival of earthworms, 12 transparent plastic cuvettes with a volume of 500 ml were used for soil from gas stations No. 1, 3. The experiments were carried out twice. 400 g of clay soil from gas station No. 1 was placed in two cuvettes, 400 g of sandy soil from gas station No. 3 was placed in the other two cuvettes, and 30 ml of water was introduced into each cuvette. 400 g of clay soil from gas station No. 1, 30 ml of water, 30 g of chitosan were placed in the next two cuvettes. 400 g of sandy soil from gas station No. 3, 30 ml of water, 30 g of chitosan were placed in the other two cuvettes. The control consisted of two cuvettes, into which 400 g of chestnut clay soil and 30 ml of water were introduced.

10 earthworms (*Lumbricus rubellus*) were introduced to the surface in each cell. The experiments were carried out at a temperature of 19-21 ° C. Survival was determined taking into account the mortality of worms during the experiment.

Experimental studies to determine diagnostic indicators of soil pollution using a fungus of the genus *Botrytis cinerea*

A pre-prepared water extract from 2 soil samples was prepared according to the method of E.V. Arinushkina according to GOST 26423-85 (GOST 26423-85, 2011): 50 g of air-dry soil was quantitatively transferred to a flask, 250 ml of distilled water was added, then the container was vigorously shaken for 3 min., after shaking, the entire suspension of the soil was filtered.

To cultivate *B. cinerea*, laboratory utensils and culture medium were sterilized, respectively, by dry heat in an autoclave at a pressure of 1.0 atm (Tepper et al., 2004). Then 50 ml of culture medium and various dilutions from water extracts of 2 soil samples were added to the flasks in 3-fold repetition: 10^{-2}, 10^{-3}, 10^{-4}. 50 ml of culture medium was introduced into the control flasks under sterile conditions. After that, a suspension of *B. cinerea* conidia was prepared in a culture medium containing 10^3 CFU/ml, and 250 mkl of suspension was added to each flask. Chapek's medium was used as a liquid culture medium. After 10-14 days, the total microbial number (TMN) of the soil was calculated and compared with the control (Tepper et al., 2004).

The calculation of the total microbial number (TMN) of the soil can be expressed by the formula:

$$TMN = \frac{X \times P}{V},$$

where TMN is the total microbial number of the soil, CFU in 1 cm^3 of the aqueous extract of the soil; X is the microbial number, CFU in 1 cm^3 of the medium for cultivating the fungus *B. cinerea* (a mixture of nutrient medium and aqueous extract of the soil); P is 1/degree of dilution; V is the volume of the medium for cultivating the fungus *B. cinerea*.

3. Results and discussion

Diagnostics of soil contamination with petroleum products and heavy metals using earthworms *Lumbricus rubbellus*

It is known that the duration of the adaptation period in soils contaminated with petroleum products varies greatly in different climatic conditions and also depends on the concentration of oil in soils (Sukhasonova et al., 2009). A model experience using earthworms of the genus *Lumbricus rubbellus* is illustrated in Figure 3.

Fig. 3. Model experience using earthworms of the genus *Lumbricus rubbellus*

Previously, we have shown the effectiveness of using chitosan of various aggregate composition for detoxification of soils contaminated with oil and petroleum products. Its use reduces the content of PP in light chestnut sandy soil by 1.2-4.8 times, in light chestnut clay by 10.2-77.4 times (Kokorina et al., 2012).

A model experiment with the earthworms Lumbricus rubbellus

Observations showed that in cuvette, with the AI-92 gasoline introduced, the death of all earthworms occurred 2 minutes after the start of the experiment. In the first minute, 7 earthworms died in the first cuvette, 5 in the second, 6 in the third. The behavioral reaction in the first minute was a sharp twisting of the earthworm into a ball.

In a plastic cuvette with AI-95 gasoline in all three cuvettes, all worms died after 3 minutes. In all three cuvettes, all 10 worms were alive in the first minute. The behavioral reaction is a sharp twisting of the worm into a ball. After 2 minutes have passed since the beginning of the experiment, 6 worms out of 10 died in the first cuvette, 8 died in the second cuvette, and 7 died in the third cuvette.

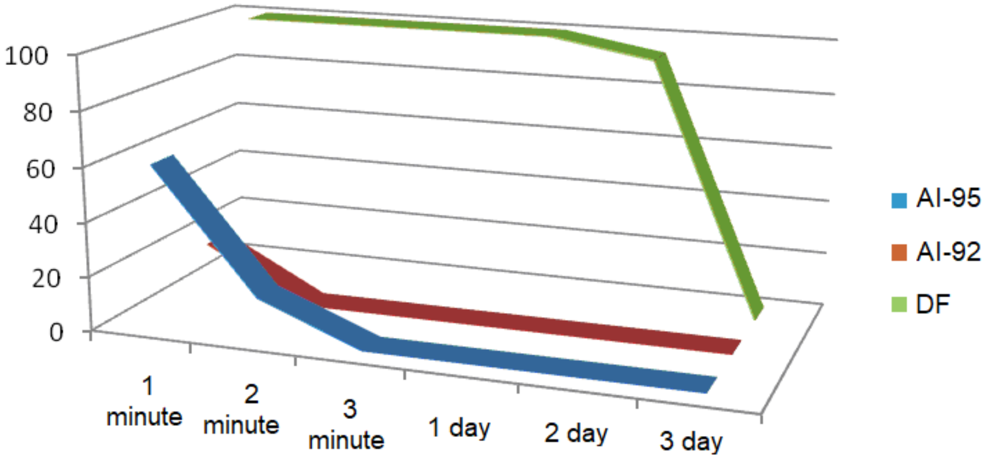

Fig. 4. Graphical dependence of mortality of earthworms *Lumbricus rubellus* with 1 ml of fuel and lubricants

In three cuvettes with diesel fuel (DF) introduced, the death of worms occurred after 3 days. In the first cuvette on the second day, 1 worm out of 10 died. In the second and third cuvettes, all 10 worms were alive. Behavioral reaction – worms were actively crawling in all three diesel fuel cuvettes, there was an effect of burrowing into the soil.

In the reference samples (control), all ten worms actively crawled on the soil surface. The death of worms within 30 days was not detected. The results of the experimental model experience are presented in Figure 4.

Based on the graph shown in Figure 4, it can be seen that the mortality of worms occurs at the 3rd minute in experiments with AI-95, at the 2nd minute – with AI-92 and on the 3rd day when diesel fuel (DF) is introduced.

Our experiments showed that the survival rate of earthworms of the genus *Lumbricus rubellus* was the lowest percentage in the experiment with gasoline AI-92. In the first variant of the experiment (10 ml), the total mortality of worms was recorded 1 minute after its start, the survival rate was 0 %, in the second variant (1 ml) – after 2 minutes. The survival rate in the 1st minute was 40 %, in the 2nd minute – 0.

In second place in the survival rate of worms was an experiment with gasoline AI-95. The total mortality of worms in the first experiment was 2 minutes after the start of the experiments. The survival rate in the 1st minute was 20 %, in the 2nd – 0. In the second experiment, the survival rate in the 1st minute is 100 %, in the 2nd – 30 %, in the 3rd minute – everyone died. The greatest survival rate was recorded in experiments with locomotive diesel fuel (DF). In the first experiment, the total mortality of worms was recorded on day 3. The survival rate on the 1st day was 100 %, on the 2nd day – 90, on the 3rd day – all died. In the second experiment, the complete death of *Lumbricus rubellus* was also observed on the third day. The survival rate on the 1st day was 100 %, on the 2nd day – 96.7 %, on the 3rd day – all died.

In the control experiment, the death of *Lumbricus rubellus* within 30 days was not detected.

Experiment without chitosan

For the first three days, the worms were alive in all the ditches. On the fourth day, 2 out of 10 worms died in the soils taken from gas station No. 1 and gas station No. 3. On the fifth day, 6 out of 10 worms died in the sandy soil from gas station No. 3, in the clay soil from gas station No. 1 – 5 out of 10 worms. On the sixth day, 8 worms died in the soil from gas station No. 1, 9 worms died in the soil from gas station No. 3. A week later, all 10 worms died in experiments without chitosan (Table 1).

Table 1. Survival of earthworms of the genus Lumbricus rubbellus in oil-polluted light chestnut soils, %

Experience time, days	Number of surviving worms								
	Control			Without chitosan			With chitosan		
	I	II	Average	I	II	Average	I	II	Average
1	2	3	4	5	6	7	8	9	10
Clay soil, Gas station No. 1, PP = 135 mg/kg, HM_{Σ} = 188.19 mg/kg									
1	10	10	10	10	10	10	10	10	10
4	10	10	10	8±0,71	9±0,71	8±0,71	10	10	10
5	10	10	10	4±1,41	6±1,41	5±1,41	10	10	10
6	10	10	10	2±0,71	3±0,71	2±0,71	10	10	10
7	10	10	10	0	0	0	10	10	10
31	10	10	10	0	0	0	7±0,71	8±0,71	7±0,71
Sandy soil, Gas station No. 3, PP = 202 mg/kg, HM_{Σ} = 242.74 mg/kg									
1	10	10	10	10	10	10	10	10	10
4	10	10	10	9±0,71	8±0,71	8±0,71	10	10	10
5	10	10	10	5±0,71	4±0,71	4±0,71	10	10	10
6	10	10	10	2±0,71	1±0,71	1±0,71	10	10	10
7	10	10	10	0	0	0	10	10	10
31	10	10	10	0	0	0	6±0,71	7±0,71	6±0,71

Experiment with chitosan

Within a week, all the worms were alive. After 31 days, 3 worms died in the clay soil from gas station No. 1, 4 – in the sandy soil from gas station No. 3. In the control, no dead worms were observed for 31 days (Table 1).

The analysis of the received data shows the following. The content of petroleum products and heavy metals in the soil negatively affects the test organism (*Lumbricus rubellus*). In clay and sandy light chestnut soils, 100% mortality was noted on the seventh day. Chitosan effectively reduces the toxicity of oil-contaminated soils. Without introducing chitosan into the soil from gas station No. 1 and from gas station No. 3, worms died on the seventh day, and when it was introduced into the soil from gas station No. 1, 3, 3-4 worms died after 31 days.

In the clay soil of gas station No. 1, the concentration of petroleum products is 135 mg/kg, the gross content of heavy metals is as follows: Cu – 55.79 mg/kg, Ni – 55.34 mg/kg, Zn – 77.06 mg/kg (HM_{Σ} = 188.19 mg/kg); in the sandy soil of gas station No. 3, the concentration of PP = 202 mg/kg, gross content of heavy metals: Cu – 37.33 mg/kg, Ni – 43.32 mg/kg, Zn – 162.09 mg/kg (HM_{Σ} = 242.74 mg/kg).

Diagnostics of soil contamination with petroleum products and heavy metals using a fungus of the genus *Botrytis cinerea*

Terms of cultivation

After 7 days, the spores of the *Botrytis cinerea* fungus began to grow on the control and soil of gas station No. 3. And after 14 days they grew on the remaining soils.

The total microbial number (TMN) of the soil (Table 2)

At the control (only on the nutrient medium of Chapek), the TMN was 245333 CFU / cm^3 of the water extract of the soil.

The largest total microbial number of soil was detected at the highest dilution of 10^{-4} in the sandy soil of gas station No. 3 (133333 CFU / cm^3 of water soil extract), which is 1.84 times less than in the control and 5.37 times higher than in the clay soil of gas station No. 1 (24823). The dependence of the total microbial number estimated by the fungus of the genus *Botrytis cinerea* on the concentration of petroleum products (PP) in the aqueous extract of the soil is shown in Figure 5, for heavy metals it is similar.

Table 2. Results of diagnostics of soil contamination with petroleum products and heavy metals using a fungus of the genus *Botrytis cinerea*

An object	Concentration of PP in water extraction of soil, mg/kg	The total concentration of HM in the water extract of the soil (HM_{Σ}), mg/kg	Breeding	TMN of the soil, CFU / cm^3 of water extraction of soil	Mycelium mass of *Botrytis cinerea* fungus, g
1	2	3	4	5	6
Control	-	-	-	245333±36961	0,0850±0,0220
Gas station No. 1	17,00	7,99	10^{-2}	6773±3815	0,0573±0,0010
			10^{-3}	2482±567	0,0466±0,0020
			10^{-4}	24823±5675	0,0683±0,0280
Gas station No. 3	52,00	9,52	10^{-2}	14234±1108	0,0572±0,0010
			10^{-3}	3243±882	0,0514±0,0008
			10^{-4}	133333±25137	0,0800±0,0120

The lowest total microbial number of soil in light chestnut soils was observed at an average dilution of 10^{-3} in the clay soil of gas station No. 1 (2482 CFU / cm^3 of water soil extract), which is 98.84 times lower than the control and 1.5 times lower than in the soil of gas station No. 3 (3243). In light chestnut soils, the following dependence was revealed: the total microbial number (TMN) of the soil is higher in the sandy soil of gas station No. 3 (133333 CFU/cm^3 of water extract of the soil) with a high content of PP = 52.00 mg/kg and HM_{Σ} = 9.52 mg/kg (water–soluble forms of Cu –

1.59 mg/kg, Ni – 2.00 mg/kg , Zn – 5.93 mg/kg) and with the highest dilution of 10^{-4} and lower in the clay soil of gas station No. 1 (24823) with the lowest dilution of 10^{-2} and with a lower content of PP = 17.00 mg/kg and HM_{Σ} = 7.99 mg/kg (water–soluble forms of Cu – 2.26 mg/kg, Ni – 2.00 mg/kg , Zn – 3.73 mg/ kg), which may be due to the granulometric composition of the soil and a high content of Corg (2.70%) and HM_{Σ} = 9.52 mg/ kg in the soil of gas station No. 3 compared with gas station No. 1 – Corg (0.82%) and HM_{Σ} =7.99 mg/kg.

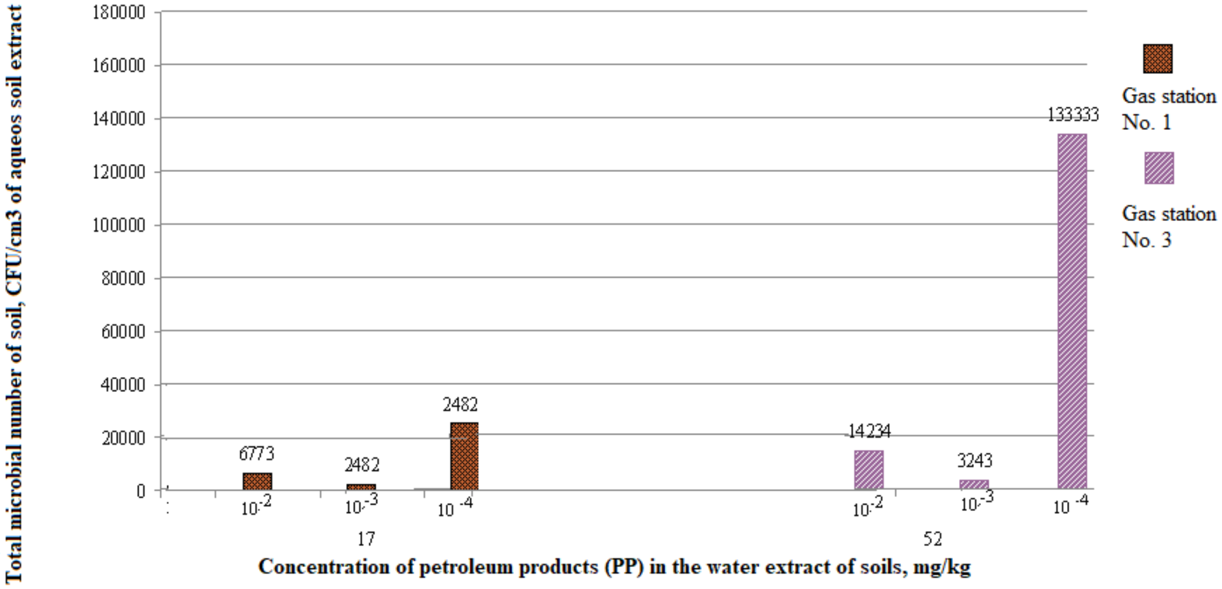

Fig. 5. Dependence of the total microbial number estimated by the fungus of the genus Botrytis cinerea on the concentration of PP in water extraction of soil: 10^{-2}, 10^{-3}, 10^{-4} – dilutions

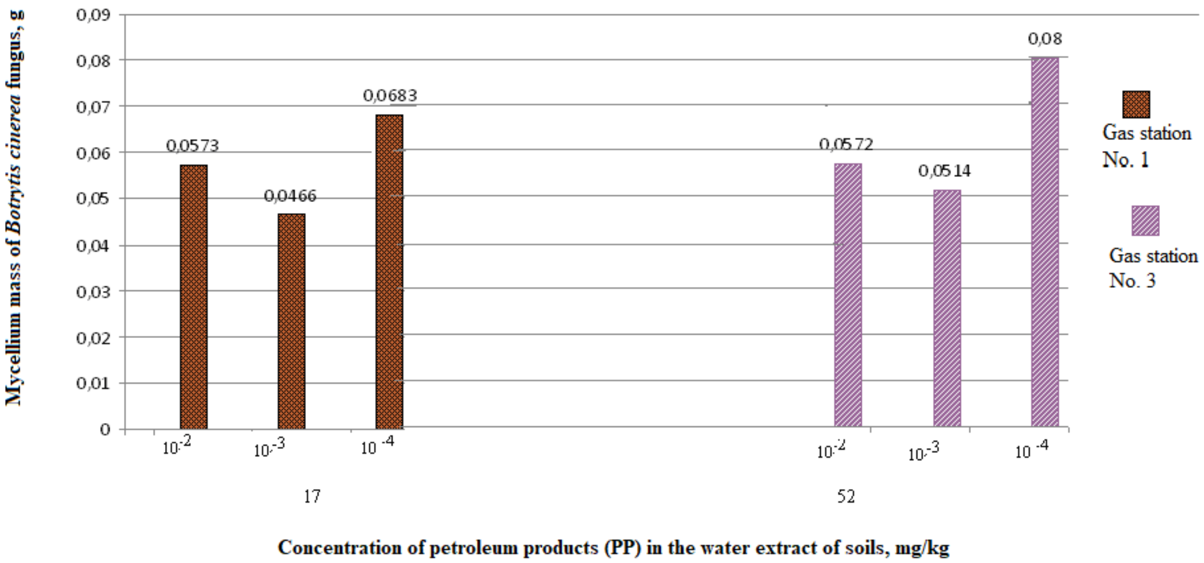

Fig. 6. Dependence of the mycelium mass of the fungus of the genus Botrytis cinerea on the concentration of PP in the aqueous extract of the soil: 10^{-2}, 10^{-3}, 10^{-4} – dilutions

Mycelium mass of the fungus *Botrytis cinerea*

In the control, the mycelium mass of the Botrytis cinerea fungus was 0.0850 g (Table 2). The dependence of the mycelium mass of the *Botrytis cinerea* fungus on the concentration of petroleum products (PP) in the aqueous extract of the soil is shown in Figure 6, for heavy metals it is similar. The maximum mycelium mass of *B. cinerea* fungus was observed at the highest dilution of 10^{-4} in the sandy soil of gas station No. 3 (0.0800 g), which is 0.94 times lower compared to the control and 1.17 times higher than in the clay soil of gas station No. 1 (0.0673). The minimum mycelium mass of *B. cinerea* fungus is observed at an average dilution of 10^{-3} in clay soil of gas station No. 1 (0.0466 g), which is 1.82 times lower compared to the control and 1.10 times lower than in the soil of gas station No. 3 (0.0514).

In light chestnut soils, the following dependence is observed: a large mass of mycelium of the fungus *B. cinerea* was detected in the sandy soil of gas station No. 3 (0.0800 g) with a higher content of PP = 52.00 mg/kg and HM_{Σ} = 9.52 mg/kg (water–soluble forms Cu - 1.59 mg/kg, Ni – 2.00 mg/kg, Zn – 5.93 mg/kg), and its smaller mass is in the clay soil of gas station No. 1 (0.0466 g) with the lowest dilution of 10^{-2} and with a lower content of PP = 17.00 mg/kg and HM_{Σ} = 7.99 mg/kg. This is also possible due to the granulometric composition of the soil and the high content of Corg (2.70%) and HM_{Σ} = 9.52 mg/kg in the soil of gas station No. 3 compared to gas station No. 1 – Corg (0.82 %) and HM_{Σ} =7.99 mg/kg (water–soluble forms Cu - 1.59 mg/kg, Ni – 2.00 mg/kg, Zn - 5.93 mg/kg).

4. Conclusion

The content of petroleum products and heavy metals in the soil negatively affects the survival of the earthworms *Lumbricus rubellus*. In clay and sandy light chestnut soils, 100 % mortality was noted on the seventh day. The survival rate of earthworms does not depend on the content of PP and HM_{Σ} in soils and its granulometric composition. For the first three days, the worms were alive in all the cuvettes. On the fourth day, 2 out of 10 worms died in the soils taken from gas station No. 1 and gas station No. 3. On the fifth day, 6 out of 10 worms died in the sandy soil from gas station No. 3, in the clay soil from gas station No. 1 – 5 out of 10 worms. On the sixth day, 8 worms died in the soil from gas station No. 1, 9 worms died in the soil from gas station No. 3. A week later, all 10 worms died in experiments without chitosan. Chitosan effectively reduces the toxicity of oil-contaminated soils. With the introduction of chitosan into the soil for 10 days in both experiments, the worms lived for 7 days. In the experiment with clay soil of gas station No. 1 (PP = 135 mg/kg, HM_{Σ} = 188.19 mg/kg), 3 worms died on 31 days, 4 worms died on 31 days from gas station No. 3 (PP = 202 mg/kg, HM_{Σ} = 242.74 mg/kg).

After 7 days, the spores of the fungus of the genus *Botrytis cinerea* began to grow on the control and water extraction soil of gas station No. 3. And after 14 days they grew on the water extracts of the remaining soils. The largest total microbial number of light chestnut soil was found in the sandy soil of gas station No. 3 (133333 CFU / cm^3 of water soil extract) with the highest dilution of 10^{-4}, which is 1.84 times less than in the control and 5.37 times higher than in the clay soil of gas station No. 1 (24823). The lowest total microbial number of light chestnut soil was observed at an average dilution of 10^{-3} in the clay soil of gas station No. 1 (2482 CFU / cm^3 of water soil extract), which is 98.84 times lower than the control and 1.5 times lower than in the soil of gas station No. 3 (3243). In light chestnut soils, the maximum mycelium mass of the fungus of the genus *Botrytis cinerea* was noted at the highest dilution of 10^{-4} in the sandy soil of gas station No. 3 (0.0800 g), which is 0.94 times lower compared to the control and 1.17 times higher than in the clay soil of gas station No. 1 (0.0673).

The minimum mycelium mass of the fungus of the genus *Botrytis cinerea* in light chestnut soils is observed at an average dilution of 10^{-3} in the clay soil of gas station No. 1 (0.0466 g), which is 1.82 times lower compared to the control and 1.10 times lower than in the soil of gas station No. 3 (0.0514).

In light chestnut soils, a direct dependence of the total microbial number of the soil and the mycelium mass of the fungus Botrytis cinerea on petroleum products (PP) and heavy metals was found.

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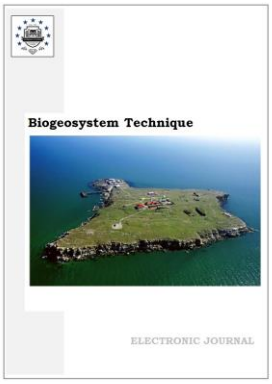
Published in the USA
Biogeosystem Technique
Issued since 2014.
E-ISSN: 2413-7316
2022. 9(1): 15-48

DOI: 10.13187/bgt.2022.1.15
https://bgt.cherkasgu.press



Some Methods to Improve the Quality of Animal Dung and Compost for Better Yields and Quality

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Paper Review Summary:
Received: 2022, February 20
Received in revised form: 2022, June 20
Acceptance: 2022, July 1

Abstract

In this article some measures are discussed to improve the yields and quality of organic (and conventional) agriculture with sea minerals, ditch dredge and rock flours.

Sea minerals restore the health of plants, animals and men. These sea minerals result in healthy urine and dung of the animals. This dung is a good basis for a healthy plant growth. The dung should also be mixed with carbon rich materials (straw; elephant grass; natural hay) and with earth, stone meal or ditch dredge. By binding the nutrients with carbon and earth particles the putrefactive microbes are avoided and in this way the breakdown of organic nutrients in inorganic salts is prevented. The symbiotic microbes hold the upper hand. They transform the nutrients in microbial protein and other organic compounds, and, once in the fields, help the plants to collect the organically bound nutrients from the soil and humic compounds and transport them to the plants.

Rock flours are also a good source of fresh macro and trace elements. The preferable type of rock flour depends among others on the type of soil, and the already available elements. Microbes are necessary for freeing the elements from the rock flours.

The yields and the quality in organic agriculture rise then for three reasons: more plant available macro and trace elements for the crops. And the presence of the symbiotic microbes which free and supply the nutrients for the plants. To support these farmers in animal husbandry should give less protein and especially less Non Protein Nitrogen and Non Protein Sulfur in the feed of the animals in order to improve the quality of the dung and the compost.

For many centuries farmers used salt, sea minerals, earth, ditch dredge and rock flours to improve the quality and quantity of the animal dung and plant residuals. And although some scientists have confirmed their results, the overwhelming majority of modern agricultural science has ignored this and persisted her own ideas about the necessary mineralization of nutrients before plants can take them up as salts for their growth.

Farmers who buy artificial fertilizers pay yearly 100-150 billion US dollars solely for the pollution of the environment, because of the huge losses of nitrogen and phosphate. Also a lot of potassium is lost, but the effects of potassium salts on the ecosystems are not investigated.

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By the use of animal feed with less protein, and with less NPN and NPS, and by adding sea minerals, carbon rich materials, rock flour, earth or ditch dredge to the dung, the farmers can avoid the problems of mineralized nutrients. Especially the problems of ammonia, nitrate, potassium, chloride, sulphate and phosphate: less losses, better yields and quality by rebalancing, and more biodiversity at lower costs.

By avoiding ammonia, urea and nitrate plants can again assimilate nitrogen from the air. Considerable amounts of nitrogen can be got for free in this way. The risks of mineral nitrogen are avoided, if not too much of good organic fertilizers is given.

Keywords: animal dung, sea minerals, organic fertilizers, ammonia and nitrate, symbiotic microbes, ditch dredge.

1. Introduction

The yields in organic agriculture are lagging behind compared to those in conventional agriculture. Some authors think this is because mineralization of organic nitrogen is too slow or too little (Nigten, 2021b). But mineralised nitrogen is not the only way in which plants can get their nitrogen. Plants can take up organic nutrients as well. And under the right conditions all plants can assimilate also nitrogen N_2 from the air (Nigten, 2021a).

The intake of inorganic nitrogen is not a safe way for plants to get their nitrogen.

But also not all the organic nitrogen is good for plants. When the symbiotic microbes are put aside by putrefactive microbes, the latter produce a lot of rotting organic nitrogen and sulphur compounds, followed by toxic inorganic nitrogen and sulphur compounds, and also microbial toxins which hinder and even block the growth of the plants. At least temporarily.

Putrefactive microbes in the animal dung take the upper hand when the fodder of the animals contains too much protein, non protein nitrogen (NPN) and non protein sulphur (NPS), is not in balance for its macro-elements, and misses the necessary trace elements. The farmyard manure and the slurry of these animals are no longer a good fertilizer. The same for heated composts. Heated composts have lost a great deal of nitrogen, carbon and other nutrients during processing and contain no longer the microbes which belong to the rhizosphere. Farmyard manure, slurry and heated composts lose a lot of nutrients, unless special measures are taken to prevent this.

In my last article (Nigten, 2021b) we saw already that using dung worms to convert animal dung and plant residuals or the adding of earth to manure or to plant residues gives fertilizers with completely different results compared to giving just animal dung or heated composts.

The positive effects of vermicomposting on yield and quality were demonstrated in the last article. Here I will elaborate further on the use of seaminerals, earth, rock flour or ditch dredge in dung or plant residuals. It is interesting that the feeding to earthworms of vermicompost which is made by dung worms (*Eisenia fetida* e.g.) results also in mixing with earth – by the earthworms as their name says. Chaudhuri has demonstrated that vermicompost is a very good food for earthworms (e.g. *Lumbricus rubellus* and *Lumbricus terrestris*) (Chaudhuri, 2016). Dung worms make vermicompost without earth, and earthworms make it in combination with earth.

2. Results and discussion

Nitrogen in organic agriculture – What should be done?

Sea minerals are a very special product, available in different forms. The origin of sea minerals is the land. The minerals from the mountains are weathered and after being used as food for microbes, plants and animals from the soils they stream through the waterways or via the air into the seas. Part of the land minerals go directly into the oceans after volcanic eruptions or via the rivers or by the wind. Huge amounts of desert sands are blown to the oceans. But this is only half the story. In the oceans a big separation takes place. Sodium chloride becomes the most voluminous compound in the sea water, followed by magnesium chloride. Potassium, nitrogen, oxygen, phosphor, sulphur and calcium are found only in smaller amounts in the sea water. Almost all other elements of the earth we find also as trace elements in the oceans. We can say there exists a very strong equilibrium in the seas, but I don't know why this equilibrium is there, or how it is regulated, nor the specific role of sodium chloride in it[*].

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[*] I got the idea that sodium chloride protects the seas against too much putrefying microbes. After all, everything is there for such putrefying microbes: big and small cadavers of all kind of sea animals; poop and

And the oceans have still another refreshment which gives new elements every day – the big black smokers from the ocean floors where the ocean plates drift apart and give room for eruptions from the earth mantle. These eruptions continue to give new material on which sea life prospers – every minute, every hour, year after year.

The seawater has everywhere on earth the same composition (Murray, 2003), with the places where rivers end in the sea, and where the black smokers erupt, as exceptions. There the composition differs from the normal composition of the oceans. The black smokers contain lots of iron, sulfur and magnesium. Many elements sink to the bottom of the seas. Like potassium, phosphor and manganese.

We can collect sea minerals in different ways: as seawater; brackish water; seasalt; seasalt without or with little sodium chloride*; seaweeds; plants along the seashores; fish residuals; shells. The composition of most of these products differs from pure seawater minerals, but all are very rich in minerals and trace elements, and all are used by mankind to fertilize their crops. Or people consume them directly. See for the elemental composition of seawater annex 1.

I discuss first the use of seawater and Seacrop. Seacrop is a product made of seawater from which NaCl is largely removed.

The use of sea minerals

Cows grazing on the salt marshes (the Kwelders at the seashores in the Netherlands) do not avoid the grass around the pats. A dairy farmer in the province Groningen, the Netherlands, pointed out to me that the grass around the pats on the salt marshes is eaten to the bottom. In other words, the plants on the salt marshes – saline grasslands – contain something that ensures that the digestion runs smoothly and that the dung no longer rots but matures. The plants on the salt marshes absorb sea minerals. And that is exactly the experience on farms where the cows are fed the products Sea-Crop or Sea 90. Sea-Crop is concentrated seawater from which the salt - NaCl – has been largely removed. With this product containing a lot of magnesium chloride, enzymes and trace elements, the disrupted digestion can be repaired quickly and easily. A possible explanation for this is that this magnesium compound binds phosphate and ammonium in struvite (and possibly also binds sulfur) in the rumen in such a way that they are no longer harmful, but that these compounds still remain accessible to the rumen bacteria. Clay minerals – as in celtic seasalt – strengthen this recovery process by binding (other) harmful substances. The result: good rumen and intestine functioning, a healthy liver and healthy kidneys, good utilization of the nutrients, good dung and urine with not too much nitrogen. In the rumen and the rest of the digestive tract, the harmful putrefactive bacteria disappear, and the lactic acid bacteria and other symbionts return.

Another explanation is that the microbes in the soil, the rumen and the intestines use the sodium, magnesium and trace elements in the Sea-crop or Sea-90 to convert the nitrogen, sulphur and phosphor in true proteins, or other organic compounds which are adapted to the physiology of plants, animals and men, thereby restoring the health in the metabolism. These microbes become again true symbionts, the putrefactive bacteria are set aside and the bacteriophages on the slimey surfaces of the intestines and in the stomach/rumen are also reconditioned.

Concentrated seawater, collected from the sea of Cortez, is after strong dilution, used in agriculture to protect crops against pests and diseases (Sea 90, 2021). Sea crop is a product from which most NaCl is removed. Celtic seasalt is harvested in Brittany, France. Sea-90, Sea-crop and Celtic seasalt are three brand names, available in the market.

In 2020 a dairy farm with salt marshes at Goeree Overflakkee in the Netherlands won the first price for its Schorren cheese, made with the milk of his yersey cows, in the International Cheese and Dairy Awards: 'Best of the Best 2020'. The milk of these Jersey cows is rich in fat, protein, vitamins, carotene and CLA's (conjugated linoleic acids), and has the double amount of minerals compared to Holstein milk. The cows graze at the Schorren or Kwelders. Schorren are pieces of grassland outside the dikes of the island, which are regularly overflown with seawater. See also annex 4 for the effects of sea minerals on milk quality and on a better conversion of inorganic nitrogen into amino acids and proteins.

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urine; the residuals of plants and other vegetable life… Bacteriophages also play an important role in the oceans by preventing overgrowth of (putrifying) bacteria.

[*] The product Seacrop is an example of this type of sea minerals.

Through Neveu's research, we know that magnesium chloride also works as a universal 'vaccine' (Neveu et al., 2009). It restores the natural resistance of the organism, and then the organism is again able to defend itself against harmful organisms. Magnesium also helps to avoid diabetes (Erbs, 2014). In addition, orally consumed magnesium chloride has no negative side effects (Neveu et al., 2009). And I presume that as a consequence also the lactic acid bacteria and other symbionts in the intestines get the upper hand above the putrefactive bacteria.

Future research

Here is a challenge for future research: what makes magnesium chloride such an excellent compound, able to stop viral, bacterial and fungal infestations (Neveu et al., 2009)? How does it stop the putrefactive micro-organisms in the digestive system? Why is the number of white blood cells in men 300 percent higher after the consumption of magnesium chloride (Delbet, 1979, Moro Buronzo, 2012)?

Lactic acid bacteria are exactly the bacteria that you also want around your plant roots. Rusch, one of the founders of organic farming in Switzerland, has demonstrated with numerous measurements that these are important soil symbionts for the plants (Rusch, 1968). But we expel these symbionts if we fail to get the cows' digestive system in order (and that also applies to pigs and chickens). The same happens if we add heated composts in the soils. The bad organic fertilizer that then arises does not stimulate symbiotic soil life. Decay bacteria that produce harmful compounds and toxins will dominate over lactic acid bacteria and other rhizosphere symbionts that supply the plants with the appropriate bacterial protein and other organic compounds. Decay bacteria and their products inhibit plant growth. If a dairy farmer sees that his cows are permanently suffering from diarrhea, and that the pats are not frequented by insects, beetles and worms, then that should make him think: time for action…

From bacteroids back to bacteria… and vice versa

Hugo Schanderl's work occupies a special place when it comes to bacterial research. Schanderl demonstrated that microbes which live as symbionts in the interior of plants can step out and regain their original, non-symbiotic form (Schanderl, 1947). They change in four or five steps from bacteroids back to real bacteria. His hypothesis was that plants can exert influence on the type of bacteria in the rhizosphere through this exit mechanism. For example, he has demonstrated that lactic acid bacteroids can step out.

The 'Zentralblatt der Bakteriologie' in Germany reacted with hostility at the time and refused to publish his research (Krämer, 2012). That despite the fact that many others have neatly reproduced his evidence that bacteroids actually exit and can turn back again into bacteria – remutation as Schanderl called it (Krämer, 2012). Only Rippel and some others disagreed.

Schanderl's commentary on the negative findings of Burcik, Rippel and Schaede boils down to the following:

- A wrongly chosen medium;
- An incubation time that is too short;
- An observation period that is too short;
- Wrong conclusions based on the observations made;
- Unknown 'methodical errors';

For a detailed description of Schanderl's work, see my article from 2019 about his work (Nigten, 2019b).

The results of the research by White and his colleagues at the Rutgers University, New Jersey USA, fully agree with the views of Schanderl and show that he was right, and therefore contradicted the German 'Zentralblatt'. White et al., 2018 studied the way in which the plants get their nutrition. An important route is the "denuding" of the symbiotic bacteria. But that happens in a very special way:

"In the rhizophagy cycle symbiotic microbes (often seed transmitted bacteria) alternate between an intracellular/endophytic phase and a free-living soil phase. We hypothesize that microbes acquire soil nutrients in the free-living soil phase and that those nutrients are extracted from microbes oxidatively in the intracellular/endophytic phase " (White et al., 2018).

In White's research, leaving and re-entering is a dynamic and symbiotic process, even more so than with Schanderl. White was able to reach his conclusions through very detailed observations.

Recently Pradeu has shown that there are also viroids in the cells of bacteria, archaea, insects, plants and animals that make an important contribution as symbionts to various life processes

(Pradeu et al., 2016a). And Hunter demonstrated that many bacteriophages live inside bacteria and play symbiotic roles there:

"...the number of bacteria that are found to depend on phages for crucial functions increases almost by the day (..) ...it seems that some phages have become almost permanent components of bacteria". (Hunter, 2008).

So the role of bacteriophages is more complicated than thought before: they are not simply 'viruses that eat bacteria'. Schanderl already predicted in 1947 that symbiotic viroids can also step out. Altenburg posited in 1946 that the symbiotic viruses can attack the host under changed circumstances (Altenburg, 1946). I presume that Altenburg built on the work of Béchamp, who made similar observations as early as the 19th century (Béchamp, 1883; Béchamp, 1912).

Béchamp was Pasteur's big opponent (Douglas Hume, 1947). In Pasteur's view, we, or the plants, are simply unlucky when harmful microbes from the environment find their prey. This is known as the germ theory. Béchamp was of the opinion that only organisms with a weakened resistance can be attacked by these microbes. In his view, the environment – in this case the organism with a weakened resistance - creates the opportunity for microbes to attack and scavenge that organism. They often come from within, says Béchamp. So he opposed the germ theory of Pasteur. *Helicobacter pylori*[*], *E. Coli*, *Herpes simplex* and *Herpes zoster* are good examples. They live normally in our bodies without doing any harm. Probably they act there as symbionts (Blaser, 2006). But when conditions change, they can become harmful to very harmful. Even the poliovirus lives normally as enterovirus C. in our intestines.

A fairly recent change in our internal environment is that we ingest more NPN and NPS and polyphosphates (e.g. soft drinks and ultraprocessed foods). And maybe also urea from plants. Maybe *Helicobacter pylori* becomes more aggressive because of its urea or ammonia consumption. See for this possibility Eaton (Eaton et al., 1991). And it is my hypothesis that inorganic phosphate from crops overfed with the salt Superphosphate, is also a source of disruption of the physiology of higher organisms. Probably the same for iron and manganese. Iron in red meat is an important source of different types of cancer, and manganese is found in large amounts in the brains of people with dementia. In a complicated way which is not yet understood these elements are not assimilated properly.

The work of Pradeu et al. shows that the other way of thinking about the role of viruses has been taken up seriously again in recent decades. The definition about viruses is undergoing major changes, and their role in evolution is also currently being thoroughly revised. The simple idea that viruses are mainly parasites has proved unsustainable. See for instance the complex roles of bacteriophages in the ecosystems, and on the slimey surfaces and in the cells of higher organisms. You could say that the evolution from "lower" to "higher" organisms is an almost process-based balance between parasitism and symbiotism.

The term symbiosis refers to dynamic processes. Symbiosis is not a permanent fact, but can change into a parasitic relationship when circumstances change.

Only those forms of symbiosis that are based on favorable preconditions will survive until the natural death follows. In nature, the 'weaker forms' of symbiosis are more likely not to persist. In other words, if a human, animal or plant does not have the living environment that is necessary for its survival, it will inevitably fall prey to parasites over time. If the "normal" natural resistance fails, the higher organisms will disintegrate and fall back into their lower life forms - viruses, bacteria, yeasts, archaea, and fungi.

Thanks to the work of Pradeu et al., we can form a clear picture of the ongoing debate about the role of viruses. Their work firmly overturns the prevailing ideas about what life is and what the role of viruses is in it. Pradeu writes very clear and accessible about this complex matter (Pradeu, 2016a, Pradeu, 2016b).

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[*] "Some studies suggest that H. pylori plays an important role in the natural stomach ecology, e.g. by influencing the type of bacteria that colonize the gastrointestinal tract. (Blaser, 2006) Other studies suggest that non-pathogenic strains of H. pylori may beneficially normalize stomach acid secretion,[21] and regulate appetite.[21]". Source: Wikipedia the free encyclopedy, keyword: Helicobacter pylori. Blaser informs us about helicobacter as follows: "Although H. pylori was once present in almost every adult human, the bacterium is now rapidly disappearing from human populations owing to changes in sanitation, demographics and antibiotic usage. Today, fewer than 10 % of children in the USA harbour this bacterium in their stomach" (Blaser, 2006).

How to get back the bacteroids or symbionts?

In 2020 I wrote an article in this journal about the necessity of balance in our crops. And I gave an example of carrots in almost perfect balance in Normandy, described by Eugene Marchand in 1869 (Nigten, 2020). Marchand told that the farmers in Normandy at that time fertilized their fields with farmyard manure, guanodung, seaweed; herring waste and brine. Recently I found an article of Marchand in which he and Girardin describe how the farmers treated the herring waste and brine and what were the results (Girardin, Marchand, 1859). Here a short summary:

- What is in the brine water? Lots of seasalt; blood, eggs, scales, spleen, oil etc of the herrings;
- Marchand has measured in detail which elements and compounds are in it: salt; sulphur; phosphorus (3.8 g dm^{-3}; nitrogen (5.9 g dm^{-3}); magnesium; organic compounds; proteins; lactic acids; propylamine.The exact measurements[*] you find at page 242 of (Girardin, Marchand, 1859).
- When the brine plus the herring waste became too old it became poisonous [through putrefaction];
- The salt ('avec ses qualités stimulantes'); the nitrogen and the phosphorus make this product so valuable for the farmers;
- 543 ltr of good quality brine plus herring waste has as fas as nitrogen is concerned the same value as 1 m^3 of manure. And 393 ltr of the brine+ (= seaweed + herring waste + brine) contains the same amount of phosphor as 1 m^3 of manure.
- No more than 13 to 14 barrels (1765 – 1900 ltr) with the brine and the herring waste plus seaweed per hectare are necessary for calcareous soils; For wheat 10 – 12 barrels suffice;
- Most crops do very well when amended with the brine +, combined with manure and/or compost: wheat; barley; oats; potatoes; fodder beets, rapeseed and flax. Not sugarbeets.
- And especially the gardeners appreciate it very much. And the dairy farmers as well.

"In Dieppe, Saint-Vallèry, Fécamp, gardeners and market gardeners make great use of brines, and it is thanks to their use that they obtain such beautiful tender and tasty vegetables in the sandy soils of the coast that they cultivate. They also eagerly seek out scales which are sold separately, and spoiled or broken fish which are sold under the name of caque. These two kinds of residues generally cost 50 c. per barrel more than brines. (..) On pastures, especially those of which ryegrass forms the basis, they produce excellent effects; they increase the production of herbs which, by assimilating a certain proportion of sodium chloride, acquire very special properties to cause fattening of animals". Translated in english from:" (Girardin, Marchand, 1859: 248).

In three ways the sea products (= seaweed + herring waste + brine) are brought up the soil:

- After dilution with water;
- After mixing with farmyard manure;
- Or by mixing them with earth or composts;

The last method is preferred by the good cultivators. And because sea products are not a complete fertilizer, the farmers should use them in combination with the manure or the compost. Or the manure in the fall, and the sea products in the spring. Or the sea products and the compost together in the spring.

To make the best composts with the sea products, the following method is used:

"To make excellent composts with brines, we operate in the following way. We incorporate road soil, sludge or clippings of ditches, ponds, small lakes with about a third of chalk or well crumbled white marl; we form graves with it that we sprinkle with the brines, until they are almost saturated. We turn these graves from month to month until the time of their spreading on meadows, which can take place 3 to 4 months after starting to mix. The only precaution to observe it is to prevent the graves from drying out; we get there easily covering them with earth or old straw, when you cannot build them in a place sheltered from the sun. – 500 to 600 kilo of such compost is more than enough to fertilize one hectare of meadows". Translated in english from:" (Girardin, Marchand, 1859: 250).

So here we see that also earth or ditch dredge or sludge is used. And the interesting thing is that the salt in the brine is not a problem. Normally only lactic acid bacteria can survive in a salty surrounding.

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[*] At that time the measurement of small amounts of trace elements was not yet possible... or the importance of trace elements was unknown.

We can learn here that the fertilizing with animal dung and compost, enriched with seaminerals and earth gives very good results: good yields and balanced crops. The amount of NPN and NPS we don't know, because in that period these compounds were not measured.

Magnesium chloride and seacrop

In general we can say that plants, animals and men don't get enough magnesium, sodium, iodine and trace elements. (Seelig, 1981; Fan et al., 2008; Thomas, 2003; Davis et al., 2004; White and Broadly, 2005; Shivay et al., 2010; Dimkpa, Bindrapan, 2016; Abraham, 2005; Mariem et al., 2020). As a consequence, the whole digestion becomes disturbed with all its health consequences. Fats, proteins and carbohydrates are not assimilated well by the bodies or the plants. The best solution is to restore the balance in the crops by better fertilizing. But for the moment a second best solution for us as humans or for animals, is supplementation with sodium, magnesium, iodine and trace elements.

And of all the magnesium compounds magnesium chloride is the best. Neveu has proven that it works better than vaccins, because there are no side effects, unless you take too much.Neveu was a medical doctor and during thirty years he was able to cure men and animals with the most divergent diseases with magnesium chloride. And together with zinc, selenium, iodine, vitamin C, E and A we can prevent cancer and heart diseases to mention a few (Ramesha et al., 1990; Seelig, 1981; Singh, 1990; Voss, 2010; Schroll, 2002).

Seacrop, like Skrill[*] and bischofite, is a product from seawater with a lot of magnesium chloride. Only the salt – NaCl – In it is largely removed[†]. And Seacrop and Skrill contain a lot of enzymes and trace elements. Seacrop contains 88 elements. The experience is that within a few week animals and men recover completely from most diseases after using magnesium chloride, unless vital organs are already (partly) destroyed. Neveu has proven that most infections – polio; diphtheria; tetanus; influenza; asthma etc.; stop within two or three days if you treat the patients – animals and men – quickly with magnesium chloride (Neveu et al., 2009). This knowledge is ignored by the medics, because it undermines their earnings model. In the Netherlands we use it now especially on dairy farms with great success. And very likely it helps also against the corona virus. But when I informed in 2020 the Dutch virologists they showed no interest whatsoever. And in a simple trial with corona patients they were also not interested.

Sea-crop is also important for another reason. Many Dutch dairy farms add extra trace elements in the form of supplements into the fodder or on the pastures. But the number of trace elements most farmers add is limited. The advice of the Dutch 'Gezondheidsdienst voor dieren, (Healthcare for animals)[‡] concerns only iodine, selenium, zinc, molybdenum, and copper (Gezondheidsdienst voor dieren, 2021).

An extra complication is that some private firms which sell these trace elements, sell the dairy farmers not what they promise to sell. In other words: what is written ón the sacks is not available ín the sacks. And nobody knows.

And not all the trace elements which are used end in the animals. As a consequence these trace elements accumulate in the soil through the manure (Petersen et al., 2007). In the Netherlands the pig industry used in the past so much copper as a supplement, that the fields became poisoned through their dung. Sheep could no longer eat the fodder from these fields, They died because of copper poisoning. And the leeks grown on these soils contained too much copper making them unfit for human consumption. Today zinc accumulates also in the same way. An alternative for these risky supplements is the use of rock dust which contain the intended trace elements (see annex 2: Trace elements from rock dusts). Or, as said, sea minerals.

The same happens today with magnesium oxide. Dairy farmers give this to their cattle to counterbalance the huge amounts of potassium in their roughage in order to avoid the risks of tetany. But, depending on the size of the magnesium oxide grains, only about 4 % of it is assimilated by the cows. The rest goes via the manure to the pastures where it accumulates and

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[*] Skrill is used a.o. in Brasil (Primavesi, 1995).

[†] The NaCl salt is removed, because too much salt burns the plants. But there is another problem which is not solved. During the evaporation of the seawater by the heat of the sun in order to get seasalt, the iodine is also lost through the same evaporation. So you have to add iodine for getting enough iodine in the plants, and the animals. And humans also need extra iodine. Kelp is a good source.

[‡] The GD – Gezondheidsdienst voor dieren – is an independent and market-oriented company in the Netherlands for all aspects of animal health on farms.

disrupts the cation balance in the soil. This disruption is aggravated by the loss of calcium. When you use nitrate fertilizers, part of the nitrate binds to calcium and this calcium nitrate is rinsed out into the groundwater or drains (Nutritech, 2021: verbal communication).

If you use seacrop, skrill or bischofite, enriched with kelp for the iodine, these problems are very small, or nil, because of the very small amounts.

Seacrop[*] (or 'immunites') you can order by telephone or e-mail at www.immutines.com. Direct contact via hak.b@hakwood.com is even easier (Seacrop, 2021). The website gives a lot of background information and results of trials with seacrop. I think bischovite is a good alternative for eastern Europe and Russia. But it misses probably part of the trace elements and enzymes from the sea.

The use of soil

A great deal of ammonia, methane, hydrogen cyanide (HCN), nitrogen oxides, phosphine, hydrogen chloride, hydrogen sulfide and volatile (fatty) acids escape directly from the animals (through their breath and skin) and from the manure, both in the stables where straw is added, and from the slurry pits, and further on in the pastures and the fields during and after spreading it (Mosquera et al., 2005, 2005b; Vanhoof, Nigten, 2020; Casey et al., 2006; Petersen et al., 2007; Hristov et al., 2010). There are solutions for these losses. The older research (Girard, Müntz, 1891) shows that peat, sawdust and straw partially bind the ammonia – in that order from more to less. In the Netherlands it is nowadays no longer allowed to use peat. Sawdust and straw without pesticide residuals are only available to a limited extent for organic farming[†]. But Girard pointed to another possibility: earth. Earth in the stables had a very favorable effect. In a sheep stable with plenty of straw, in 1891 the air contained 400 times more ammonia than the air outside. So straw clearly does not bind all ammonia. The results of Mosquera's research confirm this for solid manure in the current stables and during the storage of the manure. A lot is lost[‡]. A few years ago I visited an organic chicken farm. When we entered the chicken shed the stinking was almost unbearable. As if we breathed in lightly diluted ammonia. And the chickens produced almost only pure diarrhea. They breathed this terrible sting day and night.

If soil was added in cattle stables, the air in the stables became clean. Girard said light soil with a lot of humus worked best. Thomas Way, Thompson and Bowditch had previously also come to this conclusion in England (Way, 1850; Thompson, 1850; Bowditch, 1856). Just like Strumpf in Germany (Strumpf, 1853). And Marchand and Girardin described it for Normandy (Girardin, Marchand, 1859). Here we have the cow by the tail. Not everywhere in the Netherlands, but still in many regions, such soil with humus is available. Namely in the form of ditch dredge. And there is still recent experience with this in the Netherlands, namely at the dairy farms of the Spruit family and the Tilburg family. On both dairy farms, the manure is mixed with ditch dredge. One farm is on peat soil and the other on clay. And it works for both. The ditches of the Spruit family are now a very rich source of biodiversity, because the ditches are dredged, together with the aquatic plants being removed annually (Weeda et al., 2004). Thereby, nitrogen and phosphate etc. are also removed from the ditches. And at the van Tilburg farm the drain water is measured[§]. Here the loss of nitrate in the drain water was only a third of that of the other farms on the same clay soils in that area, according to the measurements by the RIVM. Ammonium was even more than 12 times lower in his drain water. The silicates and the plant residues in the dredge bind the ammonium, nitrate and phosphate from the manure very well, and together they prove to be good plant nutrition. The maize yields of the Tilburg family have been excellent since the use of this soil-and-humus-enriched manure. Every three months during the winter at van Tilburg's farm, the stable is emptied and then the manure is mixed with the ditch dredge.

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[*] From the website www.immutines.com: "The North American seawater concentrate Sea-Crop is certified by the Washington State Department of Agriculture (WSDA) as animal feed. Immutines has been GMP certified". "Immutines = seacrop.

[†] The use of Elephant grass is a new possibility. Every organic farmer can grow it himself. No pesticides are needed, and Elephant grass absorbs water three times better than straw (Oral communication by Eddo de Veer, the Netherlands).

[‡] "Using nitrogen mass balance approaches, daily ammonia nitrogen losses of 25 to 50 % of the nitrogen excreted in manure have been estimated for dairy cows and feedlot cattle" (Hristov et al., 2010).

[§] The relevant data from RIVM have been made available to me by the Tilburg family. RIVM is the Dutch State Agency responsible for public health and environment.

That could be done even better, and now I return to the work of Howard, one of the founders of organic agriculture. Howard left the oxen to stand on fresh soil at his experimental farm in Indore, India. When this soil was saturated with urine, it was brought to the compost heap, and new soil was brought in. He calculated that in this way he retained more than 100 % of the nitrogen (Howard, 1943). Even after heating.

"At Indore the work-cattle were kept in well-ventilated sheds with earthen floors and were bedded down daily with mixed vegetable wastes including about 5 per cent. by volume of hard resistant material such as wood shavings and sawdust. The cattle slept on this bedding during the night when it was still further broken up and impregnated with urine. Next morning the soiled bedding and cattle dung were removed to the pits for composting; the earthen floor was then swept clean and all wet places were covered with new earth, after scraping out the very wet patches. In this way all the urine of the animals was absorbed; all smell in the cattle sheds was avoided, and the breeding of flies in the earth underneath the animals was entirely prevented. A new layer of bedding for the next day was then laid. Every three months the earth under the cattle was changed, the urine-impregnated soil was broken up in a mortar mill and stored under cover near the compost pits. This urine earth, mixed with any wood ashes available, served as a combined activator and base in composting" (Howard, 1943).

Rusch, the cofounder of the "organisch biologischen Landwirtschaft' in Austria promoted also the use of rock flour in the stables (see annex 3) (Biolit, 2021).

Rudolf Steiner, the founder of biodynamic agriculture, also advised the use of soil in composting: one third of soil; one third of manure and one third of plant material (Steiner, 1924). Pfeiffer, a student of Steiner, worked it out in practice. In his book 'De vruchtbaarheid der Aarde' (The fertility of the Earth) he describes in detail how to make compost with earth, farmyard manure, plant residuals, and special Biodynamic preparations. And he also describes the effect for the plants: the complete restoration of their health. According to Pfeiffer 10-20 % of soil is enough.

He gives an interesting example: healthy tomato plants in green houses. These tomato plants got special Biodynamic compost made from residuals of tomato plants (this is only possible for tomatoes as far as we know: tomato compost for tomatoes) and earth. And the application of the other Bio-dynamic preparations. Only in the first year there was a little bit mildew and leaf roll disease. The next eight years the tomatoes stayed practically complete free of pests and diseases, although they were planted year after year at the same place. And good yields: 87 % first quality; 7 % B quality (too big tomatoes), and 6 % C quality (small tomatoes). But the use of the seeds from the homegrown tomato plants was a precondition (Pfeiffer, 1936).

In the description for compost making Pfeiffer said that after a short time the prepared compost is full of worms. In heated compost you never find any worm.

And Pfeiffer states that no extra fertilizers are needed if you treat the residuals of animals and plants correctly. I think he is right if you also use the human slurry, without the usual contaminations and with a correct treatment. In Belgium there is already experience with it. Here also rock flour was added. By using animal dung, plant residuals and human excrements, combined with earth the nutrient cycle is almost closed. Only the missing macro elements and trace elements have to be added regularly.

But we have forgotten these lessons or have not understood their meaning. I initially too have overlooked the role of the added earth. Maybe because these authors didn't explain why the use of earth is so important.

Till now I only found three examples in the recent literature of waste treatment with soil in the USA, Hungary, and France. It was about dairy waste, and pig slurry respectively. And the results are interesting:

"A soil treatment process called a barriered landscape wastewater renovation system (BLWRS) was developed in the USA and consists of a mound of soil over an impermeable barrier and a drainage system. Thus, an aerobic zone was created in the top portion while an anaerobic zone was created in the bottom portion of the BLWRS (Ritter and Eastburn, 1978). Evaluated for two years for the treatment of liquid dairy wastes, the system was capable of removing 90, 90 and 99 % of the COD, N and P, respectively. Again, the filter medium likely required replacing once saturated with P" (..)

"A four-stage soil filtering system was investigated by Kuli et al. (1996) in Hungary for the treatment of highly diluted pig slurries with 0.4 to 0.6 % TS. The simple low-cost system is operated from a straw pre-filter followed by a beds of wood shavings, gravel and sandy soil. The system was able to take loads of 2.5-5.0 m3 /day and its overall COD and BOD removal efficiencies were 43-76 and 46-88 % respectively, while 58-99 % of the TSS were removed" (..)

"In France, the soil filter system, Solepur, was highly successful at removing organic matter and nitrogen (N) from pig slurry during its first five years of operation (Martinez, 1997). The system consisted of three operations: application of large volumes of pig slurry to a managed field; collection and treatment [= denitrification, author] *of the nitrate-rich leachate; and irrigation of the treated water over other fields" (Martinez et al., 2009).*

But as I read it, these treatments were not intended to keep the nitrogen in the used soil, but to get rid of it as N_2, at least in the system of Ritter and Eastburn, and in the Solepur system. In the Solepur system the nitrate rich leachate was spread over other fields after a treatment for denitrification in which 85 % of the nitrogen was removed as N_2. The phosphorus was held in the soil, until it also leaked. Then the soil had to be renewed.

In my approach the earth is meant for keeping all the nutrients in the material, and not to get rid of it quickly.

That brings me to the following advice:

Collect as much ditch dredge as possible and put it to dry. Check whether your ditch dredge has been contaminated by sewer overflow, or by pesticides from your neighbors, or from your own farm (herbicides; insecticides; vermicides; fungicides; cleaning agents; antibiotics etc). Apply the dried dredge as a thick underlay in your deep litter stable in the beginning of the winter season. Put a layer of straw, elephant grass, or finely chopped natural hay[*], for a good carbon to nitrogen ratio, on top, and top it up daily with straw, elephant grass or hay from nature protection areas as you always do when the animals enter the stable. The urine drops through the straw and the natural hay, where it is partly bound, to the layer with dried dredge. There, the unbound nitrogen, phosphorus and sulfur etc. bind to the dredge and the plant residues from the ditch. And regularly sprinkle some rock flour in the stable. This is laborious, but it pays for itself in the form of even fewer nitrogen losses[†] (Shah, 2013). Instead of rock flour, you can also use dry dredge to sprinkle on top, but you can't sprinkle dredge properly, unless we find a way to do that[‡] – (by drying, crumpling and sieving?). When the bottom layer is saturated, remove all combined material from your stable and place it – preferably indoors – on a heap until you can spread it in the fields.

Make sure that the temperature in the heap does not rise too much: the maximum is 35 degrees C. If there is enough soil, the pile will automatically remain cool. Cover everything you have taken out of the stable with some compost or dredge to bind the last nitrogen, and prevent in this way the residual evaporation. Boussingault pointed out the importance of sufficient water in the manure heap, so that no heating occurs (Boussingault, Dumas, 1844). The optimum level for moisture is, according to Witte, between 35 % and 50 % (Witte, 2014). And avoid fresh oxygen entering into the heap. Now that the ammonia is bound, you can also introduce worms in the heap. I suppose that the worm *Dendrobena veneta* is most suitable, because there is also soil in the

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[*] In the Netherlands there is a lot of natural hay from nature protection areas available for dairy farmers as fodder or as litter. And if there is no ditch dredge available, you can also use earth from the heathers, as the farmers in the past did: heather sods. If you make big pits for water storage for dry summers, you can save the soil also for the farmyard dung or the compost heap. Or the earth from potato or (sugar)beet harvesting.

[†] Shah demonstrated that the combination of irrigation and lava meal gave huge reductions of NH_3 emissions. Lava meal alone gave a reduction of 46 %, while 10 mm irrigation alone of covered manure during spreading gave a reduction of 92 %. A combination gave a reduction of 97 % (Shah, 2013: 102).

[‡] Strumpf mentions this method – sprinkling soil on top of it – in his chapter on binding the ammonia in the stables (Strumpf, 1853: 329). (Last month I found out that the ditch dredge which had been kept for a year, broke down easily in small particles, while one year before this was almost impossible). Strumpf also mentions on p. 336 how magnesium chloride helps to bind the ammonium and phosphorus to struvite without impeding its uptake by the plants. He refers to Boussingault's research in this regard, in which he added magnesium chloride to the urine (Boussingault, 1845). Pierre (p. 290) showed that all grains reacted well and that buckwheat yields increased even sixfold when fertilized with this struvite (Pierre, 1852).

heap[*]. We are currently testing this with a worm test in the Wageningen Binnenveld in the Netherlands. In the stable you repeat the procedure: put down ditch dredge, sprinkle with straw, elephant grass, or natural hay, and rock flour etc, etc. And empty it again at the end of the stable season or if the layer becomes too thick.

The use of rock flours

If you have a slurry pit, you can add rock flour. In Austria this is done in many dairy farms with a slurry pit. But in a review from 2009 the authors conclude that for slurry it is still uncertain that rock flours reduce emissions. In fact, they found no studies in which an effect is proven (IBK, 2009).

In the IBK study the authors don't mention how the farmers use the rock flour. In the Netherlands the rock flour is brought into the slurry pit at the moment of spreading out the slurry in the spring. All the rock flour is brought into the pit in one go and immediately thereafter the slurry with the rock flour is spread over the fields. This is not the best way. During the winter a lot of ammonia and other gases are lost already. Last year we did a small experiment on a dairy farm. Here the rock flour was spread every day during the winter in the cowshed. From there it went into the slurry pit – day after day. The result was a complete termination of smells from the slurry pit. This seems to me a better method.

The IBK advises more thorough long term studies, and on specific rock flours and other additives.

Swoboda states that rock flour binds ammonia (Swoboda, 2016). For deep litter stables the positive effects are proven:

"Three different experiments were set up with fresh, composted and anaerobically stored solid cattle manure. Irrigation alone reduced the NH_3 *emissions by 30% for fresh manure, whereas it was not effective for composted cattle manure (..). The reduction for anaerobically stored manure was 65-92 % (5mm-10mm irrigation respectively). Rock dust that was mixed with anerobically stored compost prior to application and reduced the* NH_3 *emissions by 46 %. The combined use of rock dust and irrigation reduced* NH_3 *emissions by 97 % for anaerobically stored cattle manure*" (Shah et al., 2012).

And for slurry? Swoboda mentions also the use of Biolit in relation to ammonia reduction in slurry. Biolit is a rock flour of basaltic volcanoes, situated in Austria. At the website of Biolit is mentioned an Austrian study on this subject:

"*Das Austrian Research Center ARC, Abt. Umweltforschung, A-2444 Seibersdorf, hat am 06.10.2006 Rindergülle in Bezug auf die Ausgasung von Ammoniak getestet. Durch Zugabe von 5 % BIOLIT reduzierten sich die Werte um 27 %. Durch Zugabe von Kalk erfolgte keine Reduktion der Ausgasung von Ammoniak*". (Biolit, 2021[†]). Biolit is a basaltic rock flour.

Do rock flours, with or without slurry, work in the fields?

A complication is that temperature, acidity and rainfall play a big role in the degree of effectiveness of rock flour applications:

"The results confirmed the suitability of rock dust for warm, humid environments. Highly weathered soils in tropical environments are commonly characterized by a low pH, which favours mineral dissolution. Apart from the pH, minerals tend to dissolve faster as the temperature increases, which is caused by activation energy considerations[‡]. Tropical environments may also have higher precipitation rates, which additionally favours silicate dissolution (Harley and Gilkes, 2000)" (Swoboda, 2016[§]).

Swoboda concludes for the type of rock dust as follows:

"*A review of the trials confirmed the contradictions outlined in earlier studies, the majority of trials however resulted in minor to significant agricultural ameliorations. Basalt and volcanic*

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[*] The manure worms *Eisenia fetida* and *Eisenia andrei* are less suitable, because these cannot process soil. *Dendrobena Veneta* (its other name is *Eisenia hortensis*) lives in the top soil. For this reason, I hope he can process also soil particles. See: (Dominguez, Edwards, 2010).

[†] On the website of Biolit there is more literature about the binding of ammonia: Adams, Stevenson, 1964; Gollner et al., 2011.

[‡] It is not clear what the author means with: "*activation energy considerations*". I suppose it is something like an energetical stimulans for chemical or biological reactions.

[§] Swoboda gives a very good overview of the incertainties, the chances and the shortcomings of the different rock flours.

rocks generally performed better than granite or rocks containing primarily feldspar[*]" (Swoboda, 2016).

But granitic rock flour can provide potassium to potassium poor soils. And that is often cheaper than potassium chloride, and less harmfull. In many African soils there is lack of potassium. Feldspar in general gives less potassium than other potassium-minerals like biotite and nepheline. For the problems and limitations of potassium fertilization with granitic rock dust, see Swoboda (Swoboda, 2016). For the possibilities see Bernard (Bernard, 1956).

In Cameroon Tchouankoue and his colleagues did an interesting trial with four different kinds of basaltic rock flour. Their question was if these rock flours could be an alternative for artificial fertilzers. They got the best results with the most mafic rock flour. This flour contained the least silicon oxide and the highest magnesium amount. The yield for twelve tons of this basalt per hectare was ten times higher than the control. The control didn't get any basalt nor other fertilizers (Tchouankoue et al., 2015).

In another study in Cameroun with basalt, tuff, granite and pyroclastic materials, combined with green manures, the best result for carrots was the combination of basalt with green manures: a yield of 280 % compared to the control. And for cabbage the results for granite, and 'basalt + pyroclastic materials' respectively, were the same, 50% higher than the control (Tetsopgang et al., 2015). In most trials the effect of these rock flours last 2 to 4 years. The rocks are inert materials which give theire macro- and trace elements only if soil life extracts them. A low pH and a high temperature plus enough moist are also good for quick weathering.

Other studies in Panama with basalt amendments had also very positive results: the biomass of trees amended with basalt was 10.22 times higher than on local soils[†].

"*These results indicate that highly infertile tropical soils can be made productive with rock powder minerals alone*" (Goreau et al., 2015).

In 1998 Leonardos gave an overview of the possibilities of remineralization with different rockpowders of empovered soils in Brazil as an alternative for NPK fertilizers which are having bad effects on tropical soils (Leonardos et al., 1998). Part of his conclusions:

"Once soil fertility is re-established with the use of rock meal and other organic materials, NPK fertilizers can still be used as a small complement. (..). Although it has not yet been widely used in Brazil, stone meal could become the ultimate sustainable fertilizer, if we want to assure nutrient conservation and chemically adequate agriculture for our leached tropical terrain. Before this happen, it is necessary that Government research institutions, like EMBRAPA in Brazil, validate the stone meal concept through nation-wide experiments. Science should be used for the Earth and not against it" (Leonardos et al., 1998).

And a study by Guimolaire Nkouathio, also in Cameroon, showed that only rock flours – in this case pyroclastic rocks - gave much lower yields than NPK fertilizer. This reminds us of the fact that for every type of nitrogen fixation by the plants or their symbionts a start fertilization with nitrogen is necessary. So amendments of manure or compost or green manures to rock flours are important.

The results of the application of rock flours depend on many complicated chemical and biological processes. Harley has given an overview in 2000:

"*Dissolution of rock powder in soil is likely to be influenced by the composition of soil solution and the action of plants with many factors including climate, temperature, pH, bulk soil solution composition, changes in rhizosphere pH and redox, and chelation by organic acids being involved. Processes within the rhizosphere may greatly enhance the weathering rates of silicate minerals, and hence the rate of release of nutrients for plant uptake*" (Harley, Gilkes, 2000[‡])

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[*] Hensel and his followers had very good results in growing crops in pure granitic rock flours: high yields, no pests and diseases, and mineral rich foods (Bernard, 1956).

[†] Recently the possibilities were researched to lower the amount of carbonic acid in the air by fertilizing soils with basaltic rock flour, and other silicates. The authors see good possibilities, especially when combined with refertilization of unfertile soils (Beerling et al, 2020).

[‡] Harley helps us to understand the complicated processes which play a role if we add rock dust to our soils. Above that he gives an overview of the different types of rock dust, and which elements are in it. Phosphor for example is only available in greater volumes in apatite. Also for the availability of trace elements his overview is handy. For zinc you need phlogopite, and for cobalt staurolite. Nickel is only available in the ortho and ring silicates. See for phosphor also Jones (Jones, 2013). She states that in good, living soils one kilogram of phosphate/ ha suffices. That is amazing, to say the least.

So it seems that a combination of the best basaltic rock flours with manures or green manures gives the best results.

Future research

An important question is which type of rock flour you should use at what soils, and with what other amendments. Also the grain size of the flours, and the presence of vegetation and their rhizosphere symbionts are important (Harley, Gilkes, 2000). In many highly weathered tropical soils potassium and sodium are lacking, while in temperate climates where potassium salts are used in huge amounts, sodium is often missing. In dry areas with irrigation agriculture sodium is often much too high. But Howard has proven that adding compost to these soils, combined with aeration and drainage significantly reduces the salt problems and even ends it (Howard, 1945). On heavily salted soils you have to start with gypsum. A comprehensive discussion you find in the chapter 'The formation of alkali Land' in (Howard, 1945). In this chapter he mentions also the great risks of the fertilizer sulphate of ammonia which leads to accelerated combustion of humus.

Compared to rock flours, Sea- crop and other concentrated sea minerals are easier to handle because of the small volumes you need to use in case of sea minerals compared to rock flours. Murray advises 100 – 600 kg seasalt per hectare per year (Murray, 2003). But in many African and South American countries the rock flours are around the corner. And potassium in sea crop is very low.

If you have already given Sea-Crop to the cows to improve their digestion, part of the trace elements and magnesium contained therein is returned to the manure. Ditto for the clay minerals and the sea salt[*] that you sprinkled over the feed. This brings the manure back into balance and gives the grass most of the elements it needs and all the biology necessary for growth. A good potassium/sodium ratio in the grass is crucial for the quality and palatability (Chiy, Phillips, 1995). Such a good ratio – between 2 to 5 – ensures the lowering of non protein nitrogen in the grasses (Chiy, Phillips, 1993; Yarrow, 2011). You can also sell part of the manure to an organic arable farmer who also benefits from this high-quality manure.

The products of the organic arable farmer and those of the dairy farmer get a higher nutritional value through this manure. And that's what customers (should) pay for. We can easily measure that nutritional value: there should be more vitamins and anti-oxidants (phenols) (Baran'ski, 2014[†]); better fats like omega 3 fatty acids; less nitrate, ammonium and other non-protein bound nitrogen, and non-protein sulfur compounds, more proteins, the macro elements in balance and more trace elements. For the necessity to balance our crop, see (Nigten, 2020).

Experiment

Finally, we could do the following experiment.

Way informs us in his article, "On the power of soils to absorb manure," (Way, 1850) about Thompson's 1845 experiments which showed that soil completely purifies the urine poured on it. At the bottom you are left with clean water (Thompson, 1850). Moisture is a major problem in deep litter stables. On the one hand it evaporates, but then part of the nitrogen also disappears as ammonia, hydrogen cyanide (hydrocyanic acid), nitrogen oxide (NO_x) or nitrous oxide (N_2O). And also the other anions: P; S; Cl. partly evaporate. What if we use the soil of the stable to drain some of the excess moisture?

For the test, we proceed as follows: we lay drainage hoses in a solid layer of earth, and we install monitoring wells to measure whether nitrogen – nitrate; ammonia; urea; – disappears through the drain water or into the deeper groundwater. We lay the ditch dredge on this earth. On top of that, finely chopped natural hay or straw (or elephant grass). And then we scatter straw, elephant grass or natural hay every day on the surface where the cows walk. And rock flour also

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[*] A number of seaweed species are also suitable, provided that the macro elements are in balance, such as that of Fucus siliquocus. This Fucus is low in potassium, and rich in sodium (Wolff, 1871). So it is a good fodder supplement for the grass and silage from the potassium rich and sodium poor soils in the Netherlands.

[†] According to this study by Baran'ski et al., current organic products already contain 20-40 % more anti-oxidants than conventional products and four times less pesticide residuals, and less cadmium. And: "For most of the minerals (including many plant macro- and micronutrients), the meta-analyses could not detect significant composition differences between organic and conventional crops" (Baran'ski et al., 2014).

every few days[*]. Some of the fluid from the urine or dung drops down and is filtered. Shah's research has already shown that rock flour binds a lot of ammonia in deep litter stables (Shah, 2013). Next a part of the ammonia (and other inorganic N compounds) is bound by the straw, the elephant grass, or the natural hay. And then what is left is bound to the humus and the earth particles in the ditch dredge. The water that in the end drops down in the earth layer must be virtually clean. We use the monitoring wells and the drain water to check whether this is indeed the case.

For the subsurface we have to build three compartments: one with clay, one with sand and one with peat in this test. So three separate compartments. It is to be expected that the amount of water that seeps through is the greatest in the section with sand and/or the compartment with peat. But that will become clear when we measure the amount of drain water and the humidity of the top layer on which the cows walk. If the system works, we have probably realized the cheapest and most environmentally friendly stable imaginable, with cows that don't stand in their own faeces and urine. However, the feed fence must slowly rise as the deep litter layer thickens, otherwise the cows can’t eat in the end when the layer with manure becomes too high.

In this way roughly 90 % of all the iron structures now used in stables are not necessary. This is favorable for the stable climate, because we create less harmful electromagnetic fields. And we no longer need a concrete floor. So, it saves considerably on raw materials. The wallet stays filled. So much for this experiment.

At a presentation about sustainable livestock farming that I recently held for organic dairy farmers, I was asked how you can improve slurry. If you want to completely get rid of the slurry, you can convert the cubicle shed as follows

1. Remove all cubicles and other ironwork. Level the entire space so that you can drive in it with the tractor or shovel to fill it and empty it again later;
2. Make sure that the feed fence can slide upwards as the deep litter layer thickens;
3. And turn the entire space that is created into a stable as described above. The old slurry pit then serves as a collection for the leakage water from the stable manure;
4. Add to this the costs of an installation for spreading the stable with straw from overhead.

If your cubicle shed is still too new, or if you are afraid of all the adjustments, you can also improve the slurry considerably by adjusting the digestion via the feed track and by post-treatment of the slurry in the pit. The feed track is of course also very important for good deep litter manure. See the Vanhoof report (Vanhoof, Nigten, 2020). The general rule is: take care for a good balance between energy and protein (most dairy farmers give too much protein); and add enough seaminerals which are necessary for a good conversion of nitrogen, phosphor and sulphur into real proteins and healthy organic compounds. And take care that no pesticides, no cleaning agents and no veterinary medicines go into the slurry pit. They disrupt the normal organic processes in the pit, and later on in the soil and the plants. If the grasses and herbs are in balance and don’t contain NPN, NPS and inorganic phosphate, the animals don’t need insecticdes, vermicides, antiobiotics, etc. Their immune system will be able to protect them against pests and diseases. Pests and diseases prosper well on NPN, NPS and inorganic phosphate.

“Small amounts of slurry – 9 ton per hectare per time – with a good carbon to nitrogen ratio, widely spread ón the fields are not as disturbing as great amounts with a low C/N ratio which is concentrated in small strips ín the soil was one of the findings in our report of 2020 (Vanhoof, Nigten, 2020).

For a detailed explanation, you can also organize one or more thematic meetings with a group of colleagues, on which we explain the Vanhoof report, and the findings in this article.

True proteins

There are many physiological processes which prevent that the rotting or pathogenic microbes which thrive on NPN, NPS, proteins and nucleic acids can do their work. I suppose the following mechanisms play a role:

- The breakdown of the proteins, amino acids and nucleic acids in the rumen into harmful compounds is inhibited when most of the hydrogen ions which come free from carbohydrates and

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[*] A dairy farmer in the Netherlands places the rock flour on the straw and then distributes the straw mechanically. That saves a lot of work. Another farmer wets the rock flour before spreading it to avoid the dust from the rock flour.

sugars from the breakdown of cellulose, hemicellulose and lignin, are used to produce acetic acid[*] and some propionic acid and butyric acid. Free NPN and NPS, and too much protein – perfect food for putrefactive bacteria – disturb this process by the production of too much extra hydrogen ions from protein breakdown. The hydrogen ions form compounds with nitrogen, carbon, sulphur, and phosphor. All these compounds are poisonous: ammonia; phosphine; hydrogen sulphide and hydrocyanic acid. A normal pH for the rumen is between 6 and 6.5. Cows keep the pH between the correct borders with bicarbonate from the chewing.

Future research

In the literature some authors say that too much protein is really the culprit for the problems in the rumen and the intestines (Schmack, 2020). In fact, here is a serious problem. The laboratories in general measure only crude protein. But in fact they only measure nitrogen, and then they calculate with the Kjeldal formula how much protein there should be, or probably will be. This is not science, but gambling. For a correct judgement we have to know how much true protein there is and how much NPN, NPS and inorganic phosphate. Only then we will be able to study if the cause of many physiological problems in crops, animals and men is the amount of proteins or the (high) percentages NPN, NPS and/or P in feed, roughage, and food. Or in both combined. A plant can only make real protein out of nitrogen and sulphur if enough magnesium, zinc, sodium and trace elements are available. We know this because the health of sick cows is restored if we give them a sufficient amount of sodium, magnesium and trace elements. We suppose that microbes are in this case able to make real protein and 'physiological' phosphor out of the available nitrogen, sulphur and phosphor, carbon, oxygen and hydrogen. Even if these animals get the same fodder and concentrate they are able to restore after getting sodium, magnesium plus trace elements.

So for science the question is, do high levels of protein and organic phosphor cause the problems, or high levels of NPN, NPS and inorganic phosphate. Or both?

Another question is if it is clever to give fodder and concentrate with high levels of true protein. Why should you if it makes no difference for health and production. It is a fact that concentrate is expensive. Grass with a high level of true protein is probably better.

- In the stomach of monogastric animals part of the proteins is partly broken down into peptides and amino acids. A further breakdown is prevented while putrefactive bacteria can't survive in the very acid surrounding of the stomach. The pH of the stomach is between 1.35 and 3.5. Normally 2.

- The breakdown of remaining proteins, peptides, amino acids and nucleic acids in the intestines into harmful compounds is inhibited while most of the hydrogen ions which come free from remaining carbohydrates and sugars from resistant starch, are partially bound by lactic acid bacteria into lactic acid. The body of mammals and men can bind the remnant hydrogen ions with sodium bicarbonate from the pancreas. A normal pH for the duodenum is 7 - 9. For lactic acid bacteria a pH of 4.2 to 4 plus salt help to prevent the growth of pathogenic bacteria. How exactly the lactic acid bacteria survive in a basic environment I don't know. Maybe they defend themselves by creating small acidic micro-environments around themselves, which protect them against pathogenic microbes. Another way in which the intestines defend themselves is with the help of bacteriophages which live on the slimy surface of the villi of the intestines. These phages break down, or transform, the pathogenic bacteria (Barr et al., 2013[†]). The phages form an important part of our defense system, if the observations of Barr are correct.

- The last century some medical doctors, veterinarians and farmers who try to protect their animals and crops, or men, have gained a lot of experience with treatments with pure magnesium chloride, and with magnesium chloride plus trace elements from seawater. Based on these experiences we can say that these treatments help humans, animals and plants to restore health (Delbet, 1979; Neveu et al., 2009; Voss, 2010; Singh, 1990; Ramesha et al., 1990; Erbs, 2014). The mechanism is probably that the symbiotic microbes in all these organisms can convert all the harmful compounds of nitrogen, sulphur and phosphor which are accumulated in their systems into health supporting proteins etc. with the help of magnesium chloride and trace elements.

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[*] Bifidobacteria can produce acetic acid as well lactic acid. Also some lactobacilli can produce both. L*actobacilli* live at the end of the small intestine, and the *bifidobacteria* in the colon.

[†] Barr and his colleagues did their research on metazoa. But in the abstract they mention also the phages in the slimy surfaces of humans. An interesting question is if they also live on the dry surfaces of our skin.

So healthy mammals and men keep the pH between very narrow borders in the rumen, in the stomach and in the intestines. And probably also the level of oxygen. And magnesium chloride plus trace elements help to transform NPN, NPS and NPP in true proteins and other physiological compounds.

So rotting of the food is prevented. The lactic acid bacteria and the other rhizosphere/ intestines symbionts are then no longer suppressed by the exudates of the putrefactive bacteria or the putrefactive bacteria themselves. The symbiotic microbes help to make the organic and inorganic nitrogen in the soil available to the plants in the form of the proteins ín the symbiotic microbes themselves (White, 2019) after the manure has been spread. And the mycorrhizal fungi are now returning also, because all ammonia, nitrate, sulphate and phosphate is bound to clay particles and/or humic acids. Ammonia, nitrate, sulphate, and phosphate salts are substances that make life impossible for mycorrhizal fungi and symbiotic bacteria and viruses, unless they are bound to humic acids and/or earth particles. Humic acids can bind inorganic nutrients, such as in vermicompost, and improve the uptake of macro and micro elements (El-Boray, 2021).

The same mycorrhizal fungi and other microbial symbionts in turn ensure that the ammonium and nitrate, that are bound to the soil and humus particles and in struvite[*] or converted in the complex organic nitrogen and sulphur compounds from the cultivation layer are brought to the plant roots in the form of amino acids and proteins, as well as the chelated other macro elements, trace elements and the phosphorus. Bacteria and plants produce organic compounds – siderofores and ionofores - which bind metallic ions, and microbes help to transport them into the plant roots.

In short, by binding the metallic ions, the ammonia, the phosphate, the sulphur, the silicon, and the nitrate in the manure, we restore the soil biology and prevent further transition of nitrogen and the other elements from organic to inorganic forms. The small quantities of remaining inorganic nitrogen remain available to the plants without their harmful side effects. The plant feeds its symbionts with exudates and, in return, the symbionts supply organically bound nitrogen, phosphor, sulphur, silicon and metallic ions at the right time, in the right quantities and in the right forms. The symbionts make both the organic nitrogen ánd the bound inorganic nitrogen, ammonium and nitrate, (bound to humic acids for example) properly available to the plant as microbial protein. I suppose that in the intestines of animals and men comparable processes are at work.

The restauration of the survival and activities of mycorrhizae in the soil has still another advantage. According to a model-based assesment by Orwin et al. (2011) the mycorrhizae help to store carbon in the soil:

"We show that organic nutrient uptake can significantly increase soil C storage, and that it has a greater effect under nutrient-limited conditions. The main mechanism behind this was an increase in plant C fixation and subsequent increased C inputs to soil through mycorrhizal fungi. Reduced decomposition due to increased nutrient limitation of saprotrophs also played a role. Our results indicate that direct uptake of nutrients from organic pools by mycorrhizal fungi could have a significant effect on ecosystem C cycling and storage" (Orwin et al., 2011).

Future research

An important lesson from plants and cattle whose physiology is disrupted by the salts of nitrogen, sulfur, potassium, calcium, chloride and phosphorus etc. is that the health effects of these salts are far-reaching. Our research efforts should focus on a better understanding of these disruptive processes, and in particular on the roles of microbes in them. The study of these microbes is complicated because there are so many different microbes at work around the roots and in the intestines. And the same microbe can be harmful or beneficial, depending on the circumstances. Modern microbiology always tries to understand this by assuming that there are 'different strains' at work. But they forget that the same species can behave ánd be different when circumstances change. Microbes are very much polymorphic. And of the microbes we know only a very small number:

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[*] Struvite is a mineral in which magnesium, ammonia and phosphate are bound together. This is a safe compound. Superphosphate is not. Superphosphate makes the plants weak just like nitrate and ammonia. This conflict was fought out in 'the phosphate battle' from 1880 until 1910 (Jamieson, 1910). But the producers of superphosphate refused to practise this conclusion. See also Jones about the risks of superphosphate (Jones, 2013).

‘The biodiversity of the prokaryotes is unknown, but may be very large. A May 2016 estimate, based on laws of scaling from known numbers of species against the size of organism, gives an estimate of perhaps 1 trillion species on the planet, of which most would be microorganisms. Currently, only one-thousandth of one percent of that total have been described. Archael cells of some species aggregate and transfer DNA from one cell to another through direct contact, particularly under stressful environmental conditions that cause DNA damage’ (Locey, lennon, 2016).

Goss states that many pathogenic microbes survive in the soil after amendments with liquid and solid manure, and also antibiotics.

“Pathogens pose the greatest risk to human health from the use of organic amendments but few practices ensure that pathogens cannot contaminate food or water resources. Within the European Union (EU), the guidelines developed for the United Kingdom (ADAS, 2001) prohibit the use of untreated sewage biosolids on vegetable or salad crops.

These guidelines require that the application of conventionally treated biosolids to land for vegetable production is limited to crops, such as potatoes, that are cooked before consumption. Even then, an application cannot be later than 12 months before the crop is harvested” (Goss et al., 2013).

So an important research question is what happens to these pathogenic microbes after adding soil or rock flour to the solid and / or liquid manure. From the research on vermicompost we know that most pathogens are destroyed by the worms and their intestinal symbionts. Or are they transformed back into symbiotic microbes by the worms?

The lesson is that we should have read Howard, Steiner, and Rusch and their predecessors, and Marchand, Girardin and Murray better at the time. Then we would have previously understood the importance of soil and/or rock flour in manure, of seaminerals for the animals and crops and would have long since been using it widely. In my trials at Droevendaal – the experimental farm for organic agriculture at the Wageningen university in the Netherlands – such manure with earth and plant residuals gave an increase in grass yield of 20 % within eight weeks. And the animals showed a strong preference for this grass, possibly because I had also added salt to the dung. Moreover, such stabilized and balanced stable manure that is spread over the pasture is excellent feed for the insects, the dung beetles and earthworms. This is how we also get back the meadow birds (Onrust, 2017).

The main reasons for lower yields and quality in organic agriculture, and for low quality in conventional agriculture

So here we have the reasons why the yields in organic agriculture are suboptimal, and the crops not that healthy:

- There is NPN and NPS (and inorganic phosphate?) in the food, the fodder and the concentrates for men, cows, pigs, chickens etc. This, together with putrefactive bacteria and their toxins, disrupts the metabolism of plants, animals and men;
- A lot of nitrogen, carbon, sulphur, phosphor and other nutrients are lost during digestion, from the slurry pits and deep litter stables, and during heated composting. Also in storage and while spreading the materials in the fields;
- There is imbalance of the macro-elements in the feeds: too much nitrogen (Schmack, 2020), potassium, chloride and sulphur (Theel, 1933), and problably also too much phosphor (Thomas, 2003). And too little sodium, magnesium, calcium and silicon. Especially the healing role of sodium and magnesium, and the protective role of silicon in roughage and concentrate is heavily underestimated (Ma, 2004);
- This results in farmyard manure and slurry which is also not in balance and not healthy. With too much NPN and NPS. They contain putrefactive bacteria and other harmful microbes. And these produce rotting products, ammonia and nitrate, and toxins. The rotting compounds, and putrefactive bacteria and their toxins inhibit the growth of the plants and suppress the symbiotic bacteria, viruses and fungi. Too much ammonia and nitrate also disturbs the growth of the plants.
- And heated compost also has the wrong bacteria, and it has lost a lot of nitrogen, carbon, phosphor, potassium and other macro- and trace elements during processing. Heating leads to mineralization ánd big losses.
- A number of the organic farmers use antibiotics, cleaning agents, insecticides and vermicides for their animals and in the stables, because the animal health is suboptimal, as the fodder and concentrates are out of balance. The cows get fertility and birth problems, abomasum twisting, mastitis and foot diseases, and attract flies and intestinal worms and other parasites,

which have to be controlled with antibiotics, fungicides, bactericides, insecticides and vermicides. The residuals of these products end in the dung, and from there in the soil and the grasses and other fodder products. Most farmers don't know the power of herbs, magnesiumchloride and trace elements to restore the health of their animals.

Together all these factors hinder the uptake of organic nitrogen by the plants, and block the nitrogen fixation in the soil and above the ground on the leaves and stems. So in this situation the plants can only grow on 'mineralized' nitrogen - ammonia and nitrate – and mineralized phosphorus, potassium, calcium, sodium, sulphur and magnesium etc. And these in turn block the symbiotic microbes and their support for the plants.

In fact almost the same happens in conventional agriculture, but here the effects are even worse because of higher amounts of inorganic nutrients, especially NPK, sulphur and calcium, much more pesticides, and less carbon left in the soils. So the price in the longer run of higher yields in the short run is very high.

Insofar as conventional agriculture uses animal dung and compost the effects are comparable to these in organic agriculture. But many conventional farmers use then also extra inorganic fertilizers. In that case the effects are even worse (Vanhoof, Nigten, 2020).

The moment of distribution of organic fertilizers is also important.

The release of the nutrients from organic fertilizers starts already during the winter, even when the soil is cold. And the microbes eat them (Krasil'nikov, 1958), but when the manures and composts are given in the early spring, the regular practice in the Netherlands, the mineralization must still start and the toxins and growth inhibiting rotting products which accompany the mineralization hinder the plants. When the soil is cold, nitrate is taken up by the plants before potassium can be taken up, and potassium is taken up before magnesium is taken up. And because the putrefactive bacteria which produce ammonia and nitrate etc. also produce rotting products and toxins which hinder the growth, the plants can't get help from their symbionts to get organic nutrients.

With artificial ammonia, urea, nitrate and superphosphate you avoid these 'rotting' barriers, but these artificial fertilizers also result in crops which are not in balance and unhealthy. The plants themselves start 'rotting' in a certain way. Most crops can't survive without pesticides because they are sick. So animals and men eat sick plants.

So the only way out is the production and release of amino acids, proteins, nucleic acids and organically bound cations and anions such as siderofores and ionofores from the manure and from the organic residuals from plants.

To reach this a farmer must create the right conditions. These are the measures I propose:

- Take care for less proteins, NPN, and NPS, inorganic phosphate, inorganic sulfur and potassium in the feed and roughage;
- To correct the imbalance of the roughage and concentrates, and to prevent the occurrence of NPN + NPS, you give the animals seaminerals – seaweed, seasalt and Seacrop[*]. Seasalt as a foliar fertilization on the grass is even better, because it improves the quality of the grass directly and you need only little of it;
- To bind the toxins in the digestive tract you give the animals in the beginning also special clay particles;
- To bind the inorganic nitrogen, sulphur and phosphor in the manure and the slurry you add ditch dredge and rock flour to the manure in the deep litter stable, or rock floor to the slurry[†]. The ditch dredge contains earth particles and plant residuals which are themselves already rich in nutrients. In the classic Biodynamic agriculture the farmers gave 1/3 earth[‡], 1/3 plant residuals and

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[*] You should check the amount of iodine in these products, because iodine evaporates from it during drying by the sun. Kelp contains high levels of iodine.

[†] When you add ditch dredge to the slurry it won't mix properly and sinks to the bottom of the slurry pit. And my experience is that is works sometimes even contraproductive. Maybe others have better results. When I tried to use ditch dredge in slurry in 2020, the mix started stinking like hell, and that continued for months. But one year later – spring 2021 – I repeated this experiment with a slurry with a low amount of nitrogen. I added the same ditch dredge, and also separate rock meal and now the stinking is much less. And the same slurry or rock meal gives also little stinking. So it seems that for slurry rock meal is an equivalent alternative for ditch dredge. In july 2021 we started measuring the amount of ammonia and carbon dioxide from both mixes to find out if we did smell well. The result was that the amount of lost ammonia was comparable- fairly little.

[‡] Later on Pfeiffer concluded that 10-20 % earth is enough (Pfeiffer, 1936).

1/3 animal dung. In my field trials this gave also a higher yield of 20 %, compared to modern biodynamic dung to which no earth is added, but only straw or wood residuals. In biodynamic agriculture slurry pits are not allowed.

- If you have no animal dung but only plant residuals you can also add ditch dredge, and use manure worms to eat the residuals in order to avoid the heating and additional losses of heated compost. Manure worms make an excellent product from plant residuals. But the ratio of nitrogen to carbon should be low enough: 1/(12-15). Although the best vermicompost is prepared from cow dung, Chaudhuri (2016) had also very good results with a vermicompost prepared from only the leaves of rubber trees.
- Farmers can stimulate their crops to let them assimilate nitrogen from the air. But here is also more fundamental research necessary, as Doty has argued in her 2017 article (Doty, 2017). Possibly many modern varieties are no longer able to assimilate nitrogen from the air (Sait, 2018). In that case we need the older varieties to start with. And farmers themselves can experiment with their crops with the purpose of restoring the autonomous capacity of plants to fix nitrogen from the air. Two rules are important: you have to give very low levels of nitrogen as a start, preferable via vermicompost, or through mycorrhiza, and sufficient sodium, magnesium chloride and trace elements. (Sherry) yeast will also help (Schanderl, 1947), and plant growth stimulating compounds like auxins and gibberellins (Abdel-Mouty, El-Greadly, 2008). Also vermicompost tea can be an important stimulus. Bernard claims that pure rock flours also stimulate the uptake of nitrogen from the air. Just like Jamieson he said that all plants can collect nitrogen from the air, not only the leguminosae (Bernard, 1956).

So the yields and the health of plants, animals and men can be restored.

Through the modern organic and inorganic fertilizers, feed and food plants, animals and men can't stay healthy. The assimilation and dissimilation are disturbed, and as a consequence many assimilation products are incomplete and can't reach the cells. So they pile up in places where they shouldn't be. And the dissimilation products, like nitrate and ammonia, can't be removed in time and complete, so they also pile up somewhere in the systems. The consequence is disturbed growth, lack of energy, and diseases. Only with the help of products from pharmacy and the pesticide industry they are kept more or less alive. And these products disturb again the life processes.

The only way out is the prevention of these disturbing mechanisms. And a small group of farmers, advisers, agricultural scientists, veterinarians and physicians have developed ways to reach this. Let us learn from them.

The costs

And what about the costs of such an operation?

First I give some data of the direct costs of artificial fertilizers:

Christine Jones (Australia) calculated that farmers worldwide paid 100 billion US dollars for **nitrogen fertilizers** in 2015. 60 % and more is not used and ends in the environment. So the farmers pay 60 billion US dollars and maybe even more to pollute the environment with ammonia[*], nitrate etc. (Jones, 2015).

Khan calculated that farmers in Illinois pay $40 million per year for potassium fertilizers from Canada. And he calculated that the soils in Illinois have enough potassium for 8000 years, if the farmers bring back all the potassium containing plant residuals and manure. Above that, in most of the situations he researched, potassium chloride only sometimes gives extra yields and very often it is harmful for the crops (Khan et al., 2013). For tropical soils potassium containing rock powder is a cheap and save alternative (Swoboda, 2016).

The Global potash production (potassium chloride) was estimated at 68.1 million tonnes in 2018. 95 % of it is used as fertilizer. The prices of potassium chloride were very volatile during the last decennium[†]. In december 2018 the price was 268 US dollars per ton. So the farmers paid more

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[*] Doty calculated how much artificial nitrogen fertilizer was produced: "The so-called green revolution of the twentieth century was made possible through the Haber-Bosch process for production of chemical N fertilizer. Using high temperature (400-650° C) and pressure (200-400 atm), and approximately 2 % of global fossil fuels, this method produces over 450M tons of N fertilizer each year" (Doty, 2017).

[†] The price for potassium was $ 844 in January 2009. It then trended upward to reach $ 870 in February and March 2009. The price began to decrease in April 2009 and was down to $313 by March 2010 before bouncing back to $ 484 in February 2012. It continued on its downward trend until 2016 when it reached

than 17 billion US dollar for this fertilizer in that year (The Canadese Government, 2018). I didn't find data about how much potassium is lost. But we have a lot of data that crops which are fertilized with potassium fertilizers contain often three to five times too much potassium, as a consequence of luxury consumption of it. And this potassium is largely lost through our sewage treatment plants into the oceans.

Then phosphates:

More than 70 % of the phosphate salts is lost[*]. The estimates of Jones are even higher:

"The application of large quantities of water-soluble P, such as found in superphosphate, MAP, DAP [†]etc. inhibits strigolactone production by plant roots. That is, the use of these products will reduce root extension, root hair development and colonisation by mycorrhizal fungi. The long term result is destabilisation of soil aggregates, loss of porosity, reduced aeration, increased soil compaction and mineral deficient plants[‡]. *In addition to having adverse effects on soil structure, the application of inorganic phosphorus is highly inefficient. Around 80% adsorbs to aluminium and iron oxides and/or forms calcium, aluminium or iron phosphates, which, in the absence of microbial activity, are not plant available (Czarnecki et al., 2013). Only 10–15% of fertiliser P is taken up by crops in the year of application" (Jones, 2013).*

According to data from '*The phosphate fertilizer market Industry*', '*the global phosphate fertilizers market was worth $* 65.69 *billion in 2019. It is expected to grow at a rate of about 7 % and reach $84.04 billion by 2023' (*Phosphate fertilizers, 2021). So farmers paid in 2020 yearly roughly 50 billion US dollars for environmental pollution, and 15 billion for growing their crops with phosphate fertilizers.

What do farmers pay in total for the three most important artificial fertilzers: N, P and K?

In 2018 resp. 2019, the farmers paid for nitrogen, phosphorus and potassium per year 100 + 17 + 65 = 182 billion dollars. But this needs to be corrected, because the prices for potassium and phosphorus here above are the prices that the primary producers receive. The share of the intermediaries and for extra transport is added to that. So in 2019, the farmers paid at least $ 200 billion for the three fertilizers. And probably much more. The prices of the other fertilizers are added to that. Of this 200 billion US dollars at least 60 billion for nitrogen + 50 billion for phosphor were paid for environmental pollution. And probably even much more. And a great deal of the costs for potassium fertilizers were not necessary, because the soils in many parts of the world contain enough potassium for a long time. With an exception for the tropics and in sandy soils.

Above that the huge amounts of potassium which are given as salts, together with ammonium, nitrate, urea and superphosphate, disturb the electrolyte balance in the crops. By giving also sodium salts a lot of problems can be prevented. As leaf fertilizer you have to give about five to ten kilogram per hectare instead of hundred and more kilograms on the soil.

If all the losses from slurry, deep litter manure and heated compost are avoided, then the need for extra fertilizers would be only a fraction of this 200 ++ billion US dollar scheme. If scientists and farmers understand how to avoid producing losses, and if the governments stimulated the recovery of phosphor, potassium, ammonia and the other elements from the human sewage, the compost factories and the slaughterhouses we would solve the following problems:

- The high costs for the farmers would go down ;
- The environmental pollution in agriculture would stop almost completey;
- And biodiversity would be restored;
- The crops would get enough nutriënts without being overfed by nitrogen, sulphur, potassium and phosphor. So also pesticides will be redundant.

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lows of $ 215 and $ 216 between September and December of that year, and $ 214 between February and April 2017. Prices began to increase in the second half of 2017 and had attained $ 268 by December 2018.

[*] In an article in the Guardian of 6 september 2019 'Phosphate fertiliser 'crisis' threatens world food supply' the author writes: "Excessive use of phosphate is not only running down supplies but is also causing widespread pollution that leads to dead zones in rivers and seas. In 2015, research published in the journal Science cited phosphorus pollution as one of the most serious problems the planet faces, ahead of climate change". That sounds alarming.

[†] MAP is Monoammonium phosphate. DAP is diammonium phosphate.

[‡] So Jones confirms the conclusions of Jamieson in the phosphate battle of 1880–1910.

- And animals and people will get enough and healthy food;
- There will be no phosphorus shortage in the future, because enough will be reused.

For the Netherlands the benefits are even more. In 2015 25 % of the natural gas which is pumped up in our country, was used by the fertilizer industry[*]. And the price of this natural gas for the fertilizer production was kept low with big subsidies. In three to five years this fertilizer production can be brougth down to zero. And I calculated that ten percent of all the Dutch CO_2 emissions can be saved too in this way.

Methane, carbonic acid and nitrous oxide gas from cows, slurry and dung can be brought down also to a much lower level by producing healthy grass and concentrate, and by correct treatment of slurry, farmyard manure and plant residuals. So I estimate that at least 20-25 % of all the greenhouse gasses in the Netherlands can be saved. Also worldwide the savings can be huge.

If all the crops for food and feed are grown according to the lines sketched above, they can bring down huge amounts of sugars and carbonic acid into the soil with the help of the mycorrhiza and basaltic lava meal, where it is stored as organic carbon.

But these measures cost something:

- Extra time for collecting earth and processing it with the slurry, the deep litter and/or the plant residuals;
- The costs of seasalt, and Sea-crop, or Skrill, bischovite[†] and rock flour;
- Special clay for removing the toxins in the animals, at least in the first years;
- The preparation and spreading of vermicompost tea;
- And attention and love for all living creatures.

And the phasing out of the big bio-industry for chicken, pig and calf meat and eggs, which has no or too little soil where the animal manures can be used without over-fertilizing these soils, takes time.

Farms where animal husbandry and crop production are combined have preference.

In the Netherlands there is developed the view that cows should be kept on grazing land with only a little extra concentrates from food industry residuals. And the same for pigs and chickens: we should feed them what is left by humans, and the food industry, not by imported foodstuffs (de Boer, 2020).

We have to realize that the utilization of nitrogen from grains by e.g. chickens is also very inefficient. These are data from a review from Nigeria (only part of the table is copied) (Ogbuewu et al., 2012):

Table 1. The data from a review from Nigeria

Chemical analysis and amino acids composition of dried poultry waste on the basis (%).[‡]					
Nutrient	**a**	**b**	**c**	**d**	**e**
Moisture	7.36	9.40	11.40	4.50	7.40
Crude protein N	24.21	31.08	28.70	24.28	23.80
True protein N	10.84	23.18	10.50	14.73	10.60
Non protein N	13.37	7.90	18.20	9.55	-

So the amount of NPN in chicken dung is on average only somewhat less than the true protein-N[§].

NPN/TPN = 83 %.

In the same study are also data about total N in chicken manure: 4.3 %[**] (Ogbuewu et al., 2012). The average N % for cow dung in the study of Hopkins was: 0,53 % (Hopkins, 1956, page

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[*] According to Bisseling, Professor of Developmental Biology, at Wageningen University "No less than 30 percent of the energy costs in agriculture concerns the production of nitrogen fertilizer" (Boo, 2012).

[†] "In 1930–1950, vast bischofite deposits were discovered near the Volga River in Russia" Source; wikipedia english. Keyword: bischovite.

[‡] These data are collected from several investigations (a – e).

[§] In this table true protein is in fact true protein N, otherwise non protein N plus true protein can't be summed up to crude protein (N).

[**] This number is derived from Materechera and Mkhabela (2002), cited by (Ogbuewu, 2012).

74). So chicken dung contains 8 times more nitrogen than cow dung. That means the chickens use the available nitrogen very inefficiënt. Only 20 – 35 % of the N intake is used. 65 – 80 % is excreted (IAEA/FAO (2008). That could be done better.

Ogbuewu et al. (2012) propose to use the dung of chickens and pig after processing as feed for cows and sheep:

"Dried animal waste such as poultry dung is broadly equivalent to cereal such as barley in terms of protein and essential amino acids (Mcllroy and Martz, 1978). In UK, for example, when properly processed, dried poultry waste present no serious hazards to ruminants and poultry and had no negative effects on meat, egg or milk quality (Mcllroy and Martz, 1978)" (Ogbuewu et al., 2012).

I think it is better to improve the metabolism of the chickens and pigs, in order to lower the losses of valuable nutrients via the dung.

And the role and power of big agribusiness in agriculture would become much more modest. In fact farmers and consumers can miss them if the governments take their responsibility for reorganizing agriculture, for nutrient recycling and for organizing the local food chains with fair prices and wages for farmers and farm workers.

Governments can diminish quickly the huge losses from slurry, deep litter manure and heated composts by stimulating the measurements proposed here in order to stop the unnecessary losses. And by laws which forbid in say 5– 8 years emissions from animals, farmyard manure, slurry and heated composts, and from the sewage treatment plants, compost factories and slaughter houses : phosphine; ammonia; hydrogen sulphide; hydrogen cyanide; laughing gas; nitrogen oxide, carbon dioxide, methane, volatile fatty acids and many other compounds.

What I didn't mention so explicitly in this article is the loss of carbon from slurry, deep litter manure and heated compost. From a colleague of the University in Wageningen I understand that by heating compost at least half of all the carbon is lost, and problably even more. The same for deep litter and slurry. A large part of this carbon can be brought back into the soil instead of emitting it into the air as CO_2, cyanide and methane. The by effect is that plants bring down huge amounts of their sugars into the earth for feeding the microbes. These sugars help to heighten the carbon sequestration in the soil even more than the residuals of manure and plants (Jones, 2015).

We can understand this if we compare the conversion processes of aninal dung and plant residuals plus soil with making sauerkraut. In both cases the quality goes up[*], the digestibility (in the soil, and on the plate) improves, the losses are small, there is no heating, and the volume remains almost the same. And bacteria – mostly lactic acid bacteria - do the work, supported by some extra salt.

Schaumann has stated it as follows:

"In such an ordered state [of the nutrients in the soil, author], the substances must therefore:

1. Be available to the plant when needed,
2. Not be able to penetrate into the plant if the current life situation does not require it,
3. Not be flushed out of the ground, and
4. Not be fixed in the ground.

Our consideration therefore leads to the conclusion that many substances must be present in a curious suspended state. In inorganic nature, such labile intermediate states of matter are great exceptions; there the substances react with each other and quickly enter in a stable final state, in which they stay until new relations bring forward new reactions. In living organisms, however, all material processes take place in such labile equilibrium states. The chemical reactions are never carried all the way to the final stage, unless in case of illness. Health consists precisely in the fact that the material processes neither enter the phase of the solution nor that of the hardening, but are always just in a state of equilibrium between the two" (Schaumann, 2016).

There are in the Netherlands some other methods in the market with which farmers also try to improve the quality of manure, slurry and/or plant residuals. I mention them here only shortly:

1. By adding air in a controlled way into the slurry pit;
2. By adding special bacteria into the slurry pit;

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[*] Sauerkraut contains more vitamin B, C and K than the original white cabbage. For the other positive health effects see wikipedia English. Keyword: sauerkraut.

3. By adding lactid acid bacteria in the manure heap and some extra materials like sea shells to stimulate fermentation processes. The heap must be covered with plastic or compost in order to keep oxygen out;
4. By restructuring the water in the slurry pit with a Grander device. A Grander is a device which restructures the water in the slurry in order to get a better quality. We don't know how this water influences the quality of the slurry. But it works as fields trials have shown;
5. By giving special herbs like pumpkin seeds, and plantain to the cows to improve their rumen performance.
6. By microbial composting (Witte, 2014);
7. By enriching the slurry with carbon;
8. By spreading vermicompost tea;
9. By diluting the slurry with water;
10. By supplementing slurry fertilizer with amino acid fertilizers ('You need 50% less slurry');

Many farmers use also combinations of these methods.

Future research

Experience learns that local or regional situations always differ. So we need again the old by the government supported agricultural experimental stations to find out which treatments fit the best in what situation (Schreiner, Anderson, 1938). In regional programs these experimental stations have to test which methods or combinations of methods offer the best results for the farmers, for nature and for the consumers. And these tests have to be set up together with the farmers. Their practical experience plus science together can help to find good solutions for the many problems we face today in agriculture. In fact, until now practical innovations of farmers have given better solutions than agricultural science alone. But in many cases science has neglected them, to say the least. So agricultural science should pose itself in a humble way – supporting, not leading.

3. Conclusion

In this article the focus is on sea minerals and on rock flours. And on earth and ditch dredge as means to bind nutrients in dung and plant residuals.

Sea minerals are excellent materials to correct the deficiencies of magnesium, sodium, calcium, silicium and trace elements in our crops. And for restoring the imbalance of the cations. They stop the damaging effects of NPN and NPS. Seaminerals can be given straightaway to the crops in the form of sea salt. Murray advises 100 – 600 kg seasalt per hectare per year (Murray, 2003). Or they can be consumed by animals and men, partly after removal of a bigger part of the NaCl. Experience on dairy farms learns that the digestion is restored by these NaCl poor seaminerals or pure seasalt (Yarrow, 2011). This matches with the experiences of people like Neveu who was able to stop many diseases of people and animals in a very short time when he gave them magnesiumchloride. Seasalt is rich in magnesium chloride. The medical business has ignored these wonderfull effects of magnesiumchloride.

Seasalt on crops helps to restore the health and the natural resistance of the crops against pests and diseases. As such they are a save alternative for pesticides, especially in combination with vermicompost tea. Murray and his followers have proven this through many field trials. Crops fertilized with sea minerals in their turn help to restore the health of animals and men.

Rock flours are a good alternative for artificial fertlizers if given under the right conditions. These rock flours can also be used to bind part of the nutrients which evaporate or rinse out from animal dung or plant residuals. Through this binding less costly nutrients are lost into the environment, and the farmers need to buy much less articial fertilzers and pesticides. Basaltic rock flours can also lock up lots of carbonic acid from the air.

When managed well sea minerals and rock flours prevent the rotting of animal dung and of heated composts. Through this mechanism the putrefactive bacteria disappear from the dung and the compost, and the symbionts return. These symbionts are important for restoring plant health. Healthy plants give huge amounts of sugar to their soil symbionts. And part of these sugars enrich the soils with extra carbon. These symbionts are necessary for the plants to get their nutrients form the soil.

The mixing of earth or ditch dredge with animal dung and/or plant residuals also binds the nutrients in animal dung and compost heaps. Then plants can use these nutrients selectivey through their symbionts. In this way they are not overfed with potassium and inorganic nitrogen, phosphate or sulfur compounds. And the structure of soils is restored because these materials are excellent food for worms and other soil life.

Organic agriculture will produce more and better products by the use of sea minerals, rock flours and earth and ditch dredge in the animal dung and the compost heaps. And for the same reasons conventional agriculture needs less artificial fertilizers and pesticides. Both ways of farming grow closer to each other in this way.

Ditch dredge is interesting for another reason: Taken away from the ditches the rinsed out nutrients are also brought back to the fields via the dung and compost heaps. The biodiversity of the ditches is as a consequence restored, and the nutrients don't go into the surrounding environment.

Through al these measurements farmers save a lot of money. The same for the society. Healthy crops and healthy animals can help to restore the health of people.

4. Acknowledgements

Finally, I would like to thank Mr Van Bruchem for being one of the first scientists in the Netherlands to point out the risks of feed and concentrate that are too high in protein in dairy farming. I would also like to thank mr. Vriesinga, mr Wildenbeest, mr Kennes, mr de Veer, and mr. Vanhoof ànd many farmers who learned me so much about cows, their feed and their health problems.

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Annex 1. The mineral composition of seawater:

MINERAL MAKEUP OF SEAWATER
In order of most to least:

ELEMENT	PPM IN SEAWATER	MOLAR CONCENTRATION
Chloride	18980	0.55
Sodium	10561	0.47
Magnesium	1272	0.052

Sulfur	884	0.028
Calcium	400	0.01
Potassium	380	0.01

Etc.

All the other elements you can find at [Electronic resource]. URL: https://web.stanford.edu› Urchin: mineral makeup of seawater.

Annex 2. Trace elements from rock dusts

"Micronutrient deficiency is a common constraint in organic farming worldwide. Therefore, Shivay et al. (2010) investigated the potential release of copper (Cu), manganese (Mn) and zinc (Zn) from a Cu and Zn-rich rock dust (table 5 /line g). The rocks constituted a waste material from a copper mine in Norway and the particle size distribution was described as 26, 42, 68 and 100 % in < 0.063, < 0.125, < 0.250 and < 0.500 mm. As an additional alternative source of micronutrients, city waste compost was applied in a separate treatment. Both treatments were analysed in terms of a leaching test in quartz sand over a period of 140 days and compared to inorganic micronutrient fertilizers. A weak citric acid was used in this leaching experiment to create a soil environment similar to what is found in the rhizosphere of acid mineral soils.

The micronutrient fertilizers released almost 100% of the respective nutrient applied, whereas the rock dust recovered varying amounts dependent on the respective treatment (table 12). For Mn and Cu, the release of micronutrients from the rock dust was faster in the initial weeks after application and significantly released afterwards, whereas the pattern for Zn showed a slower but longer release. It is argued that the rock dust must contain an easily soluble or adsorbable fraction of those nutrients. Furthermore, the specific pattern of release might be related to the mineralogical matrix of the quartz sand, which has a low saturation of Zn adsorbing oxides. Final calculations including the potential supply of rock derived micro nutrients and the normal micronutrient demand of barley suggest that Cu and Zn demand can be supplied by amounts of 477 kg rock dust ha–1, whereas higher amounts would be needed to meet Mn demands. However, since 477 kg per ha represents a very low application amount, Shivay et al. (2010) concludes that rock dust can successfully be used as micronutrient fertilizer for organic farming" (Swoboda, 2016).

Recently Gross published an interesting article about the utilisation of phosphorus derived from desert dust from the Sahara by plant leaves (wheat and chickpea in this case). This dust is rich in phosphorus, and the plant leaves keep the dust on their surface bound by wetting it. And then the phosphorus is freed from the apatite by the acids in their moisture (Gross et al., 2020). So now we can collect the Sahara dust from our cars and spread it in our gardens.

Annex 3. The use of the basaltic rockflour Biolit in the "Organisch biologischen Landwirtschaft in Austria"

"(..) the previously disposed of rockpowder (it had been buried up to this point) was given away to farmers in the area on a test basis, mainly as infill for the barn with 0.5 kg/LU/day. Although the grain sizes were relatively coarse at that time, up to 0.190 mm, the first successes were visible in the barn. The transit openings became free and the resulting slurry thinner. Building on the well-known work of the time (RUSCH, UTERMÖHLEN, HENSEL) it was already known that finer rock flour worked better and we could even improve the grain size to 0.125 mm with the technical possibilities of the time. The results spoke for themselves (..)

[We] immediately recognized that blowing the volcanic rock flour into the deep litter (30-40 kg/m3) is a pioneering way to convert the putrefaction of the deep litter into the desired fermentation - with the nice side effect of healthier grassland and a higher forage consumption (up to 15 % higher). (..) It has been known for years how BIOLIT improves the environment in the

soil and in the manure. The effects of the bioactive lactic acid bacteria[*] *lead to fermentation and therefore pathogenic germs are reliably switched off. The effect of the more stable and stress-resistant plants can ostensibly be explained by the improved availability of nutrients through improved electron flow and enzymatic processes.*

(..) Soils treated with BIOLIT show a significant improvement. Comparative studies of ecologically managed grassland areas showed that the Biolit-treated soils showed more favorable redox values of +330 to +370 mV (lower values are more favorable values). Ecologically managed areas not treated with Biolit tend to have higher redox values of +370 to +440 mV. Conventional soils tend to have [even] higher redox values in the range of +500 to +600 mV, when using Biolit these values can turn out to be significantly more favorable with approx. +450 to +500 mV.

(..) The administration of BIOLIT reduces (= improves) the redox potential and improves the nutrient flow as well as the electron transport. Aggressive oxygen species that arise in various deficiency situations are reduced or completely dissolved. Even the smallest improvements have a major impact on soil biology. This results in significantly less stress-free growing conditions in a short time" (Biolit, 2021).

Biolit mentions one investigation in which a reduction of ammonia emissions is proven:

"Das Austrian Research Center ARC, Abt. Umweltforschung, A-2444 Seibersdorf, hat am 06.10.2006 Rindergülle in Bezug auf die Ausgasung von Ammoniak getestet. Durch Zugabe von 5 % BIOLIT reduzierten sich die Werte um 27 %. Durch Zugabe von Kalk erfolgte keine Reduktion der Ausgasung von Ammoniak" (Biolit, 2021).

But in the IBKreport I found this conclusion from Schechtner:

"*Schechtner (1993) verglich unbehandelte Gülle mit solcher unter Zusatz von Biolit und Agriben und fand, dass die geprüften Zusätze keine Verringerung der Stickstoffverluste während der Lagerung bewirken*" (IBK, 2009).

So indeed, more research is necessary.

Recently we experienced on a dairy farm that the daily use of basaltic rock powder into the slurry had as a consequence that the smell of the slurry during spreading in the pastures had gone completely. So the interesting question is if with the disappearance of the smell also the ammonia etc. did no longer evaporate.

Three questions for future research are as far as I can oversee it, important:

1. Do you have to spread the basaltic rock flour on a daily basis?
2. And how much is needed to absorb all the volatile compounds (including ammonia)?
3. And then the main question: is the ammonia in the slurry pit in a sufficient way absorbed by basaltic rock flour if enough of this rock flour is added on a daily basis?

In many dairy farms in the Netherlands where basaltic rock flour is used, the farmer blows the rock flour all at once into the slurry pit at the end of the winter season, just before spreading it out in the pastures. So during the winter great losses have already taken place.

Annex 4. Minerals, Milk & Immunity: Sea Energy for Optimum Nutrient Density and Diversity

"In 2004 I helped Bob Cain [to] start SeaAgri to market Dr.Maynard Murray's "sea solids" to American farmers. Our second trailer of Sea of Cortez sea minerals was shipped by rail to central New York. A truck hauled the load to Twin Oaks Organic Dairy in Truxton, where Kathy & Rick Arnold unloaded six tons. The other 14 tons trucked three hours east to my Hudson Valley farmhouse.

Soon after, Organic Valley dairy farmer Jim Gardiner stopped by Twin Oaks. Jim took an interest in the sea minerals, and took a ton back to his farm in Otselic. I never met Jim, but months later he left a phone message about "unusual" results using sea minerals on his farm. I tried to talk Jim by phone, but he was ever elusive – either outdoors, or away on a trek. Nearly four years later, February 2008, Bob Cain invited me to MOSES in LaCrosse, Wisconsin, [for] the Midwest winter conference. Bob gave a talk and slide show on the history of sea minerals and recent stories about SEA-90. After Bob's talk, a farmer stood to say, "I'm Jim Gardiner, organic dairy farmer in Otselic,

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[*] Many farmers in this area buy 'Biolit lactic acid bacteria' and add these to the deep litter.

New York." I leaned forward to focus on this man's words. Jim said he got a ton of sea minerals three years ago, and rationed them to his cows in measured daily amounts.

Protein and Butterfat

Jim was surprised when, after a few days, milk protein rose 6 percent, and butterfat was up two points. Jim said maybe the bump was quirk or coincidence. Stopped the sea minerals. Protein and butterfat declined to normal. So, since sea minerals seemed to be working, Jim fed them again. Free choiced them, so cows can eat as much as they want. They ate quite a bit, Jim observed. As before, protein and butterfat rose-[the] evidence [that] sea minerals were causing this response. So, Jim left cows on sea minerals. But, Jim went on, after cows were on sea minerals a few weeks, something happened "that really got my attention. The somatic cell count[*] dropped to near-zero – and stayed there." He had no need to even think to use antibiotics to control infection. Jim said this got his attention so much, he told other dairymen in NY, Pennsylvania and Midwest about his cows' response to a full spectrum mineral supplement. They were collecting orders for a fourth 24-ton trailer of SEA-90 sea minerals.

This unexpected story was a timely gift.

Jim's information on sea mineral effects on nutrient quality and immunity was neither new nor astonishing. His experiment is evidence today to confirm Dr. Murray's research done 50 years ago. His results reveal key insights on minerals and health. Timely, since my godson Daniel Kittredge was launching the Real Food Campaign to train Northeast growers how to produce nutrient-dense foods. We know nutrient-density is easy to achieve with vegetable, fruit and grain by soil application and inoculation. Jim's experience shows nutrient-dense is possible in livestock —and measurable in milk. His story highlights how just this one cultural practice produced an animal food with superior nutrition. And biological farming offers a host of further materials and methods to upgrade soil fertility, plant health and nutrient quality.

Quality, not Quantity

Higher protein and butterfat is a valuable quantitative effect. But this shift isn't just a measurable jump in milk nutrients. True value to a farmer isn't a higher price for premium product. Heightened immunity and productivity from healthier cows means lower vet bills, less stressful farming. Jim can also expect lower feed bills and better birth rates. And slowly his cows' manure will spread full spectrum minerals and microbes into his soils. So, other benefits cascade from this nutrition enhancement. Most important is greater health for animals, farm and farmers. It's hard to put a price on health. Probably foolish to try.

Extra milk protein and fat.

- plus other unmeasured molecules – aren't ordinary chemicals, nor a common casein or lipid. These particular proteins build special enzymes, hormones and other unusual biochemicals that perform special functions in cell structure and metabolism. Often they are catalysts to accelerate chemical reactions, and regulators, to coordinate complex enzyme systems. Their unique energy states allow biology to operate evermore efficiently-optimally-intelligently. This is because sea minerals contain rare elements that supply special orbital geometries and valence energies to create unusual shapes and functions for biomolecules and cells.

Nate Harkness fed his cows Sea-90 for three years. "We're an Organic Valley dairy. We started to transition our herd April 06," Nate explained. "We went 'on the truck' the first part of May 07. From April 06 to May 07, we farmed organic, but got paid conventional milk price. 'On the truck' means you grow organic product, and get paid organic prices. It's like you reached the promised land. "Our farm started using SEA-90 in September 2007. Jim Gardiner started me on it. He said Bob Cain recommended 4 to 6 ounces per cow per day. I'm a typical farmer, too much feed means less money, so we fed four. "We did that until December, at which point we kinda backed off. We'd been using this for four months. We should see results. We hadn't seen any obvious results. Nothing that was jumping out at you saying this is something. "We called Bob Cain. He said farmers in Michigan feeding six ounces a day are seeing results. So, we bumped it up to six ounces[†] per cow per day in December. And then we started seeing some really good results. "One of the

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[*] A somatic cell count (SCC) is a cell count in a fluid specimen, usually milk. In dairying, the SCC is an indicator of the quality of milk—specifically, its low likeliness to contain harmful bacteria, and thus its highfood safety. Source Wikipedia, english.

[†] One american ounce is 26,35 gram. So six ounces is 170 gram. Also per cow per year you need 62 kg sea salt.

most obvious that my wife noticed the most was the odor. We're in a stanchion barn, enclosed, wintertime. You always have a little hint of ammonia or urine smell. Kinda lingers. Fans are running, but you always have that. "And that went away. That was the first, most obvious change we noticed."

Ammonia, enzymes and microbes.

This subtle shift in scent has immense significance. At the least, it was more pleasant for everyone in the barn—humans, cows, chickens. Fewer flies. Less irritation to eyes, nose and throat. Internally, less irritation to blood, kidneys, bladder.

But more critical, cows no longer excreted Nitrogen. Instead, they now made full use of available N. Likely, dormant metabolic cycles kicked in to convert toxic elemental N into stable biological forms. Excess N is now becoming biomolecules—notably amino acids, and then into proteins.

A key insight into the Nitrogen Cycle is it's almost entirely run by bacteria. Several families of microbes, working together, fix nitrogen gas ($N2$) into nitrate ($NO3-$) to start the N Cycle. Other families use varied chemical pathways to convert $NO3-$ into ammonia ($NH4+$). Still others convert $NH4+$ back to $NO3-$.

Scientific study of N-Cycle microbiology is still young, and more advanced in other nations than chemical-dependent USA agriculture. Yet, even the National Science Foundation report on N-fixing bacteria is over 250 dense pages.

The alternative to these biological ways to fix and manage N is industrial fertilizer: NPK. Nearly all the huge energy needed to manufacture N is from fossil fuel. Half of US hydrogen is used to make industrial N fertilizers, and it all comes from methane.

Only by reviving and regenerating N-Cycle soil microbes can US farms move away from industrial chemical dependence (Yarrow, 2011). Uploaded from Acres USA. [Electronic resource]. URL: https://seaagri.com

A Review of the
Nutrition Claims
Made by
Proponents of
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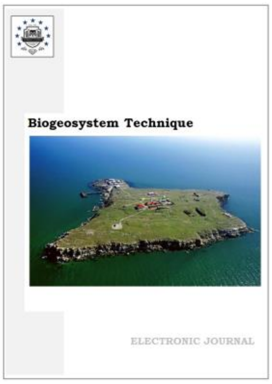
Published in the USA
Biogeosystem Technique
Issued since 2014.
E-ISSN: 2413-7316
2022. 9(1): 49-59

DOI: 10.13187/bgt.2022.1.49
https://bgt.cherkasgu.press



Assessment of Pollution of the Oilfield Territories in Mongolia

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Paper Review Summary:
Received: 2022, June 14
Received in revised form: 2022, July 18
Acceptance: 2022, July 19

Abstract

For balanced approach to Sustainable Development Goals, the physical and chemical degradation of soils in result of oil pollution were studied. The data on the particle-size distribution and the content of chemical components in the soils of the Tamtsagbulag and Zuunbayan oil-producing areas are presented. Due to arid and could climate and geographical location of inland and mid-latitude highlands the studied soils are characterized by similar physical and chemical properties: high content of physical sand (particle size > 0.01 mm) up to 86-91 %, alkaline reaction pH up to 8.7-8.8, density of the solid phase 2.63-2.64 g/cm^3. However, the total carbon content is much higher in Tamtsagbulag soils (kastanozem soils of dry steppe zone) than in Zuunbayan soils (semi-desert brown soils) – 1.07 and 0.24 % respectively. The content of petroleum hydrocarbons (HC) in the Zuunbayan soils varies from 9 to 60 mg/kg, in the Tamtsagbulag soils – from 7 to 670 mg/kg with a maximum in the vicinity of the operating wells. According to the level of hydrocarbon pollution, Zuunbayan soils can be attributed to uncontaminated ("background" concentration of HC, less than 100 mg/kg), Tamtsagbulag soils – from "background" concentration of HC up to "moderate level" of pollution (locally, near the well). Despite the locality and "moderate level" of oil pollution of Tamtsagbulag soils, a study conducted using remote sensing methods showed that pollution has a certain effect on vegetation cover. The maximum vegetation index value is some but reliably lower in an oilfield (within a radius of 4 km) than adjacent territory.

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For sustainable solutions planning of the oil production, transportation, and pollution prevention the transcendental Biogeosystem Technique methodology will be helpful for Land Degradation Neutrality implementation.

Keywords: oil production, soils, hydrocarbons, pollution, Mongolia.

1. Introduction

To date, daily oil production in Mongolia reaches 23 Kbbl, although intensive geological investigation began only in the 1940s. By 1948, the first Zuunbayan oilfield was explored and put into operation. In the same year, the first oil exploration in the Tamtsag Basin began. Since 1960 for 30 years the research has stopped and since 1990 new stage of development in the given area has begun. Further geological exploration work has shown that the most prospective areas for oil exploration are the Mesozoic sedimentary basins (Figure 1A). After the resumption of upstream petroleum activities in the early 1990s, oil production steadily increased. Circa 65 Mbbl of oil have cumulatively been produced in Mongolia between 1996 and 2019. As of 2020, there are a total of 33 petroleum blocks (Figure 1B). Three of these blocks have advanced to production, while exploration is being conducted on 17 blocks under 18 PSCs (Production Sharing Contracts). Today two deposits of the East Mogolia (Tamtsagbulag and Zuunbayan) are intensively explored. More than 90 % of the country's annual production has been solely from Blocks XIX and XXI in Tamtsag basin in eastern Mongolia in recent years. Mongolia in difficult economic conditions supports the foreign investment in geological investigation of oil and conclusion of a bilateral sharing of production. There are two companies PetroChina Daqing Tamsag" LLC and "Dongsheng petroleum Mongolia" LLC currently operating in these oilfields. PetroChina's subsidiary – "PetroChina Daqing Tamsag" LLC is one of them and leading in oil production and export. In 2019, about 6,9 Mbbl of petroleum was sold and 6,5 Mbbl were exported (Oil in Mongolia; Mongolia…, 2020).

Physical and chemical degradation of soils, biological degradation of soil organic matter in result of oil pollution in oil-producing regions are the worldwide environment and high cost problems (Villacís et al., 2016). In Mongolia, as in most oil-producing regions of the world, the decline in reserves and production volumes of "light" oils has recently caused increased interest in the resources of hard-to-recover oils and the production of heavy and high-viscosity oils. Such oils have a high content of paraffins and resins (Shirchin et al., 2003; Golovko et al., 2004; Khongorzul et al., 2007; Sugimoto et al., 2012; Serebriakov, Kondratiev, 2012; Myagmargerel et al., 2021), which leads not only to technological complications during oil production, transportation and processing, but also to serious environmental problems. Contamination of soils in oil production areas with "heavy" oils, the destruction of which in situ proceeds extremely slowly, causes serious violations of their functioning and self-purification.

According to the zoning map of Mongolian soils (Figure 2), the main acting and potential oil production facilities are concentrated in the dry steppe zone with kastanozem soils and brown semi-desert soils zone. The soils are very different from similar soils of the same latitude due to its mountainous, geological structure, and climatic characteristics. Mongolia has an arid and cold climate due to its geographical location of inland and mid-latitude highlands. Soils of Mongolia are characterized by severe frost in the upper part of winter with deep freezing up to 3-4.5 m, a long period with seasonal permafrost (6-9 months a year). The coincidence of warm months with rainiest seasons of the year promotes biological activity (Dorjgotov, 2009; Khadbaatar, 2021).

Dry steppe zone with kastanozem soils is widely distributed in the eastern part of Mongolia and extends westwards through the Khangai mountain range to the Great Lakes depression. Mongolian kastanozems are characterized by carbonate accumulation (no gypsum), which is associated with extreme climates and precipitation distribution. Annual precipitation is about 200-250 mm and growing season occurs for 150-170 days. The morphological features of these soils are brownish and dry, with a lot of gravel, unclear granular structure. The predominant textures are loam, light loam, and sand. Some layers of soils are rich in gravels. The thickness of the humus layer varies from 20 up to 50 cm (usually 20-30 cm), and the humus content – from 1.0 up to 4.5 %. The desert steppe (Gobi) brown soil zone includes the Great Lakes depression, the Lakes Valley, the Gobi-Altai Mountains, and the eastern part of the Gobi. Due to low rainfall (100-125 mm per yr and less), high winds, and dry heats in this area, soil formation takes place in dry conditions. The general characteristics of the soil are well-defined layers, loamy, low humus, effervescence in hydrochloric acid from the surface or topsoil, and not solonchak, lack of moisture, no gypsum, covered with gravel. The Gobi brown soil humus content reaches up to 0.3-0.8 % and the lower layer has a more humus content. This is due to the high temperatures of the soil surface, the mineralization of humus, and the spread of plant roots to about 10–30 cm (Dorjgotov, 2009; Doljin, Yembuu, 2021; Khadbaatar, 2021).

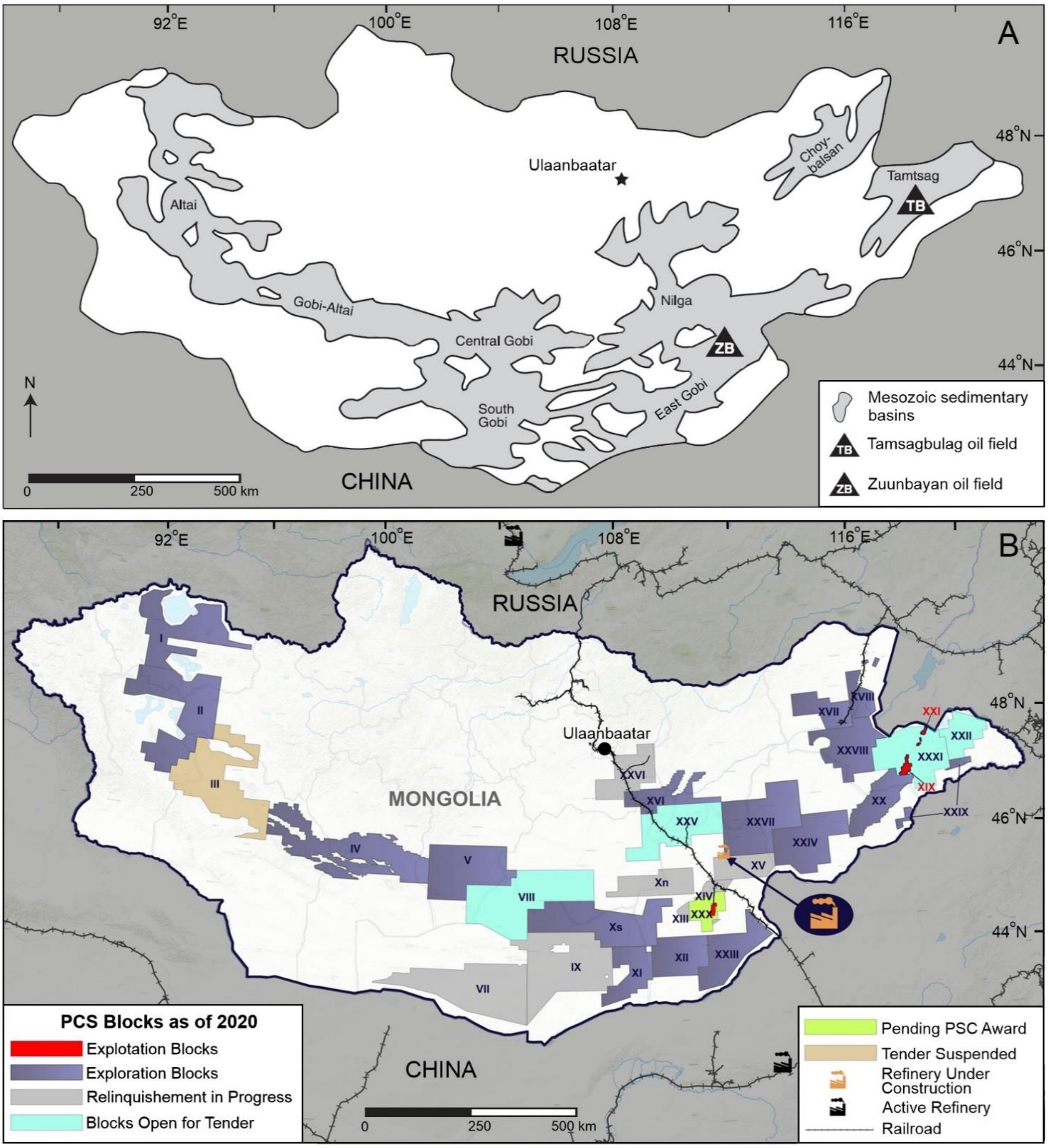

Fig. 1. A. Regional map showing general outlines of Mesozoic sedimentary basins of Mongolia (by Johnson et al., 2003; Penttila, 1994; Steinshouer et al., 1999). **B.** Oilfield blocks in Mongolia (Oil in Mongolia)

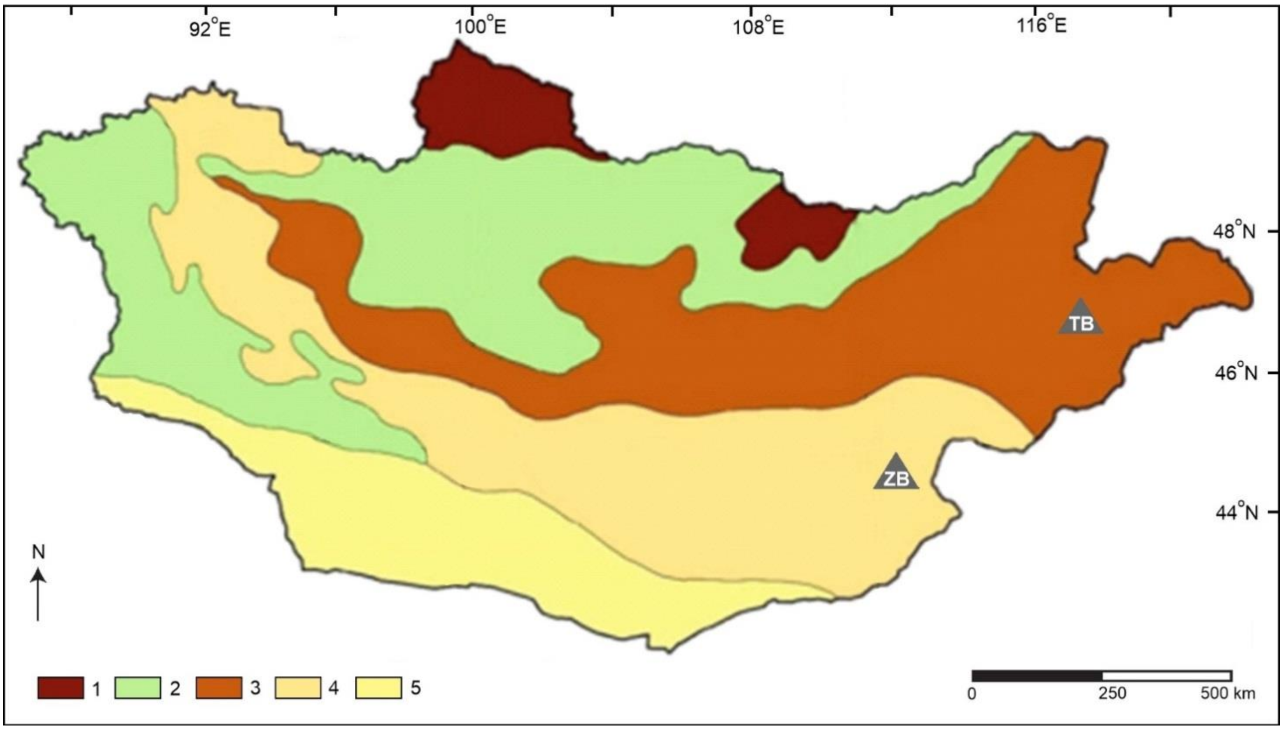

Fig. 2. Soil belt and zones: 1 – mountain taiga belt with cryomorphic-taiga and derno taiga soils, 2 – mountain forest steppe belt with chernozem, dark kastanozem, forest dark colored, and derno taiga soils, 3 – dry steppe zone with kastanozem soils, 4 – semi-desert brown soils zone, 5 – gray-brown desert soils zone (Dorjgotov, 2009; Khadbaatar, 2021).

The aim of this work is to assess the state of the soils and soil cover in the areas of the Tamtsagbulag and Zuunbayan oilfields, their lithological and mineral composition. In this paper, we focus on the Sustainable Development Goals (SDGs), and land restoration (Keesstra et al., 2016, 2018). Aspiration to achieve the SDGs in 2015 adopted by the United Nations is of high importance to avoid further land degradation and to achieve the lofty goals of Land Degradation Neutrality by 2030 is a base of the current and strategic world development framework agendas. The first stage of solving environmental problems in case of soil contamination with heavy oils is the choice of reliable and objective criteria for contamination of soil cover (Gantumur et al., 2021).

2. Objects and methods

Study area and soils

The study was focused on the soils of Tamtsagbulag and Zuunbayan oil fields. They are located in the Matad area of Dornod province (dry steppe zone with kastanozem soils) and the Zuunbayan area Dornogovi province of Mongolia (semi-desert brown soils zone) respectively. Tamtsagbulag soil samples were taken in October 2019 near the well (47°40'49" N and 117°02'59" E) along the perimeter at a distance of 2, 5 and 10 m (in total 12 samples). Zuunbayan soil samples were taken in December 2018 near one (44°27'07" N and 110°05'17" E) of the wells along the perimeter at a distance of 2, 5 and 30 m from the well (in total 5 samples). As control we used "unpolluted" sample sites (10 and 30 m from the wells), because the main soil contamination occurs when oil is taken.

Methods of study

The study was based on granulometric and gross analyses, which were supplemented by electron microscopic studies (SEM analysis) of soils and analysis of soil cover vegetation indices obtained by remote sensing methods. Soil sampling and chemical analysis was carried out in accordance with IS 17.4.3.01-83. Soil samples were taken to the depth of the soil moistening (0-20 cm). The samples (0.5 kg) were selected by the envelope method for physical and chemical analyzes. Than they, dried to the air-dry state, were ground in a porcelain mortar with a pestle with a rubber tip and passed through a 1mm mesh sieve. The granulometric composition of the samples as a whole was determined by the Kaczynski method (Vadjunina, Korchagina, 1973). The gross composition was determined by the X-ray fluorescence method (Pioneer S4, Bruker AXS, Germany) using the silicate analysis technique. The SEM analysis was carried out on a scanning electron microscope VEGA 3 LMH (TESCAN, Czech Republic). For the survey, the samples (preliminary grinded and sieved through a 2-mm sieve) were prepared by the method of pouring, Pt-spraying, magnification – up to 20,000. A backscattered electron detector (BSE detector) was used for the analysis of phases with a high atomic number. When images are acquired using a BSE detector, phases with a high average atomic number are reflected in contrast more vividly than those with a lower atomic number. The X-max 80 energy dispersive spectrometer (Oxford Instruments, Great Britain) was used to analyze the elemental composition of the most representative regions. The capture area of the microanalysis is about 1 μm in diameter. If the analyzed object has smaller, the result of the analysis is distorted due to the influence of the surrounding matrix or the carbon table of the device. The XRF and SEM analyses were carried out in the Analytical Centre at the Institute for Tectonics and Geophysics, Khabarovsk, Far East Branch of the Russian Academy of Sciences. The specific surface was determined using low-temperature adsorption of nitrogen with specific surface analyzer of Sorptometr M series (Shein et al, 2017). Organic carbon was determined by coulometric titration in oxygen flow with AN 7529 express carbon analyzer (Gomel, Belarus) (Milanovskii et al., 2011). Hydrogen test of soil water extract (1:5) was carried out using a combined meter (Seven Multi S-47k, Mettler-Toledo, Switzerland). Determination of the mass fraction of hydrocarbons (HC) in the soils was performed according to the method (END F 16.1:2.2.22–98). The hydrocarbon fraction was isolated by extraction with carbon tetrachloride, purified from accompanying polar compounds on a column with aluminum oxide of the 2nd degree of Brockman activity. The measurements were carried out on the concentration meter (KN-2M, Sibekopribor, Russia).

The remote sensing methods were used to assess oil pollution of the soil cover of the oilfields – we analyzed the change in vegetation cover using vegetation indices NDVI (Normalized Difference Vegetation Index) and SAVI (Soil Adjusted Vegetation Index). SAVI has an additional correction factor in its formula. This coefficient varies from 0 to 1, and minimizes the effect of soil brightness. SAVI is often used in desert areas where vegetation coverage is negligible. The NDVI and SAVI were determined as follow: $NDVI = (NIR–RED)/(NIR+RED)$ and $SAVI=(NIR–RED)/(NIR+RED+L)*(1+L)$, where NIR – near-infrared reflectance, RED – red band reflectance and L – soil adjusted coefficient. These indices were calculated for test sites (4 km^2) during the period of maximum vegetation growth from 2015 to 2019. For this purpose, Landsat-8 and MODIS Terra satellite images at 30 and 250 m resolution, respectively, were used (Eckert et al., 2015; Sun et al., 2019; Gantumur et al., 2021).

3. Results and discussion

Before characterizing the oil pollution of the studied soils, we introduced data on the gross composition and the particle size distribution of soils, which are their fundamental features and, coupled with the content of humus and carbonates, largely determine not only the physical and chemical properties, but also the ability of soils to absorb and retain oil. According to the obtained data (Table 1), with a close gross composition of oilfield soils Zuunbayan soils compared to Tamtsagbulag soils are somewhat enriched with not only SiO_2, but also Al_2O_3, Na_2O and K_2O. This is due to the presence in their composition of a weighty amount of primary minerals, namely quartz and feldspar (SEM data). Zuunbayan soils are also distinguished by an increased content of physical sand (particle size greater than 0.01 mm) of 90.5 and 85.9 %, respectively. Here and further, we give the average values, since the high content of clastogenic grains of primary minerals (including quartz) in Zuunbayan and Tamtsagbulag soils, in addition to natural spatial variation of soil properties, leads to a the significant difference of the min-max values of the results.

According to the gross composition of soils and the content of physical sand in them, it was possible to expect an increased content of coarser sand fractions in Zuunbayan soils. However, the content of coarse and medium sand (particle size 0.25-1 mm) in Tamtsagbulag soils is significantly higher than in Zuunbayan soils 38.5 and 32.9 %, respectively, and the content of fractions of fine (particle size 0.05-0.25 mm) and medium and coarse sand is close – 39.9 and 38.5 %, respectively. Whereas the fraction of fine sand prevails in Zuunbayan soils (45.3 %).

Table 1. Physical and chemical properties and hydrocarbon content in soils of Tamtsagbulag and Zuunbayan oilfieds

Parameter	Tamtsagbulag area (n=12)			Zuunbayan area (n=5)		
	average	min	max	average	min	max
Gross composition, %						
SiO_2	**72.72**	68.17	77.34	**79.92**	75.93	82.17
TiO_2	**0.23**	0.16	0.28	**0.37**	0.32	0.40
Al_2O_3	**7.05**	6.07	7.92	**11.58**	10.90	11.90
Fe_2O_3	**1.79**	1.41	2.13	**2.05**	1.83	2.43
MnO	**0.04**	0.03	0.04	**0.07**	0.06	0.08
CaO	**1.74**	1.05	2.65	**1.02**	0.72	1.75
MgO	**0.64**	0.55	0.76	**0.65**	0.55	0.84
Na_2O	**2.47**	2.14	2.77	**4.00**	3.64	4.27
K_2O	**2.68**	2.54	2.81	**3.80**	3.60	3.93
Particle size (in mm) distribution, %						
>0.01	**85.88**	82.55	90.75	**90.78**	85.59	95.76
0.05–0.25	**39.90**	24.21	48.15	**45.33**	36.04	57.36
0.25–1	**38.47**	28.54	47.93	**32.87**	23.59	42.99
Physical and chemical properties of soils						
pH	**8.4**	7.6	8.8	**8.3**	8.2	8.7
W_{hygr}, %	**0.87**	0.67	1.26	**0.83**	0.61	1.23
ρ, g/cm^3	**2.64**	2.49	2.82	**2.63**	2.53	2.75
C_{total}*, %	**0.73/1.07**	0.20/0.88	0.53/1.32	**0.20/0.24**	0.07/0.17	0.13/0.52
C_{org}, %	**0.53/0.76**	0.24/0.38	0.82/1.17	**0.13/0.13**	0.10/0.05	0.15/0.19
$C_{carb.}$, %	**0.20/0.31**	0/0.09	0.36/0.54	**0.07/0.11**	0/0.03	0.23/0.33
S, m^2/g	**4.2*****	0.8	5.3	**5.4**	3.3	9.6
HC, mg/kg	**30****	10	670	**12****	9	60

Note. S – nitrogen specific surface area; ρ – density of the solid phase of soils; * – numerator and denominator data for soil fractions smaller than 1 and 0.25 mm, respectively; ** – averaging of data with the exception of abnormally high (300-600 and 50-60 mg/kg for soils of Tamtsagbulag and Zuunbayan oilfields, respectively); *** – averaging of data with the exception of abnormally low values (0.8–1.2 m^2/g for soils of Tamtsagbulag oilfield).

The predominance of fine sand in the granulometric composition of Zuunbayan soils explains their higher specific surface area (it largely determines the ability of soils to adsorption) compared to Tamtsagbulag soils – 5.4 and 4.2 m^2/g. For Tamtsagbulag soils, the average values are given without taking into account the abnormally low values of oil-contaminated samples, we will return to these data below. The remaining physical and chemical properties of soils (solid phase density, hygroscopic humidity, pH), with the exception of carbon content, are close. Compared with the Zuunbayan soils (semi-desert brown soils), the Tamtsagbulag soils (kastanozem of dry steppe zone) differ in a much higher content of both total carbon and carbon of organic matter. This is especially clear for soil fraction with a particle size of less than 0.25 mm: the values differ by more than 5 times. The latter allows assuming that the absorption of oil should take place with the participation of this particular fraction.

The content of hydrocarbons (HC) in Zuunbayan soils varied from 9 to 60 mg/kg with the maximum content in samples taken at a distance of 2 m from the well (53-60 mg/kg). With distance from the well soil pollution by oil drops sharply and at a distance of 5 and 30 m are 15 and 9 mg/kg respectively. The range of HC content variation in Tamtsagbulag soils is significantly higher. If the minimum values are almost the same (7-9 mg/kg), then the maximum value is an order of magnitude higher and is 670 mg/kg. This concentration and the concentration of 320 mg/kg were detected only in the south direction from the well at a distance of 2 and 5 m, respectively. According to SEM analysis, microclots of oil and microaggregates with its participation up to 150-200 μm in size are diagnosed in these samples (Figure 3). The composition of microaggregates, in addition to oil microclots, includes clay minerals and calcium carbonate. It should be noted that in the Zuunbayan soils, oil microclots and microaggregates occur singly; their size is significantly smaller, up to 30-50 μm. In other directions (including the southern one at a distance of 10 m from the well), the HC content, taking into account the accuracy of the HC determination method, does not exceed 100 mg/kg and averages 30 mg/kg.

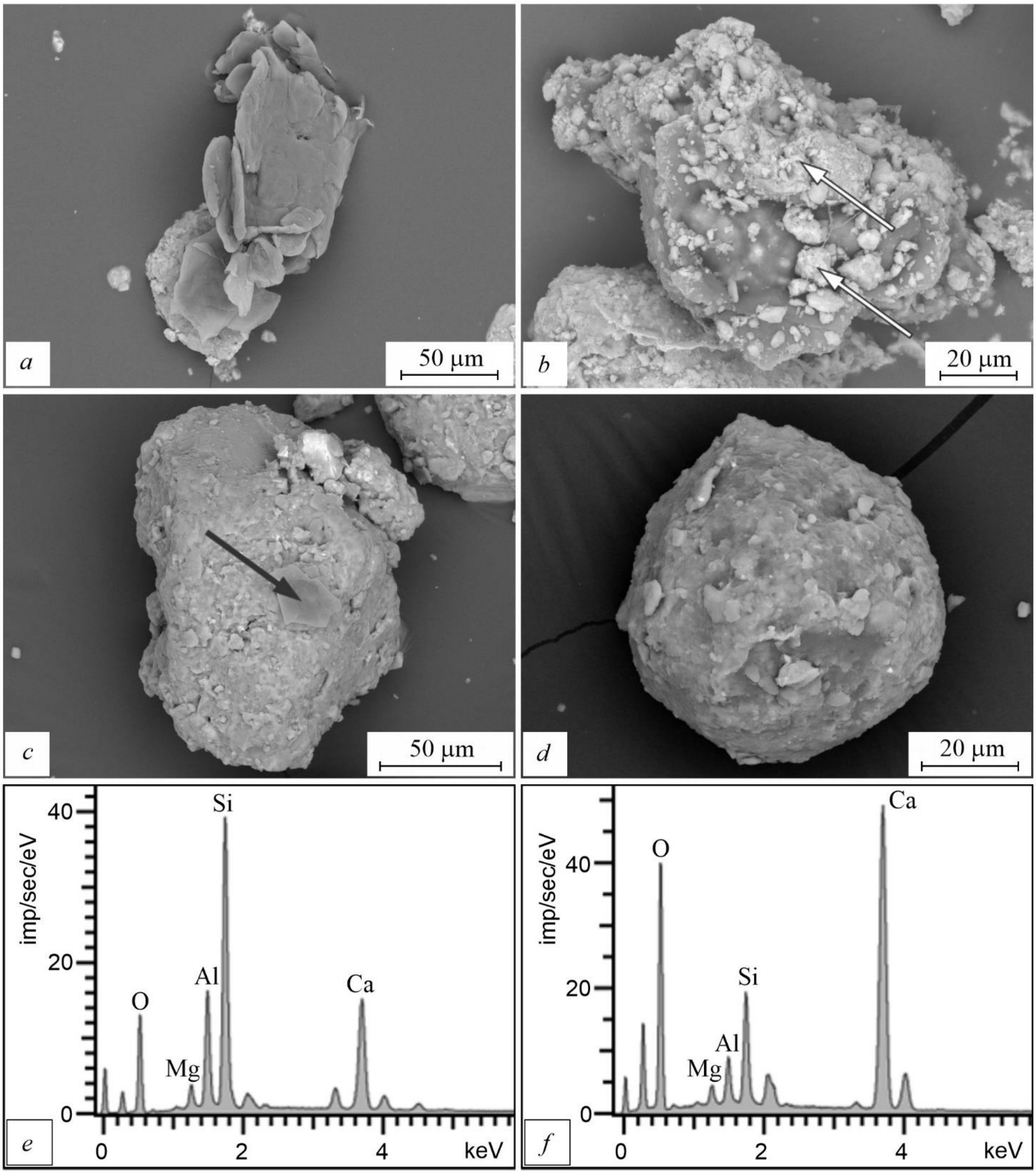

Fig. 3. SEM images of oil microclots (a, c – black arrow) and microaggregates (b, d) from soils of Tamtsagbulag (a, b) and Zuunbayan (c, d) oilfields and EDS-spectrum of points indicated by the white arrows (e and f). For further explanations see text

Currently, in Mongolia there is no regulatory document that defines the maximum allowable concentration (MAC) of oil. It should be noted that the problem of the hydrocarbon MAC for the soils is practically not solved in the world. Many approaches to the assessment of soil pollution with oil have been proposed and the classification boundaries do not always coincide. Thus, under the classification of V.I. Uvarova (1988), according to the content of petroleum hydrocarbons (mg/kg of dry soil), soils can be divided into: clean – 0-5.5, slightly polluted – 5.5-25.5, moderately polluted – 25.6-55.5, polluted – 55.6-205.5, dirty – 205.6-500, very dirty > 500. According to a latter classification (Pikovsky, 1993), the content of oil products in the soil up to 100 mg/kg corresponds to "background" concentration, 100-500 – "increased background", 500-1000 – "moderate level" of pollution, 1000-2000 – "moderately hazardous", 2000-5000 – "strong" and more than 5000 mg/kg – "dangerous" pollution. If to adhere to this classification, Zuunbayan soils characterized by "background" concentration of HC, Tamtsagbulag soils – from "background" concentration of HC up to "moderate level" of pollution (locally, near the well).

In the work of E.A. Rogozina (2006) it's proposed to assess the degree of pollution of soils by hydrocarbons by the excess of the content of HC over the background value in a specific area and in a specific territory. Therefore, the remote sensing methods were used to assess oil pollution of the soil cover of the oilfields – we analyzed the change in vegetation cover using vegetation indices NDVI and SAVI. These indices allow us to assess the impact of oil pollution on the soil indirectly, namely by the state of vegetation.

Usually, the influence of oil polluting effect on vegetation is quite strong and contributes either to the complete destruction of the cover, or to the development of serious developmental anomalies. Unfortunately, due to the extremely sparse vegetation in the Zuunbayan oilfield area, we were unable to calculate vegetation indices. But for Tamtsagbulag oilfield area, certain results were obtained. Due to the peculiarity of the studied territories, it was necessary to conduct additional research on changes in vegetation cover in the vicinity of the Tamtsagbulag oilfield. For a preliminary assessment and analysis of seasonal changes in the vegetation index, we used the values of weekly NDVI composites obtained using the VEGA-SCIENCE system (MODIS spectroradiometer, 250 m).

The general scheme of processing optical images obtained from the Landsat 8 satellite in the period from May to September 2019 is shown in Figure 4(A). Each spatial-temporal image was a set of 240,000 pixels with a size of 30x30 m. NDVI and SAVI values were calculated for each pixel. Preliminary filtering of outliers and verification of sampling uniformity was carried out. Thus, pixels that fell on roads and various technical objects were removed. Repeated filtration was also carried out on each site measuring 600×900 m, 600 such sites were considered. The total area of the territory was 324 km^2, with sides equal to 18 km. At the last stage, the average values of vegetation indices for the sites were smoothed by a linear method.

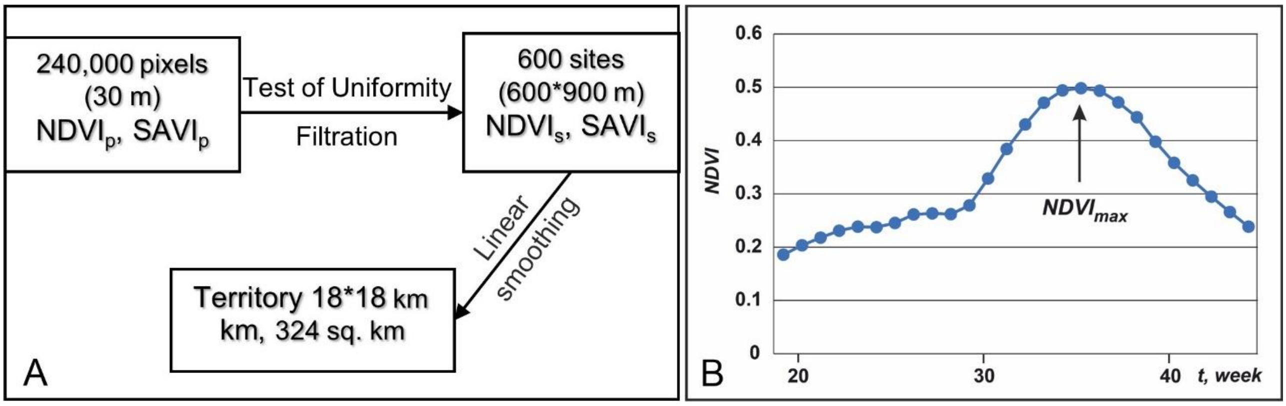

Fig. 4. Scheme of processing optical images obtained from the Landsat 8 satellite (A). Seasonal dynamics of NDVI (MODIS) values in the vicinity of Tamtsagbulag oilfield in 2015–2019 (B).

Further, according to the data of 2015–2019, a time period was established when the vegetation activity and, accordingly, the values of the vegetation indices are maximum (Figure 4B). This is due to the fact that the maximum is the most stable indicator, and it is advisable to use the values of the extremum for comparative characteristics of vegetation of different sites. It was found that the maximum NDVI occurs in the 35th calendar week, which corresponds to the 20th of August.

To assess changes in vegetation indices depending on the distance from the wells of the Tamtsagbulag oilfield, five sites 2×2 km were selected as test sites: central site where the main operating wells are located (the coordinates of the site center coincide with the coordinates of the studied well – 47°40'49" N and 117°02'59" E) and sites oriented to the cardinal directions and equidistant from the conditional center by 4 km (objects I) and 8 km (objects II). NDVI and SAVI 2019 were calculated for all test sites. The values of vegetation indices in both cases increase reliably with the distance of the test sites from the center of the oilfield. The average range was from 0.53 to 0.61 for NDVI and from 0.36 to 0.41 for SAVI (35th calendar week). It was established that the spatial dynamics of NDVI and SAVI had the same orientation in 2019. At the same time, the calculation of the NDVI index is characterized by greater simplicity. Based on the sum of these circumstances, the spatial-temporal dynamics of the maximum vegetation activity for 2015–2019 was estimated by NDVI.

The average $NDVI_{max}$ values in 2015 were in the range circa 0.5-0.55, in 2016 – 0.30-0.34, in 2017 – 0.34-0.40, in 2018 – 0.46-0.58, and in 2019 – 0.53-0.61. There is a clear trend of increasing NDVI values with distance from the center of the oilfield. Using two-factor analysis of variance, it was found that the $NDVI_{max}$ values significantly differ depending on the year and the distance from the oilfield, the significance level $p<0.01$.

A posteriori analysis using the Tukey criterion showed that the values of the maximum vegetation index reliably increase at a distance of 4 km from the source of oil pollution. For objects I, the significance level was $p < 0.01$, and $p < 0.05$ for objects II. At the same time, there was no reliable difference in the values of indicators for objects I and II.

Thus, despite the locality and "moderate level" of oil pollution of Tamtsagbulag oilfield soils, the study conducted using remote sensing methods showed that pollution has a certain effect on vegetation cover, in particular, the value of the vegetation index decreases at a distance of 4 km from the oilfield. The proposed method using Earth remote sensing data can be used for areas with similar vegetation cover. We hope that the completed works set the vector for further research. After all, in fact, a sufficient number of scientific papers have been published to study the state and contamination of soils in oil production areas. However, there is no single approach that allows using the assessment of the totality of influencing factors to make recommendations on soil remediation. To implement the approach, it is necessary to solve a number of interdisciplinary tasks that are aimed, firstly, at studying the physical and chemical, microbiological and landscape characteristics of soils, and secondly, at studying the dynamics of changes in these indicators based on the information systems and using mathematical methods.

4. Conclusion

The identified physical and chemical features of the studied soils together with specific climatic conditions and peculiarities of the oil composition of the Tamtsagbulag and Zuunbayan oilfields (prevalence of heavy paraffin fractions) characterize their low potential for self-purification from pollution by hydrocarbons. If according to the level of hydrocarbon pollution, Zuunbayan soils can be classified as uncontaminated (HC concentration less than 100 mg/kg is "background"), then Tamtsagbulag soils are characterized by a "moderate level" of pollution (locally, near wells, the content of hydrocarbons reaches 670 mg/kg). Study conducted using remote sensing methods showed some negative impact of oil pollution on vegetation cover Tamtsagbulag oilfield area within a radius of 4 km; in particular, vegetation index values are statistically reliably reduced. Sustainable solutions for planning the oil production, transportation, and pollution prevention will help to implement Land Degradation Neutrality and refine the currently not effective strategic world development principles.

5. Acknowledgments

The work was carried out within the framework of the Russian-Mongolian interinstitutional agreement on scientific cooperation and the Russian project "Physical bases of ecological functions of soils: technologies of monitoring, forecasting and management" № 121040800146-3.

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