Retraction Notice

Title of retracted article: **Temporal Dynamics of Land Use and Water Quality in Three Sub-Catchments of the Rur River, Germany**

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☐ Editor with hints from
  ○ Journal owner (publisher)
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Date initiative is launched: 2020-10-26

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History
Expression of Concern:
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Correction:
☐ yes, date: yyyy-mm-dd
X no

Comment:

Free style text with summary of information from above and more details that can not be expressed by ticking boxes.

This article has been retracted due to conflicts of interest among authors. In making this decision the Editorial Board follows COPE's Retraction Guidelines. Aim is to promote the circulation of scientific research by offering an ideal research publication platform with due consideration of internationally accepted standards on publication ethics. The Editorial Board would like to extend its sincere apologies for any inconvenience this retraction may have caused.

Editor guiding this retraction: Prof. Valentine Udoh James (Editor-in-Chief)

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Temporal Dynamics of Land Use and Water Quality in Three Sub-Catchments of the Rur River, Germany

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Abstract

The Rur catchment has over time undergone land use change which could have affected the biogeochemical processes of the river. Three sub-catchments in the Rur, Upper Rur, Inde and Wurm have different kinds of land use. Upper Rur is more natural catchment; Inde is mixed type and Wurm is highly modified by anthropogenic activities. This study investigated how land use changes from 2000 to 2018 have influenced SO_4 and Cl dynamics in the Rur catchment. Land use maps were developed in QGIS environment for land use change calculation. Historical water quality data were collected from the online public source by Ministry of Environment and Nature Conservation in Germany. R-software was used for statistical analysis and graphical presentation. Less land use change was observed in the Upper Rur between 2000 to 2018. But in the Inde and Wurm decrease in agricultural land and associated increase in industrial, commercial and urban land were observed. Increase in mining area inside the catchment has enhanced the level of SO_4 and EC in the Inde river. Conversion rates of natural to human dominated land use could be quantified in this study through land use change mapping, which will further help in making water management plan for these and comparable German and European catchments. However, high quality historical data set is a key requirement to maximize the output in process of relating impact of land use change in water quality.

Keywords

Agriculture, Catchment, Land Use Change, Season, Urban, Water Quality

1. Introduction

It has been accepted globally that activities on the terrestrial ecosystem strongly influences the hydrological processes (Cuo et al., 2013; Recha et al., 2013). After the Second World War, there was a rapid population growth in European countries, which caused expansion of urban areas, intensification in agriculture and development of large chemical and electrical industries. This helped to develop large cities in Meuse river basin (Tu et al., 2005; Lambin & Gheist, 2006). The Rur River, one of the tributaries to the Meuse River, has also undergone land use land cover change (LULCC) which might influence in stream hydro-chemical processes of the Rur River (Rodolfo et al., 2018).

Land use change is mostly occurring to enhance the economic value of that land and this might lead to ecological degradation (Paul & Rashid, 2017). LULCC shows the interaction between the natural environment and human activities and when the land use changes continuously it causes land cover change (Gaitanis et al., 2015; Kanianska et al., 2014). Socio-economic factor, policy-regulation and nature conservation factors are the common drivers of land use change in Europe (Ustsoglu & Williams, 2017). It is important to find out the dynamics of the global land use to maintain environmental sustainability (Gaitanis et al., 2015). LULCC such as, enhanced agricultural practices and urbanization will lead to water quality degradation through more soil erosion, sediment load, leaching of nutrients, leaching from wastewater treatment plants and industrial effluents. The results in increased oxygen depletion, growth of cyanobacteria, fish killing and increase in waterborne diseases (Foley et al., 2005).

The River Continuum Concept (RCC) explains about the variation of organic matter throughout the longitudinal dimension of the river (Vannote et al., 1980). But the anthropogenic alteration in its riparian land use can disturb the river continuum along with its quality and quantity of water (Nautiyal & Mishra, 2013). Similar activities can be observed in the Rur catchment, where origin part of the river is still in natural condition. But the downstream areas are modified for agriculture, urban settlements, and industries. In this case, concept of Urban Stream Syndrome (USS) helps to describe how urbanized catchments have influenced the ecological and hydrological characteristics of a river (Meyer et al., 2005). And Urban Watershed Continuum (UWC) enables us to understand how urban growth impacts on watershed functions. It also considers how long-term changes and continues growth of infrastructures are associated with characteristics of urban streams (Kaushal & Belt, 2012).

Concept of Land Use and Land Cover Change (LULCC) in a River Catchment

LULCC of a catchment have been taken as important topic of environmental research (Cai, 2001). When the vegetated ground coverage is changed to concrete land, biogeochemical alteration occurs in a catchment (Yu et al., 2016). Urban expansion is major activity which increases heavy metals, organic matter, sediments and nutrients to the river (Wang et al., 2014; Sharma et. al., 2005). Different drivers of LULCC can be either social or natural such as demography, economy, technology, climate change, and energy transition (Zondag & Brosboom, 2009; Liu et al., 2010). Landscapes and land use types are diverse topographical areas which consists of interlink between human actions and the environment (Kumar et al., 2018).

By finding out the trend of LULCC we can predict impacts in river water quality as well as water issues that might occur in future (Lambin, 1997). Different ecosystem services provided by river like water quality regulation, biodiversity conservation, CO_2 sequestration and microclimate regulation will be degraded by LULCC (Lambin et al., 2000). Among various processes for collecting data about catchment health, LULCC mapping by the use of GIS (Geographical Information System) and RS (Remote Sensing) are commonly used tools (Tekle & Hedlund, 2000), which helps in making strategic management plan for water resource management (ESCAP, 1997). The Rur River catchment has diverse type of land uses in different sub-catchments. There is waste water discharge from 1.1 million local inhabitants and from industries while intensive agriculture is also taking place in large flat terrain (Schulze & Matthies, 2001; Waldhoff et al., 2017). Thus, this research mainly focuses to find the LULCC in this area and its impact on river water quality variables such as SO_4, Cl and EC.

2. Materials and Methods

2.1. Site Description

Rur River passes through three different countries; Belgium, Germany, and the Netherlands. It's total length of 160.7 km and the total catchment area is 2361 km^2. This river originates in the high peatland area from southwest of the catchment which lies in Belgium. Then it flows towards the Germany and get mixed into the Meuse River in the Netherlands (**Figure 1**). Most of the river area (90%) lies in the North-Rhine Westphalia state of Germany. Mean annual precipitation of this place is 880 mm and evapotranspiration is 450 - 550 mm which gives mean annual flow of 22.8 m^3/s (WVER, 2018).

The Rur catchment can be divided into two topographic regions. Bed rocks of Eifel Mountains forms the southern part where as devonian and carboniferous sedimentary rocks forms the northern part. In southern part, annual precipitation is 850 to 1300 mm and evapotranspiration is 450 to 550 mm (Bogena et al., 2018). Northern region receives annual precipitation of 650 to 850 mm and evapotranspiration of 580 - 600 mm (Montzka et al., 2008).

Different anthropogenic activities can be observed in the Rur catchment. The northern part is mostly covered with agricultural land and the southern part is covered with forests and pasture land (**Figure 1**). Urban areas cover only 10% of the total catchment area. There are six artificial reservoirs in the German part of the catchment and they are used for drinking water, hydropower generation and flood control in downstream. Some reservoirs also provide recreational services to nature lovers (Batsatsashvili, 2017). Three different sub-catchments of the

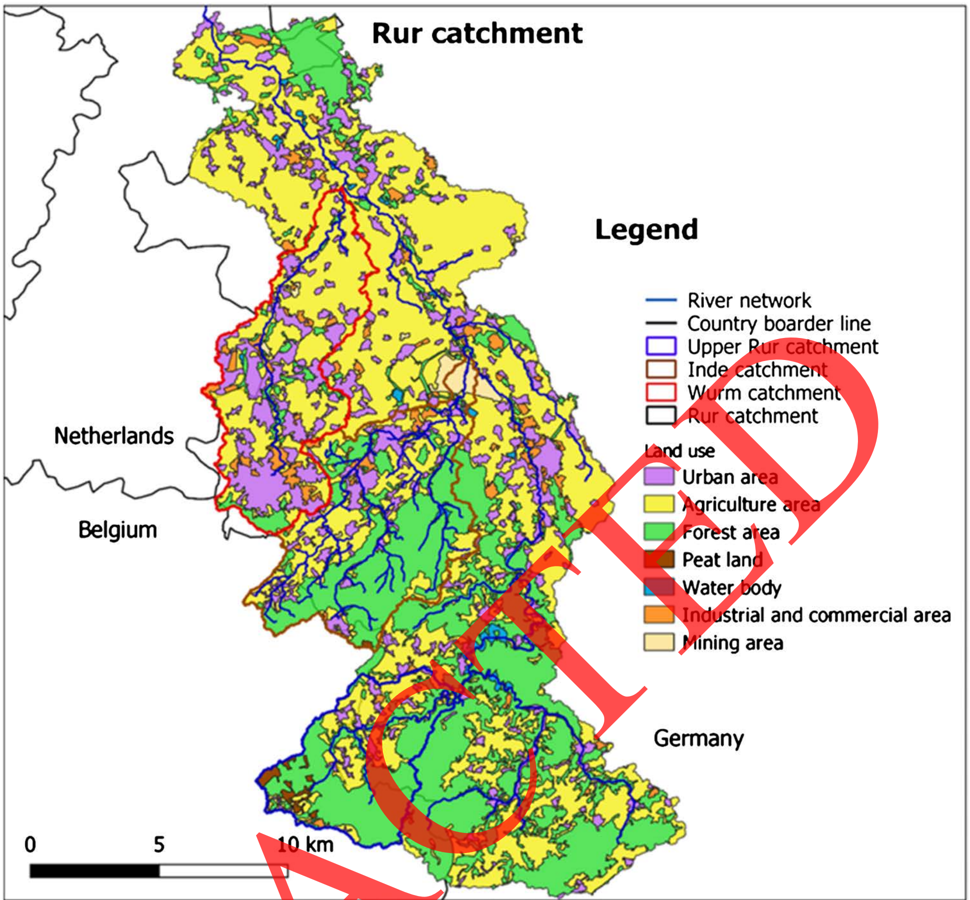

Figure 1. Study area with land-use map of the Rur catchment including three sub-catchments Upper Rur, Inde and Wurm.

Rur: Upper Rur, Inde and Wurm were selected to focus this study in different land use. Where Upper Rur is more natural with higher percentage of forest area. Inde is mixed type catchment with mining areas, human influenced and forested areas. The Wurm is the northernmost catchment highly influenced by human activities (WVER, 2018).

Upper Rur

The Upper Rur is the origin area of the Rur River which has High Fens area (an area which was declared as a nature reserve in 1957 situated in high mountain plateau region at Liege province of Belgium. It is a typical plain area with high annual rainfall. This place is rich in peatland which is important for water storage. Then the river flows through Rhenish Uplands which is a low mountain type of river. The sediments of this part of the river consist of gravels particles brought from the mountain areas (WVER, 2018).

Inde

The Inde River originates from eastern part of Belgium in High Fens area. After flowing 2.5 kilometres downstream it passes through the state boarder in Munsterwald. Then it flows through hills of Aachen and urban area of Stolenberg and meets with its tributary; the Vichtbach. Again it flows through a plain area of Eschweiler where it mixes with its second large tributary; the Wehebach. Finally, after flowing 47 km from Wehebach, it joins the Rur River near Julich-Kirchberg. Here, the river sediments are mostly composed of coarse gravel transported from the uplands. River Inde is the longest tributary of the Rur River (WVER, 2018).

Wurm

The Wurm River rises from the forest of Aachen and when it reaches to the urban areas, it passes through underground channel and starts flowing openly when it reaches the northern periphery of the city. There it mixes other piped waters from city areas and it flows through 25 km of channelized way. After that, it goes towards the border areas of Herzogenrath, Wurselen, Kerkrade, Ubach-Palenberg, Geilenkirchen and finally joins to Rur River at Heinsberg-Kempen. Since it was piped along the city areas, the bed sediments have less coarse gravel particles but as the river reaches to Ubach-Palenberg, coarse rocks can be found as bed material (WVER, 2018).

2.2. Mapping Land Use Change

Land use and land cover change maps were prepared with the help of satellite image from Coordination of Information on the Environment (CORINE). The land use maps were developed by using QGIS. CORINE land cover baseline map of whole Europe of 2000 and 2018 were used for making land use maps of three sub-catchments and calculating change in area of each land use class. First of all three sub-catchments were delineated, than land use map of 2000 and 2018 were developed for these three catchments. Area of different land use types were calculated by using spatial analysis tool in QGIS. Which helped to find the land use change in three sub-catchments from 2000 to 2018.

2.3. Collection of Past Water Quality Data

Past water quality data were obtained from the the record of (MENC, 2018). It is the website which has a record of water quality data from different stations in the Rur catchment. Regular sampling sites at the outlet of each catchment were selected to observe the long-term change in water quality. As Upper Rur is more natural than the Inde and Wurm, it was taken as reference site. Which helped to relate the change in land use with change in water quality. For finding the trend of change in concentration of SO_4 and Cl, simple linear regression model was used. R-software was used for statistical analysis and graphical presentation.

3. Results

Land use change calculation from 2000 to 2018 shows that Upper Rur had minimal change than the Inde and Wurm (**Figure 2**).

EC, SO_4 and Cl were significantly different ($P < 0.0001$) among three rivers; Upper Rur, Inde and Wurm. Lower values were observed in Upper Rur which is more natural catchment and higher values were observed in the Wurm, where

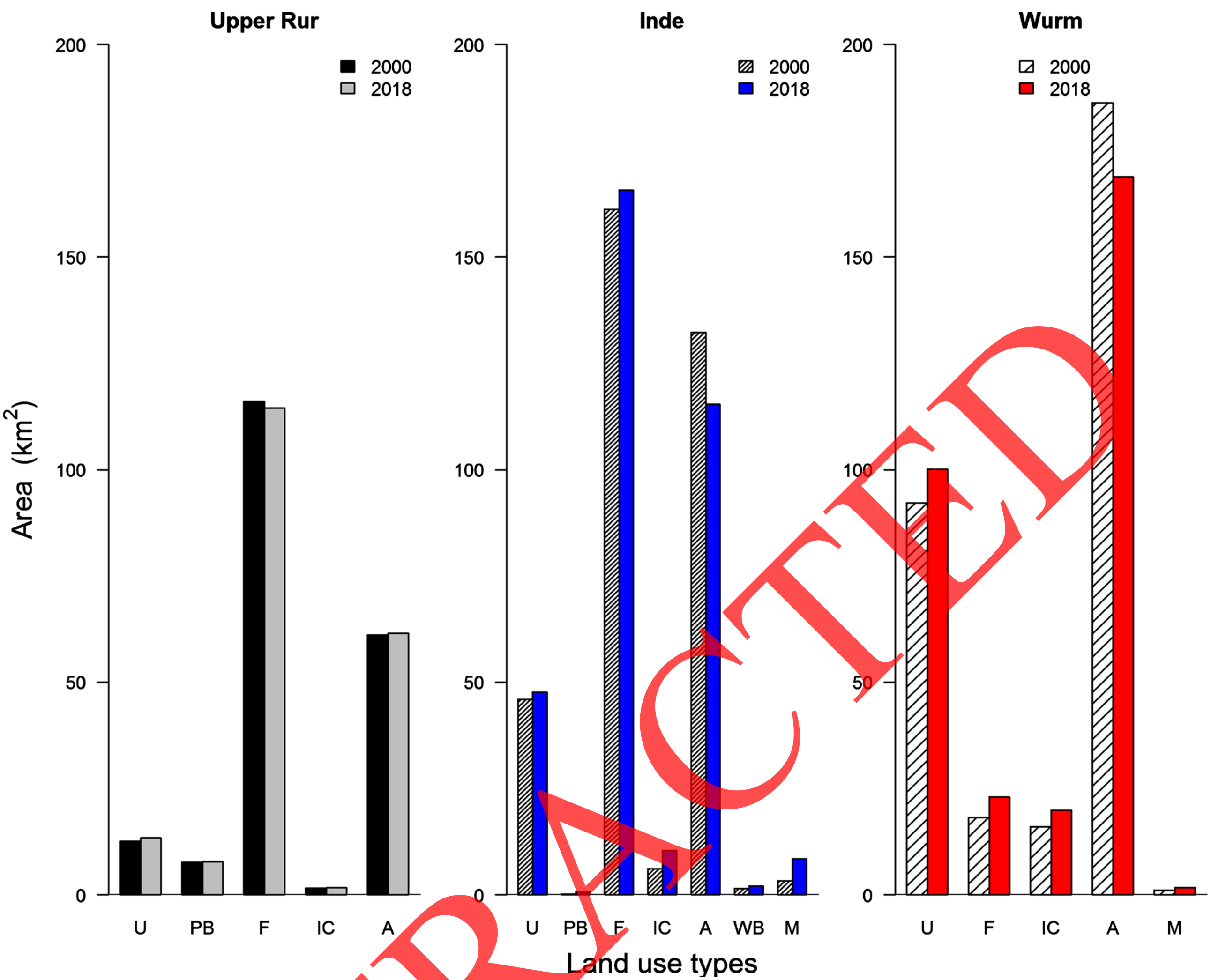

Figure 2. Change in different land-use types from 2000 to 2018 in Upper Rur, Inde and Wurm, PB: peat bog, U: Urban area, F: Forest area, IC: Industrial and commercial area, A: Agricultural area, M: Mining area, WB: Water body. Mining area is absent in Upper Rur, peatbog is absent in Wurm.

anthropogenic activities were also higher. Significant change in EC in the Upper Rur had not significantly changed in last two decades. In the Inde, significant increase in EC was observed at the outlet point with rate of 0.4 mS·m^{-1}·year^{-1}. In the Wurm, it was significantly decreasing with rate of 1.1 mS·m^{-1}·year^{-1} (Figure 3).

SO_4 was significantly decreasing with rate of 0.8 mg·L^{-1}·year^{-1} in the Upper Rur. In the Inde, it was increasing with rate of 3 mg·L^{-1}·year^{-1}. In the Wurm, it was significantly decreasing with rate of 4.9 mg·L^{-1}·year^{-1}. Chloride concentration increased significantly in the Upper Rur at the rate of 0.3 mg·L^{-1}·year^{-1}. In the Inde, it increased significantly at rate of 0.7 mgL^{-1} year^{-1} and 0.6 mgL^{-1} year^{-1} in the Wurm.

4. Discussion

Difference in rate of change in land use in three different sub-catchments indicates the variation in human activities taking place within the Rur catchment.

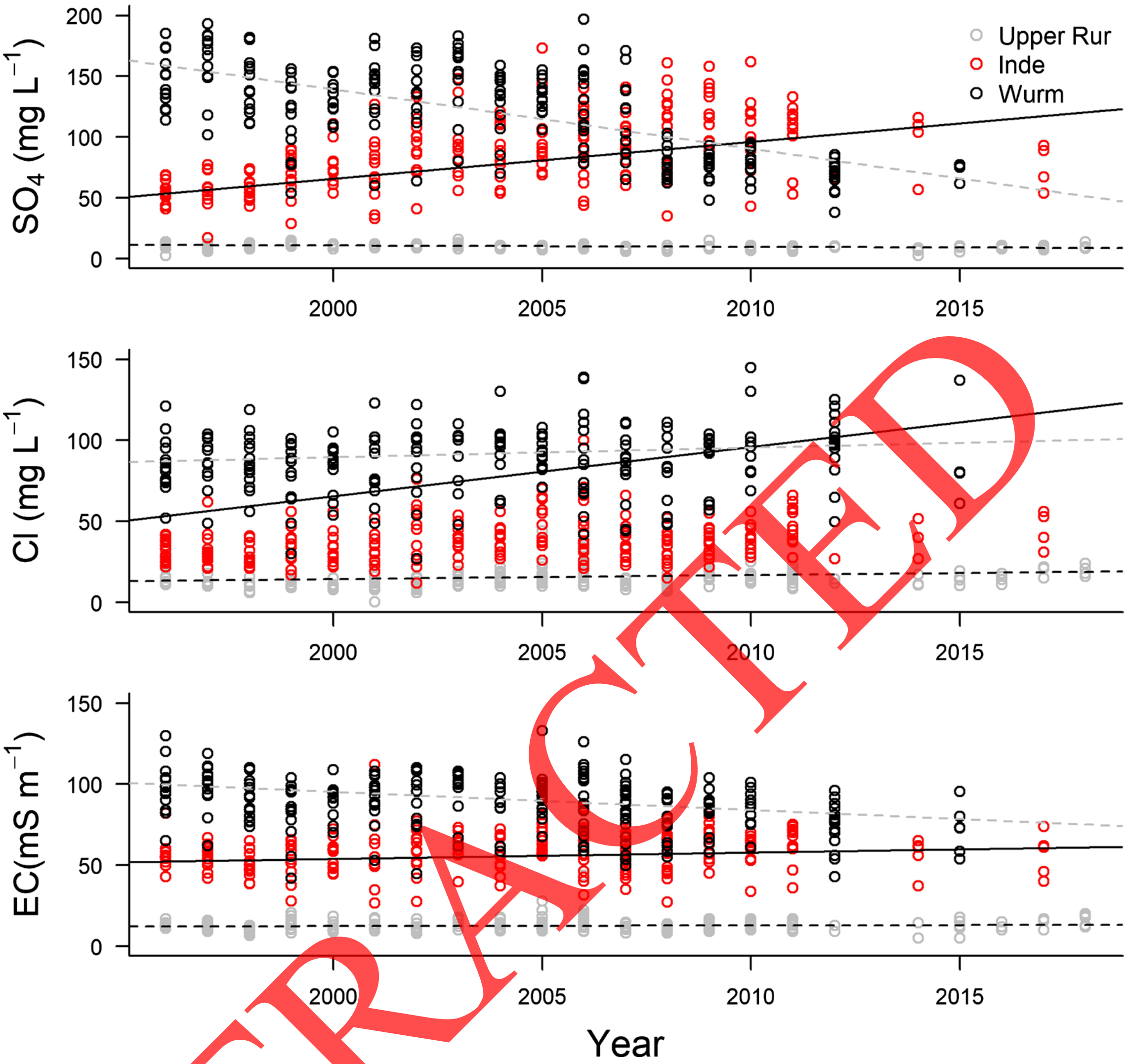

Figure 3. Change in concentration of EC, SO_4 and Cl in different years. Black dotted line, black solid line and grey dotted line: Regression line of Upper Rur, Inde and Wurm respectively.

Remarkable change in land use like increase in settlement and agricultural area, decrease in wetlands and forest area over past thirty eight years was observed in Koga watershed in Ethiopia (Sewnet & Gebeyehu, 2018). Similar change was also observed in Xiaotjiang watershed in China (Jiang et al., 2008). In Europe, remarkable conversion of agricultural area to urban area has occurred in these two decades and some parts of the Netherlands, Belgium, Poland and UK are even facing challenge of rapid urban growth (Van Vliet et al., 2015; Ustsoglu & Williams, 2017). The trend of decline in agricultural area and increase in urban area in the Rur catchment indicates possible future impact in biodiversity, ecosystem services, soil and aquatic environment. Finding from similar research from Europe says when agricultural area is changed to settlements or industries, it will affect the overall sustainability of environment leaving negative impact in all biotic and abiotic components (Van Vliet et al., 2015). And this might influence the target of sustainable development goal to protect all the surface water by 2030.

Relation of Change in Land Use with River Water Quality

Significant difference in SO_4, Cl and EC were observed among the three rivers which is due to land use of the each catchments. Upper Rur is more natural, with minimal or no land use change. So, concentration of SO_4, Cl and EC level was also low. Larger part of land use in the Inde and Wurm is agricultural area and there is increase in mining area and industrial and commercial activities. This might have caused the higher level of SO_4, Cl and EC.

From the result of this research, it was observed that mining area increased from 3.23 km^2 to 8.39 km^2 in the Inde, which was increase of 159.65% from 2000 to 2018. Lignite mining in the Inde might have increased the SO_4 concentration over the time period of two decades because SO_4 is one of the main composition of the lignite. So, the rate of increase of SO_4 is also higher at this point. The trend of increase in EC in the Inde I14 is higher than in I5 because in the upstream there is increase in urban area and intensive agriculture. But in the downstream at the outlet point, there is increase in mining site as well as the increase in industrial and commercial activities. The I14 point lies just below the mining area. The discharge from the mining industries might have increased the EC level in the Inde at outlet point I14. As SO_4 is an anion it might have increased the electrical conductivity of the water. Similar study also found that, for processing of the lignite, mining industries withdraw groundwater from that area and finally discharge the water into the Inde River (Batsatsashvili, 2017).

Since mining area increased from 1.02 km^2 to 1.69 km^2 in the Wurm, the decreasing trend of SO_4 and EC over two decades time period in the upstream site W7 and outlet site W12 in the Wurm catchment can be the result of shutting down larger underground mining areas. Bigger underground coal mining companies of the Wurm catchment such as Emil Mayrisch, stopped their operation by 1992 (Maaß & Schuttrumpf, 2018). Similarly, the enforcement of EU Water Framework directive from 23rd October 2000 have increased the water quality status of the Wurm catchment. This directive obligates all the European Union member countries to reach the target of maintaining good standard of water quality and quantity in all types of water bodies by 2015 (WVER, 2019). Beside this restoration of the non-operational lignite mines by forest area and cultivation land is going on in Aachen, where Wurm catchment is also located (RWE Power, 2019).

Sustainable development goal number six "Clean water and sanitation" explains about maintaining benchmark of water quality variables in rivers by 2030 in order to conserve freshwater ecosystem and bio-diversity (Indicator Report, 2017). Observations of this study from the Upper Rur, Inde and Wurm shows that the target of maintaining benchmark of water quality variables in these rivers by 2030 can be achieved by proper monitoring and action, especially in the Inde and Wurm river flowing through catchments with higher human activities.

5. Conclusion

From the observation of land use maps of 2000 and 2018, it can be concluded that land use change is happening in different parts of the Upper Rur, Inde and Wurm. Conversion of agricultural land to urban area and increase in industrial and commercial area are noticeable land use change in the study area. After observation of increasing trend in SO_4 and EC in last two decades time period in the outlet point (I14) of Inde River, it can be concluded that increase in opencast lignite mining supplemented by increased urban, industrial and commercial area is affecting the river water quality. It can also be concluded that the Upper Rur catchment is in more natural state which has helped in maintaining good river water quality. From this study, it can also be concluded that good set of historical data set is required for relating land use change with different water quality variables.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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