Occurrence, risk assessment and elimination of chemicals of emerging concerns in wasterwater treatment plants in Western Kenya

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installing and loading the required libraries

##   
## Attaching package: 'dplyr'

## The following objects are masked from 'package:stats':  
##   
## filter, lag

## The following objects are masked from 'package:base':  
##   
## intersect, setdiff, setequal, union

#Nzoia Filtering Nzoia\_EFF with highest detection of above 200

## # A tibble: 12 × 2  
## WWTPs Nzoia\_EFF  
## <chr> <dbl>  
## 1 0016\_Diuron 213.  
## 2 2284\_2-Oxindole 233.  
## 3 5074\_Methyl 3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate 1434.  
## 4 2239\_Acetamiprid 322.  
## 5 0229\_Atrazine 243.  
## 6 0431\_Metolachlor OA 251.  
## 7 0464\_10,11-Dihydro-10,11-dihydroxycarbamazepine 711.  
## 8 0204\_Carbamazepine 311.  
## 9 0567\_Fluconazole 1479.  
## 10 0186\_Ibuprofen 501.  
## 11 0466\_Cetirizine 1033.  
## 12 0209\_Sucralose 2016.

filtering Nzoia\_INF with highest detection > 200

## # A tibble: 69 × 4  
## Compound\_class WWTPs Nzoia\_INF Nzoia\_EFF  
## <chr> <chr> <dbl> <dbl>  
## 1 biocide 0016\_Diuron 211. 213.   
## 2 biocide 0837\_Methylparaben 2251. 0   
## 3 biocide 0310\_Hexadecylpyridinium\_M+ 1268. 0   
## 4 biocide 0838\_Propylparaben 584. 0   
## 5 corrosion inhibitor 0231\_1H-Benzotriazole 212. 0.223  
## 6 food ingredient 4113\_Piperine 202. 0.307  
## 7 food ingredient 0497\_Daidzein 1139. 0   
## 8 human metabolite 4887\_Chenodeoxycholic acid\_M+NH4 8483. 0   
## 9 human metabolite 4870\_Deoxycholic acid 356471. 9.37   
## 10 human metabolite 0265\_Cholic acid 211414. 0   
## # … with 59 more rows

Percentage removal of each chemical compound present in Nzoai with an influent value greater than 200

| Nzoia.WWTPs | per\_removal |
| --- | --- |
| 0016\_Diuron | -1.12016 |
| 0837\_Methylparaben | 100.00000 |
| 0310\_Hexadecylpyridinium\_M+ | 100.00000 |
| 0838\_Propylparaben | 100.00000 |
| 0231\_1H-Benzotriazole | 99.89456 |
| 4113\_Piperine | 99.84850 |
| 0497\_Daidzein | 100.00000 |
| 4887\_Chenodeoxycholic acid\_M+NH4 | 100.00000 |
| 4870\_Deoxycholic acid | 99.99737 |
| 0265\_Cholic acid | 100.00000 |
| 4812\_7-Oxolithocholic acid | 100.00000 |
| 0504\_Bisphenol S | 99.92315 |
| 0808\_Tri-n-butyl citrate | 100.00000 |
| 0492\_2,4-Dichlorophenol | 100.00000 |
| 1290\_Aniline | 100.00000 |
| 0073\_2-Methylbenzothiazole | 100.00000 |
| 2284\_2-Oxindole | 99.39083 |
| 5074\_Methyl 3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate | 91.64514 |
| 2808\_Triethylene Glycol Monobutyl Ether\_M+NH4 | 100.00000 |
| 0206\_Bisphenol A | 100.00000 |
| 2331\_Bisphenol E | 100.00000 |
| 5114\_3,5-Di-tert-butyl-4’-hydroxyacetophenone | 93.05541 |
| 2738\_Cyclohexylamine | 100.00000 |
| 0948\_Tetrahydrophthalimide | 100.00000 |
| 4769\_Diacetylethylenediamine | 100.00000 |
| 0382\_1-Naphthol | 99.86584 |
| 4847\_2-(2-(2-Methoxyethoxy)ethoxy)ethanol | 100.00000 |
| 0117\_Imidacloprid | 92.72869 |
| 2263\_Carbaryl | 99.49588 |
| 2839\_2,4-DB | 100.00000 |
| 0459\_Trimethoprim | 99.74525 |
| 0235\_Diclofenac | 99.50563 |
| 0176\_Sulfamethoxazole | 99.24502 |
| 0464\_10,11-Dihydro-10,11-dihydroxycarbamazepine | 59.98654 |
| 2155\_Losartan | 90.99103 |
| 2300\_Abacavir | 100.00000 |
| 0033\_Diazinon | 92.68616 |
| 0028\_Atenolol | 98.91940 |
| 0567\_Fluconazole | 46.65853 |
| 0331\_Metformin | 99.88885 |
| 0186\_Ibuprofen | 99.66902 |
| 0466\_Cetirizine | 98.69589 |
| 2199\_Dehydroabietic acid | 99.25047 |
| 0511\_Acetyl-sulfamethoxazole | 99.67613 |
| 4425\_Enoxolone | 98.31374 |
| 4304\_Phenytoin | 88.81456 |
| 0084\_Hydrochlorothiazide | 99.88726 |
| 2801\_Indole-3-carboxyaldehyde | 98.44172 |
| 5022\_Esculetin | 100.00000 |
| 4858\_Ursolic acid | 100.00000 |
| 0789\_Diethylphthalate | 100.00000 |
| 0827\_Bis(2-ethylhexyl)phosphate | 99.99784 |
| 0413\_Mono-iso-butyl phthalate | 100.00000 |
| 0369\_2-(Methylthio)benzothiazole | 97.07674 |
| 2421\_2-Hydroxybenzothiazole | 100.00000 |
| 0421\_Benzothiazole | 100.00000 |
| 0598\_Nicotine | 100.00000 |
| 0190\_Caffeine | 100.00000 |
| 3098\_Dioctylsulfosuccinate | 100.00000 |
| 0517\_Lauramidopropylbetaine\_M+ | 99.67487 |
| 0208\_Nonylphenol\_isomers | 96.87960 |
| 0312\_Lauryl diethanolamide | 99.97615 |
| 0318\_Dodecyl sulfate | 100.00000 |
| 2455\_Tetradecylsulfate | 100.00000 |
| 0334\_Lauric isopropanolamide | 100.00000 |
| 2775\_Decylsulfate | 100.00000 |
| 0209\_Sucralose | -54.74067 |
| 0215\_Cyclamate | 100.00000 |
| 0213\_Saccharin | 100.00000 |

The Average concentration & STD concentration for each compound Class in Nzoia

| Compound\_class | average\_INF | std\_INF | average\_EFF | std\_EFF |
| --- | --- | --- | --- | --- |
| biocide | 1078.3702 | 895.64784 | 53.337800 | 106.6756000 |
| corrosion inhibitor | 211.6761 | NA | 0.223200 | NA |
| food ingredient | 670.7541 | 662.39204 | 0.153300 | 0.2167989 |
| human metabolite | 162238.4819 | 154728.61520 | 2.343250 | 4.6865000 |
| industrial | 4206.9821 | 9978.23245 | 108.037425 | 358.4807927 |
| pesticide | 587.3712 | 88.41147 | 14.653167 | 22.4476969 |
| pharmaceutical | 15946.5517 | 39753.82323 | 234.214706 | 439.5094399 |
| plant metabolite | 1948.9193 | 1703.91548 | 18.952500 | 32.8266929 |
| plastic additive | 11734.9637 | 11430.97637 | 0.085000 | 0.1472243 |
| rubber additive | 910.8571 | 772.85331 | 7.191267 | 12.4556392 |
| stimulans | 4458.6218 | 5189.83737 | 0.000000 | 0.0000000 |
| surfactant | 20470.0937 | 38602.46593 | 5.815700 | 10.3052794 |
| sweetener | 1400.9336 | 466.20522 | 672.140433 | 1164.1813804 |

Removal Efficiency for each compound class in Nzoia

| Compound\_class | percentage\_Efficiency |
| --- | --- |
| biocide | 95.05385 |
| corrosion inhibitor | 99.89456 |
| food ingredient | 99.97715 |
| human metabolite | 99.99856 |
| industrial | 97.43195 |
| pesticide | 97.50530 |
| pharmaceutical | 98.53125 |
| plant metabolite | 99.02754 |
| plastic additive | 99.99928 |
| rubber additive | 99.21049 |
| stimulans | 100.00000 |
| surfactant | 99.97159 |
| sweetener | 52.02196 |

#DLK Filtering out the chemical compounds with influent values greater than 200

## # A tibble: 5 × 4  
## Compound\_class WWTPs DLK\_INF DLK\_EFF  
## <chr> <chr> <dbl> <dbl>  
## 1 biocide 0837\_Methylparaben 821. 143.  
## 2 human metabolite 0265\_Cholic acid 372. 496.  
## 3 industrial 0206\_Bisphenol A 295. 0   
## 4 stimulans 0190\_Caffeine 271482. 140773.  
## 5 surfactant 0318\_Dodecyl sulfate 578. 3105.

Removal efficiency for each chemical componet in DLK

| Compound\_class | WWTPs | DLK\_INF | DLK\_EFF | percentage\_removal |
| --- | --- | --- | --- | --- |
| biocide | 0837\_Methylparaben | 820.7624 | 143.4122 | 82.52695 |
| human metabolite | 0265\_Cholic acid | 371.9450 | 495.9080 | -33.32831 |
| industrial | 0206\_Bisphenol A | 294.9260 | 0.0000 | 100.00000 |
| stimulans | 0190\_Caffeine | 271481.5320 | 140773.4200 | 48.14623 |
| surfactant | 0318\_Dodecyl sulfate | 578.2230 | 3105.2360 | -437.03087 |

Average concentration & STD concentration for each compound Class in DLK

| Compound\_class | average\_INF | std\_INF | average\_EFF | std\_EFF |
| --- | --- | --- | --- | --- |
| biocide | 820.7624 | NA | 143.4122 | NA |
| human metabolite | 371.9450 | NA | 495.9080 | NA |
| industrial | 294.9260 | NA | 0.0000 | NA |
| stimulans | 271481.5320 | NA | 140773.4200 | NA |
| surfactant | 578.2230 | NA | 3105.2360 | NA |

Removal efficiency for each compound class in DLK

| Compound\_class | percentage\_Efficiency |
| --- | --- |
| biocide | 82.52695 |
| human metabolite | -33.32831 |
| industrial | 100.00000 |
| stimulans | 48.14623 |
| surfactant | -437.03087 |

#Moi filtering the chemical substances with an influent value greater than 200

## # A tibble: 13 × 4  
## Compound\_class WWTPs Moi\_INF Moi\_EFF  
## <chr> <chr> <dbl> <dbl>  
## 1 human metabolite 4887\_Chenodeoxycholic acid\_M+NH4 306. 0   
## 2 human metabolite 4870\_Deoxycholic acid 352. 3.43e1  
## 3 human metabolite 0265\_Cholic acid 255. 4.28e1  
## 4 industrial 5074\_Methyl 3-(3,5-di-tert-butyl-4-hydroxyp… 351. 1.59e4  
## 5 pesticide 0977\_Propoxur 206. 0   
## 6 pharmaceutical 2245\_Albendazole 232. 1.56e0  
## 7 pharmaceutical 0331\_Metformin 213. 2.43e1  
## 8 pharmaceutical 0186\_Ibuprofen 4939. 6.84e1  
## 9 pharmaceutical 2199\_Dehydroabietic acid 229. 3.71e1  
## 10 plastic additive 0789\_Diethylphthalate 2078. 0   
## 11 surfactant 0318\_Dodecyl sulfate 416. 6.43e2  
## 12 sweetener 0209\_Sucralose 372. 3.50e2  
## 13 sweetener 0213\_Saccharin 508. 0

removal efficiency for each chemical subtance in Moi

| Moi.WWTPs | percentage\_removal |
| --- | --- |
| 4887\_Chenodeoxycholic acid\_M+NH4 | 100.000000 |
| 4870\_Deoxycholic acid | 90.258997 |
| 0265\_Cholic acid | 83.222132 |
| 5074\_Methyl 3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate | -4439.407459 |
| 0977\_Propoxur | 100.000000 |
| 2245\_Albendazole | 99.326898 |
| 0331\_Metformin | 88.587062 |
| 0186\_Ibuprofen | 98.614197 |
| 2199\_Dehydroabietic acid | 83.803677 |
| 0789\_Diethylphthalate | 100.000000 |
| 0318\_Dodecyl sulfate | -54.367067 |
| 0209\_Sucralose | 5.789364 |
| 0213\_Saccharin | 100.000000 |

Average concentration & STD concentration for every compound Class in Moi

| Compound\_class | average\_INF | std\_INF | average\_EFF | std\_EFF |
| --- | --- | --- | --- | --- |
| human metabolite | 304.2791 | 48.66451 | 25.69533 | 22.65147 |
| industrial | 350.5580 | NA | 15913.25600 | NA |
| pesticide | 205.5939 | NA | 0.00000 | NA |
| pharmaceutical | 1403.2405 | 2356.86070 | 32.87058 | 27.90695 |
| plastic additive | 2077.6700 | NA | 0.00000 | NA |
| surfactant | 416.4580 | NA | 642.87400 | NA |
| sweetener | 439.9468 | 96.53174 | 175.08505 | 247.60765 |

Removal efficiency for each compound class in Moi

| Compound\_class | percentage\_Efficiency |
| --- | --- |
| human metabolite | 91.55534 |
| industrial | -4439.40746 |
| pesticide | 100.00000 |
| pharmaceutical | 97.65752 |
| plastic additive | 100.00000 |
| surfactant | -54.36707 |
| sweetener | 60.20313 |

#Eldo filtering the chemical substances with an influent value greater than 200

Removal efficiency for every chemical substance in Eldo

| Eldo.WWTPs | percentage\_removal |
| --- | --- |
| 0837\_Methylparaben | 99.55082 |
| 0305\_Didecyldimethylammonium\_M+ | 96.85158 |
| 0310\_Hexadecylpyridinium\_M+ | 100.00000 |
| 0838\_Propylparaben | 100.00000 |
| 0493\_2-Phenylphenol | 100.00000 |
| 0496\_Genistein | 99.17112 |
| 4113\_Piperine | 98.14853 |
| 0497\_Daidzein | 99.05367 |
| 4887\_Chenodeoxycholic acid\_M+NH4 | 100.00000 |
| 4870\_Deoxycholic acid | 99.99168 |
| 0265\_Cholic acid | 99.97878 |
| 4812\_7-Oxolithocholic acid | 100.00000 |
| 0504\_Bisphenol S | 62.27969 |
| 0808\_Tri-n-butyl citrate | 100.00000 |
| 4805\_Tripropylamine | 88.44609 |
| 0492\_2,4-Dichlorophenol | 100.00000 |
| 2284\_2-Oxindole | 99.68823 |
| 5074\_Methyl 3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate | 11.98198 |
| 2808\_Triethylene Glycol Monobutyl Ether\_M+NH4 | 100.00000 |
| 0206\_Bisphenol A | 94.19923 |
| 2331\_Bisphenol E | 100.00000 |
| 5114\_3,5-Di-tert-butyl-4’-hydroxyacetophenone | -5571.66325 |
| 2738\_Cyclohexylamine | 100.00000 |
| 0177\_TMDD\_M+NH4 | 100.00000 |
| 0948\_Tetrahydrophthalimide | 100.00000 |
| 4769\_Diacetylethylenediamine | 89.53587 |
| 4836\_Indole-3-acrylic acid | 68.63153 |
| 0382\_1-Naphthol | 99.73576 |
| 2239\_Acetamiprid | 59.64540 |
| 0117\_Imidacloprid | 80.53577 |
| 0005\_Dichlorvos | 99.91817 |
| 0459\_Trimethoprim | 99.03291 |
| 0235\_Diclofenac | 91.98094 |
| 0176\_Sulfamethoxazole | 88.39200 |
| 0464\_10,11-Dihydro-10,11-dihydroxycarbamazepine | 73.79365 |
| 2155\_Losartan | 70.61752 |
| 0580\_Loperamide | 99.84398 |
| 2300\_Abacavir | 94.77387 |
| 0174\_Ketoprofen | 99.11184 |
| 0033\_Diazinon | 75.86146 |
| 0567\_Fluconazole | 55.17860 |
| 0443\_Tramadol | 36.98657 |
| 0027\_Ofloxacin | 81.27187 |
| 0331\_Metformin | 96.72713 |
| 4675\_Cimetidine | 100.00000 |
| 0186\_Ibuprofen | 96.70649 |
| 0466\_Cetirizine | 83.86896 |
| 2199\_Dehydroabietic acid | 96.88810 |
| 0511\_Acetyl-sulfamethoxazole | 91.44621 |
| 0445\_Mycophenolic acid | 92.47535 |
| 0034\_Furosemide | 98.16865 |
| 2801\_Indole-3-carboxyaldehyde | 95.54228 |
| 4964\_Matairesinol | 100.00000 |
| 4858\_Ursolic acid | 99.94852 |
| 0789\_Diethylphthalate | 100.00000 |
| 0827\_Bis(2-ethylhexyl)phosphate | 89.44743 |
| 0369\_2-(Methylthio)benzothiazole | 94.27660 |
| 0421\_Benzothiazole | 100.00000 |
| 0598\_Nicotine | 98.21121 |
| 0190\_Caffeine | 96.15735 |
| 3098\_Dioctylsulfosuccinate | 97.58655 |
| 0517\_Lauramidopropylbetaine\_M+ | 99.76523 |
| 0208\_Nonylphenol\_isomers | 93.48147 |
| 0312\_Lauryl diethanolamide | 99.95191 |
| 0318\_Dodecyl sulfate | 100.00000 |
| 2455\_Tetradecylsulfate | 99.11986 |
| 0334\_Lauric isopropanolamide | 100.00000 |
| 2775\_Decylsulfate | 100.00000 |
| 0209\_Sucralose | 46.42447 |
| 0215\_Cyclamate | 100.00000 |
| 0213\_Saccharin | 100.00000 |
| 0293\_Benzophenone-4 | 74.62799 |

Average concentration & STD concentration for each compound Class in Eldo

| Compound\_class | average\_INF | std\_INF | average\_EFF | std\_EFF |
| --- | --- | --- | --- | --- |
| UV filter | 259.4450 | NA | 65.826400 | NA |
| biocide | 961.7864 | 621.2963 | 7.628980 | 13.436788 |
| food ingredient | 534.3335 | 515.0357 | 5.719367 | 4.511926 |
| human metabolite | 85369.1292 | 69046.0724 | 8.824250 | 10.543053 |
| industrial | 2411.5081 | 5132.3823 | 3074.977675 | 9933.488474 |
| pesticide | 2125.9234 | 3182.7923 | 60.769300 | 61.229099 |
| pharmaceutical | 2388.8692 | 4448.1612 | 163.479605 | 203.097122 |
| plant metabolite | 1452.0075 | 436.1314 | 25.440300 | 43.301443 |
| plastic additive | 8265.9305 | 9266.1656 | 90.423000 | 127.877433 |
| rubber additive | 463.8933 | 148.1370 | 10.277650 | 14.534792 |
| stimulans | 2094.2813 | 2438.1405 | 76.673550 | 99.066296 |
| surfactant | 5687.2708 | 9385.5677 | 21.692412 | 28.867143 |
| sweetener | 1631.9950 | 492.2818 | 344.040267 | 595.895222 |

Removal efficiency for each compound class in DLK

| Compound\_class | percentage\_Efficiency |
| --- | --- |
| UV filter | 74.62799 |
| biocide | 99.20679 |
| food ingredient | 98.92963 |
| human metabolite | 99.98966 |
| industrial | -27.51264 |
| pesticide | 97.14151 |
| pharmaceutical | 93.15661 |
| plant metabolite | 98.24792 |
| plastic additive | 98.90608 |
| rubber additive | 97.78448 |
| stimulans | 96.33891 |
| surfactant | 99.61858 |
| sweetener | 78.91904 |