THE IMPORTANCE OF IMPLEMENTING POLLUTION PREVENTION PRINCIPLE IN EFFLUENT WATER MANAGEMENT FOR ENVIRONMENTAL LEGAL COMPLIANCE IN A COAL POWER STATION, A CASE OF KENDAL POWER STATION, MPUMALANGA PROVINCE, SOUTH AFRICA.

By

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DECLARATION

I, **Madike, Podile Emeldah,** declare that the work presented in this mini dissertation is original. Where other works and opinions have been used references were provided as required. This mini dissertation is my own work and has not been submitted to any other institution. The mini dissertation is submitted in fulfilment of the requirements for obtaining a master's degree in Environment and Society.

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To my husband Daniel, my daughters Sharron, Pheladi and my little one Tshegofatso. Thank you for your love, care and support.

I thank my dog Dodo, for keeping me company till early hours of the morning on every night that I laboured to achieve this dream.

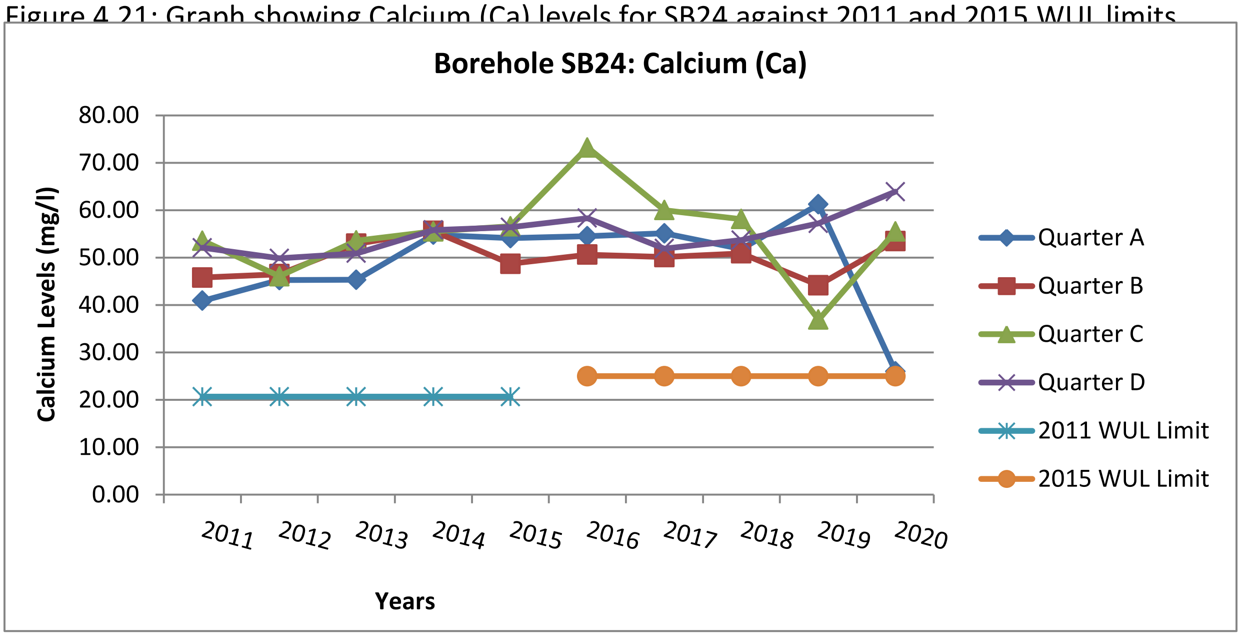
ABSTRACT

This study focuses on the Kendal Power Station located in the Nkangala District, eMalahleni Municipality in Mpumalanga Province, South Africa. The study intended to establish whether or not the effluent water management activities impact negatively on the ground water resources surrounding the power station. This was done by examining the monitoring reports on the boreholes used for monitoring potential contamination of groundwater caused by effluent water, and whether this complies with the limits as stipulated in the power station water use licence. Data from 2011 to 2020 was used. The chemical variables which formed part of the study are pH, electrical conductivity, sodium, calcium, and sulphates. Four boreholes in the vicinity of the effluent water dams were used for this study. In instances where the limits as stipulated in the water use license were exceeded, it indicated that pollution or contamination of the groundwater resources occurred. It was found that three boreholes had high instances of non-compliance with the water use license limits. The fourth borehole, which is located at the highest topographic point, had less instances of non-compliances to the water use license limits, compared to the two boreholes in close proximity. It was also found that the highest incidences of non-compliance were with sodium, followed by sulphates, electrical conductivity, and calcium, with pH having the least incidences of non-compliances. It was thus concluded that the Kendal Power Station did not implement pollution prevention principles in effluent water management.

Keywords: pollution prevention, effluent water management, compliance, Kendal Power Station.

TABLE OF CONTENTS

LIST OF FIGURES


Borehole SB24: Calcium (Ca)
Calcium Levels (mg/l)
80.00
70.00
60.00
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40.00
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2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Years
Quarter A
Quarter B
Quarter C
Quarter D
2011 WUL Limit
2015 WUL Limit

LIST OF TABLES

LIST OF ABBREVIATIONS

AEL: Atmospheric Emission Licence

BAT: Best Available Techniques

DEA: Department of Environmental Affairs

DEAF: Department of Environmental Affairs and Forestry

DFFE: Department of Forestry, Fisheries and Environment

DWA: Department of Water Affairs

DWAF: Department of Water Affairs and Forestry

DWS: Department of Water and Sanitation

DHSWS: Department of Human Settlements, Water and Sanitation

EPA: Environmental Protection Agency

GHT: Geo_Hydro Technologies

GoN: Government Notice

ISO: International Organisation for Standardization

NATA: National Association of Testing Authorities

NEMA: National Environmental Management Act

NWA: National Water Act

n.d.: No date

RG: Regulations

PPA: Pollution Prevention Act

SABS: South African Bureau of Standards

SANAS: South African National Accreditation System

USA: United States of America

WUL: Water Use License

ZLED: Zero Liquid Effluent Discharge

CHAPTER 1: NATURE AND SCOPE OF THE STUDY

1.1 Introduction

Electricity generation is subjected to compliance with various environmental legislations in South Africa, including national, provincial and local bylaws. These cover areas such as air quality (including management of fugitive dust), water, waste, biodiversity, and pollution management. Applicable National environmental legislation includes but are not limited to, the following legislation:

- Constitution of the Republic of South Africa, (Act No. 108 of 1996).
- National Environmental Management Act (Act no 017 of 1998) as amended by National Environmental Management Act 8 of 2004.
- National Environmental Management act: Air quality 2004 (Act 39 of 2004) as amended by National Environmental management Air Quality Act, 20 of 2014.
- National Environmental Management: Biodiversity Act (Act 10 of 2004) as amended by National Environmental Management Laws Act 14 of 2013.
- National Environmental management: Waste Act (Act 59 of 2008).
- National Water Act, 1998 (No.36 of 1998) as amended by Act No 26 of 2014 as amended by the National Water Amendment Act No 45 of 1999.
- Environment Conservation Act: Regulations: Waste Tyre (G 31901, RG 9032, GoN 149)
- Environment Conservation Act: Regulations: Prohibition of use, manufacturing, import and export of asbestos and asbestos containing materials, (G 30904, RG 8858, GoN 341) (Department of Environmental Affairs, Forestry and Fisheries: 2020).

The Constitution of the Republic of South Africa, 1996, Section 24, provides for basic rights of people in relation to environment and states the following:

"Everyone has the right –

(a) *To an environment that is not harmful to their health or well-being; and*

(b) To have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that –
(i) prevent pollution and ecological degradation;
(ii) promote conservation; and
(iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development." (The Constitution of the Republic of South Africa, 1996: s24, p. 9)

Schoeman Law INC (n.d.) indicates that environmental rights as enshrined in the constitution of the Republic of South Africa, is twofold as follows; the first part guarantees a healthy environment to every person and the second part obligates the State to ensure compliance with this environmental right. On their explanation of the environmental rights in the constitution, they conclude that the state is not only obligated to ensure environmental protection but to also ensure ecological sustainable development which can be attained by, amongst others ensuring that individuals, corporates and public servants comply with these rights and put in place appropriate measures to comply. They further indicate that where there is lack of compliance, enforcement tools should be instituted. (Schoeman Law INC (n.d.)).

As indicated in the discussions above, Section 24 (b) (i) of the Constitution of the Republic of South Africa specifies prevention of pollution and protection of ecological systems. Electricity generation industries such as Kendal Power Station were constructed way before this right was specified in the constitution and must however comply with this requirement irrespective. In this instance, the powers station had to comply with the applicable environmental legislation at that time and further, transformed legislation, in particular environmental legislation affects and dictates the way industries operates or have to operate going into the future. (Constitution of the Republic of South Africa, 1996: s24)

One of the principles stated in Chapter 1 of National Environmental Management Act (act 107 of 1998, as amended), hereafter referred to as NEMA, principle 4 (a) (ii) states "Sustainable development requires that pollution and degradation of the environment are avoided, or, where they cannot be altogether avoided, are minimised and remedied;" (NEMA, 1998: s4 (a) (ii), p. 12. par 5). This is one of the principles linked to people 's right to an environment that is not harmful to their health and well-being as stated in Section 24 of the Constitution of the Republic of South Africa (1996: s24). In the generation of electricity, just like in many other manufacturing industries, pollution derived from by-products does occur. Pollution generated, if not mitigated can adversely affect land or soil, both surface and ground water, atmosphere, ecological ecosystems including human beings who might be exposed to such pollution. NEMA, as the environmental framework legislation also specifies the importance of pollution prevention in its environmental management principles. (NEMA, 1998: s4 (a) (ii))

Prior to the democracy in South Africa, up until new water legislation was enacted, the Water Act (act 54 of 1956) with all its amendments was in force. This act was assented to in June 1956 and its commencement was in July 1956. According to this act, its purpose was *"To consolidate and amend the laws relating to the control, conservation and use of water for domestic, agricultural, urban and industrial purposes; to make provision for the control, in certain respects, of the use of sea water for certain purposes; for the control of certain activities on or in water in certain areas; for the control of activities which may alter the natural occurrence of certain types of atmospheric precipitation; for the control, in certain respects, of the establishment or the extension of townships in certain areas; and for incidental matters."* (Water Act 54: 1956; s1, p. 1201(1)).

Section 22 of the Water Act (Act 54 of 1956: s22) further requires landowners to prevent water pollution by stating the following:

"*22. Prevention of water pollution. -(I) Any person who has control over land on which anything was or is done which involved or involves a substance capable of causing water pollution, whether such substance is a solid, liquid, vapour or gas or a combination thereof, shall take such steps as may be prescribed by regulation under section 26 in order to prevent-*

(a) any public or private water on or under that land, including rainwater which falls on or flows over or penetrates such land, from being polluted by that substance, or if that water has already been polluted, from being further polluted by that substance; and

(b) any public or private water on or under any other land, or the sea, from being polluted, or if that water has already been polluted, from being further polluted, by water referred to in paragraph (a) which became polluted in the circumstances described in that paragraph." (Water Act 54 of 1956, s22, p.1231 (1)).

The above section requires an owner of land to prevent pollution of surface and underground private and public water caused by any substance in whatever form. *(*Water Act: 1956, s22). Kendal Power Station, though constructed in the 1980's to early 1990's had to comply with this piece of water legislation. It must however be noted that the Water Act 54 of 1956 was replaced by the National Water Act 36 of 1998 (ecolex.org: 2021). Nonetheless, any person who was in control of land in the time when this legislation was applicable, had to comply with the notion of pollution prevention as stated in the Water Act of 1956.

Part 4 of the National Water Act (Act 36 of 1998) hereafter referred to as NWA deals with pollution prevention in instances where pollution of water might occur or occurs as a result of activities overland. This part of legislation puts the responsibility of prevention of water resource pollution on the landowner or to the person who controls or occupies that land. Section 19 of the same act (NWA: 1998, s19) mentions that the responsible person indicated above, in instances where an activity or process has happened or a situation has occurred *"… which causes, has caused or is likely to cause pollution of a water resource must take all reasonable measures to prevent any such pollution from occurring, continuing or recurring."* (NWA Act, 1998: s19, ss1, (b), p. 18). This act further stipulates the measures to be taken to prevent pollution of water resources as follows:

"(a) cease, modify or control any act or process causing the pollution,

(b) comply with prescribed waste management standard or management practice,

(c) contain or prevent the movement of pollutants,

(d) eliminate any source of pollution,

(e) remedy the effects of the pollution,

(f) remedy the effects of any disturbance to the bed and banks of a water resource."

(NWA Act, 1998, s19, ss2 (a-e) p. 18).

It is clear from the above provisions that, industries or any other responsible persons who owns, uses, occupies or is in control of land must do everything in their power to protect water resources from pollution.

According to the Environmental Protection Agency (EPA), the Congress of United States of America passed the Pollution Prevention Act (PPA) of 1990, (United States of America; Congress of United States of America, Pollution Prevention Act: 1990), which focuses on pollution prevention at source. This legislation, amongst others, states that source reduction is more acceptable than pollution control and management and handling of waste. A policy declared under this act states *that "pollution should be prevented or reduced at the source whenever feasible; pollution that cannot be prevented should be recycled in an environmentally safe manner, whenever feasible; pollution that cannot be prevented or recycled should be treated in an environmentally safe manner whenever feasible; and disposal or other release into the environment should be employed only as a last resort and should be conducted in an environmentally safe manner."* (PPA, 1990: § 13101. Findings and policy (b)).

The PPA looks at all types of pollution, from toxic substances, waste generation etc. The Act is applicable to the prevention of pollution on water resources and indicates that disposal and releases of pollution into the environment must be the last resort. Therefore, if this Act where to apply in the South African context, the release of polluted effluent water into dams, either for reuse or final disposal, would not be deemed as an acceptable practice, an acceptable practice would be to reduce the pollution at source, rather than to dispose polluted water into the containment dams prior to reducing such pollutants. (PPA: 1990)

In recent years, the Department of Forestry, Fisheries and the Environment (DFFE) have strengthened their role in terms of ensuring compliance with permits and licenses and overall compliance with all environmental legislation by conducting inspections and issuing pre-compliance notices, compliance notices, pre-directives and directives to some of the power generating facilities due to non-compliances.

Kendal Power Station has environmental permits and licenses which have been issued by both the then Department of Water Affairs (DWA) and Department of Environmental Affairs (DEA) and these two departments have conducted compliance inspections to verify compliance with the issued permits and any other applicable environmental legislation. Below is the list of some of the environmental permits and licenses issued to Kendal Power Station:

- Atmospheric Emission Licence (AEL). The first one was issued in 2014 with Reference Number 17/4/AEL/MP312/11/15 and expired in March 2019. A new AEL was issued in September 2019. This licence stipulates conditions relating to point source emissions and imposes limits on particulate matter emissions and gaseous emissions which are sulphur dioxide and nitrous oxide. The license also imposes requirements on fugitive dust monitoring, management, and reporting.
- Water Use License was issued in November 2011 (License Number 04/B20E/BCEGI/1048, with an amendment in November 2015 and 2018.
- Water Use License for the construction and operation of Continuous Ashing facility License Number 04/B20E/ABCGI/3888, dated 08 August 2017.
- One Bulk Water Use Licence (License Number: 27/2/1/C211/1/1) issued for several power stations which stipulates water quantity allocated for each individual power station per annum.
- A waste management license was issued in 1995 for the general landfill site (Permit Number: B33/2/220/19/P161) operated and managed by the power station. An application to decommission the general landfill site due to the non-compliances to the conditions was submitted, the decommissioning license number 12/9/11/L56005/6 was

issued on the 14th of February 2017 and the permit for the landfill site was ceded in March 2017.

- A waste management environmental authorisation for the continuous disposal of ash at the existing ashing facilities dated 28 July 2015 with DEA Reference Number 14/12/16/3/3/3/63.
- Game management permit dated 14 November 2003.
- Sewerage treatment works permit dated 06 April 1998.

It is the power station's responsibility to comply with all requirements of environmental legislation including the conditions stipulated in the environmental permits and licenses issued for its operation.

In respect of the interactions with the Authorities from various Departments and sections with the DEA or Department of Environmental Affairs, Forestry and Fisheries (DFFE) and the DWS (Department of Water and Sanitation) or DHSWS, the following is a list of some of the interactions which happened from December 2015 as per the records available at Kendal Power Station.

- In December 2015, the DEA conducted an unannounced site inspection at Kendal Power Station, which was followed by the issuance of pre compliance notice dated 24 October 2016. The pre-compliance notice focussed on air quality related issues.
- A multidisciplinary site inspection was again conducted by Authorities from various sections of environmental departments at national and provincial level on 5 and 6 December 2017. The inspections focused on documentation review and site walk about on several aspects of environmental management from air quality, water management, environmental incident management and waste management.
- In July 2018, the DWS issued a pre-directive to the power station, and water management issues were raised based on the multidisciplinary site inspection which was conducted in December 2017.

- In November 2018, a multidisciplinary Intention to Issue a Compliance Notice was issued to the power station; issues raised were ranging from air quality, water management, incident management, waste management and environmental impact assessments.
- A search warrant and criminal investigation was initiated by senior officials from the DEA by coming to the station unannounced in May 2019. The officials issued the search warrant and requested various environmental monitoring and environmental performance records and documents.
- A third pre-compliance notice was issued by DEA on 14 August 2019, in terms of Section 31L of NEMA, regarding the alleged non compliances with environmental legislation.
- In June 2019 Officials from DWS conducted a site inspection to verify the response made by the power station on the pre-directive issued on water management.
- On 5 September 2019, the DWS issued a Directive together with a letter rejecting the response to the pre-directive issued in August 2019.
- On the 9th of September 2019, the same department, DWS issued a pre-directive relating to water management issues.
- Notice of criminal charges in respect of the Kendal AEL non-compliance was served on Eskom in October 2019 and responded to on 21 November 2019.
- A Compliance Notice was issued by DEA to Kendal Power Station on the 10th of December 2019, focusing on air quality issues.
- On the 31 January 2020, the Department of Environmental Affairs, Forestry and Fisheries (DFFE) issued a letter of a decision to suspend the compliance notice, pending a finalisation by the minister on the objection submitted by the Power Station in response to the compliance notice issued on the 10th of December 2019.
- On 14 May 2020, Kendal Power Station received a decision made by the Minister of DFFE on the objection that was submitted in response to the Compliance Notice issued.
- 10 November 2020, a warning letter was issued to Kendal Power Station in relation to the power station‘s Atmospheric Emission Licence requirements and a Compliance Notice already issued to the power station.

- Notice of intention to issue a compliance notice in terms of Section 31L of NEMA dated 10th of March 2021, regarding Continuous Ash Disposal was issued to the power station DEFF.

1.2 Problem Statement

Various pieces of South African environmental legislation have a requirement of pollution prevention entrenched in them. In terms of water legislation, this requirement goes as far back as 1956. Section 22 of the Water Act (Act 54 of 1956) requires landowners to prevent water pollution by stating the following:

"22. Prevention of water pollution. -(I) Any person who has control over land on which anything was or is done which involved or involves a substance capable of causing water pollution, whether such substance is a solid, liquid, vapour or gas or a combination thereof, shall take such steps as may be prescribed by regulation under section 26 in order to prevent-

(a) any public or private water on or under that land, including rainwater which falls on or flows over or penetrates such land, from being polluted by that substance, or if that water has already been polluted, from being further polluted by that substance; and

(b) any public or private water on or under any other land, or the sea, from being polluted, or if that water has already been polluted, from being further polluted, by water referred to in paragraph (a) which became polluted in the circumstances described in that paragraph."
(Water Act, 1956: s22, ss1, a-b, p. 1231 (1)).

Further, the current water legislation, the NWA, as mentioned in the previous paragraphs above emphasises the requirement of pollution prevention. The question is, has Kendal Power Station taken all reasonable measures to prevent pollution which might be caused by effluent water produced during the process of electricity generation? Is Kendal power station effluent water management activities indicating compliance with the water use licence limits issued in terms of NWA? Are there any actions which were implemented during construction phase, to ensure compliance with the requirement of pollution prevention as stated in the Water Act inculcated in 1956? (Water Act: 1956) Is Kendal Power Station implementing any actions, in instances where pollution or non-compliance with water use license limits is occurring, to stop such pollution or non-compliance from continuing?

The NWA stipulates the measures to be taken to prevent pollution of water resources as follows:

"s19 (2) (a) cease, modify or control any act or process causing the pollution

(b) comply with prescribed waste management standard or management practice.

(c) contain or prevent the movement of pollutants

(d) eliminate any source of pollution

(e) remedy the effects of the pollution

(f) remedy the effects of any disturbance to the bed and banks of a water resource."

(NWA, 1998: s19, ss2, p. 18).

In addition to the above two legislations, National Environmental Management Act (act 107 of 1998), hereafter referred to as NEMA, principle 4 (a) (ii) states "that pollution and degradation of the environment are avoided, or, where they cannot be altogether avoided, are minimised and remedied;" (NEMA,1998: s4, ss2 (b), p. 12)

It is evident from the above that pollution prevention has been and is still a requirement in terms of the past legislation as stated in the Water Act of 1956 and current environmental laws as stipulated in NWA of 1998 and NEMA of 1998. The question is, was construction of effluent water management structures at Kendal Power Station done in a manner that effluent water management will not cause pollution to the underground water resources? Compliance with environmental legislation is critical for the continual smooth operation of the power plant. Is effluent water management at Kendal Power Station conducted with an aim of enabling the facility to comply with this requirement of pollution prevention?

Decker and Pope (2005) conducted a review on why a high percentage of firms comply with environmental laws in the United States, even with less enforcement. They point out that some of the reasons that explain this behaviour is competition. If one firm complies, their rival firm does the same. They further state that firms do not want to be publicly exposed about their non-compliance by the regulatory authorities because such negative publicity affects them economically. And lastly, firms do not want to be known as not complying to avoid unnecessary intensive compliance inspections by the authorities and associated consequences such lengthy processes of obtaining environmental permits in the future.

1.3 Objectives of the study

1.3.1 Primary objective

The objective of this study is to establish the extent to which effluent water management activities adhere to the pollution prevention principle required by water legislation to ensure:

- protection of underground water resources; and
- compliance with the limits as set out in the power station's water use licence and
- that pollution prevention methods are implemented in the management of effluent water at the Kendal Power Station.

South Africa is regarded as a water scarce country. A research paper by Oke and Fourie (2017) maintains that most communities in Sub-Saharan Africa rely on ground water for their livelihood. People use underground water for domestic use, drinking and crop farming. (Oke and Fourie: 2017). It is thus important that underground water resources must also be protected from pollution as is the case with all other water resources.

1.3.2 Secondary objectives

The secondary objectives of the study are threefold:

1. To highlight the importance of pollution prevention principle in effluent water management to ensure compliance with water use license limits.
2. To provide guidelines for constructors and project managers of effluent water management facilities to ensure consideration of environmental requirement of pollution prevention beyond the construction phase. Prior to environmental impact assessment regulations, many facilities have been constructed without the forethought of how pollution can be prevented during operational phase, and this has greatly contributed to the inability of such facilities to comply with current limits stipulated in the water use licenses. The question asked is whether managers of such facilities during construction phase must be held liable for current noncompliance during operational phase or is it the managers of the operational phase of the facilities who must now bear the brunt?
3. To make recommendations regarding and, where practical, propose mitigation measures to ensure that effluent water does not cause pollution of ground water resources and the water use license limits are complied with at Kendal Power Station.

1.4 Scope of the study

1.4.1 Description of the Study Area

1.4.1.1 Basic Background and Technical Information

According to Eskom, (2013) Kendal Power Station is one of the largest indirect dry cooling power stations in the world. Construction of the first unit started around 1983 with the last unit completed in 1993. The station has 6 generating units capable of producing 686MW each, with installed total capacity of 4116MW. (Eskom: 2013).

Kendal Power Station was issued with a water use license by the then Department of Water Affairs in 2011, and later an amendment of the licence was issued in November 2015. Another water use license was issued for the construction of an ash dump facility in December 2015 and its amendment issued in August 2017. The third water use license is what is referred to as the Bulk Water Use license, License number 27/2/1/C/211/1/1, which indicates water consumption allocation for the various Eskom power stations. The focus of this study will exclude the Bulk Water Use license and the continuous ashing water use license, licence number 04/B20ABCEGI/3888 but will rather focus on the power station's 2011 Water Use License and its 2015 amendment.

The Bulk Water use license allows for 3.6 million cubic litres per annum quantity of water to be abstracted from a river system known as the Usutu and Usutu/ Vaal River System for use. The water is stored in two raw water reservoirs then pumped to the power station where it gets treated using water treatment plant before it can be boiled using coal for the generation of electricity. The process water released from this process is then released into the dirty water effluent dams (Dirty Water Dam and if it is full it overflows into Emergency Water Dam). There are two effluent dams, called Dirty Dam and Emergency Dam which are used to store dirty water and a third dam called Clean Water Dam was built to store storm water run-off and water from a stream diverted into this dam. All the three dams are built on a riverbed and the river channel was then diverted into the Clean Water Dam. Further, as part of water management infrastructure, a plant commonly known as the Cross Over Plant (Oil Skimmer plant), is constructed to extract and separate oil from the effluent water from the power station, before the water can be discharged into the Dirty Water Dam. The station subscribes to a Zero Liquid Effluent Discharge (ZLED) philosophy where water from the effluent dams is pumped back into the station for reuse.

The power station uses a dry ashing methodology which requires dust suppression to manage fugitive dust emissions at the ash disposal facility. The ash generated from combusted coal is conditioned with water prior to being transported by conveyor belts to the ash disposal facility. The ash dump design and the ashing methodology used allows for berms (created using soil from the area to be ashed onto) to be created at the ash dump for the purpose of capturing water from the ash dump facility used for either cleaning of machinery or flow from dust suppression activities as well as run off during rain fall. As the ashing advances, the old berms get ashed over and new berms are created as the ash dump progresses. This has been the ashing methodology since the construction of the power station (Makhanya (ed):2016). However, a new lined ash dump with properly designed dams is under construction currently. Water from the Dirty water dam is used for the dust suppression via dust suppression pipe network and pumps. In summary, below are the names and where applicable the sizes of the dams and ponds used for water management at Kendal Power Station:

- Dirty dam-250ML
- Emergency dam-55ML
- Clean dam-90ML
- Maturation Pond

As listed above, in addition to the dams, there is a pond used to store treated sewage effluent, which is pumped into the Dirty water dam for reuse back into the power station processes such as ash quenching prior to conveying ash to the ash dump and dust suppression on the ash dump facility. Further, around the coal stock yard, there are two attenuation ponds which temporarily store water run-off from the coal stock yard surrounding areas before the water flows to the Dirty water dam through a gravity fed pipe, to be re-used back into the power station. In terms of the water license issued for the power station, effluent water is not allowed to be discharged into the neighbouring streams or the surrounding environment. (Makhanya (ed): 2016).

Water management and process at Kendal Power Station can be summarised as follows:

Kendal Power Station gets raw water from a system called Usutu Vaal Water Scheme. The water is then stored into two raw water reservoirs. From there, raw water goes to the water treatment plant where it is purified by ion exchange process to produce demineralised water. Drinking water is also produced through coagulation/flocculation, sedimentation and filtration and disinfection and stabilisation. Online analysers and laboratory analysers are set to check the quality of the water. During the drinking and demineralised water production, waste water is produced through the processes or activities of resin regeneration process, effluent from acid and caustic chemical drain sumps, acid and caustic bulk storage bund areas and pretreatment chemicals drains. Also, a sewage treatment plant is used for sewage handling process where the final effluent water is deposited into the power station‘s Dirty water dam. Water from the generation of electricity cycle which cannot be recirculated, goes into the neutralisation sumps. This and any other dirty water go to the deep drains through water pipe lines which transport this dirty water, to a plant which removes oil and ash from the water before it gets transported into the Dirty Water Dam. The clean water drain system carries water run-off from around the power station area and disposes into the Clean water dam. Water from the clean drains is recovered for demineralised water production too.

Eskom has adopted the ZLED principle where the wastewater is reused for various other activities such as ash conditioning prior to disposing ash at the ash dump facility, dust suppression at the ash dump facility and cleaning of floors in the plant area. (Eskom: Kendal Overview Presentation, 2013)

1.4.2 Locality and Geographical Description.

The Kendal Power Station is situated approximately 50km southwest of eMalahleni, Mpumalanga Province, South Africa. The power station is situated at coordinates, S26.08805 and E28.96888. It falls under eMalahleni municipality, Nkangala District Municipality.

According to the Wetland Delineation and Impact Assessment study conducted by Wetland Consulting Services Pty (Ltd) in 2014 for an ash dump facility still which is currently under construction by the Kendal Power Station, the vegetation in the power station area is classified as Grassland Biome, Mesic Highveld Grassland Bioregion, though the area has been transformed by activities undertaken already. Further, the study shows that there are several types of wetlands identified in the vicinity, mostly in the South-western part of the power station. (Wetland Consulting Services: 2014). The study also details that Kendal Power Station is located within the Olifants River Catchment (Primary Catchment B); more specifically along the watershed of quaternary catchments B20E. B20E quaternary catchment is drained by the Wilge River (Wetland Consulting Services: 2014).

Figure 1.1: Map of South Africa
(Source: www.Ontheworldmap.com. 20 February 2020)

Figure 1.2: Map of Mpumalanga Province indicating water management areas. (Source:www.researchgate.net accessed on 26 January 2022.)

Figure 1.3: Image of Kendal Power Station

(**Source: https://www.businessinsider.co.za/ accessed 27 February 2020)**

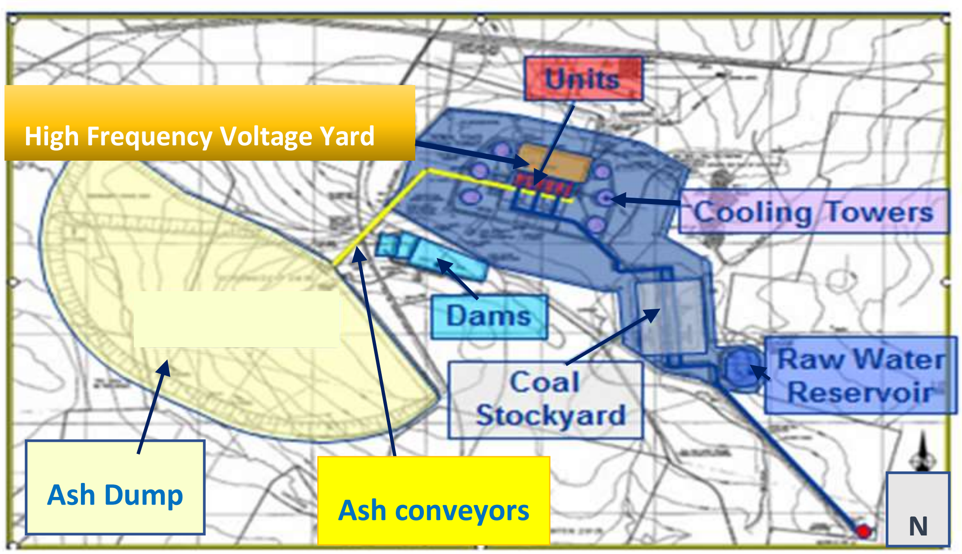


Figure 1.4: Simplified site layout (not drawn to scale): Kendal Power Station
(Source: Kendal Power Station Overview Presentation: 2013)

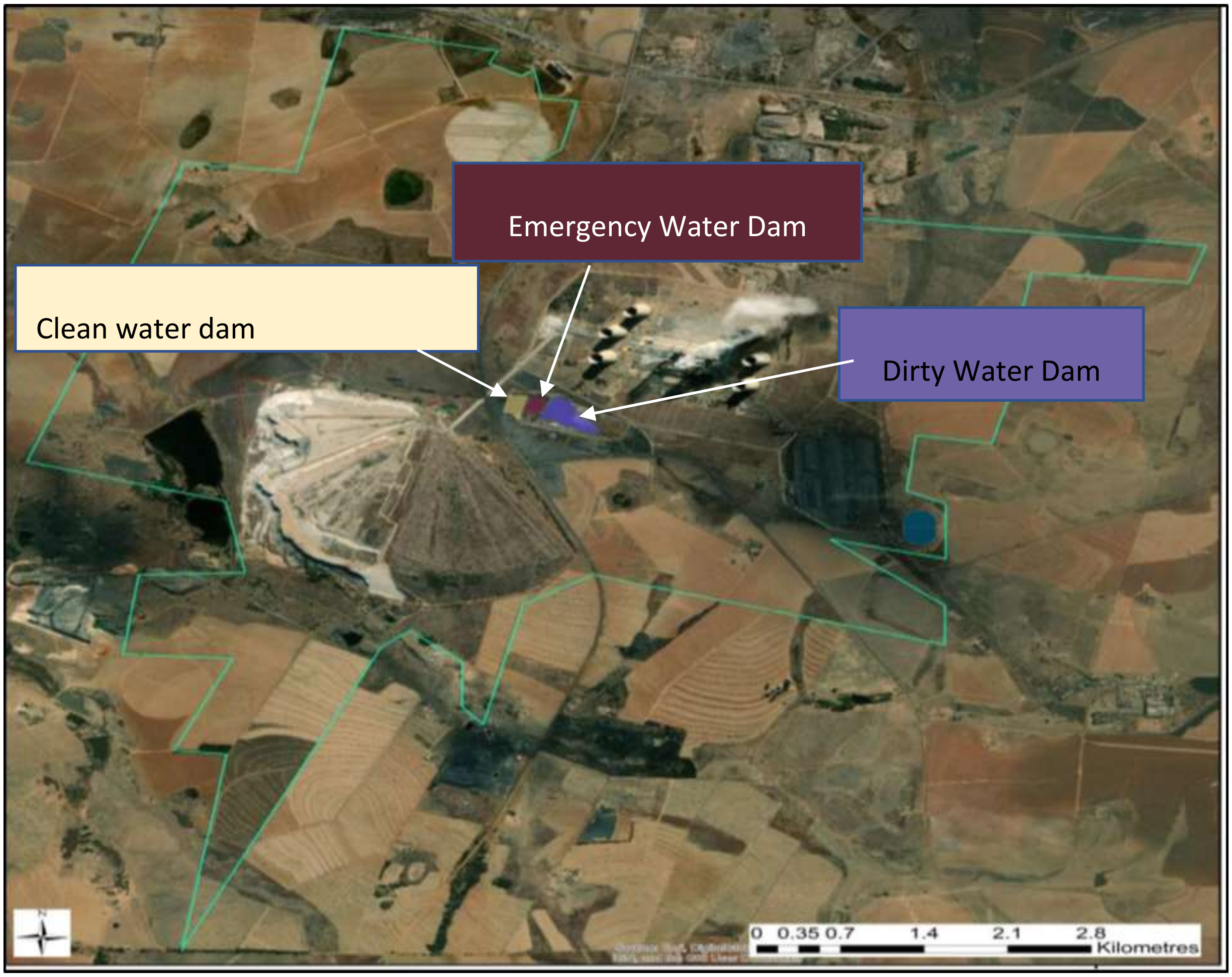


Figure 1.5: Arial Map of Kendal Power Station

(Source: McClurg (2021) Fish Assessment Report – Kendal Power Station)

1.4.3 Size Area

Mpumalanga Province is divided into three district municipalities being Enhlazeni, Nkangala and Gert Sibande. The three district municipalities are further subdivided into 24 local municipalities, Kendal Power Station is located in Nkangala District, eMalahleni local municipality. Ngamone and de Jager (2012). The total size area of Nkangala District municipality is 16 758km^2. (Department of Agriculture, Rural Development and Land Administration. 2015).

1.4.4 Vegetation

Rutherford *et al*., (2006) on the Biomes and Bioregions of Southern Africa, identify 9 major biomes in South Africa being, **"**Albany Thicket, Desert, Forests, Fynbos, Grassland, Indian Ocean Coastal Belt, Nama-Karoo, Savanna and Succulent Karoo." (Rutherford *et al.*, (2006), p.34). On these biomes classifications, Mpumalanga Province has both the Grassland Biome and the Savanna Biome.

Further, the Wetland Delineation and Impact Assessment study done by Wetland Consulting Services, indicate that according to Mucina and Rutherford, on their document titled The *Vegetation of South Africa, Lesotho and Swaziland* (Mucina and Rutherford: 2006), it is indicated that Kendal Power Station is in the Grassland Biome, Mesic Highveld Grassland Bioregion. On the smallest scale the area is classified under Rand Highveld Grassland. However, most of the surrounding area has been transformed by crop cultivation.

1.4.5 Soils

Soils and Land Capability Studies done by Earth Science Solutions for Zitholele Consulting, describe the soils in the vicinity of Kendal Power Stations as ranging from shallow sub-outcrop and outcrop to moderately deep sandy loams and sandy clay loams. (Earth Science Solutions: 2014)

1.4.6 Climate

Kendal Power Station is located in eMalahleni Municipality where the average temperature is 16 degrees Celsius with the warmest month being January with an average of 20.6 degrees Celsius. June as the lowest temperature month has an average of 9.9 degrees Celsius. The average amount of rainfall for the year is 690.9 mm. November has the most rainfall with an average of 121.9mm. July has the least rainfall with an average of 5.1mm. The month with most days of precipitation is January. There are 83.7 days of rainfall in a year. (Travel Weather Averages (Weatherbase): 2021).

1.5 Limitations of the study

The study is limited in instances where ground water monitoring reports are not available and or samples were not taken for a specific chemical constituent during monitoring. Further, the data being analysed was not collected by the researcher, therefore the outcome of the analyses is based on the data collected by consultants appointed be the power station to do such work. The researcher will not be able to replace the missing data therefore the conclusions made will be in the exception of any data which was not available.

Further, the scope of the study is limited to effluent water dams, Clean water dam and maturation pond which is part of the sewage effluent management processes. The Clean water dam, though it is not regarded as an effluent water dam is part of the study because it is situated close to the Emergency water dam which carries effluent dirty water and it overflows into the Clean water dam when it is full. It must be noted that the dams forming part of the scope of this study are not the only water containment dams at Kendal Power Station, there are also temporary water containment berms at the ash disposal facility. Two of the berms contain water most of the year whereas the rest of the berms sometimes become dry during the winter season. These berms get ashed over as the dry ashing progresses over time. There are also attenuation dams/ponds which contain run off from the coal stock yard before the water gets disposed into the Dirty water dam.

1.6 Layout of the study

The study comprises five chapters. Chapter 1 serves as an introduction to the study topic including the problem statement. The locality of the study area and other attributes relating to the study area are highlighted. The chapter also focuses on explaining the aims or objectives of conducting the study. Further, the methodology used in conducting the study is outlined including the limitations and or challenges encountered which can affect the outcome of the study.

Chapter 2 focuses on literature review. The main terms in the study are introduced and explained in a form of literature review. In addition, this chapter focuses on the previous studies conducted relating to this topic. Further, what other scholars have studied and found out is highlighted in this part of the study.

Chapter 3 covers the research methodology applied in this study.

In Chapter 4 the variables and monitoring results are deciphered from the groundwater monitoring reports or the database and put in tables. The water use licence limits are also captured alongside the ground monitoring results. Microsoft excel is used to draw the graphs showing the results of the analysis for a specific variable in a year against the applicable water use license limit. The same information is put in a table format where non compliances are highlighted in a red colour. In instances where monitoring results for a specific monitoring phase are not available from the ground water monitoring reports or the database, the space is left blank and is greyed out on the table. This is done per borehole per variable for the period of the years from 2011 to 2020. A short interpretation of what is seen on the table and the graph in relation to water use license limits compliance or pollution is provided. This chapter answers the problem statement on whether effluent water management does not result in pollution and non-compliance with water use license limit on the selected variables which are part of the study.

Chapter five is the conclusion and summary of the results as well as recommendations.

CHAPTER 2: LITERATURE REVIEW

2.1 What is pollution?

The NWA (1998) defines pollution as the change of the characteristics of water resource such as the physical, chemical and biological composition to an extent that that water resource is less fit for the beneficial use and its use can be harmful to human beings, organisms, and property and resource quality. On the other hand, the groundwater dictionary, describes pollution as "the introduction into the environment of any substance by the action of man, which is or results in significant harmful effects to man or the environment." (Definition of ground water | Dictionary.com: 2021)

The NEMA defines pollution as any negative change or deterioration which occurs in the environment which might be caused by a substance, radioactive or any other waves or change caused by noise, dust or heat and where such change negatively impacts the health or well-being of people or negatively affect the composition or productivity of natural or managed ecosystems and any material that is beneficial to mankind. This includes potential negative impact which might occur in the future. (NEMA: 1998)

Although the Constitution of the Republic of South Africa does not explicitly define the word pollution it does infer to it through section 24 which says, "Everyone has the right—

(a) to an environment that is not harmful to their health or wellbeing" (The Constitution of the Republic of South Africa, 1996, s24, p. 9). Kidd, (1996) explains that health aspect on this part of the bill of rights might protect people who might have to drink polluted water because of lack of access to clean piped water. One can therefore surmise that the above stated part of the constitution defines pollution as an environment which is harmful to the health and wellbeing of people.

Bagtzoglou *et al*., (1990), on their study titled Application of Particle methods to reliable identification of ground water pollution sources, indicate that in the United States of America (USA) a lot of money is being used for remediation of contaminated ground water and this is because contamination of ground water has increased at alarming rates.

Kraemer *et al*.,(2001) in their paper titled Protecting Water Resources: Pollution Prevention, presented on International Conference on fresh water in Bonn 2001, state that pollution of water is of concern globally. This problem affects the value and usefulness of water resources. Water pollution causes deterioration in the quality of water and negatively impacts various water uses such as agriculture, domestic, economic development, to mention just a few. The net water loss is exacerbated by water pollution. In terms of the water pollutants, Kraemer *et al*., (2001) indicate that there are several types of pollutants which are grouped into chemical, physical and microbial factors. From the list of pollutants stated on their paper, the following pollutants are relevant to this study:

- Inorganic pollutants, which according to Kraemer et al originate from industrial wastewater
- Acidification which has to do with low pH of water. Kraemer *et al.,* (2001)

Kraemer *et al.*, (2001) indicates that water pollution is a global distress in differing levels according to the level of development of a country. They further state that water pollution has dire effects on the value of water and affect the ecosystem and various types of species negatively

According to Sakala *et al*.,(2017), underground water pollution vulnerability, amongst others, can be caused by the topographical gradient of the area with rainfall as the transporter of the pollutants. They assert that an area with a gentle gradient encourages run off to percolate into the ground water resources. If the area or the run off is carrying pollutants then the underground water will be exposed to contamination. They further indicate that Witbank area, as one of their study area, long term rain fall is between 600mm to 1100mm. As stated in the previous sections of this study, Kendal Power Station is located under the Witbank area. Hodgson and Krantz, (1998 cited in Sakala *et al.,* (2017) states that Witbank, Ermelo and Highveld coalfields are characterised by shallow aquifer of between 5m and 20m increasing the acquirer ‘s vulnerability to pollution. In their conclusion on ground water vulnerability model, they indicate that Witbank area falls under moderate underground vulnerability zone.

Dlamini and Demlie (2020) indicate that it is important to conduct water quality monitoring for early detection of contamination and implementation of rehabilitative measurers. They also state that ground and surface water pollution are mostly associated with industrial activities.

A study by Anderson et al (2007), titled Exploring environmental perceptions, behaviours and awareness: water and water pollution in South Africa, concludes that people falling under the low social economic standing are more likely to see water pollution as an environmental problem, this regardless of their level of education. This is because these people are directly affected by the water pollution problem.

According to Pather, (2000) on her paper titled Eskom and Water, one of the wastewater management practices Eskom adopted in 1987 is Zero Liquid Effluent Discharge (ZLED) as a measure to prevent water pollution by reusing water at various hierarchies of water quality. (Pather:2000). On the contrary, this research focuses on the importance of implementing pollution prevention measures in relation to effluent water management during the operational phase of the facility.

2.2 What is Effluent?

The national norms and standards for domestic water and sanitation services define effluent as "human excreta, domestic sludge, domestic waste-water, greywater or waste water resulting from the commercial or industrial use of water." (Government Gazette No. 982, DWS, 2017: p.91). At Kendal Power Station, there is a sewage treatment plant which processes sewage and the resultant treated water is transferred into a Dirty water dam where dirty water from the industrial processes gets disposed of too before the water can be reused for other activities in the power station. Therefore, effluent water referred to in this document refers to both treated water from sewage processes and industrial dirty water which passed through an oil skimmer for the removal of oils before draining into the Dirty Dam.

The DEA (2014) defines industrial effluent as "wastewater/effluent arising from industrial activities and premises. Contaminated storm water drainage from industrial premises is included in this definition." (DEA, National Guideline for the Discharge of Effluent from Land-based Sources into the Coastal Environment: 2014, p. xvi)

2.3 Contamination of Water

The water word dictionary defines contamination of water as when the water sources quality changes to a degree that it becomes hazardous for use and for public health. The degradation in quality might be caused by sewage, industrial or any other waste. When the water changes from its natural quality due to human activities then it is regarded as contaminated and in this instance the level or limits are not applicable. (Water Words Dictionary: 2000)

2.4 Pollution Prevention

As can be seen above, the term pollution is defined clearly in the NWA and inferred to in the Constitution of the Republic of South Africa. Elleuch *et al.* (2018) indicate that pollution prevention focuses on reducing the quantities of pollution produced during a specific process. They further state that the approach for pollution control focus more on managing the pollutant after it has already occurred. Therefore, pollution prevention is more of a proactive approach whereas pollution control is reactive. (Elleuch *et al.,*2018). They are of the opinion that the best way to manage pollution is to prevent it from occurring.

Sam (2009) indicates that the 1990 United States Pollution Prevention Act defines pollution prevention as an action which involves the reduction of hazard of a substance or contaminant including fugitive emissions before such can be recycled or treated or disposed and secondly reducing the hazard to the environment and people because of the release or disposal of such substance into the environment.

Section 21 of the Water Act 54 of 1956 stipulate the requirement for water purification and treatment of water used for industrial purposes before such water can be discharged into the area of abstraction or the area determined by the Minister for such a discharge. It is therefore clear that from as far back as 1956, the environmental legislation required that effluent be pollutants free prior to discharge. Kendal Power Station stores its effluent water in effluent dams without pre-treatment and zero discharge approach was introduced in Eskom where the effluent is then then reused. This section of the 1956 Water Act indicates that water or effluent that is going to be discharged into any other area must be purified or treated. According to Kempe (1983) one of the purposes of the Water Act 54 of 1956 is to protect water against unnecessary pollution and further the Act controls the disposal of effluents. Kempe (1983), further indicates that the Water Act (Act 54 of 1956), imposes permit conditions such as maximum use of effluent as a way to reduce discharge of pollutants and that water users should use latest techniques to reduce or remove pollutants from effluent

Further, Cillie *et al.,* (1979) on their paper titled Water pollution research in South Africa, indicate that the Water Act 54 of 1956 amongst others, requires that purification of effluent water be a vital process prior discharging such into the water environment where the water was abstracted, unless if exemptions are granted by the regulatory authorities. Kendal Power Station does not purify the effluent prior to disposal into the dirty and emergency dams, this might be so because the power station has a closed system where the dirty water is reused. It must be noted that there is a sewage plant where sewage effluent is treated, and the resultant water is deposited into the Dirty water dam for reuse in the power station.

Cillie *et al.,* (1979) on the study that was done in 1979, concluded that there is an increase in water pollution awareness and the dire consequences which this problem will give rise to if not addressed adequately. Both industry and domestic, Cillie *et al.*, (1979) asserts, realise that water pollution must be greatly reduced to avoid greater water problems in the future.

Harrington (2013), in the study titled Effectiveness of state pollution prevention programs and policies, on which the focus was on toxic emission releases to the environment and the adoption and implementation of pollution prevention policies by facilities, concludes that countries which have a requirement for compulsory reporting of emissions and planning, implement more pollution prevention measures even if such countries do not emphasize toxic reduction significantly. Though this study focussed on emission releases, it can be applied to water related pollutants released into the environment.

Legge *et al.*, (2015) on their paper titled Pollution prevention awareness for municipal managers in South Africa, indicates that South African legislation (NWA) requires reasonable measures to be taken to prevent pollution and or to remedy such, in instances where pollution has already occurred. Their paper focussed on disposal of solid municipal waste by landfill and management of municipal effluent licence applications. They concluded that, development of checklists for use prior to submission of license application to confirm compliance with relevant regulations can be beneficial on saving of resources such as finance, human resources and time. Therefore, one can only perceive that such checklists can be developed and implemented on any license application to ensure compliance with regulations and legislation relevant to specific permits and license applications. From Legge *et al., (2015)*, 's paper, one can infer that compliance to legislation and pollution prevention at the planning stage is indeed beneficial.

According to Oke and Fourie (2017), human activities impact negatively on ground water qualities and quantities in the sub-Saharan Africa. They further state that industrial activities are one of the main causes of ground water contamination and pollution loading. Added to this, they maintain that anthropogenic activities can change the quantities of natural chemicals which are in the ground water and can lead to the water being not suitable for drinking purposes. They indicate that ground water pollution is an undesirable change in ground water quality resulting from human activities.

Ground water qualities are divided into 3 aspects being physical characteristics, chemical and biological composition. Harter, (2003). In this study the focus will be on some of the chemical constituents as listed on Kendal Water Use License.

There are some ground water pollutants that are associated with significant impact to the environment including human health. Gupt *et al*., (2021) list these contaminants as iron, manganese, arsenic, chlorides, and fluorides. They indicate that these pollutants "are naturally occurring in soils and rocks and could be easily dissolved in groundwater". (Gupt *et al.,* 2021, p. 82)

The Kendal water use licence number /04/B20E/BCEGI/1048 issued in the year 2011 has the following variables with prescribed limits listed for ground water monitoring. Should these limits be exceeded, it will imply non-compliance with the limits as required by the water use license. The 2011 water use license limits were amended in 2015 and new increased limits were stated for ground water quality. Both 2011 and 2015 limits are used in this study. However, this study will not focus on all the variables or chemicals as stated on the table below.

Table 2.1: Groundwater Constituents and limits according to Kendal Power Station WUL

Chemical/Constituent Name	2011 WUL Limits	2015 WUL Limits
pH	8.34	6.5-8.4
Electrical Conductivity	37.51 mS/m	40 mS/m
Sodium	10.45 mg/l	20 mg/l
Magnesium	5.61 mg/l	20 mg/l
Calcium	20.68 mg/l	25 mg/l
Chloride	8.80 mg/l	20 mg/l
Sulphate	14.85 mg/l	30 mg/l
Nitrate	0.48 mg/l	6 mg/l

2.5 Environmental Compliance and Enforcement

Holdsworth, (2012), indicates that for the term environmental compliance to be fully comprehended, one has to take into account other concepts which are closely linked to this term such as, “corporate social and environmental responsibility and voluntary standards.”

(Holdsworth: 2012, p.88). He points out that these are not the only important notions, corporate governance performance standards and regulatory reforms are also vital in understanding environmental compliance. Further, he indicates that environmental compliance is not just a simple process of abiding by environmental regulatory requirements as expected but also needs one to consider other factors such as political, sociological, psychological, ethical and professional factors. (Holdsworth: 2012). This study takes environmental compliance linked to professional factors as explained by Holdsworth (2012), which indicates that in the professional autonomy aspect of environmental compliance uses the traditional approach where a set of parameters are set by regulatory authorities and an organisation is then expected to operate within those parameters. When that happens, the organisation is seen to be compliant with the environmental requirements as set out in that specific regulations or environmental laws.

Russell (1990, cited by Heyes 2000) estimated that the rates of compliance on water qualities in United Kingdom are, in some instances even below 50% and mostly below 100%. He further indicates that most contemporary environmental regulations include self-reporting as a requirement for both water and air quality. (Heyes: 2000)

McClelland and Horowitz (1999, as cited by Sam: 2009), in their studies have found that one other factor which forces firms to comply and even over comply with water pollution regulations is community pressure and the willingness to avoid unpleasant relations with the regulatory authorities. This, according to them, mostly occurs within firms which are located wealthier communities.

Further, Sam (2009) maintains that facilities which are known to violate environmental regulations have higher rates of environmental enforcements imposed on them. Also, in countries where compliance enforcement is rife, facilities tend to be issued with several enforcement notices. Looking at the number of pre-compliance notices and compliance notices on environmental compliance issued to Kendal Power Station by the South African environmental authorities over the years, what is stated by Sam, (2009) is relevant in this case.

Hu and Shan (2020) made an investigation on the impacts of coal powered stations on the ground water resources in a study called Analysis of the Groundwater Resource Pollution of Coal-Fired Power Plants and Its Impact on Geotechnical Engineering Properties by Numerical Simulation Technology in China. The investigation used numerical model to identify and analyse certain ground water resource pollutants. They found that after 20 years of operation, the coal fired powered stations did not cause a significant impact on the ground water resource in relation to petroleum pollutants, arsenic, fluoride and chemical oxygen demand levels. Moreover, after implementing seepage prevention measures the sensitive areas which showed an increase in these pollutants decreased.

DEA (2014) indicates that compliance monitoring “means conducting surveys, inspections and examinations to determine the effectiveness of management strategies and actions to ensure compliance with permit conditions. (DEA: National Guideline for the Discharge of Effluent from Land-based Sources into the Coastal Environment: 2014, p. xiv). They also indicate that some countries such as European Union, manage industrial effluent discharge by making sure that permits issued for such activities include the requirements to implement the best available techniques (BAT) prior to disposal and implementation timeframe for the BAT is 11 years. The long timeframe is to reduce the financial burden to the industries to ensure that there are no employment losses in the process.

Kraemer *et al.,* (2001) postulate that implementation of legislation with enforcement on the conditions of water permits and licences are one of the ways for pollution abatement relating to effluent discharge. This is in addition to monitoring requirements stipulated in the water permits and licenses.

An empirical study on Regulator reputation, enforcement and environmental compliance, by Shimshack and Ward (2005) indicate that environmental policies in most industrialised countries include tools for regulators to enforce punishment on non-complying organisations. Their study focused on the impact of fines by regulators on compliance. In other words, if regulators impose fines on a specific industry, does that have a positive effect towards environmental compliance even on the other neighbour industries? They state that the expectation is that monetary fines will discourage the affected organisation to incur non compliances in the future. In addition, they maintain that the reputation of the regulator in the issuance of fines will deter other organisations from violating environmental laws. Their research investigates the impact of fines as opposed to other methods of environmental monitoring and compliance enforcement and the potential consequences of increased rate and rigorousness of sanctions. The conclusion was that environmental violations are significantly reduced through fines even amongst other organisations especially a year the regulators have instituted the fine. (Shimshack and Ward, 2005)

Earnhart and Friesen (2017) conducted a study titled, The Effects of Regulatory Monitoring and Enforcement Activities on Facilities' Compliance with Environmental Regulatory Laws. The study focussed specifically on regulated facilities. The aim was to determine whether monitoring and enforcement by regulatory authorities have an impact on organisations perceptions and induce compliance. Further, the study aimed at determining whether monitoring and enforcement perceptions affect regulated organisation responses to inspections and enforcement actions.

The study was done in chemical manufacturing facilities. They compared government interventions on facilities which perceive enforcement as effective already and to those who did not. The study found that to those facilities who regarded enforcement as effective, added or increased deterrence did not yield any results, however those facilities which perceived enforcement as ineffective, increased deterrence yielded positive results.

In the case of Kendal Power Station and compliance with pollution prevention in relation to ground water resources, there are water permits which have been issued to the power station, which stipulate the requirement for ground water monitoring at strategic areas within the facility including around the effluent water management dams. The purpose of ground water monitoring in this instance is to ensure that effluent water management does not impact deleteriously on the ground water resources. To comply with the pollution prevention requirements on effluent water management, reduction of pollutants from effluent water prior to discharge in the dams should be done. As seen from the definition of pollution prevention in the previous sections of this study, activities such as seepage prevention cannot be regarded as pollution prevention rather pollution control. It must be noted, a Design Review for the three Kendal Power Station water dams being Clean water dam, Emergency water and Dirty water dam was done in 2014 by a consulting engineering company. The as built drawings for the dams were also used by the consultants in the review. One of the findings made was the non-compliance to lining on the Dirty water dam and the Emergency water dam in terms DWA best practice guidelines of 2007. (Carvalho: 2014). This, apart from the pollution prevention and pollution control requirements stated in the water legislations from 1956 to date.

From what is stated in the earlier sections of this paper on inspections conducted by the authorities and in this case consequential pre compliances, compliance notices including directives, Kendal Power Station has been subjected to regulatory judicial reviews on environmental compliance with permits and licences issued including compliance with environmental laws and regulations in general. This intensive regulation by competent authorities has placed enormous pressure on the facility to comply with environmental requirements. The question that this paper aspires to assess and answer is, is it possible for the power station to comply with these requirements if pollution prevention on ground water resources was not the epitome during construction phases of the facility? If not, will the power station ever be able to comply with pollution prevention principle by ensuring that effluent water does not contaminate ground water resources if operations continue as is? Holdsworth (2012), states that there is no generally confirmed method of achieving environmental compliance.

2.6 Pollution Prevention and competitive advantage

A study conducted by Maas *et al*.,(2012) on third party logistics industries to determine whether pollution prevention and product stewardship can give a competitive advantage to organisations which implement these two factors in their business strategy found that pollution prevention coupled with environmental communication provide differentiation advantage. They further indicate that firms which implement pollution prevention always investigate how to reduce their environmental footprint by minimising their negative impact to the environment in their business processes such as waste, effluent and emissions reduction. They state that investment in pollution prevention reduces the costs related to pollution control equipment. Maas *et al*., (2012). They cite Hart and Ahuja, (1996) who state that pollution prevention aims at avoiding managing different types of waste by not producing such waste in the first place. This concept is likened the quality management principle of preventing defects from occurring rather than using resources to identify and repair such defects. (Maas *et al*., 2012). Hart, (1995); Porter and van der Linde, (1995) as cited by Maas *et al*.,(2012) indicate that pollution prevention strategies are associated with increased efficiencies and minimises compliance and liability costs.

Adding to the above, Chiu (2017), wrote a paper and one of the purposes of that paper was to determine whether pollution reduction expenditure improves company's proceeds. They concluded that there is a financial benefit in investing in pollution reduction expenses.

A study on The Effects of Integrated Pollution Prevention and Control (IPPC) Regulation on Company Management and Competitiveness, by Daddi *et al.,* (2013) cite Robison (1997) who analysed the economic effects of pollution prevention on third party logistic providers and indicate that Robison (1997) 'study concluded that implementation of pollution prevention by these firms offer new technologies or new ways of producing products at a lower cost. This conclusion implies that pollution prevention does not only help industries to comply with environmental laws, but it also adds positive economic impact on those companies who decide to prevent pollution (Daddi *et al*., 2013).

A case study by Kwame (2003), on Compliance and Enforcement in Environmental Management in Ghana, reveals that environmental compliance enforcement by regulatory control is not the only means to make organisations to comply with environmental laws. Some organisations comply with environmental laws voluntarily while in some instances local communities and environmental groups play a role in pushing industries to comply with the environmental requirements.

From what has been stated from the various scholars above, one can make an inference that pollution prevention has been a requirement for the protection of the environment including water resources. Further, there is a difference between pollution prevention and pollution control measures. It is clear that the implementation of pollution prevention measures is of benefit to organisations compared to pollution control. This is because organisations which prevent pollution increase their environmental compliance status and will as a result be in good standing with both the legal authorities and the communities around them. Pollution prevention is therefore an important aspect of any industry or organisation to focus on.

2.7 Conclusion

Various researchers and authors have been researching on pollution and water related pollution. This is because water resources are of utmost important for various forms of life on earth. Water resource must always be protected from pollution. Further it is evident that pollution prevention is better than pollution control.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

The research methodology and methods which are used in this study align with qualitative approach. The researcher does not use any statistical analysis of data to make inferences. The main method used to obtain information for this study was done by means of secondary data collection.

3.2 Secondary data collection

Observations and analysis of already existing numerical data of measurements conducted by consultants who were or are appointed to conduct ground water monitoring for Kendal Power Station is done.

In addition to this, the interpretation made by the consultants on the results of ground water monitoring is considered to determine whether the ground water monitoring boreholes on a specific locality or point indicate pollution or exceedance of limits as stipulated in the water use licence for the power station or not.

3.2.1 Ground water monitoring

Ground water monitoring results from boreholes closest to the effluent water monitoring boreholes at Dirty Water Dam and Emergency Dam, Clean Water Dam which contains storm water run-off and Maturation Pond were analysed to determine whether there was non-compliance with the water use licence parameters for the selected pollutants which were being monitored. The chemicals which are monitored or measured by ground water monitoring, as listed on the groundwater monitoring reports and the Kendal Water Use License are provided in Table 3.1.

Table 3.1: Groundwater variables and limits according to Kendal Power Station WUL of 2015.

Water Quality Constituents	2015 Water Use License Limits
Aluminium	0.02 mg/l
pH	6.5-8.4
Electrical Conductivity	40 mS/m
Calcium	25 mg/l
Chloride	20 mg/l
Iron	1 mg/l
Magnesium	20 mg/l
Manganese	0.18 mg/l
Nitrate	6 mg/l
Phosphate	0.05 mg/l
Sodium	20 mg/l
Sulphate	30 mg/l

The above chemicals are measured and monitored by the appointed service provider or consultant when conducting groundwater monitoring. The frequency of monitoring is quarterly as stipulated in the water use licence issued to Kendal Power Station by the DWA.

In this study, the variables which will be focused on are pH, electrical conductivity, sodium, calcium and sulphates. These variables were verified and analysed to determine whether the water use license limits were complied with or exceeded, on the groundwater monitoring phases conducted. Ground water quarterly reports produced by the appointed service provider from 2011 to 2020 were used to do the analyses on the parameters which are part of this study as stated above. Apart from the ground water monitoring reports, database which contains the data and results for ground water monitoring from 2011 to 2020 was also used and was found to be easier to use than the transferring data from the ground water monitoring reports. The database contains data which was used to compile the ground water monitoring reports. The monitoring points or boreholes which were analysed as part of this study are listed on the table 3.2 below. Kendal Power Station has a total of 43 ground water monitoring sites as indicated on figure 3.1 below.

Figure 3.1: Google Map showing ground water monitoring boreholes localities

(Source: Kendal Power Station Groundwater monitoring report by Mahlangu *et al*.,(2018) The water sampling protocols used by the two consultants who were appointed at different times (2011 to 2017 and 2018 to 2020) to conduct ground water monitoring as required by Kendal Water Use license are listed below.

3.2.2 Sampling protocol applied from 2018 to 2020

The consultants developed groundwater sampling procedures to be used during collection and management of water samples. According to the consultants, Mahlangu *et al.,*2018:p.23) the procedures developed are based on the Groundwater Sampling Comprehensive Guide, prepared for Water Research Commission (2nd Edition) by John M.C. Weaver, March 2007, and by SABS ISO 5667, First edition, 15 January 1999.

They further state that the groundwater samples were collected using low flow purging method and the water samples collected were sent to a SANAS accredited laboratory for water quality analysis. The procedures developed detail a comprehensive process followed during sampling up until submission of the water samples for analysis.

In summary, the sampling protocol which was used for water sample collection is as follows:

a) "Groundwater levels were measured using a dip meter
b) Peristaltic pump was used to purge and sample the boreholes;
c) Samples were transferred to a cooler box in the field and kept cool prior to being submitted to the laboratory;
d) Bailer was used to sample surface water were container directly filling from the surface water body was not possible; and
e) Duplicates were collected at some area for quality control purposes. "(Kimopax:2018, p.20)

The data obtained from the ground water monitoring reports and database containing chemical analysis results of all samples taken since 2011 to date was analysed in relation to compliance against the Kendal Power Station Water Use licence limits. Tables and graphs were developed using the observations made from the primary data collected and contained in the actual groundwater monitoring reports and database.

3.2.3 A summary of Sampling Protocol used from 2011 to 2017

A summary of the Sampling Protocol used from 2011 to 2017 groundwater monitoring consultants entailed the following as minimum:

- Sampling planning and preparation.
- Development of objectives of the sampling and analysis program.
- The site-specific parameters to be sampled and analysed.
- Number and frequency of samples to be collected.
- Borehole details, including location, depth and diameter of the borehole, depth and length of screened interval, depth to groundwater, borehole drilling, installation and development details. Sampling protocol, including purging procedure, in-field measurements,
- Sampling techniques and equipment, filtration and preservation requirements and quality assurance/quality control (QA/QC).
- Sample storage and transportation to the laboratory.
- Ensuring that laboratories performing analyses are accredited by National Association of Testing Authorities (NATA) for all tests conducted. In addition, the laboratory should be experienced and proficient at testing the types of samples, at the concentration ranges required, for the program.
- Schedule samples for receipt by laboratory.
- Discuss foreseeable problems with procedures, containers etc. Collect sample bottles, trip blanks, preservatives and spike solutions as required.
- Calibrate field meters (according to manufacturer’s instructions) that don’t need to be calibrated in the field and ensure that all meters are working correctly.
- Ensure correct calibration solutions are available in the field.

- Results from the past sample events including groundwater level measurements, field measurements and purge volumes.
- Readings should be retaken immediately to confirm correct reading where necessary.
- Sample documentation (e.g. QA/QC forms, chain-of-custody requirements (Appendix B),

Procedures for sampling water are also comprehensively developed and utilised (van Niekerk and Moolman: 2012, p. 27-28)

Table 3.2: Ground water monitoring boreholes in the vicinity of the effluent dams, Clean water dam and Maturation pond.

Monitoring point	Longitude	Latitude	Elevation	Site Description
PB05	28,96415	-26,09874	1600,06	Borehole at dirty water dams PP03 & PP02.
PB06	28,95936	-26,09877	1582,51	Borehole west of clean water dam PP04 south of stream.
PB23	28,95987	-26,09943	1579,40	Borehole west of clean water dam PP04 south of stream.
SB24	28,99281	-26,08254	1572,86	Borehole east of sewage plant.

Chemical analysis results data for each of the boreholes on the above table was grouped per year, per variable on an excel spreadsheet for the years 2011 to 2020. For each year data for monitoring phases was obtained from the ground water monitoring reports or database. The data was also grouped as per the chemical constituent. For instance, borehole monitoring point PB05 will have data on pH, electrical conductivity, sodium, calcium, and sulphates grouped separately per year from 2011 to 2020. On each table the water-use license limits for both 2011 and 2015 were captured for a specific chemical. In instances were values or data was not available for one reason or another, the block on the spreadsheet will be left blank and greyed out. An excel spreadsheet was used to create graphs to give a clear visual observation of whether there was any exceedance of the limits or the water-use license limits were complied with. Both the tables and graphs were presented as part of the study results and a short interpretation of the results was given.

In conclusion, data collected for a period of ten years was used for this study. Data collected for such a long period is sufficient to indicate whether Kendal Power Station complies with the water use license limits on the chemicals selected in this study or not? Though the data was available for most of the monitoring phases, the researcher had to transfer the data to a different format to make it usable and be able to analyse and present the results. As stated in the first chapter, one of the limitations identified is that where there is missing data, it is not possible to values for that period because samples had to be taken at that time when monitoring was done. The water samples are time bound and so is the results of the samples.

CHAPTER 4: RESEARCH FINDINGS

4.1 Introduction

This study uses results of water samples collected and chemical analyses conducted by ground water monitoring service providers appointed by Kendal Power Station to conduct such work as required by the power stations ‘s water use license. The power station started conducting quarterly ground water monitoring in 2011. For each year, there are four ground water monitoring reports. Any other additional reports such as reports for hydro census were not used in this study.

In summation of the process followed to collect the samples, a field inspection was conducted for every monitoring phase. Water samples were collected using a sampling procedure or protocol. The water samples were then sent to an accredited laboratory for chemical analysis. Then the service providers interpreted the results and compiled a report for Kendal Power Station. The report was then submitted to the relevant regulatory authorities as required by the water use license.

The areas of interest for this study are boreholes around the effluent dams called Dirty Water Dam, Emergency water dam, Clean water dam which contains storm water run-off and water from a river diversion as well as Maturation pond which contains treated sewage effluent before it can be pumped into the Dirty water dam for reuse in the power station.

The Dirty water dam is also used for the disposal of effluent from the power station activities such floor washing. A dirty water drain collects all the water from the industrial part of the power station to the oil reclamation plant where hydro carbons are removed and ash settles in small ponds before the effluent is disposed into the dirty water dam for reuse.

The Emergency water dam is located between the Dirty water dam and the Clean water dam. The purpose of the Emergency water dam is to contain overflow water from the Dirty water dam so that overflow from dirty water dam does not spill into the environment and thereby causing contamination or pollution.

The Clean water dam is located next to the Emergency (dirty) water dam. There is a spill way from the Emergency water dam into the Clean water dam. When the Emergency water dam is full, the water spills into the Clean water dam through this spill way. The purpose of the Clean water dam is to contain run off water from the power station surroundings. It must be noted that a periodic stream has been diverted into the Clean water dam. When the Clean water dam is full, it spills into a stream below.

Ground water monitoring at Kendal Power Station, according to the reports and data available, started in March 2011. However, there are indications that prior to that, boreholes were drilled and some form of monitoring took place but reports could not be identified as evidence that monitoring was conducted before then.

The data used in this study is from March 2011 to the end of 2020. In terms of the Kendal Water Use Licence number /04/B20E/BCEGI/1048 issued to the power station in 2011 and an amendment of the same license issued by the DWA in November 2015, ground water monitoring is required to be done on quarterly basis. Almost all the reports for this period were available. The reports are named in phases. Below is a table indicating the phases and dates of the reports available and used for this study. In instances where the data required was not available from the monitoring reports; a database containing raw data from the sampled boreholes was used to get the readings. However, there are boreholes which were not sampled in a specific phase for various reasons, in one instance the reason for not sampling a borehole was stated as because the borehole could not be located, or the borehole was not accessible. In those instances, the block which is supposed to have the value from the chemical analysis is left blank and greyed out on the table to show that data was not available. The raw data used was compiled by the service providers who were appointed by the power station to conduct both surface and ground water monitoring as per the water use licence requirements. The data in the database was then used to compile the quarterly reports which were used in this study as indicated above.

Table 4.1: Ground and surface water monitoring phases and months on which the sampling or monitoring was conducted.

Number	Monitoring Phase Number	Date of Monitoring
01	Phase 54	March 2011
02	Phase 55	June 2011
03	Phase 56	September 2011
05	Phase 57	November 2011
06	Phase 58	February 2012
06	Phase 59	May 2012
07	Phase 60	July 2012
08	Phase 61	October 2012
09	Phase 62	March 2013
10	Phase 63	May 2013
11	Phase 64	August 2013
12	Phase 65	October 2013
13	Phase 66	March 2014
14	Phase 67	July 2014
15	Phase 68	October 2014
16	Phase 69	December 2015
17	Phase 70	February 2015
18	Phase 71	May 2015
19	Phase 72	August 2015
20	Phase 73	November 2015
21	Phase 74	February 2016
22	Phase 75	May 2016

23	Phase 76	August 2016
24	Phase 77	October 2016
25	Phase 78	January 2017
26	Phase 79	May 2017
27	Phase 80	August 2017
28	Phase 81	November 2017
29	Phase 82	March 2018
30	Phase 83	June 2018
31	Phase 84	August 2018
32	Phase 85	February 2019
33	Phase 86	May 2019
34	Phase 87	August 2019
35	Phase 88	November 2019
36	Phase 89	February 2020
37	Phase 90	May 2020
38	Phase 91	August 2020
39	Phase 92	November 2020
40	Phase 93	November 2020

Analyses from the boreholes indicated on table 4.2 are part of the study. These boreholes were selected because they are located around the effluent water dams, the Clean water dam including Maturation pond which contains treated sewage effluent. Therefore, the boreholes serve the main purpose of ascertaining whether there is pollution or contamination of underground water resources due to the effluent water management activities and lack of implementation of pollution prevention requirements at the power station.

Table 4.2: Boreholes used in this study, their description and purpose.

Description of the area	Borehole number/Identification	Purpose for borehole sampling
Maturation Pond		
Sewage Plant Area/Maturation Pond/dam	SB24	Potential Seepage from sewage plant.
Clean Water Dam Area		
Borehole west of pollution control dams.	PB23	Potential Seepage from clean water dam.
Borehole west of clean water dam.	PB06	Potential Seepage from clean water dam
Dirty Water Dam Area (Including Emergency Water dam)		
Borehole north-west of dirty water dam.	PB05	Potential seepage from dirty water dam.

(Source, van Niekerk and Moolman: 2012.)

The images below show the locality of the boreholes as indicated in table 4.2 above.

Figure 4.1: Google map showing boreholes PB05, PB06, PB23 and SB24 (Source: Mahlangu *et al.*, (2018)).

Figure 4.2: **Enlarged google map view of the Dirty, Emergency and Clean water dams and boreholes PB05, PB06 and PB23.** (Source: Mahlangu *et al*., 2018)

According to the Geo Hydro Technologists (GHT) report, compiled by one of the consulting scientists who conducted the ground water monitoring for Kendal Power Station, "concentrations of more than 17 inorganic chemical parameters including constituents in the water samples were determined during the chemical analyses, only six parameters are used as indicators of contamination in the monitoring of the pollution potential in this system. These six parameters are: the electrical conductivity (EC), the major ions Ca, Na, Cl and SO4 and the minor ion Fe." (van Niekerk and Moolman., 2014, p. 37). However, as stated in the previous sections of this study, the focus of this study is pH, Electrical conductivity, major ions Sodium, Calcium and sulphates. Minor iron (Fe) is excluded from this study because in most instances the results were not available. The chemicals and constituents which are part of this study were selected because they are regarded as significant in the ground water monitoring reports for Kendal Power Station.

Table 4.3: **Chemicals forming part of the study and 2011 and 2015 WUL limits**

Variable	**WUL 2011 Limits**	**WUL November 2015 Limits**
pH	8.34	6.5 to 8.4
Electrical Conductivity	37.51 mS/m	40 mS/m
Sodium	10.45 mg/l	20 mg/l
Calcium	20.68 mg/l	25 mg/l
Sulphate	14.85 mg/l	30 mg/l

The above table shows the variables included in the study, the water-use license limit as per the water use licence issued to Kendal Power Station in 2011 and its amendment dated 15 November 2015. The limits indicated for WUL dated November 2015 started being applicable on the next monitoring phase which is February 2016 due to the fact that it is highly possible that the power station did not receive the amended WUL as per the date of signature and probably by the time the power station received the amendment, the sampling was already conducted and in addition, it is easier to plot the limits, if the limits for that year are the same.

It is highlighted that the date on which the power station received the amended WUL does not affect the sample results in any way**.**

4.2 Analysis of the data

Data of the four boreholes under this study was extracted from the ground water monitoring reports and the database and grouped per year, per phase and per a specific variable. An excel spreadsheet was used to capture the data manually using tables. Line graphs showing readings for the year for a variable for a specific borehole were plotted against the WUL limits of 2011 and 2015. Then observations were made to determine if there was compliance or non-compliance with the water use licence limits. In instances where the limits were exceeded, that implies pollution and in instances where there were no exceedances, it is concluded that there was no pollution of the underground water. The blocks which are highlighted in red on the table, indicates that water use licence limits were exceeded in that monitoring period.

4.2.1 Borehole PB05

This borehole is located close to both Dirty and Emergency water dams for the purpose of monitoring whether the two effluent dams are impacting negatively or polluting the ground water resources. The Dirty and Emergency dams contain the same type of water, as indicated in the previous chapters that the Dirty dam overflows into the Emergency dam.

Table 4.4: **pH values for PB05 from 2011 to 2020 and limits as per 2011 and 2015 Kendal Power Station WUL**.

PB05: pH	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Quarter A	6.52	6.64	6.64	7.32	7.09	7.16	7.15	6.9	7.7	6.93
Quarter B	6.27	6.42	7.01	7.74	7.15	6.9	6.9	6.66	6.42	7.08
Quarter C	6.75	6.63	6.76	6.85	8.04	7.89	6.6	7.05	6.3	6.37
Quarter D	6.49	6.76	6.85	6.53	6.89	7	6.68	7.05	6.59	6.59
2011 WUL Limit	**8.34**	**8.34**	**8.34**	**8.34**	**8.34**					
2015 WUL Limit: Lower						**6.5**	**6.5**	**6.5**	**6.5**	**6.5**
2015 WUL Limit: Upper						**8.4**	**8.4**	**8.4**	**8.4**	**8.4**

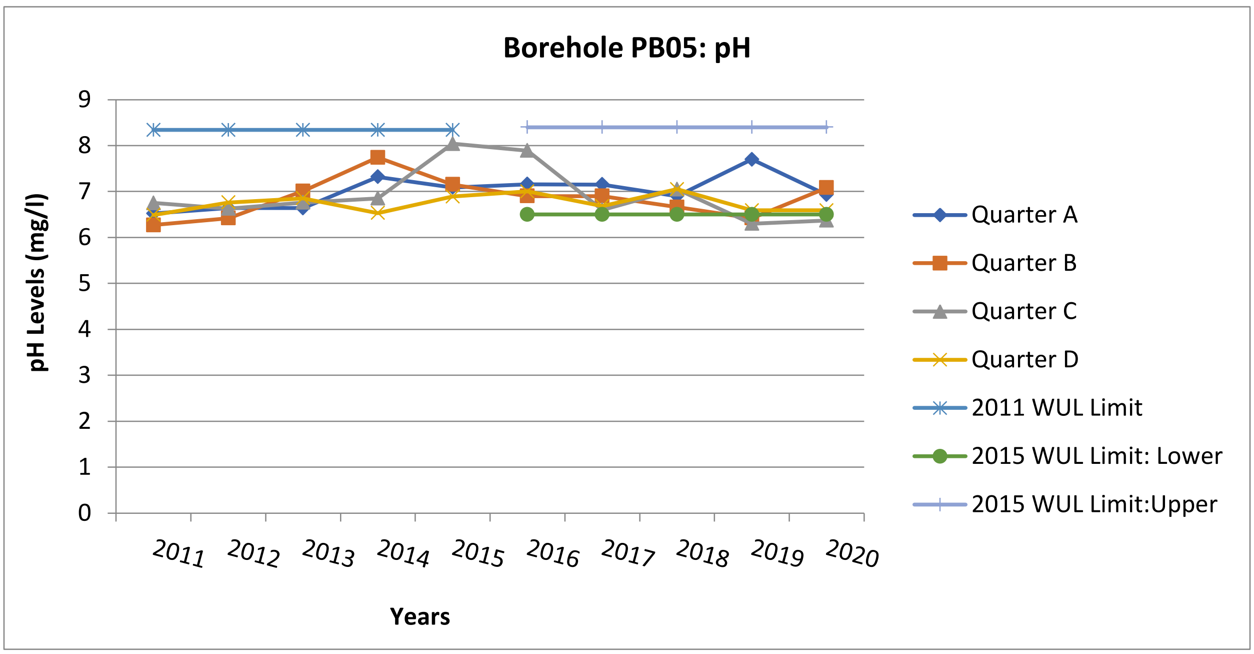


Figure 4.3: **Graph showing pH for PB05 from 2011 to 2020**

From table 4. 4 and figure 4.3 above, in 2011 to 2015, the pH level for this borehole remained below the water use licence limit of 8.34 for all the quarters in which ground water monitoring was conducted. The water-use licence limit for pH as per November 2015 amended license is between 6.5 and 8.4. For the period of 2016 to 2020, pH limit compliance was achieved in most cases except in the third quarter of both 2019 and 2020, where the pH level of 6.3 and 6.42 were recorded and in 2020 in the same quarter a reading of 6.37 was recorded.

Table 4.5: **Electrical Conductivity values for PB05 from 2011 to 2020 and limits as per 2011 and 2015 Kendal Power Station WUL.**

PB05: Electrical Conductivity (EC)	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Quarter A	8	7.96	9.55	9.56	8.96	10.9	10.9	7.9	8.03	9.19
Quarter B	9.08	7.67	8.95	8.97	12	9.65	10	11.2	9.35	8.13
Quarter C	8	6.63	10.2	8.13	13.2	10.6	10	11.3	8.5	8.13
Quarter D	8.5	8.19	8.93	8.04	25	7.34	9.73	87	8.1	9.21
2011 WUL Limit	**37.51**	**37.51**	**37.51**	**37.51**	**37.51**					
2015 WUL Limit						**40**	**40**	**40**	**40**	**40**

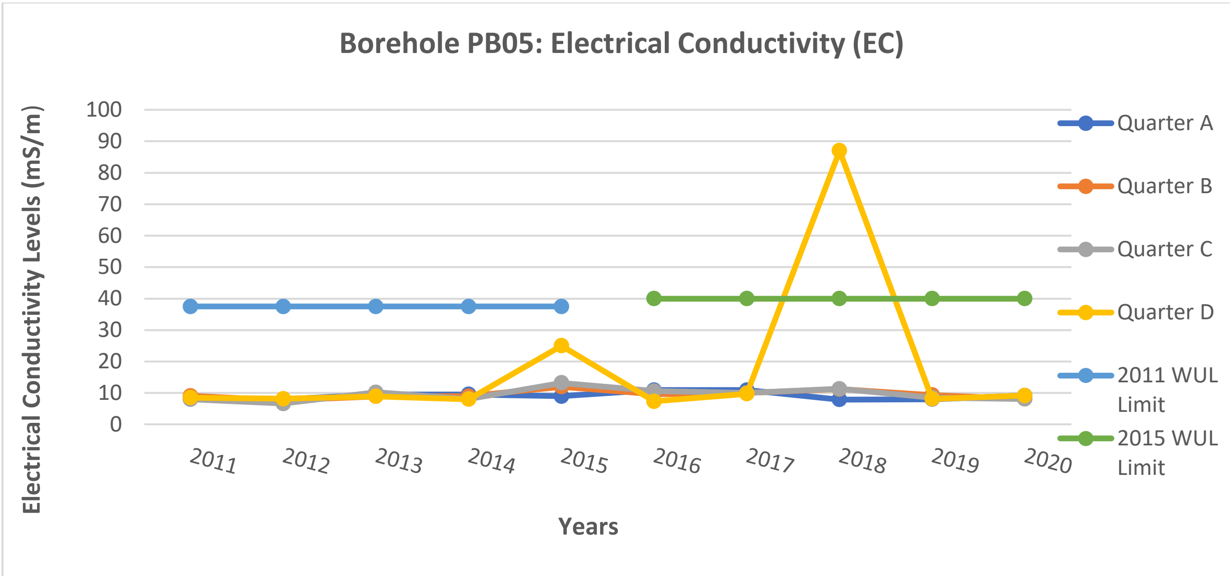


Figure 4.4: Graph showing Electrical Conductivity for PB05 from 2011 to 2020

The electrical conductivity WUL limit for 2011 is 37.51 mS/m whereas for 2015 WUL the limit was increased to 40 mS/m. In 2018, on quarter D the electrical conductivity for this borehole was 87mS/l, which is way above the licence limit of 40 mS/m. This is the only instance were a non-compliance and pollution were noted for electrical conductivity in this borehole.

Table 4.6: **Sodium (Na) for PB05 from 2011 to 2020 and limits as per 2011 and 2015 Kendal Power Station WUL**.

PB05: Sodium (Na)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Quarter A	11	5.89	4.58	6.51	9.01	9.04	8.57	8.4	8.77	9.27
Quarter B	11.5	8.86	5.61	7.25	8	7	6.2	36.9	5.32	9.08
Quarter C	8	6.82	3.82	8.45	8.6	9.43	8.4	8.8	4.8	8.01
Quarter D	7.66	5.61	4.45	6.97	10.41	7.1	8.1	8.8	8.17	9.68
2011 WUL Limit	**10.45**	**10.45**	**10.45**	**10.45**	**10.45**					
2015 WUL Limit						**20**	**20**	**20**	**20**	**20**

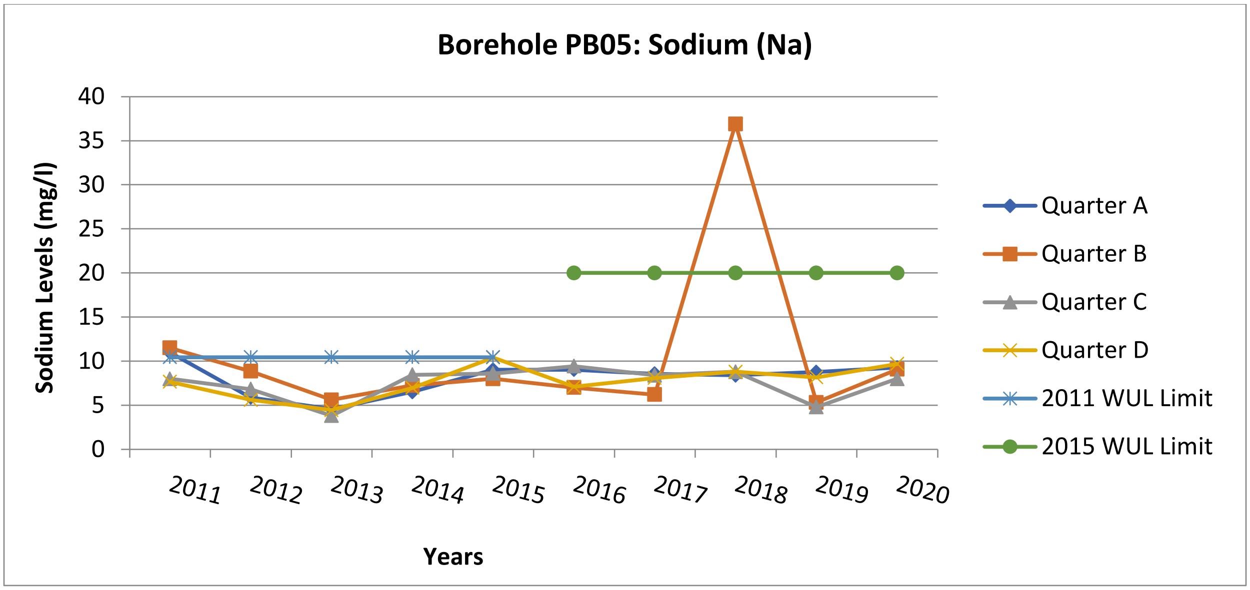


Figure 4.5: **Graph showing Sodium levels for PB05 against 2011 and 2015 WUL limits.**

In the above, table 4.6 and figure 4.5, for 2011 the WUL limit for Sodium was stipulated as 10.45mg/l. This limit was exceeded in Quarter A and Quarter B of 2011. Further, in 2018, the WUL limit of 20mg/l as per 2015 licence was exceeded in Quarter B.

Table 4.7: Calcium (ca) for PB05 from 2011 to 2020 and limits as per 2011 and 2015 Kendal Power Station WUL.

PB05 Calcium	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Quarter A	3	3.41	4.8	4.5	4.18	5	4.52	4.3	3.68	4.71
Quarter B	3.8	8.69	4.58	4.99	7.4	5	4	10.2	4.44	3.8
Quarter C	2	4.12	5.09	4.44	10.6	5.65	4	9.9	9	4.87
Quarter D	5.72	4.11	4.07	3.85	9.3	3	7.9	4.6	4.29	5.03
2011 WUL Limit	**20.68**	**20.68**	**20.68**	**20.68**	**20.68**					
2015 WUL Limit						**25**	**25**	**25**	**25**	**25**

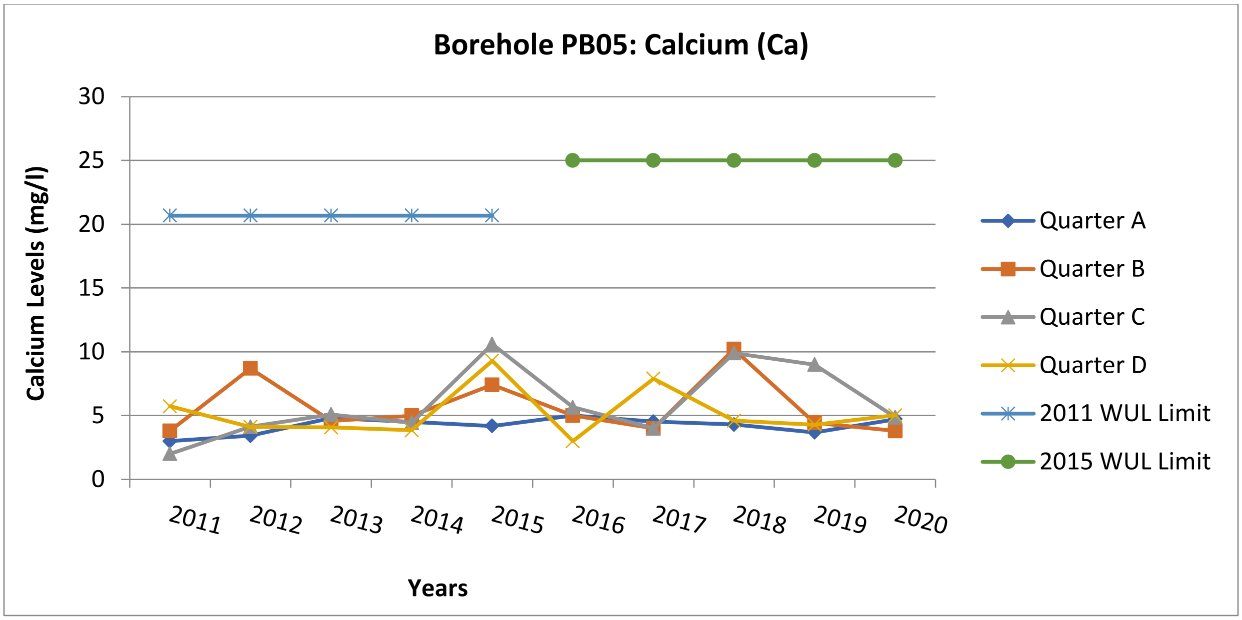


Figure 4.6: Graph showing Calcium (Ca) levels for PB05 against 2011 and 2015 WUL limits

WUL limits for 2011 and 2015 licences are 20.68mg/l and 25mg/l respectively. Both these license limits were never exceeded for the period of 2011 to 2020.

Table 4.8: Sulphates (SO4) for PB05 from 2011 to 2020 and limits as per 2011 and 2015 Kendal Power Station WUL.

PB05 Sulphates	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Quarter A	1	-0.13	1.66	1.18	2.56	-0.162	-0.14	2.5	246.41	3.73
Quarter B	0.27	6.2	3.79	3.57	<0.287	-0.2	0	3.7	2.6	2.75
Quarter C	2	-0.13	< 0.04	1.18	-0.287	2.29	2	3.1	4.6	-0.14
Quarter D	0.13	0.17	< 0.04	1.8	-0.287	-0.1	2.52	0.96	3.01	-0.14
2011 WUL Limit	**14.85**	**14.85**	**14.85**	**14.85**	**14.85**					
2015 WUL Limit						**30**	**30**	**30**	**30**	**30**

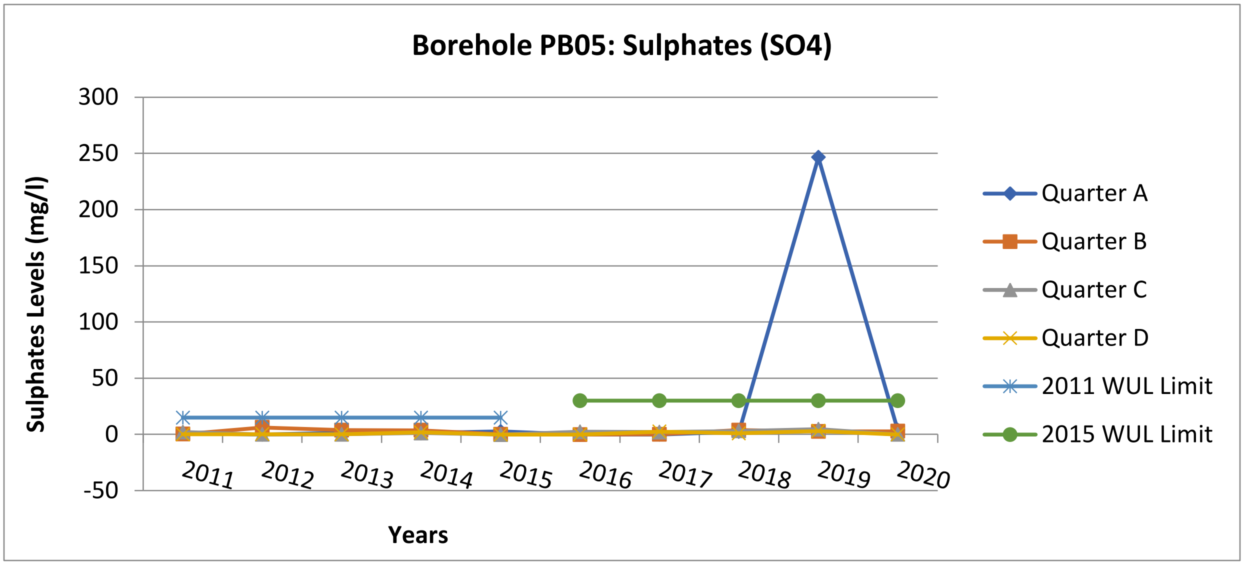


Figure 4.7: Graph showing Sulphates (SO4) levels for PB05 against 2011 and 2015 WUL limits

The sulphates level was only exceeded in Quarter A of 2019 where a value of 246.41mgs/l was recorded against a WUL limit of 30mg/l. In some instances, as can be seen on the table, negative values were recorded and in some instances values of less than 0.04mgs/l were recorded.

4.2.2 Borehole PB06

The following are the results of borehole PB06. The borehole is located near Clean water dam for the purpose of monitoring whether this dam has a negative impact to the ground water. The variables in this study are the same as the ones in borehole PB05 which are pH, Electrical conductivity, Sodium (Na),

Table 4.9: **pH values for PB06 from 2011 to 2020 and limits as per 2011 and 2015 Kendal Power Station WUL.**

Borehole PB06: pH	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Quarter A		8.23	8.42	8.26	8.24	7.74	8.37	7.88	7.88	7.95
Quarter B	8.1	8.42	8.37	8.33		8.4	8.5	7.86	8.35	8.32
Quarter C	8.35	8.22	8.36	8.08	8.44	8.25	8.5		8.1	8.24
Quarter D	8.32	8.4	7.88	8.35	8		7.93	8.08	8.01	8.46
2011 WUL Limit	**8.34**	**8.34**	**8.34**	**8.34**	**8.34**					
2015 WUL Limit: Lower						**6.5**	**6.5**	**6.5**	**6.5**	**6.5**
2015 WUL Limit: Upper						**8.4**	**8.4**	**8.4**	**8.4**	**8.4**

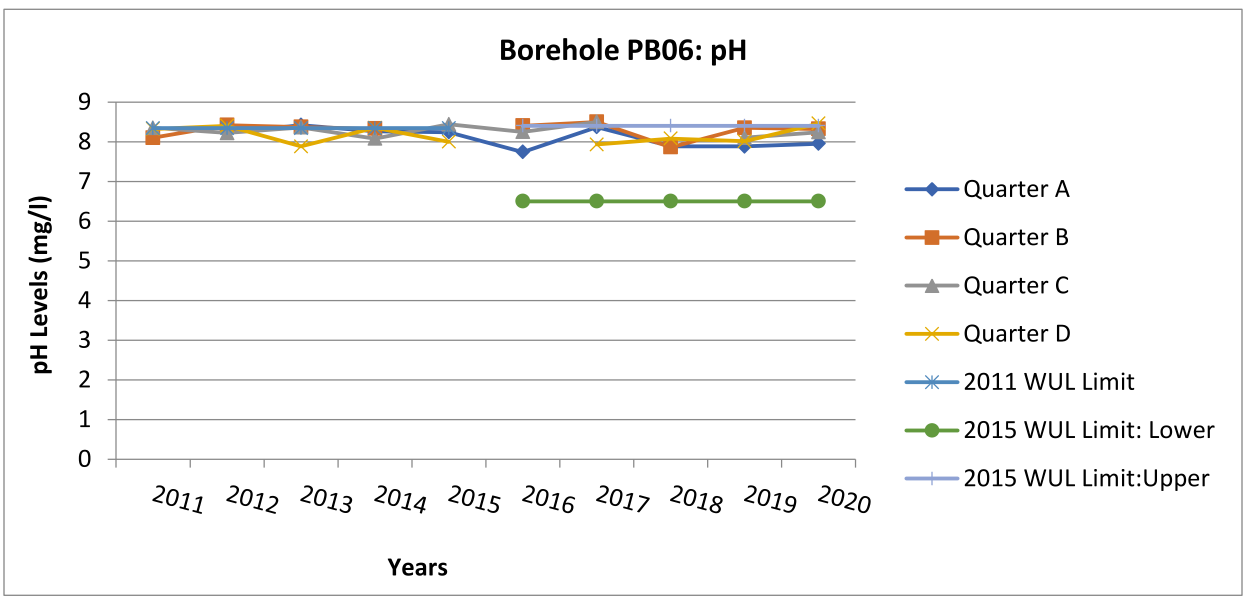


Figure 4.8: **Graph showing pH levels for PB06 against 2011 and 2015 WUL limits**

Borehole PB06 had instances where the samples were not taken and therefore not available as indicated as greyed out blocks on the table above. The following quarters did not have values:

- 2011 Quarter A
- 2015 Quarter B
- 2016 Quarter D
- 2018 Quarter D

The graphs and interpretation of the values against WUL limits exclude the non-available values. For 2011 WUL limit of 8.34., exceedances were recorded in 2011 Quarter C, 2012 Quarter B and D, 2013 Quarter A, B and C, 2014 Quarter D, and 2015 Quarter C. For the 2015 pH limit of between 6.5 and 8.4, exceedances occurred in 2017 Quarter B and C and in 2020 Quarter D.

Table 4.10: Electrical Conductivity (EC) values for PB06 from 2011 to 2020 and limits as per 2011 and 2015 Kendal Power Station WUL.

Borehole PB06: Electrical Conductivity (EC)	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Quarter A		20.49	20.6	20.8	20.8	73.4	23	20.1	18.24	21.6
Quarter B	20.4	18.25	19.6	21.8		22	20	22	20.4	20.8
Quarter C	18	21.03	19.6	20.7	21.6	21.2	21		19.37	21.3
Quarter D	20.6	19.66	23	20.8	21.4	21	21.54	215	21.1	19.9
2011 WUL Limit	**37.51**	**37.51**	**37.51**	**37.51**	**37.51**					
2015 WUL Limit						**40**	**40**	**40**	**40**	**40**

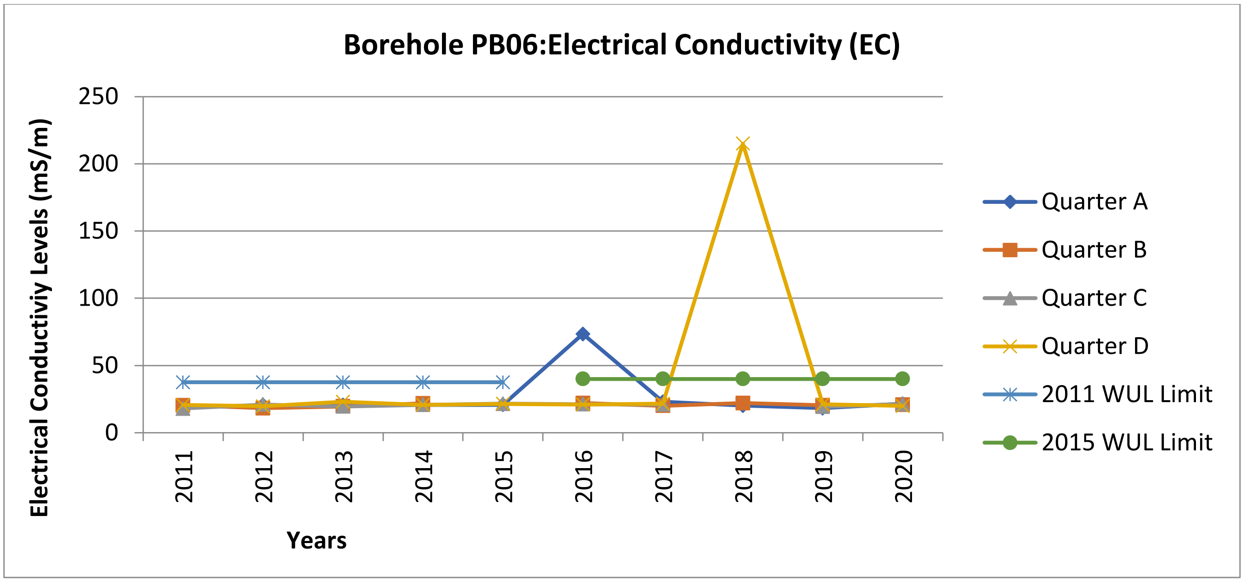


Figure 4.9: **Graph showing Electrical Conductivity (EC) levels for PB06 against 2011 and 2015 WUL limits**

For borehole PB 06, electrical conductivity WUL limits were exceeded in 2016 Quarter A and 2018 Quarter D. For the other monitoring periods where values are available, the WUL limits were not exceeded.

Table 4.11: **Sodium (Na) values for PB06 from 2011 to 2020 and limits as per 2011 and 2015 Kendal Power Station WUL.**

Borehole PB06: Sodium (Na)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Quarter A		31.92	31.5	30.7	39.8	108	39.8	32.7	35.36	37.2
Quarter B	40.5	35.37	31.4	40.2		34.4	41.1	117.4	35.69	36.1
Quarter C	36	36.68	27.8	38.4	37.5	41.1	39.7		34.9	35.3
Quarter D	32.69	35.3	30.3	40.3	38.1	38.3	36.8	38.6	34.8	39.8
2011 WUL Limit	**10.45**	**10.45**	**10.45**	**10.45**	**10.45**					
2015 WUL Limit						**20**	**20**	**20**	**20**	**20**

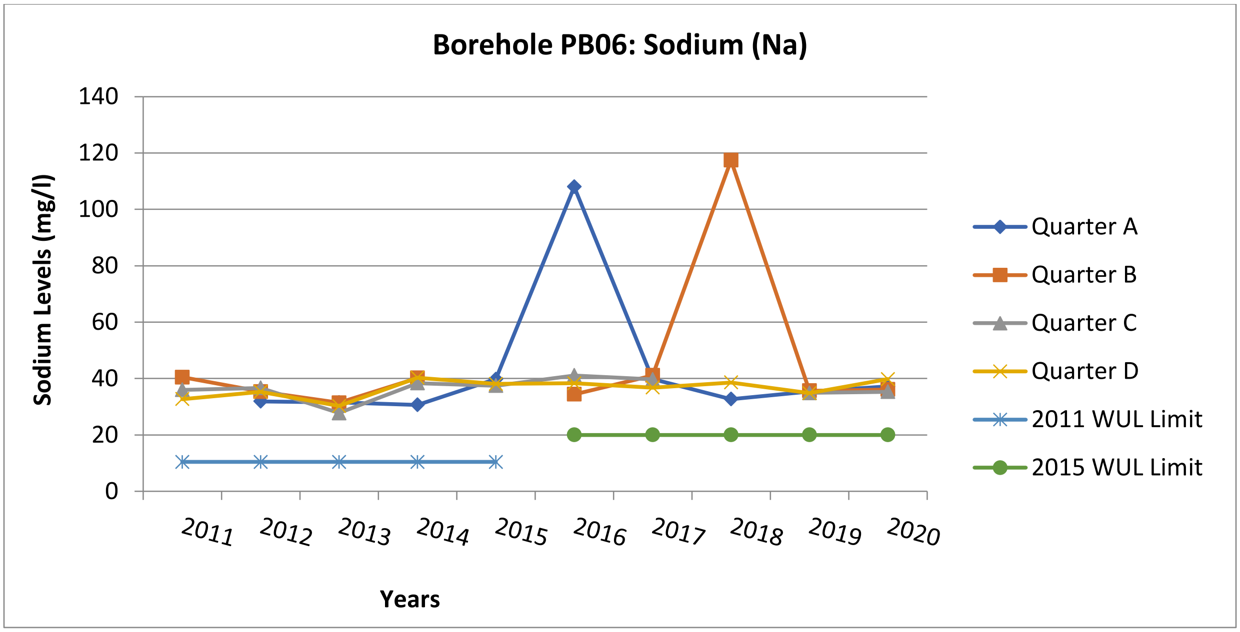


Figure 4.10: **Graph showing Sodium (Na) levels for PB06 against 2011 and 2015 WUL limits**

The observation on borehole PB 06 for Sodium WUL limits is that the 2011 Limits and 2015 Limits were exceeded in every monitoring phase except in three phases where results were not available because samples were not taken. It must be noted that the 2015 WUL amendment increased the limit from 10.45mg/l to 20mg/l however the new limit was also not complied with.

Table 4.12: **Calcium (Ca) values for PB06 from 2011 to 2020 and limits as per 2011 and 2015 Kendal Power Station WUL**.

Borehole PB06: Calcium (ca)	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
		8.35	9.61	9.92	9.02	31.3	10.6	12.7	11.56	10.4
Quarter B	7.9	9.2	10.3	10.9		10	12	20.9	8.82	11.2
Quarter C	1	7.93	10.7	10.4	12.5	11.4	10		9.6	10.1
Quarter D	9.4	8.82	10.8	14.1	10.4	11	11	53.7	10.6	11.2
2011 WUL Limit	**20.68**	**20.68**	**20.68**	**20.68**	**20.68**					
2015 WUL Limit						**25**	**25**	**25**	**25**	**25**

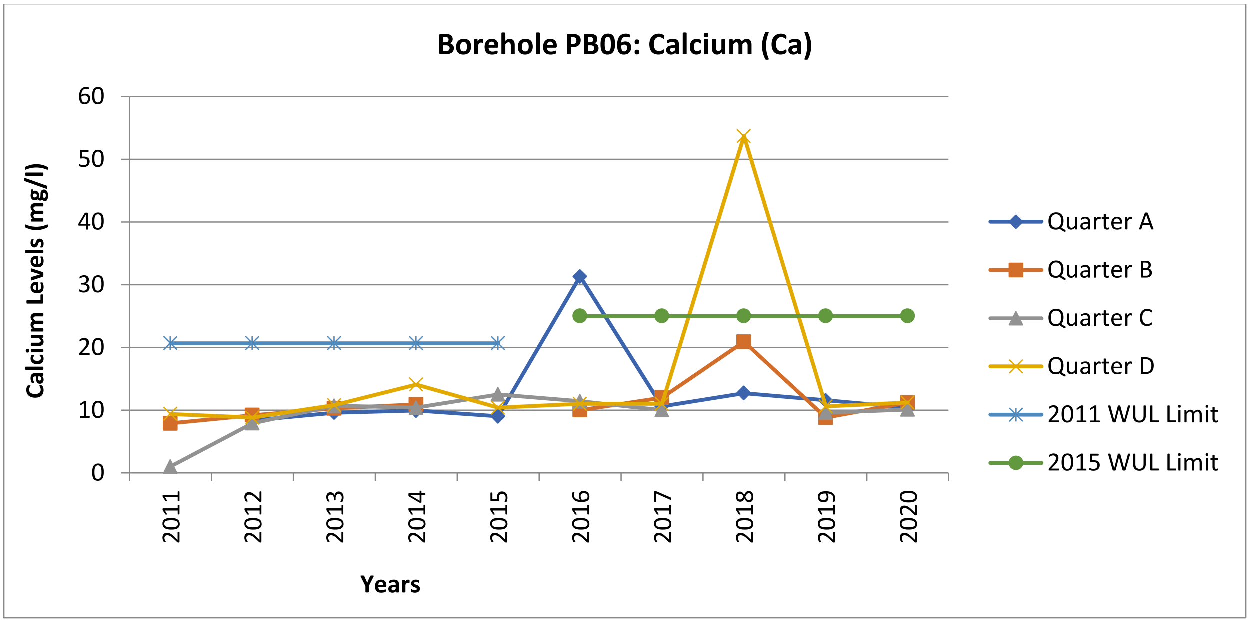


Figure 4.11: **Graph showing Calcium (Ca) levels for PB06 against 2011 and 2015 WUL limits**

On borehole PB06 above WUL calcium limits were exceeded two times, 2016 Quarter A and 2018 Quarter D. For the rest of the monitoring except the three monitoring phases where samples were not taken, there was compliance with the WUL limits.

Table 4.13: **Sulphates (SO4) values for PB06 from 2011 to 2020 and limits as per 2011 and 2015 Kendal Power Station WUL**.

Borehole PB06: Sulphates (SO4)	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
		-0.13	2.99	3.29	3.33	1.83	1.42	4.9	66.50	9.82
Quarter B	2.77	2.17	3.84	4.53		2.19	2	4.6	3.50	5.17
Quarter C	8	1.36	<0.04	3.02	0.924	0.938	4		4.30	2.24
Quarter D	0.47	2.57	1.44	4.74	<0.287	-0.141	4.3	3.34	4.43	1.74
2011 WUL Limit	**14.85**	**14.85**	**14.85**	**14.85**	**14.85**					
2015 WUL Limit						**30**	**30**	**30**	**30**	**30**

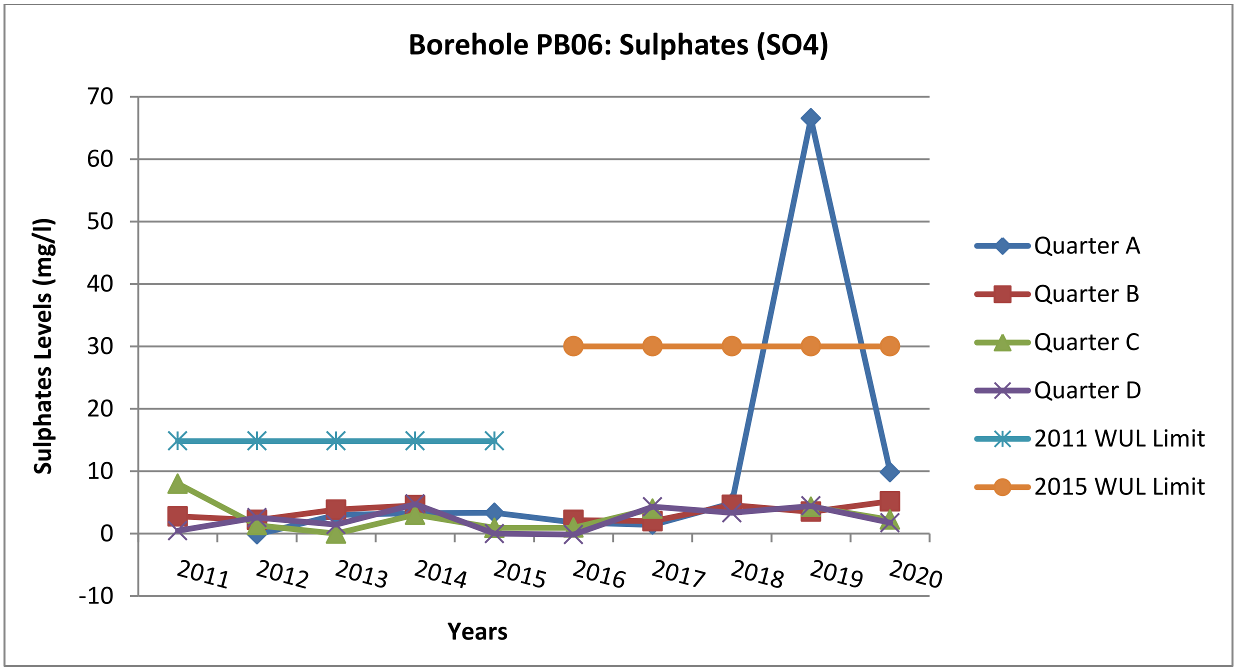


Figure 4.12: **Graph showing Sulphates (SO4) levels for PB06 against 2011 and 2015 WUL limits**

In Borehole PB06, as can be observed on the graph and table above, WUL limits were exceeded only once, in 2019 Quarter A. For the rest of the monitoring phases there is compliance with the WUL limits stated in both 2011 and 2015 WUL.

4.2.3 Borehole PB23

Borehole PB23 is located close to PB06. The purpose of this borehole is to monitor potential ground water pollution emanating from the Clean water dam. Below are the tables and graphs for the five variables selected for this study.

Table 4.14: pH values for PB23 from 2011 to 2020 and limits as per 2011 and 2015 Kendal Power Station WUL.

Borehole PB23: pH	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Quarter A	7.61	7.6	9	8.36	7.86	7.82		7.08		6.79
Quarter B	7.9	8.12	7.01	8.33	8.3	7.8		7.55	7.1	6.84
Quarter C	7.8	7.67	9.18	8.01	8.22	8.26	6.8	7.34	6.76	7
Quarter D	7.84	8.03	8.79	7.89	9.24		7.23	7.73	6.91	8.06
2011 WUL Limit	**8.34**	**8.34**	**8.34**	**8.34**	**8.34**					
2015 WUL Limit: Lower						**6.5**	**6.5**	**6.5**	**6.5**	**6.5**
2015 WUL Limit: Upper						**8.4**	**8.4**	**8.4**	**8.4**	**8.4**

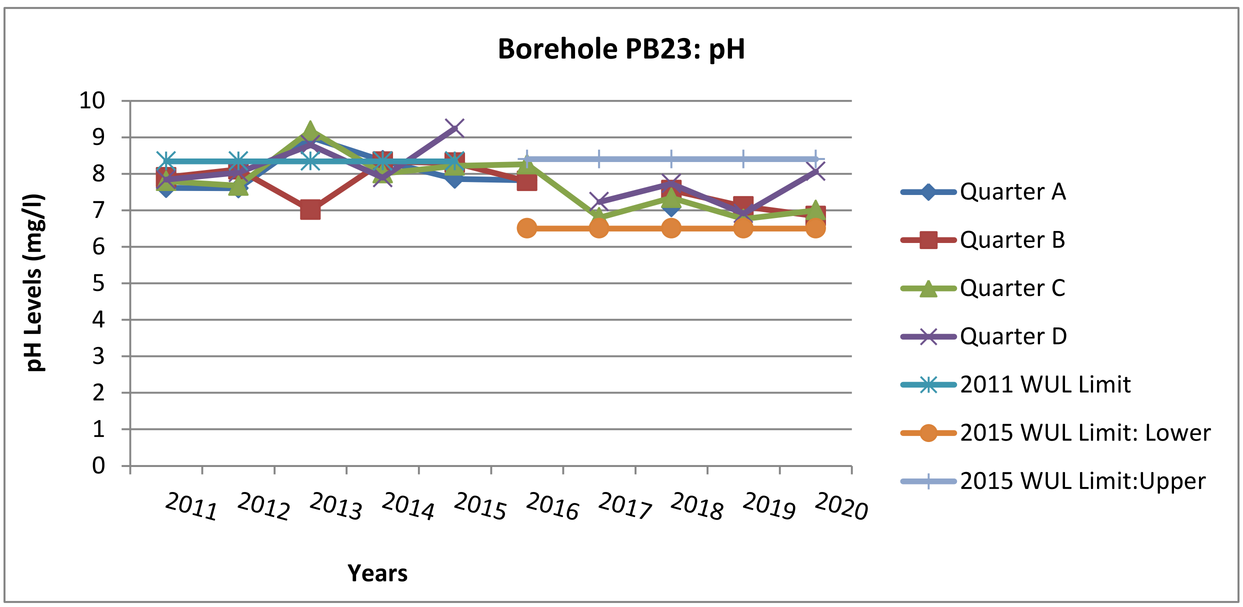


Figure 4.13: Graph showing pH levels for PB23 against 2011 and 2015 WUL limits

Borehole PB23 is also used to monitor potential negative impact from the Clean water dam. For 2016 Quarter D, 2017 Quarter A and B and 2019 Quarter a, there are no samples or analysis results for this borehole. This applies for all the variables included in this study. In terms of pH values for this borehole, exceedances of the WUL pH limit occurred 1in 2013 for Quarter C and D and in 2014 during Quarter A monitoring phase and lastly in 2015, Quarter D.

Table 4.15: **Electrical Conductivity values for PB23 from 2011 to 2020 and limits as per 2011 and 2015 Kendal Power Station WUL.**

Borehole PB23: Electrical Conductivity: (EC)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Quarter A		50.9	28.2	32	62.7	26.5		95.5		89.3
Quarter B	34.5	49.3	24.8	35.7	46	103		74.6	76.9	85.4
Quarter C	37	52.3	19.3	29.4	41.7	91.6	43	62.2	6.58	103
Quarter D	28.36	49.3	19.4	29.9	27		21.54	673	90.6	119
2011 WUL Limit	**37.51**	**37.51**	**37.51**	**37.51**	**37.51**					
2015 WUL Limit						**40**	**40**	**40**	**40**	**40**

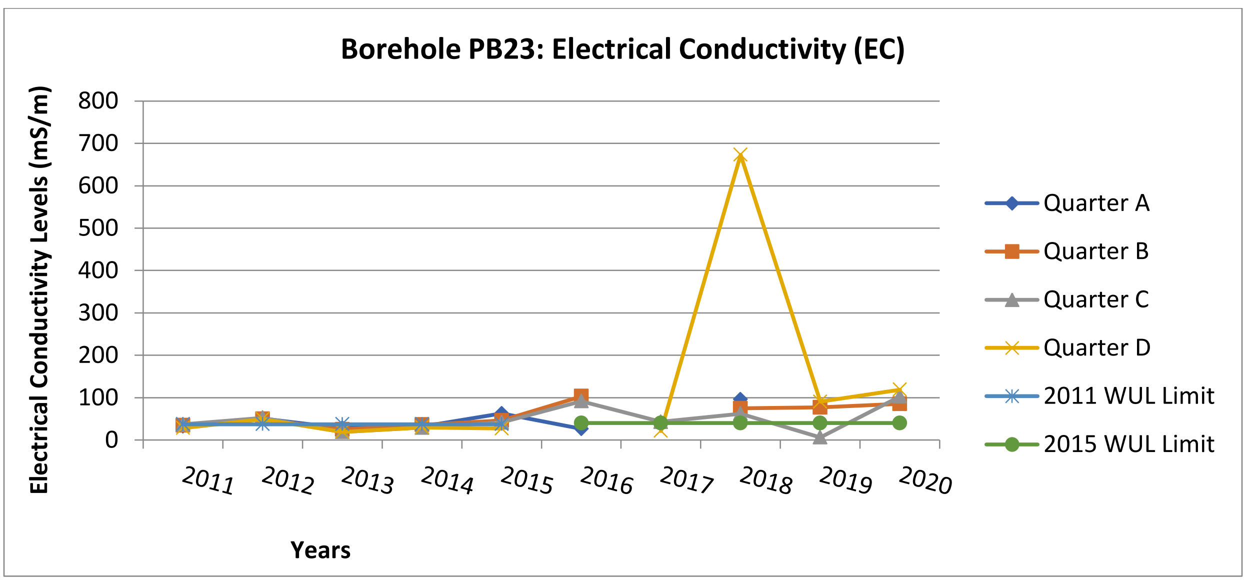


Figure 4.14: **Graph showing Electrical Conductivity (EC) levels for PB23 against 2011 and 2015 WUL limits**

Table 4.15 and figure 4.14 above indicate that on borehole PB23, electrical conductivity WUL limits were exceeded in 2012 on Quarters A, B, C and D, in 2015, Quarter A, B and C, in 2016, Quarter B and C, 2017 Quarter C, 2018, Quarter A, B, C and D, 2019 Quarter B and D and in 2020 Quarter A, B, C and D.

Table 4.16: **Sodium (Na) values for PB23 from 2011 to 2020 and limits as per 2011 and 2015 Kendal Power Station WUL.**

Borehole PB23: Sodium (Na)	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
	49	63.22	42	49.1	92	16.3		153.9		131
Quarter B	53.3	74.24	44.3	52.9	68.6	147		6.4	125.26	138
Quarter C	52	77.16	36.8	49.9	67.8	147	82.4	106.1	135.9	143
Quarter D	44.61	70.17	30.3	49.5	52.9		131.3	106.2	136	177
2011 WUL Limit	**10.45**	**10.45**	**10.45**	**10.45**	**10.45**					
2015 WUL Limit						**20**	**20**	**20**	**20**	**20**

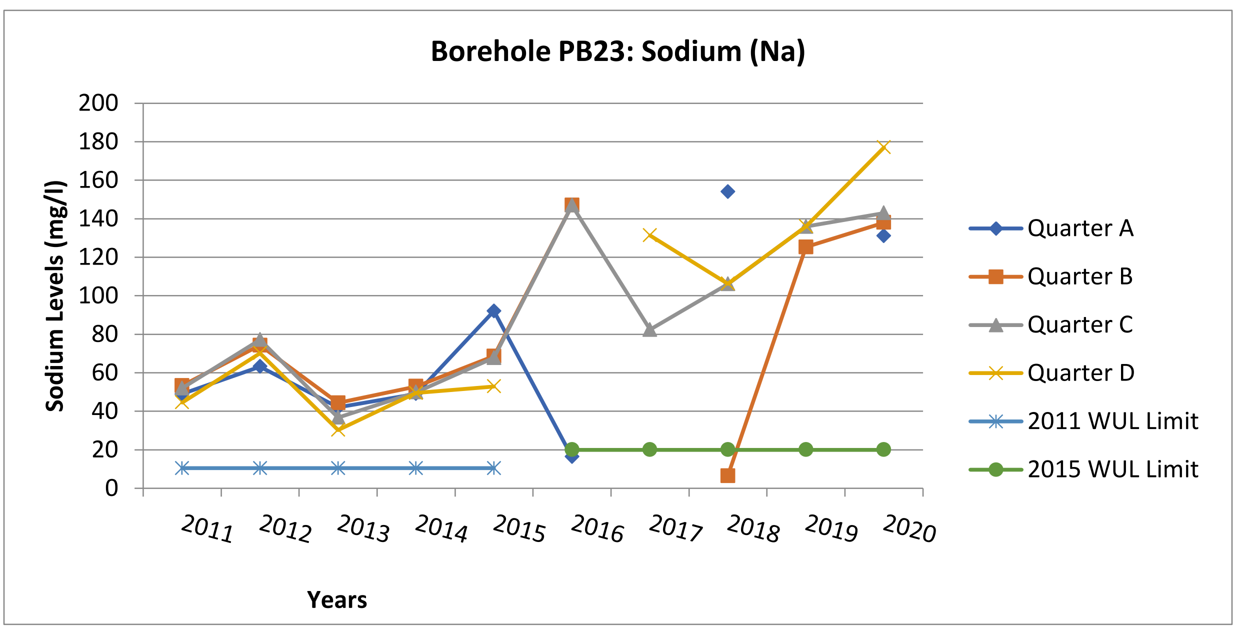


Figure 4.15: Graph showing Sodium (Na) levels for PB23 against 2011 and 2015 WUL limits.

Borehole BP23 complied with Sodium WUL limits in only one monitoring phase which is quarter B of 2019. For all the other monitoring phases from 2011 to 2020, the readings were above both the 2011 and 2015 WUL limits, this excluding four monitoring phases where samples were not taken.

Table 4.17: Calcium (Ca) values for PB23 from 2011 to 2020 and limits as per 2011 and 2015 Kendal Power Station WUL.

Borehole PB23: Calciam (Ca)	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Quarter A	11	19.88	6.34	8.42	28	28		31.5		36.6
Quarter B	3.8	23.36	5.54	15.3	11.7	42		4.5	28.08	35.4
Quarter C	7	22.51	3.44	11.6	9.23	48.8	10	18.1	39.4	44.6
Quarter D	8.39	17.79	2.73	11.2	4		28.7	18.5	3.5	56.1
2011 WUL Limit	**20.68**	**20.68**	**20.68**	**20.68**	**20.68**					
2015 WUL Limit						**25**	**25**	**25**	**25**	**25**

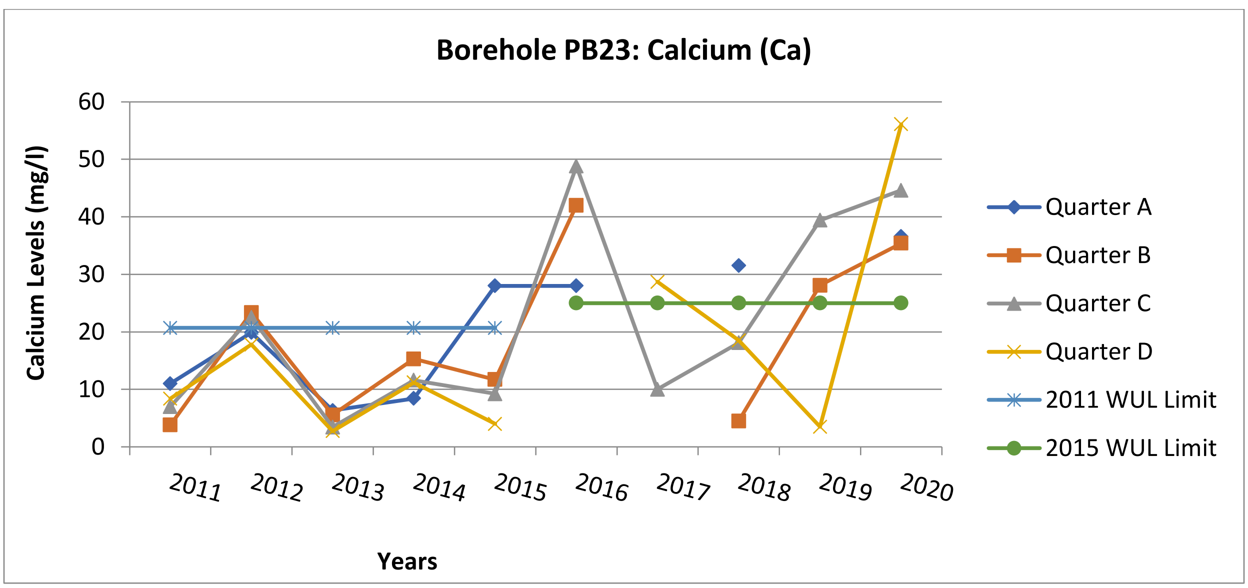


Figure 4.16: Graph showing Calcium (Ca) levels for PB23 against 2011 and 2015 WUL limits.

Both table 4.17 and figure 4.16 indicate that out 36 monitoring phases conducted, borehole PB23 exceeded the WUL limits 13 times. More exceedances occurred from 2016 to 2020 even after the WUL limit was increased from 20.68mg/l to 25mg/l.

Table 4.18: Sulphates (SO4) values for PB23 from 2011 to 2020 and limits as per 2011 and 2015 Kendal Power Station WUL.

Borehole PB23: Sulphates (SO4)	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Quarter A	63	116.06	41.9	53.8	199	1.31		380.5		347
Quarter B	74	172.62	40.5	62.4	105	393		230	269.6	347
Quarter C	92	174.29	3.91	61.2	99.8	338	44	191.5	379.2	388
Quarter D	52.73	123.47	0.37	61.3	38.4		274.9	183.48	353	547
2011 WUL Limit	**14.85**	**14.85**	**14.85**	**14.85**	**14.85**					
2015 WUL Limit						**30**	**30**	**30**	**30**	**30**

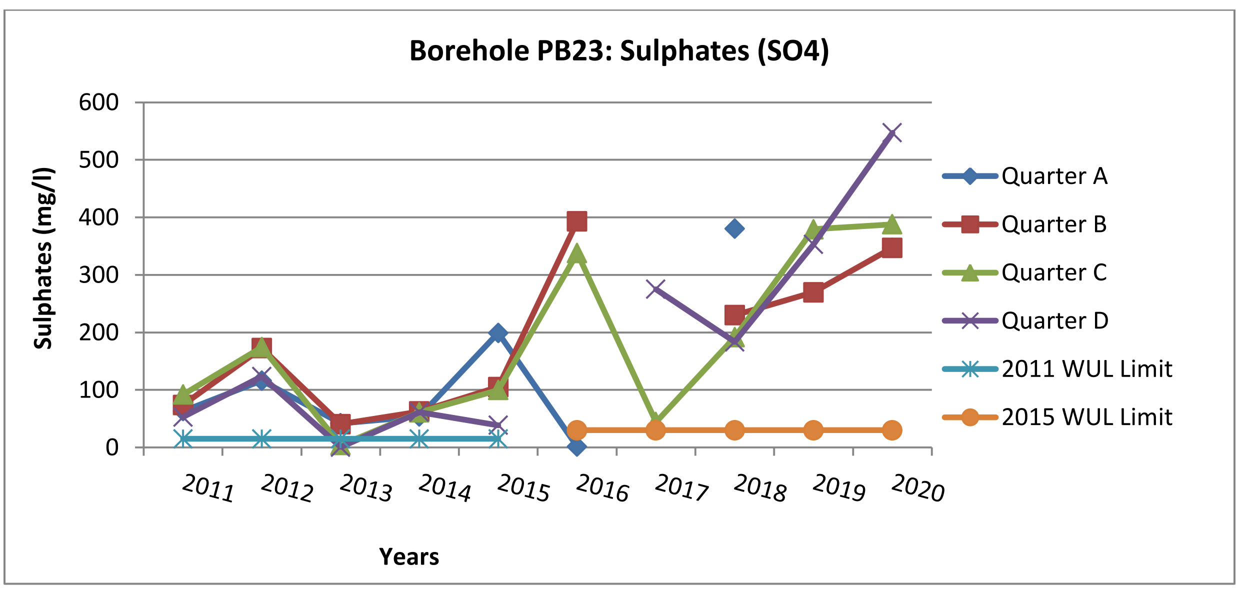


Figure 4.17: Graph showing Sulphates (SO4) levels for PB23 against 2011 and 2015 WUL limits

2011 WUL stipulated 14.85mg/l limit and 2015 WUL amendment stipulate 30mg/l limit. From the 36 monitoring phases where samples were taken, borehole PB23 complied with the limits on only two monitoring phases, Quarter C and D in 2013.

4.2.4 Borehole SB24.

This borehole is located in the vicinity of the sewage treatment plant and Maturation Pond which stores treated sewage effluent water which is transferred to the Dirty water dam for reuse in the power station. The purpose of this borehole is to monitor potential pollution of ground water by the effluent water or WUL limits compliance or non-compliance caused by the Maturation Pond. The five variables similar to the other four boreholes are part of this study being, pH, electrical conductivity, Sodium, Calcium and sulphates. The readings are in a table format and line graph.

Table 4.19: pH values for SB24 from 2011 to 2020 and limits as per 2011 and 2015 Kendal Power Station WUL.

Borehole SB24: pH	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Quarter A	7.31	7.31	7.20	7.84	7.25	7.25	7.53	6.77	6.77	7.50
Quarter B	6.89	7.02	7.55	8.30	7.58	7.58	8.47	7.02	7.48	6.96
Quarter C	7.53	7.28	7.21	7.67	8.52	8.62	8.60	7.15	6.92	7.09
Quarter D	7.30	7.49	7.47	7.09	7.34	7.22	7.49	7.19	6.98	6.94
2011 WUL Limit	**8.34**	**8.34**	**8.34**	**8.34**	**8.34**					
2015 WUL Limit: Lower						**6.5**	**6.5**	**6.5**	**6.5**	**6.5**
2015 WUL Limit: Upper						**8.4**	**8.4**	**8.4**	**8.4**	**8.4**

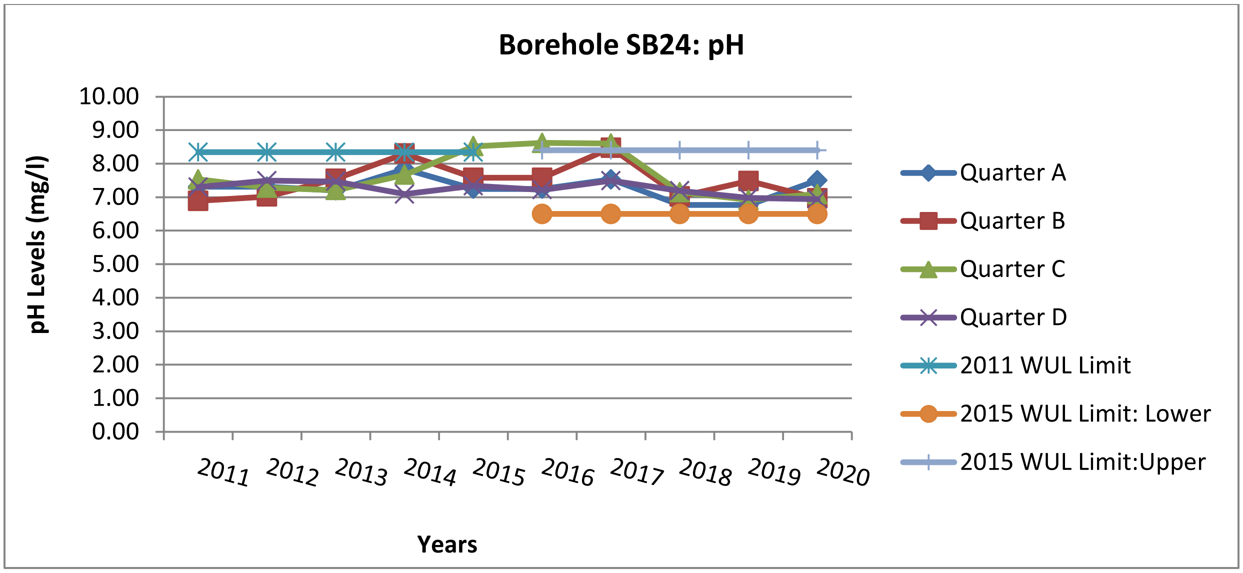


Figure 4.18: Graph showing pH levels for SB24 against 2011 and 2015 WUL limits

The above table and figure indicate that in borehole SB24 the pH WUL limits were exceeded four times out of all the monitoring phases from 2011 to 2020. The exceedances occurred in 2015 Quarter C, 2016 Quarter C and 2017 Quarter B and C.

Table 4.20: Electrical Conductivity values for SB24 from 2011 to 2020 and limits as per 2011 and 2015 Kendal Power Station WUL.

Borehole SB24: Electrical Conductivity (EC)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Quarter A	51.20	57.40	57.30	61.90	62.90	62.10	60.50	64.80	58.20	39.00
Quarter B	56.10	49.30	54.00	63.40	57.40	60.30	51.40	58.70	50.80	59.00
Quarter C	51.60	56.80	56.70	61.50	61.40	62.70	60.00	64.60	57.90	62.20
Quarter D	60.80	64.30	64.30	61.20	64.00	60.20	61.60	631.00	60.60	60.40
2011 WUL Limit	**37.51**	**37.51**	**37.51**	**37.51**	**37.51**					
2015 WUL Limit						**40**	**40**	**40**	**40**	**40**

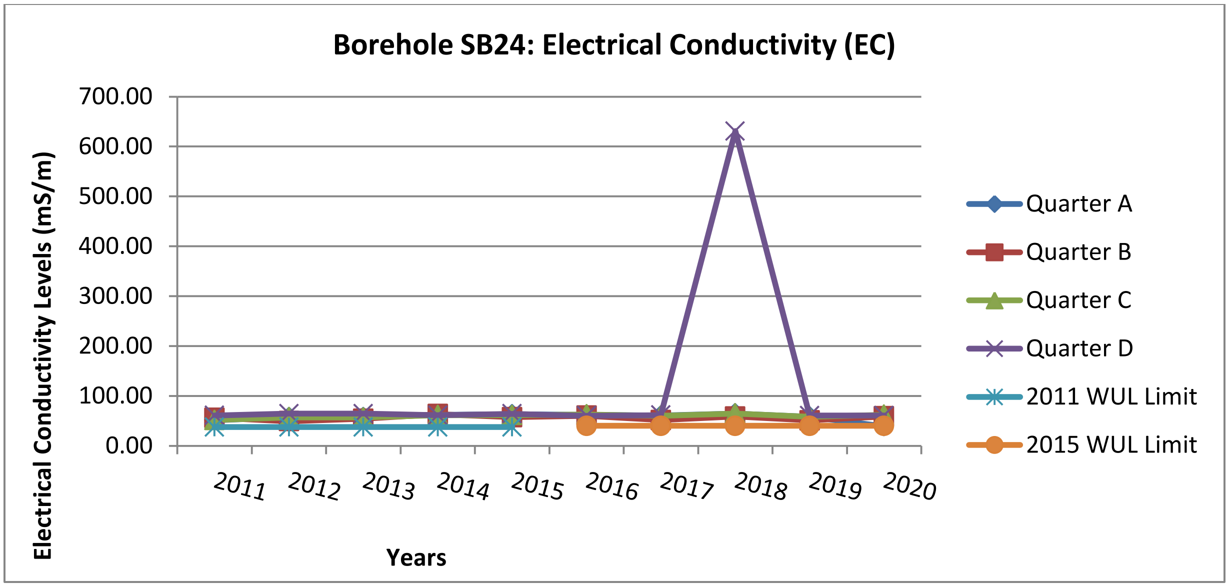


Figure 4.19: Graph showing Electrical Conductivity (EC) levels for borehole SB24 against 2011 and 2015 WUL limits

Borehole SB24 complied with the WUL limits on only one monitoring phase, which is Quarter A in 2020. In all the monitoring phases from 2011 to 2020, the WUL limits were exceeded.

Table 4.21: Sodium (Na) values for borehole SB24 from 2011 to 2020 and limits as per 2011 and 2015 Kendal Power Station WUL.

Borehole SB24: Sodium (Na)	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Quarter A	39.10	29.35	29.80	36.00	41.40	39.80	39.80	38.60	37.18	33.20
Quarter B	40.50	32.10	33.70	38.50	35.40	34.40	40.10	37.80	35.85	36.20
Quarter C	36.17	32.88	30.40	38.40	35.50	37.90	38.80	40.90	46.50	39.00
Quarter D	34.22	34.63	32.10	37.30	39.20	37.50	38.90	38.60	35.40	41.40
2011 WUL Limit	**10.45**	**10.45**	**10.45**	**10.45**	**10.45**					
2015 WUL Limit						**20**	**20**	**20**	**20**	**20**

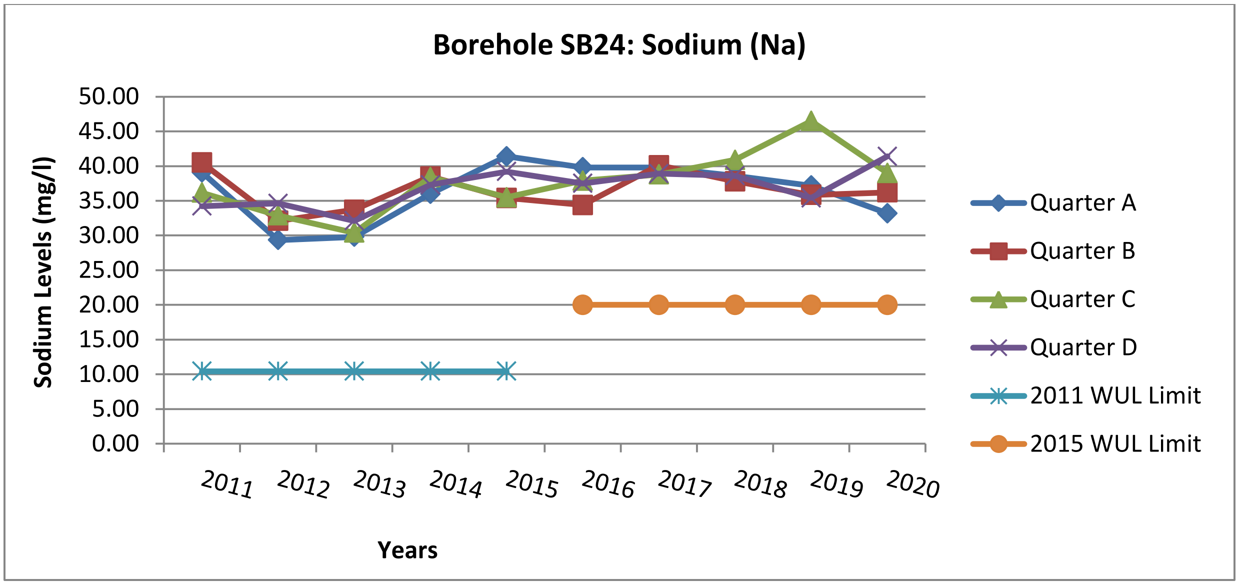


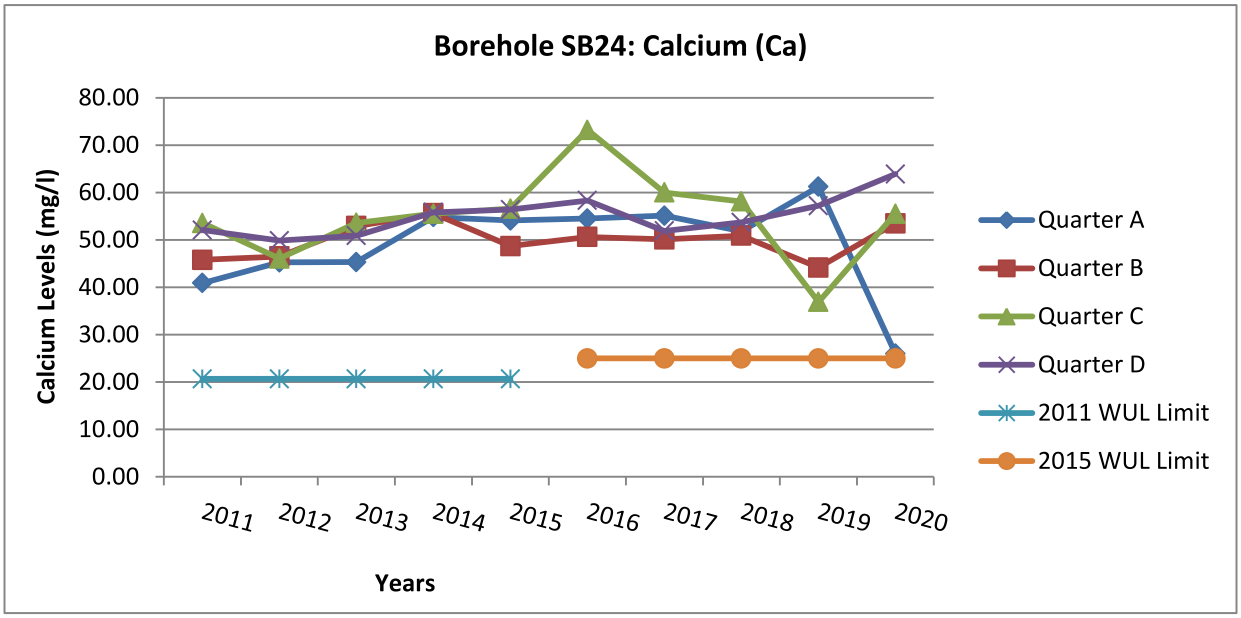
Figure 4.20: Graph showing Sodium (Na) levels for borehole SB24 against 2011 and 2015 WUL limits

In all the monitoring phases which occurred quarterly from 2011 to 2020, sodium WUL limits were exceeded in borehole SB24. 2015 amended WUL increased sodium limits from 10.45mg/l to 20mg/l however even the 2015 WUL limits were exceeded in all the monitoring phases.

Table 4.22: Calcium (Ca) values for SB24 from 2011 to 2020 and limits as per 2011 and 2015 Kendal Power Station WUL.

Borehole SB24: Calcium (ca)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Quarter A	40.90	45.24	45.30	54.80	54.10	54.50	55.10	51.80	61.20	26.00
Quarter B	45.80	46.50	52.90	55.60	48.70	50.60	50.10	50.90	44.16	53.50
Quarter C	53.56	46.06	53.60	55.50	56.60	73.20	60.00	58.10	36.90	55.50
Quarter D	52.08	49.83	50.90	55.80	56.40	58.30	51.90	53.70	57.20	63.90
2011 WUL Limit	**20.68**	**20.68**	**20.68**	**20.68**	**20.68**					
2015 WUL Limit						**25**	**25**	**25**	**25**	**25**

Figure 4.21: Graph showing Calcium (Ca) levels for SB24 against 2011 and 2015 WUL limits



Borehole SB24 exceeded calcium WUL limits from 2011 to 2020 in all the monitoring phases.

Table 4.23: Sulphates (SO4) values for SB24 from 2011 to 2020 and limits as per 2011 and 2015 Kendal Power Station WUL.

Borehole SB24: Sulphates (SO4)	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Quarter A	40.39	35.75	42.00	47.30	34.90	40.40	59.40	34.40	53.54	17.10
Quarter B	51.93	40.44	50.10	42.70	30.10	15.30	45.70	43.70	26.40	39.30
Quarter C	60.95	49.76	44.90	41.80	49.50	63.40	50.00	61.00	58.90	52.80
Quarter D	51.19	57.61	46.70	46.30	43.60	39.80	39.60	46.46	55.40	47.00
2011 WUL Limit	**14.85**	**14.85**	**14.85**	**14.85**	**14.85**					
2015 WUL Limit						**30**	**30**	**30**	**30**	**30**

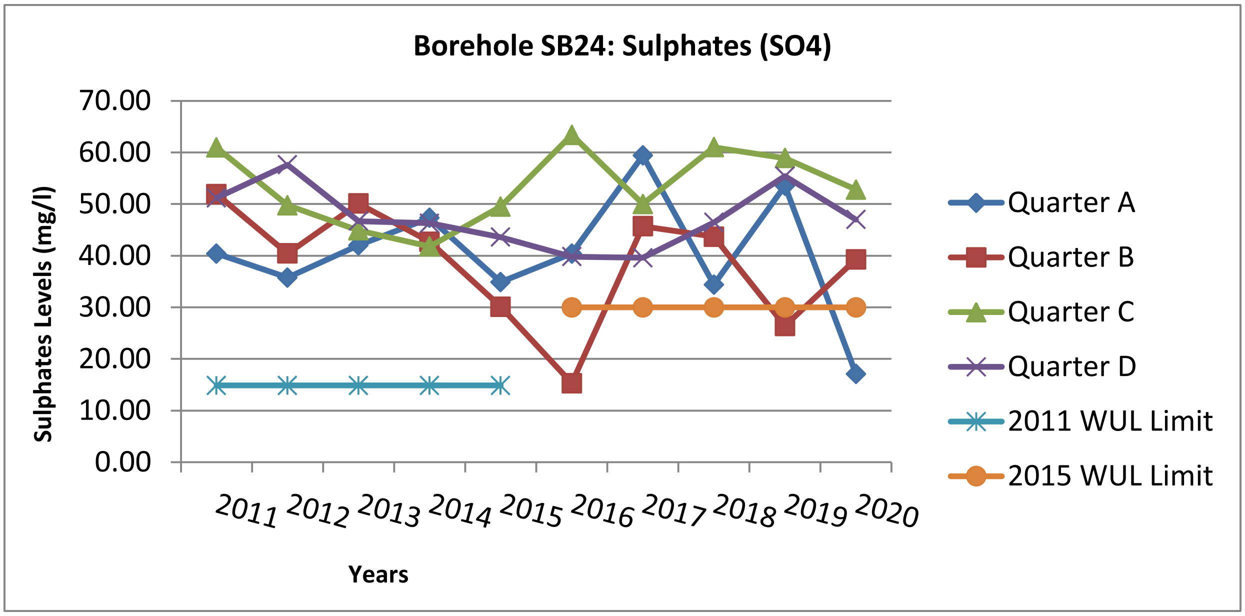


Figure 4.22: Graph showing Sulphates (SO4) levels for SB24 against 2011 and 2015 WUL limits

2011 WUL limit for sulphates is 14.85mg/l and in the 2015 amended WUL the sulphates limit is 30mg/l. In borehole SB24, these the WUL limits were only complied with three times from 2011 to 2020. The monitoring phases where there was compliance are 2016 Quarter B, 2019 Quarter B and 2020 Quarter A.

4.3 Conclusion

From the analysis of the values of variables as selected for this study, there are instances of non-compliance with the WUL limits on some of the boreholes. Records of variables such as Sodium, Calcium and Sulphates show high level of non-compliance. In some instances, electrical conductivity values shows anomalies, however there are clear instances of noncompliance. Non implementation of pollution prevention measures in effluent water management has resulted in failure of Kendal Power Station to comply with water use license limits as observed on tables and graphs above.

The groundwater monitoring results from the four boreholes located in the vicinity of the effluent water dams at Kendal power station indicate clearly that disposal of effluent water prior to reduction or removal of the water pollutants and or disposal of this water into dams which are not lined with adequate impermeable material led to non-compliance due to exceedances on chemical limits parameters as stipulated in the water use license.

Of the four boreholes which are part of this study, PB05, PB06, PB023 and SB24, the borehole which is the most non-compliant with the limits as stipulated in the power station‘s water use license is borehole SB24 which is located in the vicinity of Maturation pond at the sewage plant. For this borehole, there has been non-compliance with the water use licence limits for all the monitoring phases from 2011 to 2020 on Sodium and Calcium. Non-compliance with Electrical Conductivity limits occurred in all monitoring phases except on one. On sulphates limits, there has been exceedance on all monitoring phases except on three phases. pH limits compliances for this borehole is much better with only exceedances on four monitoring phases. It is concluded that borehole SB24 is the most non-complying of all the effluent water groundwater monitoring boreholes over the years.

The second non complying borehole is borehole PB23, used for monitoring groundwater pollution and non-compliance with WUL limits from the Clean water dam. On this borehole, sodium has the highest number of non-compliances, followed by sulphates, electrical conductivity, calcium and pH. This has been unexpected because the Clean water dam contains mostly storm water run-off and water from the stream diversion in to this dam. It must also be noted that overflows from the Emergency water dam which contains dirty effluent from the Dirty dam flows into the Clean water dam. This can also cause pollution of the Clean water dam.

The third non complying borehole is PB06, which is also used for monitoring groundwater pollution from the Clean water dam. Sodium non-compliance with the water use license limits occurred in all the monitoring phases from 2011 to 2020. On this borehole non-compliances with pH limits occurred eleven times. Electrical conductivity and calcium limits were exceeded only two times each and sulphates limits were only exceeded once.

Borehole PB05, located in the vicinity of both the Dirty and Emergency water dam is the most complying borehole. pH and Sodium non-compliance occurred three times each for all the monitoring phases from 2011 to 2020, sulphates non-compliance occurred once and both electrical conductivity and calcium complied with the limits in all the monitoring phases.

One would expect PB05, which is close to both Dirty and Emergency water dam to be the worst non complying borehole when compared to the Clean water dam. However, the location of the boreholes in relation to elevation might also have an influence. Indeed, borehole PB05's elevation is 1600, 06m above sea level whereas the rest of the boreholes in this study are lower.

This study concludes that exceedance of the WUL limits is evident on the ground water monitoring boreholes around the effluent dams including the Clean water dam. This is because the principle of pollution prevention was not implemented during construction phase of the power station where the only equipment which is used to reduce pollution from the effluent water before it flows into the Dirty water dam is the oil skimmer plant which removes only hydrocarbons. There is no other pollution prevention implemented to reduce all the other pollutants for water which flows from the power station to the Dirty water dam except the neutralisation sump which is used to neutralise the pH levels of the water prior to disposal or discharge into the Dirty water dams. Further, during construction phase, pollution control measures such as lining the effluent dams to ensure that seepage does not occur were not implemented. This is a non-compliance as mentioned in the Statutory Safety Inspection and Design Base Review conducted by Hatch Goba Company. (Carvalho: 2014).

In terms of borehole SB24, the borehole with the most instances of non-compliance with the WUL limits, the sewage effluent is treated before it gets discharged into the Maturation pond, where is then pumped to the Dirty water dam, however, as can be seen from this study, these sewage effluent treatment efforts are not effective in avoiding pollution of the underground water resources and exceedance of the WUL limits in the vicinity of the maturation pond.

The table below shows the chemicals which are the scope of this study, arranged from chemical with the highest incidences of non-compliance to the least. As it can be seen, Sodium has the highest incidences of non-compliances, followed by sulphates, electrical conductivity, calcium and the pH.

Table 4.2424: Water Quality Constituents arranged from highest incidences of non-compliance.

Number	Water Quality Constituents
1	Sodium
2	Sulphates
3	Electrical Conductivity
4	Calcium
5	pH

CHAPTER 5: SUMMARY AND RECOMMENDATIONS

5.1 Summary

In South Africa, environmental legislation, in particular pollution prevention has been a requirement for industries to comply with from as far as 1956. All industries such as power generation industries are expected to operate in full compliance with these requirements. The results of this case study indicates that for plants such as power stations to comply with the water use license limits in relation to effluent water management, the principle of pollution prevention must be implemented. The most effective method would be to avoid pollution from occurring in the first place by implementing measures to remove pollutants from effluent water before disposal. In this instance, the three effluent water containment dams together with Clean water dam which mostly contains storm water run-off were built in the early 1980's to early 1990's with the sole purpose of disposing and managing the effluent water for reuse by the power station. This, however, does not prevent the pollution of ground water beneath the effluent water dams as can be seen on the previous chapter.

Obtaining a water use license can be regarded as one of the first steps in complying with what water related environmental legislation requires in South Africa, however it is pivotal to also comply with all the conditions stipulated in such licenses. Power generation facilities such as Kendal Power Station are expected to comply with environmental laws which are applicable for their operations from construction phase, to operational and decommission phases. This is evident from the number of inspections, pre compliance notices, compliances notices and directives issued to the power station by environmental regulatory authorities.

5.2 Recommendations

Based on what has been observed in this study, compliance with groundwater limits for the chemicals variables under this study should be prioritised to avoid potential fines and or criminal charges which might be instituted by the environmental regulatory authorities. The principle of pollution prevention should be applied to avoid pollution of the ground water resources caused by effluent water management activities and water from the Clean water dam. It is imperative for studies to be conducted to determine the cause of non-compliance on boreholes PB23 and PB06 which are used for monitoring potential pollution by the Clean water dam because though the dam belongs to the power station, a river has been diverted into this dam. The results of borehole PB05 which is used to monitor potential pollution from the Dirty dam and Emergency dam do not have as many non-compliances compared to boreholes PB23 and PB06 which are used for monitoring potential pollution from the Clean water dam, however this might be influenced by locality, height and topography of where the boreholes are, which were not extensively investigated by this study. Further scientific studies must be done to determine the cause of this unexpected exceedance of WUL limits and pollution on these two boreholes.

Further, the power station should investigate possible pollution prevention measures together with pollution control measures to be implemented for the protection of the ground water resources and to ensure compliance with the WUL limits.

Based on this study, the number of monitoring boreholes can be increased in the areas where pollution is occurring or where the risk of pollution is high for instance at the Dirty water dam and Emergency water dam vicinity as well as the Maturation Pond area.

Additional studies can be conducted to analyse the impact of the organic and inorganic parameters which were not part of this study, to determine if there is compliance or pollution from the effluent dams including the Clean water dam.

Other pollution prevention measures such as rubber lining and treatment of the dirty water before disposal into the effluent management dams can be implemented.

5.2.1 Guidelines for implementation during construction phase.

It is noted that currently environmental legislation has introduced environmental impact assessment regulations where, prior to construction of specific listed activities in terms of such regulations it is required to that environmental impact assessment studies be conducted. Specific prescribed procedures are to be followed and an environmental authorisation must be obtained prior construction commencement of such projects. However, it is also important for construction managers to involve environmental specialist extensively to identify all environmental requirements including environmental best practices which can be implemented.

Construction activities should be executed with forethought of environmental compliance during operation phase, considering the possible lifespan of the facility being constructed. The managers of the operational phase of Kendal Power Station are faced with this challenge of non-compliance which could have been avoided if pollution prevention measures or at least proper pollution control measures had been implemented during the construction phase.

Environmental conditions stipulated in the environmental authorisation and environmental impact assessment reports, environmental studies together with environmental management plans must be implemented fully without any compromise to enable the operational phase of the project to run smoothly with full compliance to environmental legislation.

In conclusion, Kendal Power Station effluent management dams were constructed between the early 1980's and early 90s. As already highlighted in this study, pollution prevention requirement was already stated as a requirement in the Water Act 54 of 1956. Even if environmental impact assessment regulations and environmental authorisation requirements in terms of NEMA were not yet developed, construction of the power station effluent water management facilities should have implemented pollution prevention measures for operational phase. Further, it is clear that even pollution control measures were not properly implemented to avoid seepage and pollution of ground water, and this, should have, as a last resort been executed to protect ground water resources.

REFERENCE LIST

1. Anderson, B.A., Romani, J.H., Phillips, H., Wentzel, M and Tlabela, K. 2007. Exploring environmental perceptions, behaviours and awareness: water and water pollution in South Africa, *Population and Environment*, 28(3): 133-161, January 2007.

2. Bagtzoglou, A.C., Dougherty, D.E. and Tompson, A. F. B. 1990. Application of particle methods to reliable identification of groundwater pollution sources, *Water Resource Management,* 6:15-23, March 1992.

3. Business Insider South Africa, 04 September 2020. Kendal Power Station in Mpumalanga, Available at: https://www.businessinsider.co.za/ accessed 27 February 2020.

4. Carvalho, E. 2014. Statutory Inspection and Design Base Review, Design Base Review for the Clean Water, Emergency and Dirty Water Dams, South Africa, 23 July 2014.

5. Cillie G.G., Coombs P., and Odendaal P. E. 1979. Water Pollution Research in South Africa, *Water Pollution Control Federation*, 51, (3): 458-466, March 1979.

6. Chiu, S.C., Lin, H.C. and Wang, C.S. 2017. The Impact of Investments in Pollution Reduction on Shareholder Wealth: Evidence from Taiwanese Manufacturing Companies*, Corporate Social Responsibility and Environmental Management,* 24(6): 676-691, December 2017.

7. Daddi, T., De Giacomo, M.R., Testa, F., Frey, M and Iraldo, F. 2013. The Effects of Integrated Pollution Prevention and Control (IPPC) Regulation on Company Management and Competitiveness, *Business Strategy and the Environment,* 23(8): 520-533, 22 August 2013.

8. DEA (Department of Environmental Affairs). (1998), National Environmental Management Act 108. Government Gazette Nr 19519, 27 November 1998. Government Printers: Cape Town.

9. Decker, C.S. and Pope, C.R. 2005. Adherence to environmental law: the strategic complementarities of compliance decisions, *The Quarterly Review of Economics and Finance*, 45(4-50):641–661, September 2005.

10. Department of Agriculture, Rural Development and Land Administration. 2015. *Agri-Hubs Divided by The Province.* {Online}. Available at https://www.dalrrd.gov.za/doaDev/. Accessed on 25 January 2022.

11. Department of Environmental Affairs. 2014. National Guideline for the Discharge of Effluent from Land-based Sources into the Coastal Environment. Pretoria, South Africa. RP101/2014

12. Dlamini, A.E. and Demlie, M. 2020. Integrated hydrogeological, hydrochemical and environmental isotope investigation of the area around the Kusile Power Station, *Journal of African Earth Sciences*, 172 (103958):4-6, 9 August 2020.

13. DWAF (Department of Water Affairs). (1956). Water Act 54 of 1956. Statutes of the Republic of South Africa, 12 June 1956.

14. DWAF (Department of Water Affairs). (1998). National Water Act 36 of 1998. Government Gazette Nr 19182 (Vol 398) 26 August 1998. Government Printers: Pretoria.

15. DWS (Department of Water and Sanitation). (2017). National Norms and Standards for Domestic Water and Sanitation. Government Gazette, Nr. 982, 8 September 2017. Government Printers: Pretoria.

16. Earnhart, D. and Friesen, L. 2017. The Effects of Regulated Facilities' Perceptions about the Effectiveness of Government Interventions on Environmental Compliance, *Ecological Economics*, 142: 282-294, December 2017.

17. Ecolex.org. 2021. ECOLEX | The gateway to environmental law. [online] Available at: https://www.ecolex.org/ [Accessed 20 March 2021].

18. Elleuch, B. Bouhamed, F. Elloussaief, M.and Jaghbir, M. 2018. Environmental sustainability and pollution prevention, *Environ Sci Pollut Res*, 25:18223–18225, 03 July 2018.

19. Earth Science Solutions (Pty) Ltd, 2014. Kendal Continuous Ashing and "E" Disposal Environmental Impact Assessment Project Baseline Soils Specialist Studies, June 2014.

20. Eskom; Kendal Overview Presentation, 2013.

21. Government of South Africa, 1996, The Constitution of the Republic of South Africa, South Africa, National Authorities, ;s22.

22. Government of United States of America; 1990, Environmental Pollution Prevention Act of 1990, Congress of United States of America, United States of America.

23. Gupt, C.B, Kushwaha, A., Prakash, A., and Chandra, A. Goswami, L., Sekharan, S. 2021. *Mitigation Of Groundwater Pollution: Heavy Metal Retention Characteristics of Fly Ash Based Liner Materials*,   Singapore, Springer Nature, [Online], Available at https://link.springer.com/chapter/10.1007/978-981-15-6564-9_5, Accessed on 30 March 2021.

24. Harrington, D.R. 2013. Effectiveness of state pollution prevention programs and policies, *Contemporary Economic Policy*, 31(2): 255-278, April 2013.

25. Harter, T. 2003. Groundwater Quality and Groundwater Pollution, Division of Agriculture and Natural Resources, University of California.

26. Heyes, A. 2000. Implementing Environmental Regulation: Enforcement and Compliance, *Journal of Regulatory Economics*, 17 (2) 107-129, 2000.

27. Holdsworth, D.G. 2012. *Environmental Compliance by Industry*, Elsevier, Peterborough, Canada, 2012.

28. Hu, Z. and Shan, W. 2020. Analysis of the Groundwater Resource Pollution of Coal-Fired Power Plants and Its Impact on Geotechnical Engineering Properties by Numerical Simulation

Technology, IOP Conference Series: *Earth and Environmental Science*, China, 15-16 December 2019, 1-11,Xi'an, IOP Publishing Ltd.

29. Kempe J.O. 1983. Review of Water Pollution Problems and Control Strategies in the South African Mining Industry, *Water, Science and Technology*, 15 (2): 27–58, 1 February 1983.

30. Kidd, M. 1996. Power for the green people? The constitution and the Environment, Indicator SA, 13 (3): 80-83, Winter 1996.

31. Kwame A.D. 2003. Compliance and Enforcement in Environmental Management: A Case of Mining in Ghana, *Environmental Practice*, 5(2): 154-165.

32. Kraemer, R.A., Choudhury, K. and Kampa, E. 2001. *Protecting Water Resources: Pollution Prevention - Thematic Background Paper for the International Conference on Freshwater*, Bonn, 3-7 December 2001. 1-25, Berlin: Ecologic, Institute for International and European Environmental Policy.

33. Legge, K. Fricker, C. and Mnisi, K. 2015. Pollution prevention awareness for Municipal managers in South Africa, *Civil Engineering,* 2015(9):26-31, October 2015.

34. *Map of the Mpumalanga Province indicating water management areas.* [Online]. Available at https://www.researchgate.net/publication. Accessed on 26 January 2022.

35. Maas, S. Schuster,T. and Hartmann, E. 2014. Pollution Prevention and Service Stewardship Strategies in the Third-Party Logistics Industry: Effects on Firm Differentiation and the Moderating Role of Environmental Communication, *Business Strategy and The Environment,* 23(1): 38-55, January 2014.

36. Makhanya, M. (ed). 2016. Dry Ash Dump Facility, Kendal Power Station, pp. 1-145.

37. Mahlangu, M. and Lenkoe-Magagula, K. 2018. Kimopax, *Phase 83 Surface and Groundwater Monitoring,* Eskom, Kendal.

38. McClurg, N. 2021. *Fish Assessment Report*– Kendal Power Station, Eskom Risk and Sustainability Division, Research, Testing and Development, Gauteng, South Africa.

39. Mucina, L. and Rutherford, M.C. (eds) 2006. *The vegetation of South Africa, Lesotho and Swaziland*, Strelitzia 19. South African National Biodiversity Institute, Pretoria.

40. Oke, S.A. and Fourie, F. 2017.Guidelines to groundwater vulnerability mapping for Sub-Saharan Africa, *Groundwater for Sustainable Development*, 5: 168–177, 28 June 2017.

41. On the worldmap.com. (2020) South Africa. [Online] Available at: http://www.ontheworldmap.com. Accessed 20 February 2020.

42. Pather, V. 2000. *Eskom and Water, Proceedings of the 2004 Water Institute of Southern Africa,* Biennial Conference, 2 -6 May 2004, Cape Town, pp.669-664, Document Transformation Technologies.

43. Rutherford, M.C., Mucina, L. and Powrie, L.W. 2006, *Biomes and Bioregions of Southern Africa,* pp.32-50, Strelitzia 19.

44. SA Places. (2020). Map of the Mpumalanga. SA Places. [Online] Available at: https://www.places.co.za/html/mpumalanga_map.html Accessed on 10 July 2020.

45. Sakala, E. Fourie, F. Gomo, M., Coetzee, H. 2017. *GIS-based groundwater vulnerability modelling: A case study of the Witbank*, Ermelo and Highveld Coalfields in South Africa, Journal of African Earth Sciences, 137, 46-60, 12 September 2017

46. Sam, A.G. 2009. Impact of government-sponsored pollution prevention practices on environmental compliance and enforcement: evidence from a sample of US manufacturing facilities, *Journal of Regulatory Economics*, J Regul Econ, 37: 266–286.

47. Schoeman Law INC (n.d.); Environmental Right in Terms of the Constitution. [Online] Available at: http//www.polity.org.za. Accessed on 17 February 2020.

48. Shimshack, J.P. and. Ward, M. B. 2005. Regulator reputation, enforcement, and Environmental Compliance, *Journal of Environmental Economics and Management,* 50(3):519–540, November 2005.

49. Weatherbase. 2020. Travel Weather Averages (Weatherbase). [online] Available at: https://www.weatherbase.com/ [Accessed 16 May 2020].

50. www.dictionary.com. 2021. Definition of ground water | Dictionary.com. [online] Available at: https://www.dictionary.com/browse/groundwater [Accessed 16 May 2021].

51. USA Congress. (1990) Pollution Prevention Act of 1990. Environmental Protection Agency, USA. Available at: https://www.epa.gov/p2/pollution-prevention-act-1990. Accessed on 26 February 2020)

52. van Niekerk, L.J and D.Moolman, D. 2012. Geo- Hydro Technologies, Kendal Power Station, Routine Monitoring Phase 59, Report Number: RVN 601.13/1313.

53. van Niekerk, L.J and D.Moolman, D. 2014. Geo- Hydro Technologies, Kendal Power Station, Routine Monitoring Phase 69, Report Number: RVN 716.2/1547. (Not referenced in the text.)54. Wetland Consulting Services Pty (Ltd), 2014, Wetland Delineation & Impact Assessment for the Kendal Power Station Continuous Ash Disposal Facility, 2014.

54. Witbank, South Africa, http://www.weatherbase.com/weather/weather, Accessed on 23 Jan 2021.