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Mineral fertilizer consumption and growndwater pollution in Europe and Bulgaria

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Abstract. Groundwater is a main and easy water source for agriculture, industry, mining. It supplies with fresh water more than 10 megacities across the world, including London, Beijing, Mexico City, Buenos Aires. Applying great application rates of nitrogen fertilizer causes pollution of groundwater bodies with nitrates. EU observes and reports the water quality of 13000 groundwater bodies. According to the statistical survey 75% of groundwater bodies are classified as ones with good chemical status. The remaining part -25% of groundwater bodies is reported as one with poor chemical status. About 54% of the groundwater bodies with poor chemical status due their contamination to nitrates.
25% of Bulgarian groundwater bodies show a significant positive trend in increasing nitrate pollution in groundwater bodies
In this paper observation on groundwater chemical status of EU Member States in particularly Bulgaria and Belgium are reported by means latest statistical data.
Groundwater is a limited source for fresh water and measures for preventing nitrate pollution have to be applied in irrigation practice.

Keywords: groundwater pollution

1. INTRODUCTION

Fresh water on the Earth is very limited –water in lakes, streams and rivers and presents only 0.01 percent of Earth's water. Groundwater makes up another 0.6 percent. Salt water in oceans and salt lakes represents 97 percent of Earth's water.

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During the last decades Europe fresh water are affecting by water scarcity, droughts, floods and physical modifications (dams, wires, sluices etc.). The severe lack of water is observed particularly in South Europe.

As a consequence of droughts in EU between 1976-1990 and 1991-2006, both area and population affected have doubled [1]. Climate changes are expecting to exacerbate these impacts, with frequent and severe droughts in many part of Europe.

Over the last 50 years the world's population has doubled, the gross domestic product- has grown tenfold and the agriculture and industry has flourished. This growth and increased water usages put water resources under pressure.

During the last decades the agriculture intensifies the food production applying high input of fertilizers and pesticides. Leaching and running off a part of them, as a result of precipitations or over-irrigation leads to significant load of pollutions to ground and surface water environment.

In the developing countries the rate of increase of nitrogen fertilizer application has tripled since 1975. A quarter of growth in rice production in Asia has been attributed to increased fertilizer use. In Central and South American and South Asian regions, high rates of nitrogen fertilizer applications combined with proper irrigation technologies and favorable climatic conditions help farmers to raise three crops per year [2].

This trend of an intensified agriculture will continue during the next decades and under conditions of increasing world population and increasing demand for food and water supply.

In this paper observations on fertilizer pollution of groundwaters in Europe and Bulgaria is considered. The last statistical data for this sort of pollution are presented and commented.

2. CONTEMPORARY STATE OF NITRATE POLLUTION OF GROUNDWATER IN EUROPE AND BULGARIA

The Nitrate Directive (1991) of European Commission - Environment considers the EU recommedations for permitable nitrate concentration in groundwater that are 50 mg NO_3/l.

The chemical status of more than 13000 groundwater bodies has been monitored and their pollution is reported in 25 Member States in Europe. Good chemical status is proved to have 75% of them (by surface area), while 25 % of them are in poor status. About 3% of groundwater bodies are classified as ones with unknown chemical status [3].

Excessive nitrate concentration is responsible for 54% of groundwater bodies in Europe that have poor chemical status. Pesticides are another reason for classifying 20% of groundwater bodies as ones with poor chemical status.

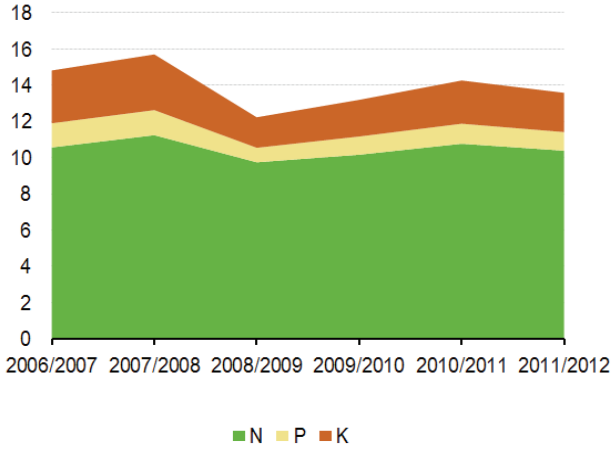

Fig.1: Mineral fertiliser consumption by agriculture in EU-27 (Fertilizers Europe), Million tonnes of nutrients, 2006-2011, [4]

Peaks of nitrogen, phosphorous and potassium fertilizer consumption for EU-27 countries are observed in 2007/2008 and 2010/2011 followed by slow decrease in 2011/2012. The mean nitrogen fertilizer consumption for EU-27 countries during the period of 2006-2012 accounts for 10.48 million tonnes of N per year. The mean phosphorous fertilizer consumption for EU-27 countries during the period of 2006-2012 is equal to 1.1 million tonnes of P per year. The mean potassium fertilizer consumption for EU-27 countries during the same period is 2.38 million tonnes of K per year.

A decreasing trend in nitrogen and phosphorous fertilizer consumption for EU-15 countries and Slovenia, Norway and Switzerland can be seen for the period of 2000-2012 but nitrogen fertilizer consumption denotes an increase for Bulgaria (BG), Czech Republic (CZ), Estonia (ES), Latvia (LT), Poland (PL), Hungary (HU) and Slovakia (SK), (Table.1).

An increasing trend in phosphorous fertilizer consumption for the same period is observed for Slovakia (SK), Romania (RO), Poland (PL) and Bulgaria (BG) (Table.2).

The data for nitrogen fertilizer consumption in Bulgaria for the period of 2000-2012 are according Table 1 and the data for 2013 are taken out from [5]. It can be seen in Fig.2 that nitrogen fertilizer consumption in Bulgaria has doubled in comperance with this one in 2000. A trend in increasing nitrogen fertilizer consumption is observed in Bulgaria for the whole observed period.

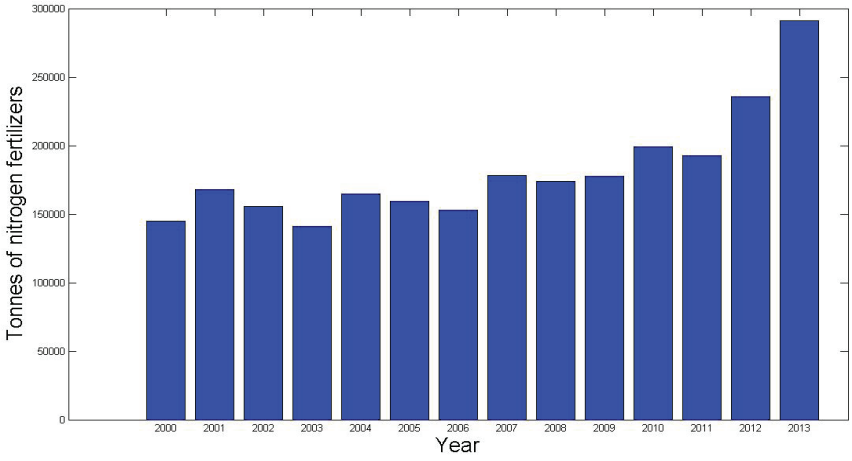

Fig.2. Consumption of nitrogen fertilizer in Bulgaria for the period of 2000-2013, [4-5]

In 2010 the maximal nitrogen fertilizer consumption per ha UAA (utilized agricultural area) is observed in Nederland (NL), Belgium (BE), Luxemburg (LU) which are respectively 120 kg N/ha, 106 kg N/ha and 103 kg N/ha.

In 2010 mean nitrogen fertilizer consumption per ha UAA for EU- 27 countries is equal to 69 kg N/ha and for EU-15 countries is correspondingly 74kg N/ha.

Nitrogen fertilizer consumption per ha UAA in Bulgaria is 56 kg N/ha.

In 2010 the maximal phosphorous fertilizer consumption per ha UAA can be observed for Poland (PL)-11kg P/ha and for Spain (EL) - 10hg P/ha. The mean phosphorous fertilizer consumptions per ha UAA for EU-27 and EU-15 countries are equal to 7 kg P/ha. Phosphorous fertilizer consumption per ha UAA in Bulgaria for the same period is 5kg P/ha.

Approximately 13% of the groundwater monitoring bodies in Europe exceed the limit of 50 mg NO_3/l. The highest proportion of the groundwater monitoring bodies, which exceed the EU Directive limit, to all monitoring ones is observed in Belgium (30%), Denmark (26%), Spain (22%) and Cyprus (19%). Bulgarian groundwater monitoring stations exceeding the accepted limit for nitrate pollution present 9% of all groundwater monitoring bodies.

Table 1: Nitrogen fertiliser consumption by agriculture, EU-27, NO and CH, 2000-2012, [4]

	Tonnes of Nitrogen												
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
EU-27	:	:	:	:	:	:	10 643 500 e	10 708 000 e	10 791 500 e	9 942 000 e	:	:	:
EU-15	10 037 500 e	9 350 000 e	9 078 500 e	8 968 000 e	8 931 000 e	8 469 000 e	8 297 000 e	8 184 000 e	8 201 000 e	7 499 500 e	7 853 000 e	:	:
BE	163 000	150 000	155 500	147 000	149 000	139 500	139 500	139 500	130 500	136 500	143 500 p	:	:
BG	145 000	168 000	155 500	141 000	165 000	159 500	153 000	178 000	174 000	177 500	199 000	192 500	235 500 p
CZ	262 500	311 000	289 000	242 500	303 500	293 000	309 500	335 500	341 500	254 000	270 500	352 500	349 000 p
DK	252 000	234 000	211 000	201 000	207 000	206 000	192 000	194 500	220 500	200 500	190 000	197 000	187 000 p
DE	2 014 500	1 847 500	1 791 500	1 788 000	1 828 000	1 778 500	1 785 000	1 600 000	1 807 000	1 550 500	1 569 000	1 786 500	1 640 500 p
EE	22 500	19 500	16 500	23 500	25 000	20 000	22 500	25 000	35 500	27 500	28 500	30 000 p	:
IE	407 500	368 500	363 500	388 000	362 500	352 000	345 000	321 500	309 000	307 000	362 500	345 500	296 500 p
EL (1)	285 000 e	261 000 e	253 000 e	259 000 e	246 000 e	228 500 e	207 000 e	201 500 e	149 000 e	181 000 e	196 000 e	174 000 ep	:
ES	1 279 000	1 131 000	1 026 500	1 198 500	1 073 000	924 000	970 000	986 000	740 000	781 000	941 000	846 500	843 500 p
FR	2 518 000	2 415 500	2 361 000	2 237 000	2 396 000	2 346 500	2 163 000	2 198 000	2 425 000	2 099 000	2 080 000	2 332 000	2 014 500 p
IT (1)	828 000 e	818 000 e	796 000 e	751 500 e	684 500 e	621 500 e	697 000 e	724 000 e	604 500 e	592 000 e	589 500 e	568 000 ep	:
CY (1)	:	:	:	:	:	:	8 000 e	7 500 e	4 500 e	5 500 e	4 000 e	4 000 ep	:
LV	23 000	31 500	27 500	37 500	35 000	41 000	42 500	46 000	47 500	52 000	59 500	60 000	65 000 p
LT (1)	:	:	:	:	:	:	145 000 e	147 000 e	123 500 e	134 500 e	144 000 e	147 000 ep	:
LU	18 000	15 000	16 000	13 000	16 500	14 000	14 000	13 500	13 500	13 500	13 500	15 000 p	:
HU	257 500	275 500	303 000	289 000	293 000	260 500	289 000	320 000	294 500	275 000	281 500	302 000	313 000 p
MT (2)	:	:	500 e	500 e	500 e	500 e	1 000 e	500 e	500 e	500 e	500 e	:	:
NL	339 500	298 500	292 000	290 500	300 500	279 000	288 000	257 500	238 000	225 500	219 500	214 000 p	:
AT	138 000	129 000	106 000	114 000	85 500	105 000	97 500	111 000	108 500	89 000	105 000	98 000	87 000 p
PL	861 500	895 500	862 000	831 500	895 000	895 500	996 500	1 056 000	1 142 500	1 095 500	1 027 500	1 091 000	1 094 500 p
PT	170 000	157 500	164 000	110 000	126 000	102 500	87 500	113 000	105 000	97 500	103 000	99 500 p	:
RO	239 500	268 500	239 000	252 000	270 000	299 000	252 000	265 500	280 000	296 000	306 000	313 500	290 000 p
SI	34 000	35 000	33 500	34 500	30 500	29 000	30 500	29 500	25 000	28 000	:	:	:
SK	84 500	102 500	111 500	97 500	97 000	100 000	97 000	113 500	121 500	96 500	106 500	120 500	128 000 p
FI	167 500	165 500	160 500	159 500	154 500	149 500	148 000	149 000	163 000	136 000	156 500	146 000	139 000 p
SE	189 500	197 000	185 000	180 000	177 000	161 500	160 500	167 000	186 500	142 500	168 000	170 000	148 000 p
UK	1 268 000	1 162 000	1 197 000	1 131 000	1 125 000	1 061 000	1 003 000	1 008 000	1 001 000	948 000	1 016 000	1 022 000	1 000 000 p
NO	105 500	98 500	99 000	102 500	104 000	105 500	103 000	106 500	102 000	91 000	84 000	95 500	94 500 p
CH	53 000	57 000	55 500	53 000	53 500	52 500	51 500	54 000	51 000	48 000	55 500	49 000 p	:

Special values

: not available

p provisional

e Eurostat estimation

(1) Data from Fertilizers Europe

(2) Data from FAOSTAT

Table 2: Phosphorous fertiliser consumption by agriculture, EU-27, NO and CH, 2000–2012, [4]

	Tonnes of Phosphorus												
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
EU-27	:	:	:	:	:	:	1 372 500 e	1 373 000 e	1 215 500 e	881 500 e	:	:	:
EU-15	1 472 000 e	1 326 000 e	1 279 500 e	1 286 500 e	1 235 500 e	1 129 500 e	1 030 500 e	1 024 000 e	8 675 00 e	598 500 e	737 000 e	:	:
BE	16 000	11 500	12 500	11 500	12 000	11 000	9 500	10 000	6 500	4 500	5 500 p	:	:
BG	7 000	3 500	9 500	10 500	13 000	11 000	11 000	13 000	13 500	13 500	17 000	13 000	21 000 p
CZ	19 000	23 000	21 500	20 500	24 000	20 500	20 500	26 500	24 000	7 500	13 500	17 500	18 500 p
DK	18 000	16 000	15 000	14 000	15 000	15 000	13 500	14 000	14 000	7 000	11 000	11 500	13 000 p
DE	183 500	153 500	137 500	143 000	124 000	132 000	119 500	115 500	138 500	76 000	102 500	125 000	108 000 p
EE	1 500	1 500	2 000	2 500	3 000	2 500	3 500	3 500	4 000	2 500	2 500	2 500	:
IE	49 500	42 500	42 000	44 000	42 500	38 500	37 000	32 500	26 500	20 000	29 500	29 000	27 500 p
EL (1)	49 500 e	49 500 e	46 500 e	48 000 e	43 500 e	38 500 e	36 000 e	33 500 e	28 000 e	33 000 e	29 000 e	23 000 ep	:
ES	249 000	266 500	264 500	268 500	257 000	224 000	197 500	242 000	118 500	115 500	147 500	158 500	164 500 p
FR	417 500	348 500	329 500	318 500	315 500	300 500	258 500	243 500	282 500	129 000	177 000	218 500	188 500 p
IT (1)	220 000 e	199 500 e	196 000 e	197 500 e	178 000 e	151 500 e	166 500 e	142 000 e	84 500 e	114 500 e	88 000 e	78 000 ep	:
CY (1)	:	:	:	:	:	:	1500	2000	500	1000	1000	1000	:
LV	2 500	3 000	3 500	4 000	5 000	6 500	6 500	7 500	6 500	6 000	7 000	7 500	8 500p
LT (1)	:	:	:	:	:	:	17 000 e	17 000 e	9 500 e	14 000 e	15 500 e	15 500 ep	:
LU	1 000	1 000	1 000	1 000	1 000	1 000	500	500	500	500	500	500	:
HU	19 500	25 000	27 000	29 000	32 500	26 500	33 000	38 000	27 500	19 000	20 000	22 000	25 500
MT (2)	:	:	0 e	0 e	0 e	0 e	0 e	0 e	0 e	0 e	0 e	:	:
NL	27 000	23 000	21 000	23 000	22 000	21 000	21 000	15 500	11 500	4 500	13 500	6 500	:
AT	25 500	20 000	19 000	19 500	16 000	16 000	14 500	18 000	14 000	7 500	12 500	10 000	9 500
PL	129 500	139 000	139 500	132 000	140 500	141 500	193 000	180 000	202 000	164 000	154 000	178 500	162 000
PT	39 500	34 000	34 500	39 000	52 000	33 500	22 500	29 500	18 000	11 500	18 000	14 000	:
RO	38 500	38 000	32 000	41 500	41 000	60 500	41 000	45 000	44 500	44 000	54 000	55 000	49 500
SI	8 000	7 000	7 000	6 500	6 500	6 000	5 500	5 500	5 000	3 500	:	:	:
SK	7 000	10 500	10 500	10 000	8 500	10 000	9 500	11 000	11 000	8 000	7 000	8 500	10 500
FI	20 500	21 500	20 000	19 500	19 000	18 500	17 000	16 000	16 000	11 000	12 500	11 000	10 500
SE	17 500	17 000	16 500	16 500	17 000	15 500	14 000	13 500	14 500	8 000	10 000	10 500	10 500
UK	138 000	122 000	124 000	123 000	121 000	113 000	103 000	98 000	94 000	56 000	80 000	84 000	82 000
NO	13 000	12 000	12 500	12 500	12 500	12 500	12 500	12 000	11 500	8 500	8 000	9 000	8 500
CH	5 000	5 500	6 500	5 000	6 000	5 000	6 000	6 500	5 000	4 000	4 500	4 500	:

Special values

: not available

0 less than 250 tonnes

p provisional

e Eurostat estimation

(1) Data from Fertilizers Europe

(2) Data from FAOSTAT

Table 3: Fertiliser consumption per ha UAA, EU-27, Norway (NO) and Switzerland (CH), 2010, [4]

	N tonnes	P tonnes	UAA (4) 1000 hectares	kg N/ha (5) hectares	kg N/ha (5) hectares
EU-27	10 308 500 e	1 032 000 e	150 059	69	7
EU-15	7 853 000 e	737 000 e	106 407	74	7
BE	143 500 p	5 500 p	1 350	106	4
BG	199 000	17 000	3 548	56	5
CZ	270 500	13 500	3 464	78	4
DK	190 000	11 000	2 548	75	4
DE	1 569 000	102 500	16 493	95	6
EE	28 500	2 500	832	34	3
IE	362 500	29 500	4 130	88	7
EL (1)	196 000 e	29 000 e	3 000	65	10
ES	941 000	147 500	18 106	52	8
FR	2 080 000	177 000	25 693	81	7
IT (1)	589 500 e	88 000 e	11 320	52	8
CY (1)	4 000 e	1000	117	34	9
LV	59 500	7 000	1 291	46	5
LT (1)	144 000 e	15 500 e	2 672	54	6
LU	13 500	500	131	103	4
HU	281 500	20 000	3 988	71	5
MT (2)	500 e	0 e	11	45	0
NL	219 500	13 500	1 828	120	7
AT	105 000	12 500	2 321	45	5
PL	1 027 500	154 000	14 163	73	11
PT	103 000	18 000	2 333	44	8
RO	306 000	54 000	11 332	27	5
SI (3)	28 000 e	3 500 e	433	65	8
SK	106 500	7 000	1 801	59	4
FI	156 500	12 500	2 268	69	6
SE	168 000	10 000	3 021	56	3
UK	1 016 000	80 000	11 865	86	7
NO	84 000	8 000	851	99	9
CH	55 500	4 500	908	61	5

Special values
p provisional
e Eurostat estimation

(1) Data from Fertilizers Europe
(2) Data from FAOSTAT
(3) Slovenia data 2009
(4) Excluding common land units, rough grazing and permanent grassland no longer used for production. Common land is included in for a minor part in Spain, Italy and Germany (minor part) and in its total in Slovenia, Cyprus and Norway.
(5) Eurostat estimation

Table 4: Groundwater nitrate concentration classes (mg NO3/l) and proportion of groundwater monitoring stations in each class per country (%), 2009, EU-27, EFTA, candidate and potential candidate countries; *Source: European Environment Agency in [6]*

	Groundwater nitrate concentration classes (mg NO3/l) and number of groundwater monitoring stations in each concentration class per country				
	≤ 10	10 < ... ≤ 25	25 < ... ≤ 50	50 <	Total
BE	1024	381	534	835	2774
BG	52	21	24	15	112
CZ	385	85	70	73	613
DK	174	92	111	132	509
DE	308	107	119	88	622
EE	171	21	21	1	214
IE	130	62	21	0	213
EL	:	:	:	:	:
ES	217	100	93	114	524
FR	679	394	431	152	1656
IT	:	:	:	:	:
CY	48	12	7	16	83
LV	63	5	6	2	76
LT	162	14	6	2	184
LU	1	1	3	0	5
HU	:	:	:	:	:
MT	:	:	:	:	:
NL	244	16	16	27	303
AT	224	150	119	88	581
PL	80	10	14	8	112
PT	122	58	27	17	224
RO	476	86	51	46	659
SI	21	14	10	2	47
SK	266	72	59	37	434
FI	38	0	0	0	38
SE	23	0	1	0	24
UK	2012	441	99	31	2583
IS	3	0	0	0	3
LI	6	0	0	0	6
NO	50	7	1	0	58
CH	10	16	7	1	34
ME	4	2	1	1	8
HR	29	0	0	0	29
RS	57	8	0	0	65
TR	72	35	11	3	121
AL	10	1	0	0	11
BA	13	0	0	0	13

Special values:
: Data not available

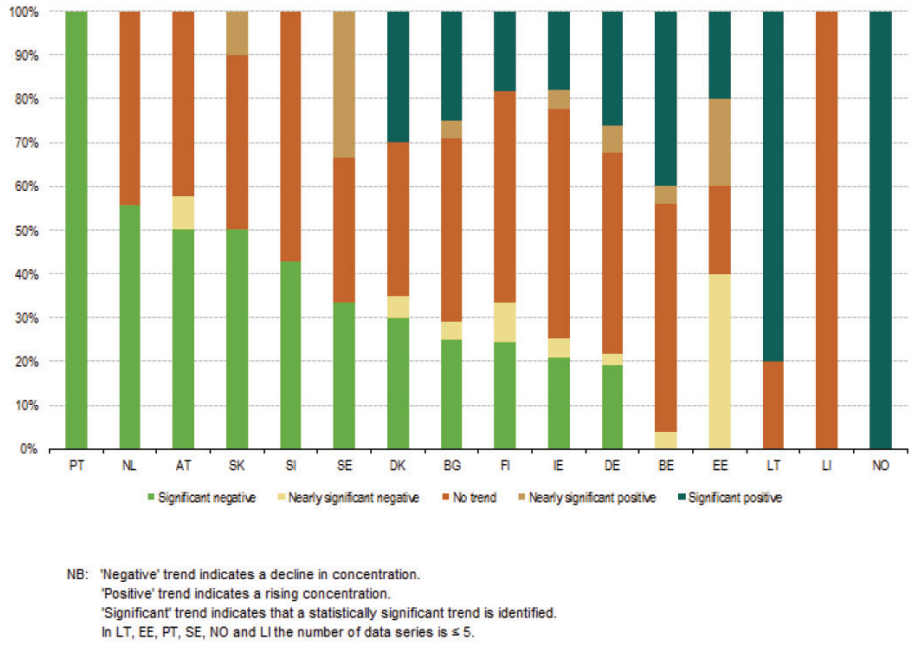

Fig. 3: Groundwater nitrate concentration classes (mg NO3/l) and share of groundwater monitoring stations in each class by country (%), 2009, EU-27, EFTA, candidate and potential candidate countries *Source: European Environment Agency in [6]*

The trends in nitrate contamination of groundwater bodies of EU-27 Member States can be seen in Fig.3. A significant positive trend, that indicates a nitrate concentration rising is valid for more than 25% of Bulgarian groundwater bodies and 40% of them are with neither positive nor negative trend. Only 25% of groundwater bodies show a negative trend which means a decline in nitrate concentrations. For Norway only one groundwater body is reported which shows a significant positive trend.

According to statistical data for 2014 nitrite concentrations above 0.01 mg NO_2/l are observed in groundwater bodies of Spain, Belgium, Romania, Italy. (Fig. 4)

Nitrate concentrations above the limit of 50mg NO_3/l are reported for groundwater pollution in Spain, Belgium, Poland, Germany, Austria, Czech Republic, Greece, Bulgaria, Romania. (Fig.5).

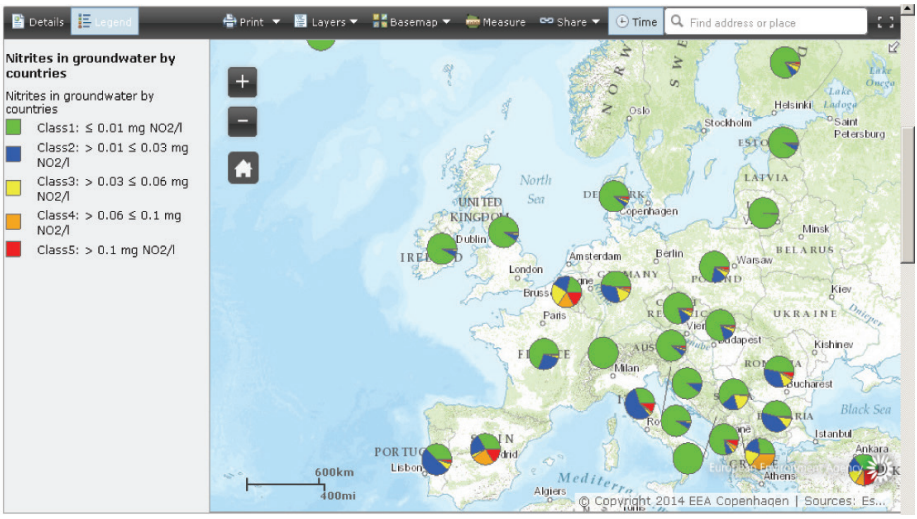

Fig.4. Map of nitrite pollution in groundwater of EU Member States, [7].

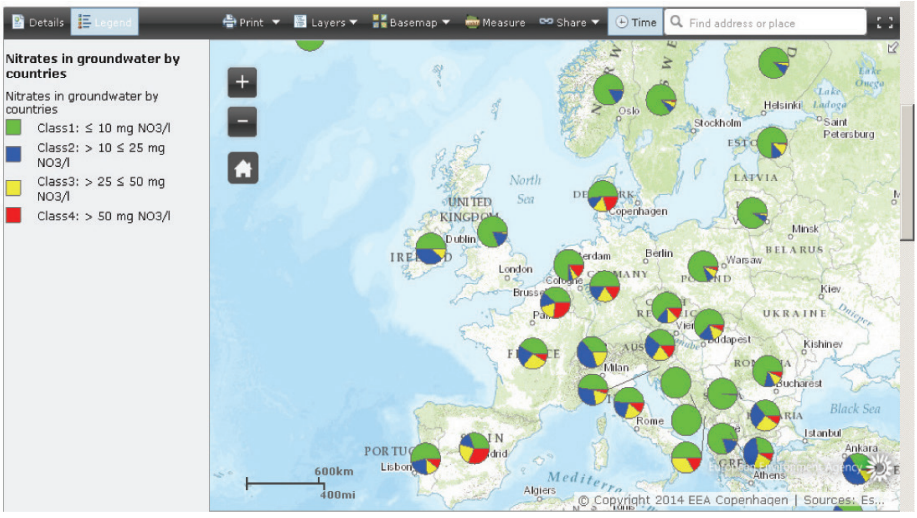

Fig.5. Map of nitrate pollution in groundwater of EU Member States, [8].

Critical concentrations of ammonium are observed in Belgium, Nederland, Spain, Estonia, Poland, Italy, Romania. (Fig.6).

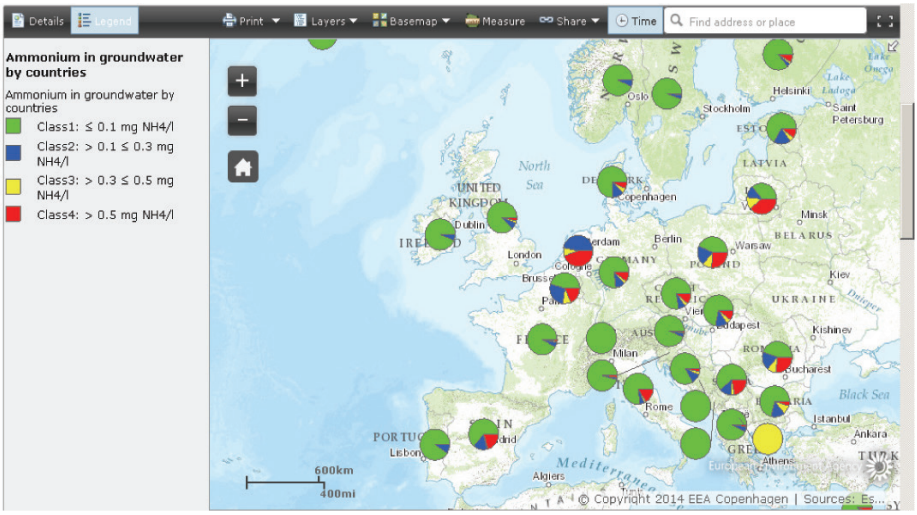

Fig.6. Map of ammonium pollution in groundwater of EU Member States, [9]

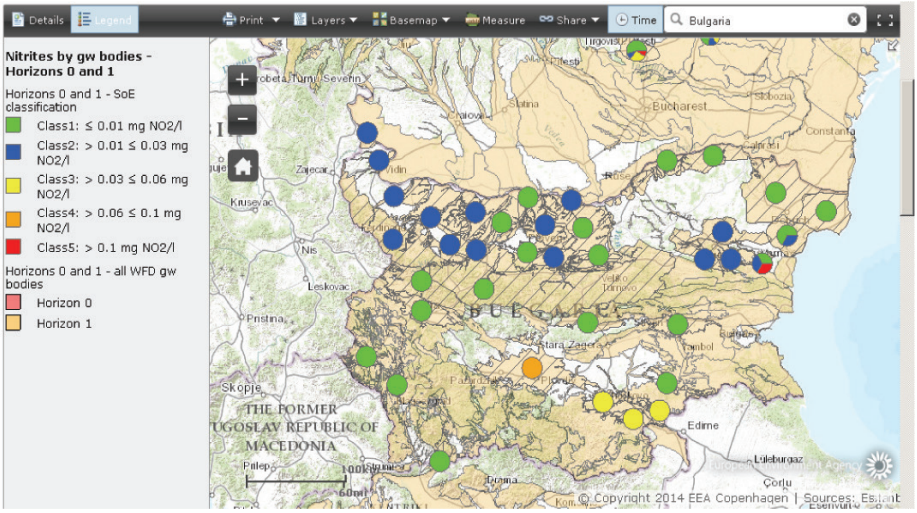

Fig.7. Map of nitrite pollution of groundwater of Bulgaria [7].

Prevailing number of groundwater bodies in Bulgaria are with lower pollution class $1 \leq 0.01$ mg NO_2/l and $0.01 <$ class $2 \leq 0.03$ mg NO_2/l. Only one groundwater body is classified as one with class $5 > 0.1$ mg NO_2/l (Fig.7).

Approximately 20 groundwater bodies in Bulgaria are classified mainly or in part with third class of nitrite pollution $(25 <$ class $3 \leq 50$ mg NO_3/l$)$. Four groundwater bodies polluted with nitrate concentration above permitted limit of class $4 > 50$ mg NO_3/l, (Fig.7).

The more strict caution measures should be taken into account in this regions. The farmers should follow strict recommendations for application rates of nitrogen fertilizers

Three groundwater bodies in Bulgaria are diagnosed as polluted with the highest class of ammonium concentrations $($ class $4 > 0.5$ mg NH_4/l$)$, followed by four groundwater bodies polluted with concentration between the limits of $0.3 <$ class $3 > 0.5$ mg NH_4/l, (Fig.9).

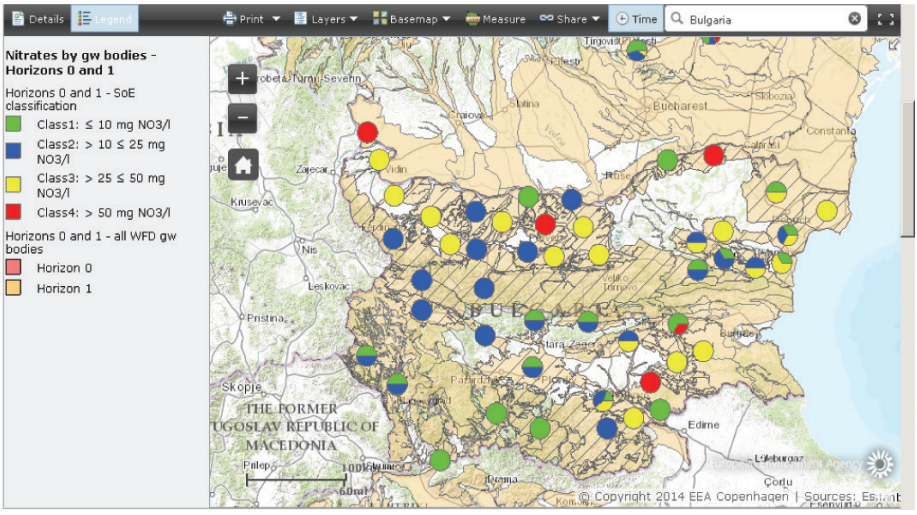

Fig.8. Map of nitrate pollution of groundwater of Bulgaria [8].

Three groundwater bodies in Bulgaria are diagnosed as polluted with the highest class of ammonium concentrations $($ class $4 > 0.5$ mg NH_4/l$)$, followed by four groundwater bodies polluted with concentration between the limits of $0.3 <$ class $3 > 0.5$ mg NH_4/l, (Fig.9).

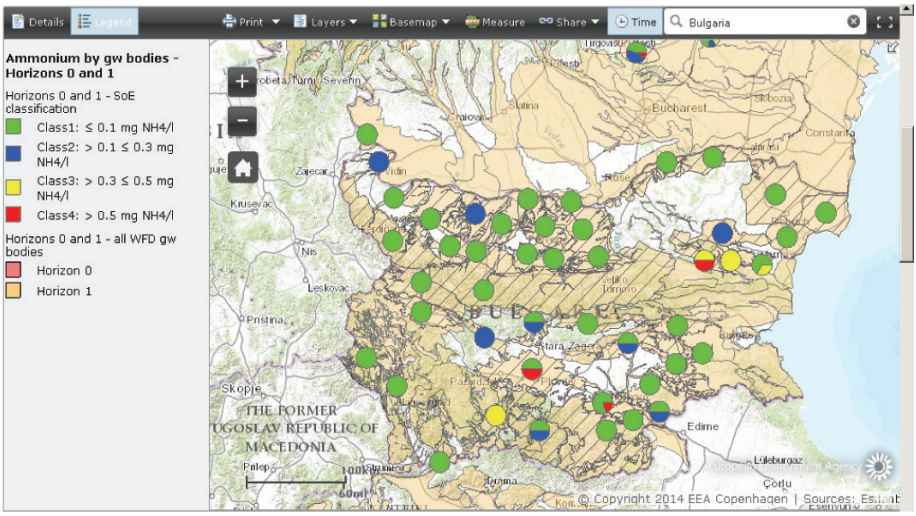

Fig.9. Map of ammonium pollution of groundwater of Bulgaria [9].

Critical is the situation with nitrite, nitrate and ammonium pollutions of groundwater bodies in 2014 in Belgium. Urgent measures should be considered and applied to pure these groundwater bodies. That could be seen correspondingly in Fig.10, Fig.11 and Fig.12.

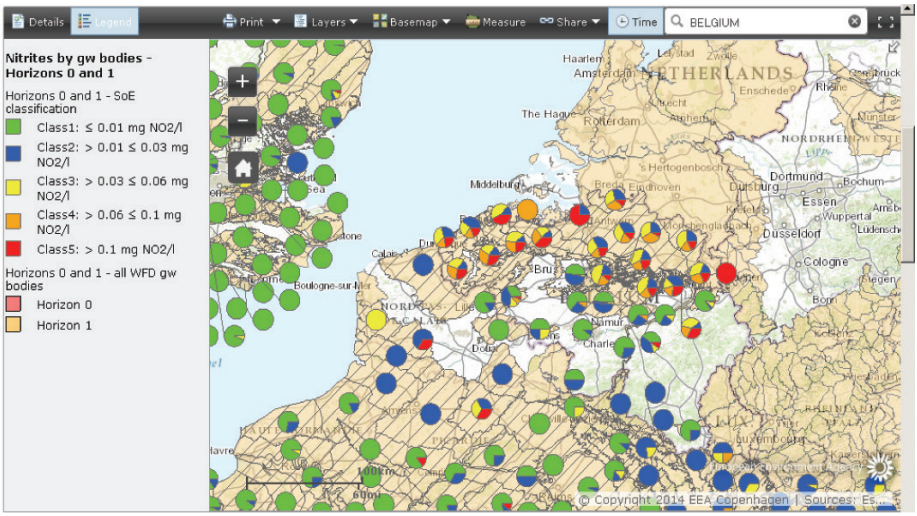

Fig.10. Map of nitrite pollution of groundwater of Belgium [7].

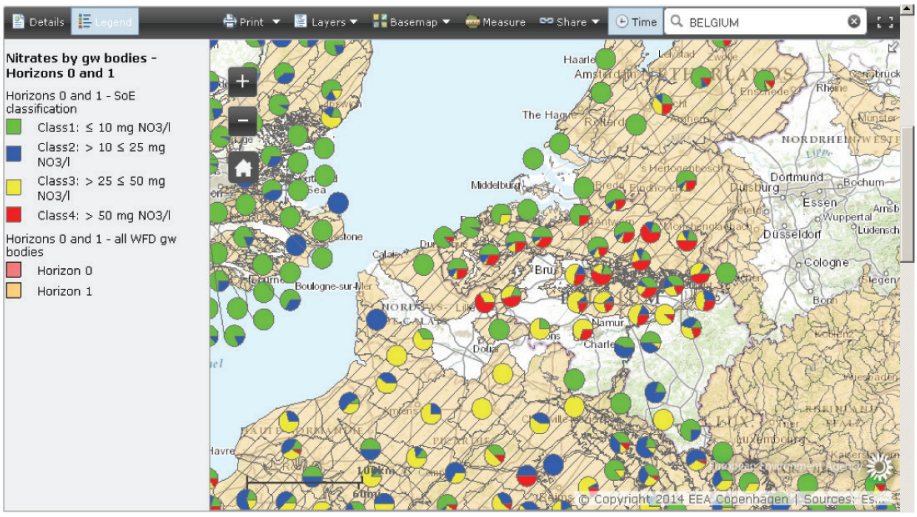

Fig.11. Map of nitrate pollution of groundwater of Belgium [8].

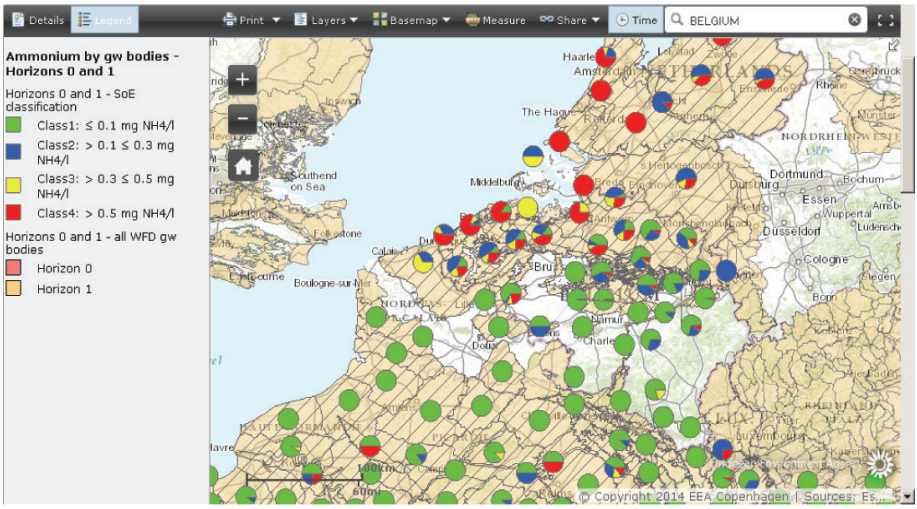

Fig.12. Map of ammonium pollution of groundwater of Belgium [9].

3. CONCLUSIONS:

Groundwater is a vital source of fresh water on the Earth. It will be of great importance as well in the future for whole human being. EU observes the contamination of groundwater bodies across Europe. Under conditions of intensified agriculture in many

parts of the Europe and particularly in Bulgaria and Belgium adequate measures should be conformed and put into practice in order future pollution of groundwater bodies to be preventing.

REFERENCES:

The European environmental state and outlook 2010, Water resources: quantity and flows. European Environmental Agency, 2010.
http://www.eea.europa.eu/soer/europe/water-resources-quantity-and-flows, (Available June 2015)

Groundwater and its susceptibility of degradation. A global assessment of the problem and options for management. United Nation Environmental Program (UNEP), 2003.
http://www.unep.org/dewa/Portals/67/pdf/Groundwater_Prelims_SCREEN.pdf, (Available June 2015)

European waters- assessment of status and pressures, European Environmental Agency, 2012,
http://krw.stowa.nl/Upload/European%20waters%20- %20assessment%20of%20status%20and%20pressures.pdf, (Available June 2015)

4. Agri-environmental indicator – mineral fertilizer consumption, EUROSTAT Statistics Explained http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_mineral_fertiliser_consumption, (Available June 2015)

Agri-environmental indicator –Consumption estimate of manufactured fertilizer: Nitrogen, EUROSTAT Statistics, http://ec.europa.eu./eurostat/data/database, (Available June 2015)

Agri-environmental indicator – nitrate pollution of water, EUROSTAT Statistics Explained,
http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_nitrate_pollution_of_water, (Available June 2015)

Interactive map of nitrite pollution of groundwater of EU Member States,
European Environmental Agency, 2014,
http://www.eea.europa.eu/data-and-maps/explore-interactive-maps/nitrites-in-groundwater-by-countries, (Available June 2015)

Interactive map of nitrate pollution of groundwater of EU Member States,
European Environmental Agency, 2014,
http://www.eea.europa.eu/data-and-maps/explore-interactive-maps/nitrates-in-groundwater-by-countries, (Available June 2015)

Interactive map of ammonium pollution of groundwater of EU Member States,
European Environmental Agency, 2014,
http://www.eea.europa.eu/data-and-maps/explore-interactive-maps/ammonium-in-groundwater-by-countries, (Available June 2015)