Effect of rural black-gray water treatment by subsurface wastewater infiltration system on soil environment of vegetable crop field

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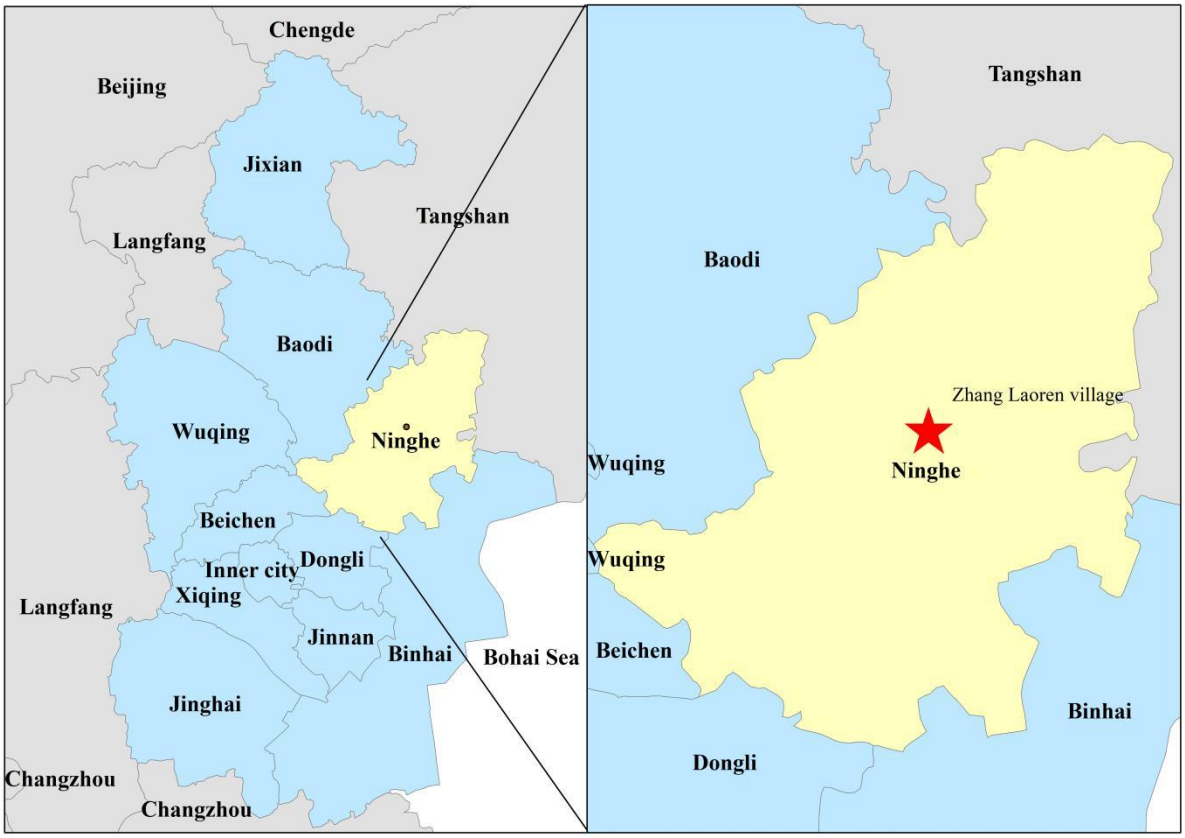

Figure S1. Location map of Zhanglaoren village.

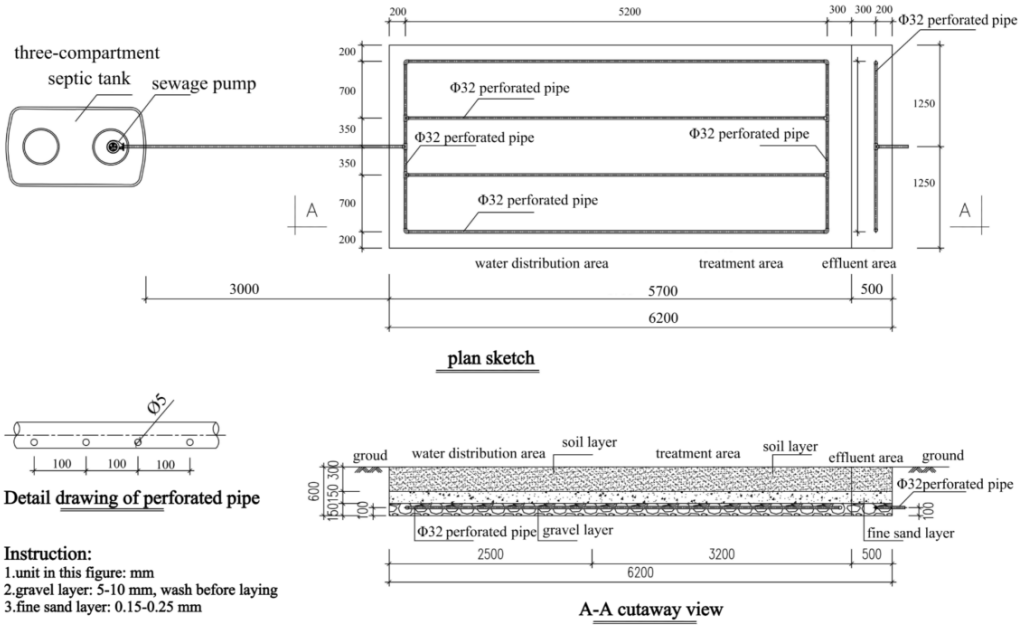

Figure S2. SWIS construction drawing.

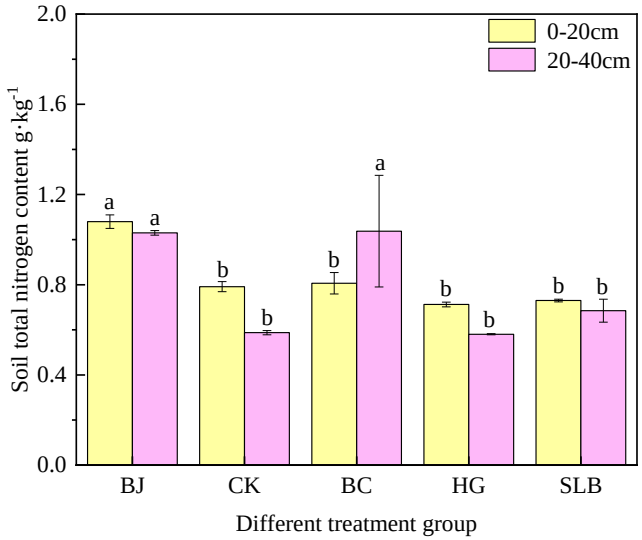

Figure S3. The TN content of each soil layer in each treatment group before and after SWIS treatment.

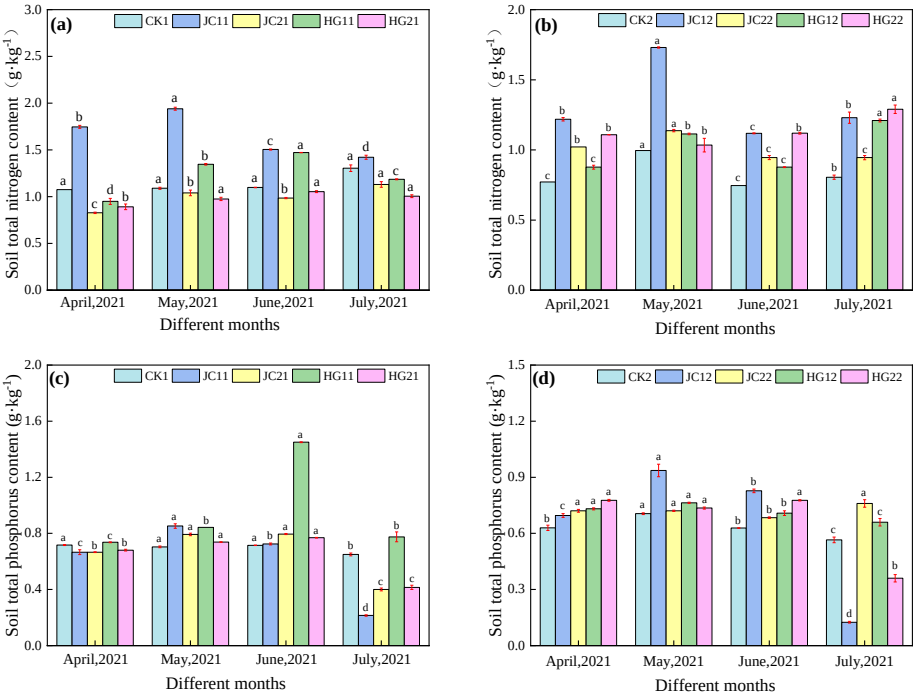

Figure S4. (a) and (b) are the changes of TN in each soil layer at different periods, (c) and (d) are the changes of TP in each soil layer at different periods in 2021.

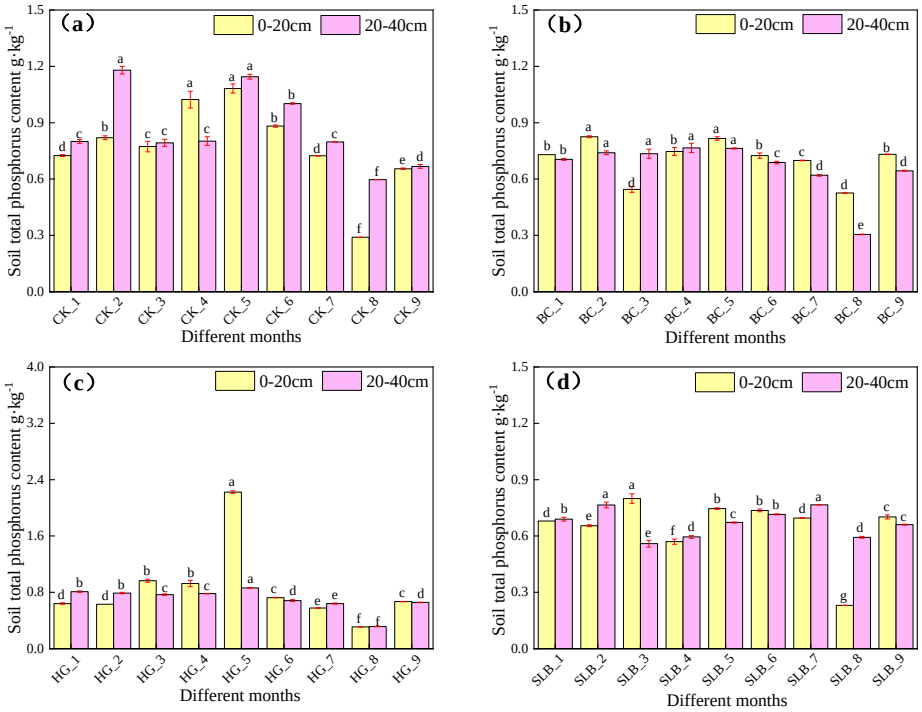

Figure S5. Changes of soil total phosphorus content in four treatment groups of vegetable fields in 2020.

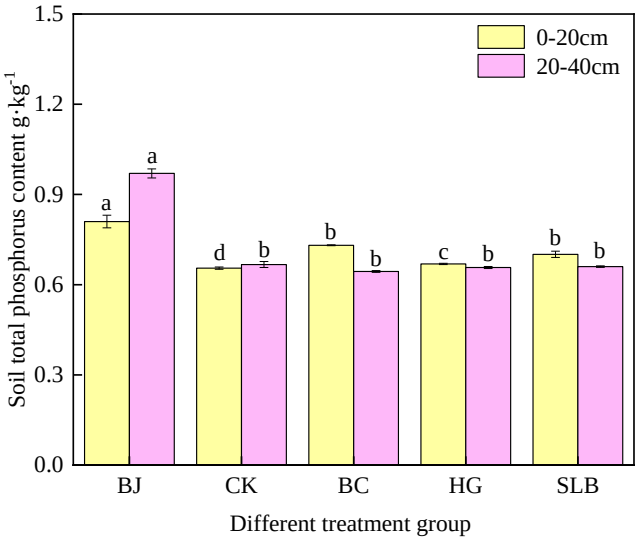

Figure S6. The TP content of each soil layer in each treatment group before and after SWIS.

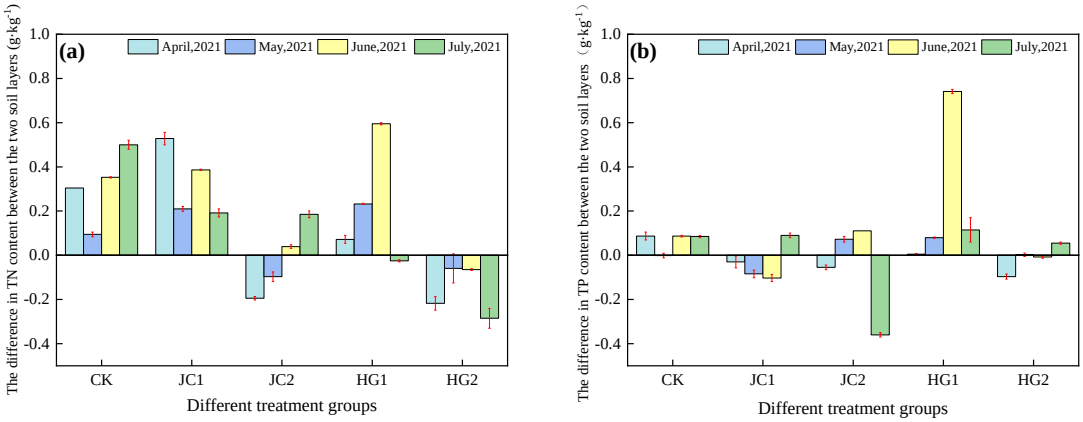

Figure S7. The difference of (a) TN and (b) TP content between the two soil layers in each treatment every month.

Table S1. Background values of soil physicochemical and sanitary indexes.

Index	0~20 cm	20~40 cm	40~60 cm	60~80 cm	80~100 cm
pH	8.06	8.49	8.21	8.09	8.26
Moisture content /（%）	23.1	22.5	22.7	23.2	22.9
CEC /（cmol·kg^{-1}）	13.5	20.7	26.6	27.5	23.0
TN /（g·kg^{-1}）	1.08	1.03	0.63	0.60	0.75
TP /（g·kg^{-1}）	0.81	0.97	0.78	0.85	0.77
NO_3^-/（mg·kg^{-1}）	806	991	550	445	380
NH_4^+/（mg·kg^{-1}）	2.85	7.40	5.50	4.45	2.60
Fluoride /（mg·kg^{-1}）	364	468	484	492	477
Fecal coliforms /（g）	400	1100	1100	430	1100
Mortality of ascarid egg /（%）	100	100	100	100	100

Table S2. The effluent water quality index of the effluent of SPT (Before facility operation).

Index	Range	Average value
pH	7.74~8.21	7.93
NH_4^+/ mg·L^{-1}	72.5~76.5	74.70
NO_3^-/ mg·L^{-1}	0.24~0.6	0.37
TN / mg·L^{-1}	87.5~96	93
TP / mg·L^{-1}	8.75~9.15	8.98
Total salt content / mg·L^{-1}	590~744	663.67
Fluoride / mg·L^{-1}	0.36~0.42	0.40
COD/ mg·L^{-1}	336~452	403
BOD_5/ mg·L^{-1}	169~209	183.33
An-ionic surfactant / mg·L^{-1}	2.36~2.57	2.48
Fecal coliforms / CFU·L^{-1}	200	200

Table S3. Daily of load pollutants in SWIS.

Index	Range	Average value
NH_4^+/（mg/d）	1812.5~1912.5	1867.5
NO_3^-/（mg/d）	6~15	9.25
TN/（mg/d）	2187.5~2400	2325
TP/（mg/d）	218.75~228.75	224.5
Total salt content/（mg/d）	14750~18600	16591.75
Fluoride/（mg/d）	9~10.5	10
COD/（mg/d）	8400~11300	10075
BOD_5/（mg/d）	4225~5225	4583.25
An-ionic surfactant/（mg/d）	59~64.25	62

Table S4. Test method and standard for the water quality index of the effluent of the SPT.

Index	Method	Standard
Total nitrogen	Water quality-Determination of total nitrogen-Alkaline potassium persulfate digestion UV spectrophotometric method	HJ 636-2012
Total phosphorus	Water quality-Determination of total phosphorus-Ammonium molybdate spectrophotometric method	GB/T 11893-1989
Ammonia nitrogen	Water quality-Determination of ammonia nitrogen-Nessle's reagent spectrophotometry	HJ 535-2009
nitrate nitrogen	Water quality-Determination of nitrate-nitrogen-Ultraviolet spectrophotometry	HJ/T 346-2007
COD	Water quality-Determination of the chemical oxygen demand-Dichromate method	HJ 828-2017
BOD_5	Water quality-Determination of biochemical oxygen demand after 5 days (BOD) for dilution and seeding method	HJ 505-2009
Fecal coliforms	Water quality-Determination of fecal coliform-Manifold zymotechnics	HJ 347.2-2018

Table S5. Vegetable sample index detection methods and standards.

Index	Standard
Nitrite	GB 5009.33-2016
Vitamin C	GB 5009.86-2016
Iron	GB 5009.90-2016
Reducing sugar	GB 5009.7-2016
pH	GB 5009.237-2016
Fecal coliform	GB 4789.39-2013
Soluble sugar	NY/T 1278-2007

Table S6. Soil microbial community diversity index table of each soil layer in each treatment group of vegetable field (2021).

Index / Treatment	Shannon		Ace		Coverage	
	April	July	April	July	April	July
CK1	7.05±0.01a	6.81±0.08c	6292.73±56.98a	5784.42±64.17a	0.943±0.000c	0.949±0.000a
JC1	5.61±0.03d	7.07±0.17a	4526.12±282.75c	6148.63±355.24a	0.960±0.002a	0.942±0.001b
JC2	6.97±0.03a	7.02±0.00a	5985.94±66.68a	5003.52±82.41b	0.946±0.001c	0.947±0.001a
HG1	6.44±0.08c	6.84±0.06b	5495.95±139.11b	6688.29±104.49a	0.951±0.000b	0.939±0.001c
HG2	6.81±0.06b	7.22±0.07a	6265.68±105.13a	6742.64±697.08a	0.948±0.000c	0.936±0.003c
CK2	6.94±0.023a	6.95±0.08a	6609.29±66.67a	6829.76±124.29a	0.940±0.00b	0.939±0.001a
JC1	6.92±0.003a	7.02±0.04a	5028.45±327.00c	5982.56±470.60a	0.943±0.00b	0.943±0.001a
JC2	6.88±0.026a	7.11±0.05a	6068.33±403.74a	6984.78±282.71a	0.940±0.00b	0.937±0.002a
HG1	6.61±0.046b	7.00±0.14a	4714.24±406.80c	6346.33±405.15a	0.953±0.00a	0.940±0.001a
HG2	6.48±0.032c	7.17±0.02a	5596.15±24.76b	6941.44±252.51a	0.950±0.00a	0.936±0.001b

Table S7. Hygiene properties of soil layers in each treatment group in vegetable field (2020).

Treatment	Soil layer /cm	Fecal coliform value /g	Mortality rate of ascaris eggs /%
BJ	0~20	0.04	100
	20~40	＞1.11	100
CK	0~20	＞1.11	100
	20~40	＞1.11	100
BC	0~20	＞1.11	100
	20~40	＞1.11	100
HG	0~20	＞1.11	100
	20~40	＞1.11	100
SLB	0~20	0.04	100
	20~40	＞1.11	100

Table S8. Comparison of safety and quality indicators of vegetables grown by experimental households and ordinary households in 2020.

Index	BC		HG		SLB	
	EH	OH	EH	OH	EH	OH
soluble sugar, %	0.21	0.27	0.22	0.36	0.22	0.34
pH	5.87	5.70	5.37	5.53	5.22	5.70
Iron, mg/kg	13.0	12.9	6.7	3.1	41.9	17.2
vitamin c, mg/100g	26.0	27.4	8.0	8.2	30.6	19.2
Fecal coliforms, MPN/g	＜3	＜3	＜3	＜3	＜3	＜3
Nitrite, mg/kg	-	-	-	-	-	-

Note: MPN/g: maximum possible number of coliforms per gram of food; EH: experimental household; OH: ordinary household; "-" : note detected, the same below.

Table S9. Comparison of safety and quality indicators of vegetables grown by experimental households and ordinary households in 2021.

Index	BC		HG		SLB	
	EH	OH	EH	OH	EH	OH
soluble sugar, %	0.48	0.3	1.98	2.13	3.74	3.53
pH	5.84	6.07	6.31	6.55	6.2	6.55
Iron, mg/kg	65.2	71.9	12.8	4.56	65.6	132
vitamin c, mg/100g	25.9	8.9	9.8	8.2	27	32
Fecal coliforms, MPN/g	＜3	＜3	＜3	＜3	＜3	＜3
Nitrite, mg/kg	-	-	-	-	-	-

Text S1. Experimental design.

(1) Effluent enters SPT through drainage pipes.

(2) The effluent stays in the SPT for a long time to make the solid settle to the bottom and form sludge.

(3) The effluent flows out of the SPT through a sewage pump and is discharged to the SWIS regularly and quantitatively through a water distribution system. (The sewage pump works from 8:00 to 9:00 every morning with flow of 25 $L \cdot h^{-1}$)

(4) The effluent were pumped to the SWIS and enters the natural soil through a series reactions (physical, chemical and biological).

(5) After the sewage permeates into the natural soil system, the harmful bacteria and viruses in the effluent would be removed through soil absorption, sedimentation and microbial metabolism..

(6) The purified water flows into groundwater finally

Text S2. SWIS set up.

The water distribution area+treatment area is a cuboid pit (Length×Width×Height = 6.2m×2.5m×0.6m). The water distribution system consists of four perforated pipes with a diameter of 32 mm. The distance between each hole of the perforated pipe is 100 mm. The four perforated pipes divide the water distribution area into three parts evenly and each part is 700 mm wide with the hole diameter of the perforated pipe is 5 mm. Filler with different thickness was filled in the perforated pipe for 300 mm, and then cover the filler with soil for 300 mm. The sewage pump works from 8:00 to 9:00 every morning with flow of 25 $L \cdot h^{-1}$. Finally, a vegetable garden was built above SWIS and planted two seasons of vegetables. The first season was from July 2020 to March 2021 with four treatments (no fertilization):

blank control group (CK), Chinese cabbage group (BC), cucumber group (HG) and radish group (SLB). The second season was from April to July 2021 with five treatment groups (fertilization): blank control group (CK), leek fertilization group (JC1), leek non fertilization group (JC2), cucumber fertilization group (HG1) and cucumber non fertilization group (HG2). The dosage of fertilizer was 50g of chemical fertilizer and 25kg of organic fertilizer.

Text S3. Designated five treatment groups in the second season.

The five treatment groups topsoil and deep soil samples in the second season (CK, JC1, JC2, HG1, HG2) were designated CK1 and CK2, JC11 and JC12, JC21 and JC22, HG11 and HG12, HG21 and HG22, respectively.

Text S4. Testing method of soil TN and TP.

TN is weighed by one ten thousandth balance, 0.5g of 100 mesh air dried soil is put into the glass tube, 5ml concentrated sulfuric acid is added, 2g Kjeldahli nitrogen catalyst is digested by graphite digester (SH220N), cooled, transferred and filtered after digestion, and then measured by continuous flow analyzer (AA3, SEAL analytical, Germany). The TP of soil is weighed by one ten thousandth balance, 0.5g of 100 mesh air dried soil is put into glass tube, 5ml concentrated sulfuric acid is added, 10 drops of perchloric acid are digested with graphite digester (SH220N), and after digestion, cooling, transfer and filtration are carried out, and then measured with continuous flow analyzer.