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Principy post-projektového hodnocení v rámci analýzy impaktů

Jana Zítková

Disertační práce

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Jana Zítková

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Abstrakt

S rozvojem lidské společnosti bezpochyby souvisí přizpůsobování si životního prostředí svým potřebám. V dnešní době, kdy životní prostředí čelí nejrůznějším negativním impaktům je více než důležité jim věnovat pozornost a využívat veškeré environmentální nástroje k jejich možné analýze, hodnocení, pochopení, k jejich zabránění či alespoň minimalizaci. Realizované projekty, postupy či technologie aj. mohou generovat negativní či pozitivní environmentální dopad, jehož identifikace a zhodnocení akceptovatelnosti je předmětem povolovacích procesů, avšak tyto predikce jsou zatíženy určitou nepřesností spojenou s neočekávanými podmínkami, nestandartními situacemi, chybnou aplikací nejrůznějších analýz apod. Post-projektová hodnocení hrají důležitou roli v široké škále environmentálních aplikací. Post-projektové hodnocení je vhodným nástrojem na zjištění reálné míry těchto dopadů, materiálně vzato skutečného užitku ve prospěch zlepšování stavu životního prostředí čili zajištění zpětné vazby, kterou je možné použít pro optimalizaci postupů do budoucna. Cílem této disertační práce je identifikace významnosti a ověření přínosu post-projektového hodnocení, jako nástroje ke zlepšení efektivnosti rozhodovacích procesů v oblasti ochrany životního prostředí. Konkrétně se tato práce zabývá: 1) zhodnocením impaktu chemické zimní údržby komunikací, a to s využitím asimilačních orgánů smrku ztepilého (*Picea abies*) a borovice lesní (*Pinus sylvestris*), jako vhodných indikátorů k zasolení; 2) identifikací a zhodnocením impaktů rozvoje rezidenční výstavby v příměstském prostoru se zaměřením na významné vlivy projektu na životní prostředí a veřejné zdraví; 3) zhodnocením typové a početní variability projektů, které byly zahrnuty do procesu posuzování vlivů na životní prostředí. Na základě výsledků všech zahrnutých studií bylo navrženo jejich praktické využití. Výsledky hodnocení chemické zimní údržby lze využít pro budoucí posouzení stupně kontaminace prostředí kolem komunikací. Analýzou impaktů rezidenčního projektu jsme získali výsledky o jeho reálných dopadech a potvrdili nutnost je posuzovat v kontextu kumulace s ostatními vlivy. Závěry studie typové a početní variability projektů nám poskytly důležitou informaci, na které typy projektů je vhodné se zaměřit při potenciální aplikaci post-projektové analýzy. Vzhledem k neúplné přesnosti předpovědí impaktů na životní prostředí je nutné je zpětně analyzovat, stejně tak jako environmentální postupy užívané k ochraně životního prostředí. Závěry a výsledky práce ukázaly nezbytnost provádění post-projektových hodnocení a poskytly validní zpětnou vazbu, kterou je možné využít ke zlepšení efektivnosti nástrojů ochrany životního prostředí. Budoucí výzkum by se měl zaměřit na ověření výsledků hodnocení a analýz v jiných oblastech, za využití dalších možných indikátorů, na jiných projektech a se zaměřením na takové typy, které představují významné efekty na životní prostředí.

Klíčová slova: ex post evaluace; EIA follow up; PPA; životní prostředí; monitoring

Abstract

The development of human society is undoubtedly linked to the adaptation of the environment to its needs. Nowadays, when the environment faces various negative impacts, it is more than important to pay attention to them and use all environmental tools to analyse, evaluate, understand, prevent, minimize, or at least compensate them. Implemented projects, processes, or technologies, etc. may generate negative or positive environmental impacts, the identification and assessment of which is subject to permitting processes, but these predictions are hampered by certain inaccuracies associated with unexpected conditions, non-standard situations, incorrect application of various analyses, etc. Post-project evaluations play an important role in a wide range of environmental applications. Post-project analysis is a useful tool to determine the real extent of these impacts, materially speaking the actual benefits in terms of environmental improvement or providing feedback that can be used to optimise practices in the future. The aim of this dissertation is to identify the relevance and validate the benefits of post-project evaluation as a tool to improve the effectiveness of environmental decision-making processes. Specifically, this dissertation addresses: 1) assessing the impact of chemical winter maintenance of roads, using the assimilative organs of Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*) as suitable indicators for salinization; 2) identifying and assessing the impacts of residential development in a suburban area, focusing on the significant environmental and public health impacts of the project; and 3) assessing the type and number of project variation included in the environmental impact assessment process. Based on the results of all included studies, their practical application was proposed. The results of the chemical winter maintenance assessment can be used for future assessment of the level of environmental contamination around roads. By analysing the impacts of the residency project, we obtained results about its real impacts and confirmed the need to assess them in the context of cumulative with other impacts. The findings of the project type and number variability study provided us with important information on which project types to focus on in the potential application of post-project analysis. Given the incomplete accuracy of predictions of environmental impacts, it is necessary to analyse them retrospectively, as well as the environmental practices used to protect the environment. The conclusions and results of the paper have shown the necessity of conducting post-project evaluations and provided valid feedback that can be used to improve the effectiveness of environmental protection tools. Future research should focus on validating the results of the evaluations and analyses in other areas, using other possible indicators, on other projects, and focusing on the types of projects that present significant environmental effects.

Keywords: ex post evaluation; EIA follow up; PPA; environment; monitoring

Obsah

Část I

Úvod a teorie

Kapitola 1

Předmluva a struktura práce

1.1 Předmluva

Člověk začal životní prostředí ovlivňovat již od doby, kdy se věnoval sběru a lovu. Od té doby však došlo ke značnému rozvoji. Demografický růst společně s ekonomickým vývojem a rozvojem technologií začaly způsobovat intenzivnější negativní impakty na životní prostředí. S tím souvisela implementace politik životního prostředí do legislativ států napříč celého světa. Antropogenní vlivy bylo nutné řešit, a tak začali vznikat environmentální nástroje k řízení těchto impaktů. Jedním z takových nástrojů je post-projektová analýza, která hraje důležitou roli v široké řadě environmentálních aplikací a je významným nástrojem k získání zpětné vazby. V této disertační práci jsou pomocí post-projektové analýzy hodnoceny významné impakty na životní prostředí a také účinnost postupů, které mají za cíl environmentální ochranu.

1.2 Struktura práce

Tato disertační práce je předkládána jako soubor čtyř publikovaných studií a rozdělena do dvou částí a osmi kapitol. **Část I** obsahuje úvod a obecné uvedení do teorie post-projektového hodnocení a analýzy impaktů. **Část II** se skládá z jednotlivých publikovaných studií:

- **Studie I:** Bioindication of road salting impact on Norway spruce (*Picea abies*).

- **Studie II:** Impact of road salting on Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*).

- **Studie III:** Applying principles of EIA Post-project analysis in the context of suburban infrastructure development.

- **Studie IV:** Environmental Impact Assessment – the range of activities covered and the potential of linking to post-project auditing.

Kapitola 2

Cíle disertace

Rámcovým cílem disertační práce je identifikace významnosti a ověření přínosu post-projektového hodnocení v rámci analýzy impaktů, jako nástroje ke zlepšení efektivnosti rozhodovacích procesů v oblasti ochrany životního prostředí.

Dílčí cíle odpovídají jednotlivým částem metodického řešení a současně i zaměření jednotlivých studií. Cíle studií jsou tematicky zaměřené na:

1. zhodnocení impaktu zimní údržby komunikací;
2. identifikaci a zhodnocení impaktů rozvoje rezidenční výstavby v příměstském prostoru;
3. zhodnocení typové a početní variability projektů zahrnutých do procesu posuzování vlivů na životní prostředí.

Kapitola 3

Teorie

3.1 Úvod

Změny životního prostředí souvisely s klimatickými výkyvy či geologickými silami a měly i zásadní vliv na vývoj člověka a celé lidské populace a postupné osidlovaní Země. Lidé se vždy přizpůsobovali změnám prostředí, reagovali na změny a také se snažili přírodní prostředí aktivně využívat, měnit a později ho i přetvářet k svým potřebám. Demografický růst a ekonomický vývoj vyvolával změny v prostředí, které pak měly zpětný efekt na lidskou společnost. Vztahy mezi lidskou společností a životním prostředím byly vždy oboustranné.

Člověk životní prostředí začal ovlivňovat již od doby, kdy se věnoval sběru a lovu. K intenzivnějším vlivům pak docházelo se zemědělskou revolucí, rozvojem kulturní krajiny, kde se střídaly ekosystémy ovlivněné nebo přímo zakládané člověkem, dále pak s rozvojem výroby a průmyslovou revolucí. Ke změnám životního prostředí přispíval i zrychlující se proces urbanizace, nároky na přesun zboží a lidí a s tím související i rozvoj dopravy a infrastrukturních staveb. To společně s růstem populace, rozvojem technologií a ekonomickým vývojem začalo způsobovat intenzivnější negativní projevy na životním prostředí a jeho složkách. Dopadů na životní prostředí je široká škála a díky provázanosti jednotlivých složek se navzájem ovlivňují. Mezi impakty způsobené výstavbou ať už rezidenční, nebo třeba průmyslovou či infrastrukturní můžeme zařadit samotnou ztrátu ekosystémů, nebo jejich zmenšování, fragmentaci krajiny, ovlivnění vodního režimu, znečišťování vody, půdy, ovzduší, zvyšování akustického tlaku, světelné znečištění, změny chemismu zejména u půdy či vody a mnoho dalších.

Ve snaze předcházet, zabránit či alespoň minimalizovat vzrůstající impakty výstavby na životní prostředí se začali vlivy měřit a analyzovat pro zjištění jejich rizikovosti či akceptovatelnosti, stanovení limitních hodnot, identifikace kumulativních efektů a v neposlední řadě zajištění způsobu jejich hodnocení a omezení v budoucnosti. Vznikaly metodiky, předpisy, odborné expertní analýzy k měření a hodnocení těchto impaktů. K významnému vývoji přispělo i začleňování environmentálních politik a implementace analýzy a posuzování impaktů jak do mezinárodní legislativy, tak i do právních systémů jednotlivých zemí a mezinárodní spolupráce v environmentální oblasti.

Analýzy antropogenních impaktů a jejich hodnocení se tak stávají nezbytným environmentálním nástrojem, který nám poskytuje důležitá data a informace na jejichž základě lze rozvíjet, upravovat a zlepšovat řízení ochrany životního prostředí.

3.2 Posuzování vlivů na životní prostředí

Posuzování vlivů na životní prostředí je jedním z důležitých environmentálních nástrojů (Wood 2003; Pölönen et al., 2010), který představuje komplexní proces, jež zkoumá důsledky připravovaných záměrů (staveb, činností a technologií) (EIA – Environmental Impact Assessment) a koncepcí (strategií, politik, programů a plánů) (SEA – Strategic Environmental Assessment) na životní prostředí s cílem zmírnit jejich nepříznivé vlivy (Baker, Wood 1999; Říha 2001). Účelem procesu je získat objektivní odborný podklad pro vydání rozhodnutí, popřípadě opatření podle zvláštních právních předpisů, a přispět tak k udržitelnému rozvoji společnosti (zákon 100/2001, Sb.).

3.2.1 Historie a vývoj posuzování vlivů na životní prostředí

Posuzování vlivů na životní prostředí bylo poprvé formálně přijato jako součást zákona NEPA (National Environmental Policy Act) v roce 1969 ve Spojených státech amerických (Hughes 1975; Wood 2003) a postupně se stalo požadavkem po celém světě (Bond et al. 2020). Do této doby byla pro každou jednotlivou složku životního prostředí (půda, voda, ovzduší atd.) speciální právní úprava z hlediska její ochrany, respektive předcházení rizikům plynoucím z uspokojování potřeb společnosti. Přínos tohoto konceptu spočíval v zavedení interdisciplinární (holistické) ochrany životního prostředí a umožnění vstupu veřejnosti do procesu a zapojení do rozhodování (O'Faircheallaigh 2007). Na přelomu 70. a 80. let docházelo k rozvoji procesu na lokální a regionální úrovni, vznikali první metodické příručky, návrhy na zmírňující opatření a monitoring, docházelo k hodnocení kumulativního impaktu či rozvoji mezistátního posuzování (Senner 2004).

V členských státech Evropské unie byla EIA představena v červenci roku 1988 v návaznosti na schválení směrnice Evropské rady 85/337/EHS (Commission of the European Communities 1985; Lee 1995). Směrnice požadovala, aby veškeré projekty uvedené v příloze č. I byly podrobeny procesu EIA. To také vyžadovalo, aby členské státy přijaly kritéria a prahové hodnoty, které určují, zda projekty v příloze č. II by měly být posuzovány či nikoli (Baker, Wood 1999). Směrnice specifikuje informace, které musí být oznamovatelem poskytnuty ve formě prohlášení o dopadu na životní prostředí (EIS – Environmental Impact Statement) a zakazuje příslušnému orgánu rozhodování před konzultací a účasti veřejnosti (Wood 2003). Proces posuzování vlivů na životní prostředí má v Evropě podobu rámcového zákona, který umožňuje členským státům určitou míru volnosti při implementaci směrnice (Lee 1995). Účinnost je pak do značné míry závislá na způsobu, kterým je tato volnost použitá. Proto je potřebné výkonost procesu porovnat na úrovni členských států (Baker, Wood 1999).

Koncem osmdesátých let došlo k přijetí EIA posuzování i nadnárodními organizacemi. Směrnici o EIA implementuje i Světová banka, kde se pro přijetí úvěru stává podmínkou souhlasné stanovisko z EIA procesu (Bond, Wathern 1999).

Ve Spojených státech amerických a v mnoha dalších zemích, včetně rozvojových, posuzování vlivů na životní prostředí neboli EIA je vedeno jako součást plánování iniciativ veřejného či soukromého sektoru, které by mohly mít vliv na životní prostředí (Caldwell 1996). Technickým základem procesu je predikce změn či dopadu u vybraných fyzikálně-chemických, biologických, kulturních a socioekonomických aspektů životního prostředí, které by mohly vyplývat z implementace navrhovaných aktivit (Clark, Canter 1997).

Evropská směrnice EIA byla prvním proniknutím Evropské Unie do oblasti plánování. Je to nástroj, který přispívá k environmentálnímu povědomí a k povědomí o ochraně životního prostředí tím, že požaduje generování *Ex-ante* informací o možných impaktech z veřejných či soukromých iniciativ na životní prostředí před samotným schválením těchto iniciativ (Wood 2003). Pro členské státy má směrnice značný vliv na postupy v rozhodovacím procesu. EIA může být považována za správní nástroj, neboť zavádí pravidla a přiřazuje úlohy a odpovědnosti jednotlivým aktérům procesu (Arts et al. 2012). EIA proces si klade za cíl vést chování aktérů směrem k větší informovanosti o životním prostředí, což vede k začlenění environmentálních hodnot do navrhovaných projektů a plánů. Když bylo posuzování vlivů na životní prostředí zavedeno, byla to inovace v oblasti environmentální správy (Caldwell 1982; Taylor 1984; Morrison-Saunders, Arts 2004a; Kidd, Fischer 2007; Richardson, Cashmore 2011). To je spojeno s různými mechanismy řízení, vložených do tohoto procesu, zahrnující formální požadavky na poskytnutí informací o životním prostředí pro projektové alternativy před finálním rozhodnutím, odpovědnost navrhovatele připravit zprávu EIA, oficiální účast veřejnosti a požadavek na následné provedení monitoringu, opatření či post-projektové hodnocení (Arts et al. 2012).

Proces EIA si klade za cíl zmírnit vlivy na životní prostředí, které by mohly mít negativní dopad (Baker, Wood 1999; Říha 2001). Tyto negativní impakty je možné do jisté míry předvídat na základě závěrů různých odborných studií, dílčích expertíz a analýz či odborných posudků, které jsou nedílnou součástí procesu posuzování vlivů na životní prostředí (Arts et al. 2001). Na základě těchto všech výsledků a posouzení se rozhoduje o povolování daných iniciativ. V konečném důsledku se však jedná o predikce, které jsou zatíženy určitou nepřesností spojenou s neočekávanými podmínkami, jejich změnami, nestandartními situacemi, chybovostí, nesprávnou aplikací nejrůznějších analýz apod. Pro postupné vylepšování předpovědí, prediktivní a selektivní síly celého procesu posuzování vlivů na životní prostředí je nutné realizovat post-projektové analýzy k porovnání predikovaných a reálných vlivů či zjištění jiných neočekávaných impaktů (Braniš, Christpoulos 2004; O'Faircheallaigh 2007).

3.3 Evaluace

Na základě již publikovaných studií (Meijer, Vliet 2000; Arts et al. 2001; Macharia 2005) lze post-projektovou analýzu charakterizovat jako proces, díky němuž je realizováno kontrolování reálných dopadů projektu (staveb, činností, technologií), ověřování účinnosti mitigačních opatření, posuzování vhodnosti navržených řešení, či stanovování celkové efektivnosti posuzovaného projektu. Tyto zmíněné procesy lze obecně shrnout jako hodnocení, tedy evaluaci. Rovněž Morrison-Saunders, Arts (2004a) uvádí, že evaluace je vedle monitoringu, managementu a komunikace jednou z nejdůležitějších částí post-projektové analýzy.

Cíle hodnocení a post-projektové analýzy se do určité míry překrývají. Proto, se následující část zabývá charakteristikou evaluací a uvádí, co evaluace je, co je jejím předmětem a proč je důležité evaluace provádět.

Klíčovou otázkou u jakéhokoliv projektu, procesu či postupu je zjistit, zda bylo jeho realizací dosaženo adekvátních výsledků dle předem navržených a schválených scénářů. Bez provedení hodnocení není možné určit, zda a v jaké míře byly predikované cíle splněny. Evaluace nám tedy poskytuje zpětnou vazbu o reálných dopadech a také přináší poučení o faktorech, které vedly k úspěšnému, či neúspěšnému naplnění stanovených cílů. Zkušenosti získané z evaluace mohou vést ke zlepšení budoucích projektů.

Monitoring a evaluace jsou do značné míry propojené. V rámci monitoringu jsou sledovány klíčové indikátory a cíle, které mají být prostřednictvím projektu naplněny. Evaluace pro hodnocení projektu využívá právě informace získané z monitoringu a snaží se identifikovat faktory, které byly pro formaci hodnot z monitoringu rozhodující. Z důvodu této provázanosti sdružuje Khandker et al. (2009), monitoring a evaluaci do společného kroku.

Boulemis, Dutwin (2005) definují evaluaci jako systematický proces sběru a analýzy dat s cílem determinovat, zda a na jaké úrovni bylo, nebo právě je dosahováno cílů. Z této definice je patrné, že Boulmetis, Dutwin (2005) vidí hlavní účel evaluace v ověření naplňování definovaných cílů. Nicméně je vhodné uvést, že kromě důrazu na posuzování výsledků evaluace zahrnuje také analýzu potřeby a dopadů hodnocené aktivity. Tyto aspekty evaluace jsou uvedeny v komplexní definici, kterou poskytuje OECD (1991): „Evaluace je objektivní a systematické hodnocení momentálně připravovaného, probíhajícího, nebo ukončeného záměru, programu, či politiky. Hodnocení může být zaměřeno na koncepční úroveň, na průběh implementace či na samotné výsledky hodnocených aktivit.“ Cílem evaluace dle OECD je určení významnosti cílů a zhodnocení jejich naplnění s ohledem na efektivnost, impakty a udržitelnost. Evaluace by také měla poskytnout objektivní a užitečné informace umožňující začlenění získaných poznatků do rozhodovacího procesu, na což také upozorňuje Patton (1982).

Evaluace je v různých podobách využívána v mnohých oblastech lidské činnosti. Hodnoceny mohou být strategie, politiky, plány, programy různého charakteru, či konkrétní projekty, činnosti a technologie. Evaluaci podléhají nejrůznější subjekty a jevy, jako např. fungování a činnost veřejných institucí, veřejné služby, politiky, výukové programy, rozvojové programy, aj.

3.3.1 Druhy evaluací

Z definice evaluace dle OECD (1991) je patrné, že evaluace může být realizována jak na strategické, tak na projektové úrovni. Projektová úroveň může mít dle Partidário, Clarka (2000) určité nedostatky. Evaluace na projektové úrovni má možnost ovlivnit rozhodování jen prostřednictvím změny postupů, či zvolené technologie, v rámci hodnoceného projektu. Lze říci, že hodnocení na projektové úrovni nevede k významné změně konceptu projektu. Na tento nedostatek reaguje evaluace na strategické úrovni, která poskytuje možnost konceptuální změny, pokud je daný záměr v rozporu s environmentálními zájmy.

Vedle úrovně, na které se evaluace provádí, můžeme dále rozlišit režim evaluace. Dle časového hlediska rozlišujeme evaluaci předběžnou (Ex-ante), průběžnou (Interim) a následnou (Ex-post). Toto členění je obecně platné a je uvedeno např. v nařízení Rady (ES) č. 1083/2006.

Ex-ante evaluace se provádí před implementací projektu. Napomáhá optimalizovat připravovaný projekt a do určité míry předpovídá a hodnotí možné impakty daného projektu. Interim evaluace se provádí v průběhu realizace projektu. Jejím účelem je reagovat na případné aktuální odchylky a změny od predikovaného scénáře, či na jiné problémy, vzniklé během implementace. Informace o případných problémech získává interim evaluace z průběžného monitoringu. Ex-post evaluace se provádí po ukončení projektu, jejímž cílem je, na základě shromážděných dat z průběhu celého procesu, vyhodnotit skutečné dopady projektu.

Ravallion (2008) uvádí, že by se oba přístupy (Ex-ante a Ex-post) měly kombinovat. Kombinace obou přístupů umožní porovnání reálné hodnoty zkoumaného jevu s jeho předpovědí, která byla uvedena v ex-ante hodnocení. Dalším důvodem, proč by měly být výše uvedené evaluace propojené je skutečnost, že Ex-ante analýza může čerpat ze zkušeností získaných z dříve realizovaných ex-post analýz (pokud se jedná o projekt podobného charakteru).

Post-projektová analýza je pojem, který Morrison-Saunders et al. (2007) definují, jako proces monitorování a hodnocení dopadu projektu, nebo plánu pro účely managementu v oblasti životního prostředí. Post-projektová analýza představuje monitoring a hodnocení dopadu projektů na životní prostředí po jejich realizaci. Dále uvádí, že tento proces zahrnuje návrh dodatečných plánů a zmírňujících opatření, prováděných za účelem dosažení souladu mezi cíli projektu a prioritami ochrany životního prostředí.

Hlavními součástmi post-projektové analýzy jsou dle Morrison-Saunderse, Artse (2004a):

- Monitoring, který je prováděn s cílem ověřit, zda jsou realizované aktivity v souladu s podmínkami, které byly stanoveny před realizací a zda jsou dopady projektu v rozmezí, které bylo predikováno.
- Evaluace, která je prováděna pro účely porovnání skutečných dopadů projektu s predikcemi a se závaznými standardy platných právních předpisů. Evaluace dokumentuje skutečné výsledky projektu a umožňuje získat ponaučení z nových poznatků, které je možno využít pro zlepšení budoucích návrhů projektů.
- Management, který operativně řeší nepředvídané a nepředpokládané dopady.

3.4 Vlivy liniových staveb na životní prostředí

Liniové stavby se vyznačují schopností vytvářet propojené sítě, které umožňují velké toky osob a zboží mezi regiony a v regionech samotných po železničních, dálničních a silničních infrastrukturách (Antonson et al. 2010). Pro efektivní fungování společnosti jsou funkční a bezpečné dopravní stavby nezbytné (Broniewicz, Ogrodnik 2020; Ongkowijoyo et al. 2020). Na mnoha místech evropských států dochází k masivnímu rozvoji dopravní infrastruktury, která způsobuje vážné vlivy zejména na složky životního prostředí a na život, komfort a veřejné zdraví obyvatel (Tzoulas et al. 2007).

Plánování, výstavba a provoz dopravní infrastruktury jsou spojeny s mnoha negativními vlivy (Broniewicz, Ogrodnik 2020). Dopravní infrastruktura způsobuje změny takřka ve všech složkách životního prostředí jako je například ztráta vlastních ekosystémů, fragmentace krajiny a změny krajinného rázu, emise hluku a vibrací či chemických polutantů do ovzduší, poruchy a změny kvality ekosystémů nebo změny v pedologických a hydrologických procesech (Rescia et al. 2006; Broniewicz, Ogrodnik 2020).

Doprava a k ní náležící dopravní infrastruktura ovlivňuje podobu a kvalitu ekosystémů (Roger et al. 2011; Rhodes et al. 2014; Keken et al. 2016; Bíl et al. 2019) i lidské zdraví (Trombulak, Frissell 2000; Wei et al. 2014; Kušta et al. 2017). Ekosystémy v okolí dopravních staveb mohou být ovlivňovány v řádech jednotek až tisíců metrů (Keken et al. 2019). Míru konečného ovlivnění definuje jak typ polutantu (Zítková et al. 2018), tak i struktura okolních biotopů (Kušta et al. 2014; Keken, Kušta 2017) či druh receptoru, na který daný polutant působí.

3.4.1 Chemická zimní údržba

Doprava je nezbytná pro kohokoli a rychlý nárůst infrastrukturní sítě přináší mnoho významných environmentálních dopadů na životní prostředí (Rescia et al. 2006). V dnešní době je silniční doprava velmi intenzivní a je velmi důležité zajistit její bezpečný, spolehlivý a plynulý provoz. V zimním období je údržba a zajišťování bezpečné dopravy mnohem náročnější vzhledem k odstraňování námrazy, ledu a napadlého sněhu (Fostad, Pedersen 2000; Hofman et al. 2012).

V Evropě začal významný nárůst silniční dopravy počátkem 60. let 20. století (Fischel 2001), tou dobou začala i cílená zimní údržba silniční infrastruktury. K zimní údržbě se začaly používat posypové materiály inertního charakteru, jako je písek, ale i chemické směsi, jejichž složení je na bázi chloridů (Cain et al. 2001; Hofman et al. 2012).

V České republice je údržba komunikací upravena zákonem č. 13/1997 Sb., o pozemních komunikacích a vyhláškou č. 104/1997 Sb., kterou se provádí zákon o pozemních komunikacích. Tyto právní předpisy stanovují základní podmínky pro plány zimní údržby. Plány zimní údržby stanovují a popisují přesně realizaci zimní údržby, použité technologie a posypové materiály.

Existuje také zákon č. 114/1992 Sb., který upravuje aplikaci chemických posypových materiálů pro zimní údržbu silnic formou zákazu aplikace chemických posypů na komunikace v národních parcích a chráněných krajinných oblastech dle §16 a §26. Zde je tedy v neshodě chemická zimní údržba silnic a ochrana zvláště chráněných území, vzhledem k tomu, že i v těchto oblastech se nachází komunikace, které je nutné v zimních měsících chemicky ošetřit. Tato vzájemná konfrontace je regulována §43 o výjimkách ze zákazů ve zvláště chráněných územích. Pro tento účel, tedy může být udělena výjimka ze zákazu ve zvláště chráněných územích (dle §43) v případě, kdy jiný veřejný zájem výrazně převažuje nad zájmem ochrany přírody. Součástí výjimky jsou také podmínky pro zmírnění negativního vlivu chemické údržby na životní prostředí, např. aplikace musí být realizována moderní technologií, která umožňuje přesné dávkování soli, regulaci dávkování a minimalizaci posypového materiálu, chemicky ošetřený sníh nesmí být ukládán v blízkosti nebo přímo do místních vodotečí apod. (AOPK 2015).

Chemické rozmrazovací materiály díky svým fyzikálním vlastnostem mají schopnost snížit bod mrazu vody pod 0 °C a tím v podstatě zabránit vytvoření ledu nebo zajistit tání sněhu či ledu na silnicích, který se již vytvořil (Melcher 2001; MD 2015). Pro tyto účely lze používat např. $NaCl$ (chlorid sodný), $CaCl_2$ (chlorid vápenatý) nebo směsi obou chloridů. Tyto látky se používají ve formě posypu, postřiku nebo jako zvlhčovaná neboli zkrápěná sůl (MD 2015).

NaCl je nejčastěji používaným rozmrazovacím činidlem díky jeho dostupnosti, nízké ceně, snadnému skladování a manipulaci. I přes jeho evidentní výhody při zajišťování bezpečné dopravy, má také mnoho negativních účinků, týkající se zejména zvýšené hladiny chloridových a sodných iontů rozplavovaných do okolního prostředí komunikací (Hofman et al. 2012).

3.4.2 Vliv NaCl na prostředí a dřeviny

Mnoho studií ukázalo negativní účinky polutantů generovaných dopravou na životní prostředí včetně přípravků k chemické zimní údržbě silnic (Ramakrishna, Viraraghavan 2005). NaCl se stal nejčastěji používaným posypovým materiálem pro zimní údržbu silnic. NaCl aplikovaný na vozovku je mobilizován tajícím ledem, sněhem nebo dešťovými srážkami a poté vstupuje do půdního a horninového prostředí, do povrchových a také podzemních vod (Howard et al. 1993).

Dle Lundmark, Olofsson (2007) a Cunningham et al. (2008) alespoň 90 % z celkového ukládání Na^+ a Cl^- v půdě se vyskytuje do vzdálenosti 20 metrů od komunikací. Tyto soli se často používají k odmrazování silnic, chodníků a veřejných prostranství. V životním prostředí se soli postupně kumulují a ovlivňují kvalitu vody (Godwin et al. 2003), strukturu a vitalitu vodních ekosystémů (Sanzo, Hecnar 2006), kvalitu půdy (Dai et al. 2012; Ordonez-Barona et al. 2018), mikroorganismy a houbové organismy (Calvo-Polanco et al. 2008; Yi et al. 2008; Day et al. 2010) i strukturu a vitalitu okolních biotopů (Langen, Prutzman 2006; Collins, Russell 2009; Hanslin 2011; Sienkiewicz-Paderewska et al. 2017).

Použité rozmrazovací soli, které se hromadí v půdě, mohou dále prosakovat do podzemních vod. Množství solí, které se dostanou do podzemních vod je závislé na propustnosti půd. Oproti povrchovým vodám (Maxe 2001) mají podzemní vody menší možnost ředění prosáknutého solného roztoku, proto jsou podzemní vody více ohroženy než povrchové (Serrano, Gaxiola 1994; Lundmark, Olofsson 2007). Dochází tak ke kontaminaci vodních zásob, což mění charakteristiku vody určené k pití (slaná chuť). Dále mohou soli zvýšit tvrdost, zásaditost a obsah celkových rozpuštěných látek ve vodě (Scholz, Grabowiecki 2007; Szota et al. 2015; Søberg et al. 2016).

Půda je normálně schopná účinně předcházet jejímu zhutňování (Page et al. 2015; Bühler et al. 2017), postupy chemické zimní údržby jako je pravidelná aplikace solí však mění chemismus půd, což může vést ke změně schopnosti půdy vytvářet podmínky pro úspěšný růst stromů (Ordonez-Barona et al. 2018) a k ovlivnění jejich kondice (Cekstere et al. 2008; Equiza et al. 2017; Ordonez-Barona et al. 2018). Expozice stromů solným roztokům může způsobit poškození listů, jehličí, pupenů či kořenového systému. Zvýšená salinita tak může ovlivňovat jak růst kořenových systémů, tak i jejich funkci (Neumann 1995; Hanslin 2011) a významně ovlivňovat prosperitu či životaschopnost jednotlivých stromů (Paludan-Müller et al. 2002; Graves, Gallagher 2003; Jonsson 2006).

3.4.3 Indikace a hodnocení vlivu chemické zimní údržby

Části stromů jsou široce využívány v biomonitoringu jako spolehlivé a nákladově efektivní bioindikátory znečištění životního prostředí, protože akumulují širokou škálu znečišťujících látek z ovzduší, vody či půdy a odrážejí tak účinky stávajícího znečištění prostředí (Tarricone et al. 2015; Fasani et al. 2016; Kargar et al. 2017).

Jedním z nejsnadněji zjistitelných účinků použití rozmrazovacích solí na komunikace je zhoršení zdravotního stavu vegetace v jejich okolním prostředí. Vegetace podél silnic se tak stává významným ukazatelem, který může poukazovat na vysokou míru aplikace solných posypových materiálů (Langen, Prutzman 2006).

Projevem poškození vegetace kolem komunikací mohou být např. usychání a nekróza jehlic a listů, vadnutí, žloutnutí listů, snížení růstu a velikosti listů, zpomalený růst, nekrotizace kořenového systému, životaschopnost semen může být snížena a jejich klíčení může být zpožděno (Langen, Prutzman 2006). Soli v půdním prostředí mohou snížit příjem vody dřevinou a její transpiraci, což může vést k redukci fotosyntézy a následně také ke snížení výšky a tloušťky stromu (Kayama et al. 2003). U jehličnanů je možné pozorovat zrudnutí nebo zhnědnutí jehlic. Vlivem solí může také docházet k předčasnému opadu jehlic, kdy se rostlina snaží nadměrné koncentrace chloridů zbavit, dále pak ke snížení vitality stromu a zpomalení jeho růstu (Cain et al. 2001). Když je chlorid sodný absorbován rostlinou, různé fyziologické vlastnosti rostliny jsou potlačeny, kvůli nadměrné koncentraci sodíku a chlóru. Vysoké hladiny solí v půdě snižují dostupnost různých živin pro rostliny. Klíčové prvky, jejichž obsah je snižován, když je hladina sodíku vysoká, jsou draslík (K), hořčík (Mg) a vápník (Ca) (Rose, Webber 2011).

Tolerance ke zvýšenému zasolení se u různých druhů rostlin liší (Wegner, Yaggi 2001). U smrkových druhů je známa jejich zvýšená citlivost k zasolení ve srovnání s jinými druhy dřevin (Larcher 1995), proto je smrk ztepilý (*Picea abies*) vhodným bioindikátorem vlivu chemické zimní údržby komunikací solnými posypovými materiály. Fostad, Pedersen (2000) ve svém výzkumu dokonce potvrdili, že smrk ztepilý (*Picea abies*) byl nejvíce citlivým k zasolení půd ze všech ostatních zkoumaných dřevin, kterými byli také javor mléč (*Acer platanoides*), bříza bělokorá (*Betula pendula*), borovice lesní (*Pinus sylvestris*).

V kontextu biomonitoringu a sledování postupného vývoje stavu jednotlivých složek životního prostředí je nutné využívat vhodné metody a vzorky pro identifikaci charakteristických kontaminantů a stanovení jejich koncentrací k posouzení dynamiky jejich pohybu v životním prostředí. Mezi vhodné typy vzorků používaných k biomonitoringu zatížení životního prostředí dopravou, respektive chemickou zimní údržbou patří biomasa z vegetace v okolí dopravní infrastruktury, konkrétněji listy či jehlice stromů (Kayama et al. 2003; Klink et al. 2018; Zítková et al. 2018).

3.5 Vlivy rezidenčních projektů na životní prostředí

Rezidenční, komerční či infrastrukturní výstavba je celosvětovým fenoménem, který je z hlediska dopadů na životní prostředí v různých zemích v různém detailu sledován a hodnocen.

Změny ve využívání krajiny a rozvoj infrastrukturní a rezidenční výstavby způsobené průmyslovým a ekonomickým rozvojem se zrychlují ve všech regionech světa (Venter et al. 2016; Ibisch et al. 2016) a patří také mezi hlavní příčiny poklesu biologické rozmanitosti (Benitez-Loopez et al. 2010; Newbold et al. 2015). K rozvoji výstavby dochází většinou v oblastech, které jsou již ovlivněny více zdroji narušení (Barber et al. 2014) a infrastruktury stejného či podobného typu se často v krajině shlukují. Pochopení dopadů vlivů projektů na složky životního prostředí je zásadní pro adekvátní posouzení jejich celkového vlivu.

Vlivy nové výstavby se totiž mohou sčítat a vzájemně v prostoru ovlivňovat s vlivem již existujících antropogenních prvků, což vede ke kumulativnímu vlivu, který je větší, než vliv jednotlivě izolovaných prvků (Johnson, St-Laurent 2011).

Rezidenční podobně jako infrastrukturní výstavba může vyvolávat širokou škálu negativních dopadů na životní prostředí i veřejné zdraví, které působí jak během výstavby, tak i provozu daného projektu. Mezi tyto negativní impakty můžeme zařadit ztrátu samotných ekosystémů, fragmentaci krajiny a zmenšování či izolaci stanovišť. Obytné projekty také vyvolávají větší nároky na obslužnost území a s tím je spojené zintenzivnění dopravy, což vyvolává zvýšení emisí polutantů, hlukového zatížení či aplikace solných materiálů během zimní údržby. Rezidenční projekty mohou také ovlivnit horninové a půdní prostředí a mohou tak způsobovat hutnění zemin, zvýšenou erozi či změny v půdních procesech. Stejně tak může docházet ke změnám v hydrologických procesech, ovlivnění vodního prostředí a změnám chemismu povrchových i podzemních vod.

Vhodným nástrojem pro hodnocení a posouzení dopadů projektů na životní prostředí a veřejné zdraví je proces EIA.

3.5.1 Hodnocení jako součást EIA procesu

Vývoj posuzování vlivů na životní prostředí jako klíčové složky managementu životního prostředí se v průběhu posledních 40 letech shodoval s tím, jak rostl počet uznání o rozsahu a důsledcích změn životního prostředí způsobené lidskou činností. Během této doby se EIA vyvíjela a měnila, což bylo ovlivněno měnícími se potřebami rozhodovacího procesu a zkušenostmi z praxe (Morgan 1998).

Zákon o politice životního prostředí – NEPA představoval první formální začlenění posuzování dopadů do legislativní podoby (O'Riordan, Sewell 1981). Zákon stanovil environmentální politiku, která měla usměrňovat činnosti, které významným způsobem ovlivňují lidi, komunity a životní prostředí, a byl také reakcí na nárůst vědeckého a společenského zájmu o současné změny životního prostředí (Ashby 1976).

Státní instituce byly podle NEPA povinny vypracovat prohlášení o dopadech na životní prostředí a zveřejnit ho veřejnosti, aby prokázaly, jak byly tyto aspekty zohledněny a řešeny. Po vzoru prvních zemí jako je Austrálie, Kanada, Irsko, Švédsko, Nový Zéland atd. (O'Riordan, Sewell 1981; Wood 2003) začlenilo mnoho dalších zemí určitou formu procesu posuzování dopadů do formálních postupů nebo právních předpisů týkajících se plánování nebo jiných oblastí rozhodujících o životním prostředí.

Na mezinárodní scéně se institucionalizace EIA v posledních přibližně 20 letech postupně rozvíjela a získávala na síle zejména kvůli rostoucímu politickému uznání problémů spojených se změnou klimatu, ztrátou biologické rozmanitosti, ohrožení zdrojů pitné vody a kvality vody, poškozování mořských oblastí a dalšími formami globálních environmentálních změn.

EIA je proces, který je založen na systematickém zkoumání a hodnocení předpokládaných vlivů na životní prostředí a jeho smyslem je zjistit, popsat a komplexně zhodnotit předpokládané vlivy záměrů na životní prostředí, veřejné zdraví a sociální sféru (Glasson et al. 1994) s cílem zmírnit jejich nepříznivé vlivy (Baker, Wood 1999; Říha 2001).

Je nezbytné zohlednit jak velký rozsah jednotlivých aktivit, tak jejich případné vzájemné interakce, či kumulativní efekt, jež mohou představovat značné vlivy na životní prostředí, sociální sféru či lidské zdraví (Říha 2001). Posuzování životního prostředí můžeme vnímat, jako lidskou odpovědnost za životní prostředí spolu s uvědoměním si dopadů lidských činností a možnost přispění k udržitelnému rozvoji společnosti.

3.5.2 Post-projektová analýza

I v návaznosti na proces posuzování vlivů na životní prostředí je možné aplikovat post-projektové hodnocení a posoudit tak jeho účinnost a efektivnost a zajistit zpětnou vazbu pro budoucí plánování a řízení dopadů těchto aktivit na životní prostředí (Wilson 1998; Wood 2000; Wood et al. 2000; Stewart-Oaten, Bence 2001; Marshall et al. 2005). Post-projektová analýza umožní revizi a kontrolu EIA procesu a porovnat předpokládaná očekávání s reálnou změnou či efektem. Post-projektová analýza se tak stává klíčovým bodem pro testování prediktivní síly EIA procesu (Braniš, Christpoulos 2005; O‘Faircheallaigh 2007). V dnešní době se však Ex-post hodnocením věnuje méně pozornosti v porovnání s rozsáhlým zaměřením na Ex-ante hodnocení (Jones, Fischer 2016; Nicolaisen, Driscoll 2016).

Morrison-Saunders, Arts (2004a) uvádí, že post-projektová analýza obecně zastřešuje termín pro monitoring, auditing, ex-post hodnocení, post-decision analýzu a post-decision management. Obecně lze říci, že se post-projektová analýza provádí s cílem zlepšení a zefektivnění posuzování vlivů na životní prostředí. Dle Morrison-

Saunders et al. (2003) může být post-projektová analýza realizována a řízena kteroukoli ze zainteresovaných stran. Iniciace a realizace post-projektové analýzy i) investorem se označuje jako 1st party Follow-up (její provádění může být součástí interních předpisů); ii) regulátorem se označuje jako 2nd party Follow-up (za účelem ověření, zda investor dodržel stanovené podmínky) a iii) veřejností je označovaná jako 3rd party Follow-up (jako důsledek zájmu občanů o životní prostředí, či požadavek plynoucí ze spolupodílení se na rozhodování).

Provádění EIA je neustále celosvětově diskutováno. Mnoho zemí jako je například Finsko, Dánsko, Estonsko, Velká Británie, Nizozemí, Litva, Austrálie, a další provedly podrobné studie efektivity procesu EIA a definovaly problémy, které je třeba v rámci procesu řešit (Simpson 2001; Ahammed, Nixon 2006; Christensen 2006; Pölönen 2006; Kruopiene et al. 2008; Heinma, Poder 2010; Pölönen et al. 2010; Runhaar et al. 2013).

Proces EIA byl zkoumán hlavně z hlediska právního, procesního, fiskálního a současně též z hlediska kvality jednotlivých výstupů (Sadler 1996; Hickie, Wade 1998; Marsden 1998; Baker, Wood 1999; Rees 1999; Baker, McLelland 2003; Cashmore et al. 2004; Bina 2007; Retief 2007; Zhu, Ru 2008). Studie se také zabývaly kvalitou EIA dokumentů, efektivitou jejich procesní implementace (Bailey 1997; Baker, Wood 1999; Pinho et al. 2006) a postavení EIA v plánování rozvoje (Sadler 1996; Hickie, Wade 1998; Hacking, Guthrie 2008; Kolhoff et al. 2013), avšak menší pozornost byla věnována tématu, zda je EIA proces účinný, účelný a užitečný v tom, čeho má skutečně dosáhnout, a sice chránit životní prostředí, dosáhnout vyšší úrovně udržitelnosti a pomoci dosáhnout vyšší informovanosti, vyšší míry participace a celkové vyváženosti rozhodování.

3.5.3 Vývoj posuzování vlivů na životní prostředí v České republice

Proces posuzování vlivů na životní prostředí byl poprvé samostatně legislativně zakotven do právního řádu České republiky v roce 1992 nabytím účinnosti zákona č. 244/1992 Sb., o posuzování vlivů na životní prostředí. Tento proces představuje jednak důležitý prvek v systému preventivních nástrojů ochrany životního prostředí a současně i významnou součást politiky životního prostředí v České republice. V lednu 2002 byl zákon č. 244/1992 Sb., konkrétně jeho část, která se týká posuzování vlivů na životní prostředí, nahrazen zákonem č. 100/2001 Sb., o posuzování vlivů na životní prostředí.

Přijetí směrnice Evropského parlamentu a Rady 2011/92/EU, o posuzování vlivů některých veřejných a soukromých záměrů na životní prostředí mělo zásadní význam na vývoj procesu EIA v členských státech EU. V květnu 2004 se Česká republika stala členem Evropské unie a musela uvést do souladu českou právní úpravu posuzování vlivů na životní prostředí s ustanoveními této směrnice. V roce 2014 pak vstoupila v platnost nová směrnice Evropského parlamentu a Rady 2014/52/EU, o posuzování vlivů některých veřejných a soukromých záměrů na životní prostředí, kterou se změnila původní směrnice. Směrnice zavádí efektivnější ochranu životního prostředí, možnost vyšší participace veřejnosti a větší transparentnost procesu EIA. V listopadu 2017 byla provedena poslední významnější novelizace zákona 100/2001 Sb.

Zákon 100/2011 Sb., vyžaduje, aby souhlas s výstavbou veřejných a soukromých projektů, které mohou mít významný vliv na životní prostředí, byl udělen pouze po předchozím posouzení jeho pravděpodobně významných vlivů na životní prostředí. Zákon v příloze č. 1 stanovuje dvě skupiny záměrů, a to kategorii I a II. Do kategorie I patří záměry a změny těchto záměrů, pokud změna kapacity nebo rozsahu sama o sobě dosahuje příslušné prahové hodnoty, pokud je stanovena. Tyto záměry a jejich změny se považují za záměry s významným vlivem na životní prostředí a vždy podléhají posouzení EIA v plném rozsahu. Do kategorie II patří záměry a změny těchto záměrů, pokud vlastní kapacitou nebo změnou rozsahu dosahují příslušné prahové hodnoty, pokud je stanovena nebo záměry, které mohou mít významný negativní vliv na životní prostředí, zejména má-li být zvýšena jejich kapacita, rozsah záměru, technologie, řízení provozu nebo způsob využití. Tyto záměry a změny záměrů podléhají EIA, pokud je tak stanoveno ve zjišťovacím řízení. Cílem zjišťovacího řízení pro projekty uvedené v kategorii I je dále specifikovat informace, které by měly být zahrnuty do dokumentace EIA. Cílem zjišťovacího řízení pro projekty uvedené v kategorii II je určit, zda projekt může mít negativní vliv na životní prostředí a zda má tedy podléhat posouzení EIA.

V době, kdy je důležitější než kdy jindy, aby se kontrolovala rozhodnutí, která by mohla mít pro lidi, komunity, a systémy, které tvoří přírodní prostředí významný vliv, je třeba zhodnotit pokrok, kterého bylo v této oblasti dosaženo, a zamyslet se nad současnými a budoucími výzvami (Morgan 2012).

Vývoj procesu posuzování vlivů na životní prostředí byl jak na státní, tak i na mezinárodní úrovni velmi dynamický. Zvýšený zájem a postoje k ochraně životního prostředí na globální úrovni je možné sledovat i skrze vývoj nástrojů, jako je posuzování vlivů na životní prostředí. Tento proces od svého počátku, kdy prakticky plnil pouze funkci informační o možných vlivech na životní prostředí se vyvinul až do plnohodnotného nástroje ochrany životního prostředí, který je dnes implementován do příslušných postupů napříč celým světem. V současném formátu posuzování vlivů na životní prostředí v České republice dle platné legislativy však post-projektové analýzy nejsou zahrnuty. Pokud se má však koncept posuzování zlepšit a lépe dosahovat svých cílů, tak jediná cesta je skrze získávání ponaučení z realizovaných posouzení a výsledků post-projektových analýz.

Hodnocení impaktů obecně je v dnešní době nutné vidět, jako nevyhnutelný prostředek, díky kterému je možné zjistit rozsah negativního vlivu a využít tak zjištěné závěry pro omezení těchto dopadů na životní prostředí a k jeho ochraně. Nezbývá než věřit, že trend zvyšujícího se zájmu o ochranu životního prostředí a vývoj nástrojů pro jeho ochranu bude i nadále alespoň stejně tak dynamický jako do teď.

Část II

Výzkum

Kapitola 4

Bioindication of Road Salting Impact on Norway Spruce (*Picea abies*)

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Abstract

Winter chemical road maintenance has a significant negative influence on the environment. The application of chemical de-icing salts affects the trees growing near the road. Sodium and chlorine ions which are washed out into the environment are absorbed by the ambient vegetation; the increased concentration of these ions has a negative influence on the vegetation health. The determination of sodium and chlorine ions content in assimilative organs of conifers is used as a bioindicator of the impacts of winter chemical maintenance. The presented research paper evaluates the influence of the contamination potential on these ions content in needles of the Norway spruce (*Picea abies*). This species of spruce was chosen because of its abundant occurrence and heightened sensitivity towards salinization. The study was conducted in the north of the Czech Republic in the Liberec Region. To assess the damage potential of the winter chemical road maintenance, samples of the Norway spruce first- and second-year needles were collected and the sodium and chlorine ions concentrations were determined. At the same time, the research assessed the contamination potential of the region and the health condition of the analysed spruce trees. The results of ions concentrations (Na, Cl) were evaluated depending on four factors: the contamination potential, the health of the tree, the distance from the road and the age of the needles. Based on the evaluation of the results, a scale with framework concentration values was designed. This scale can be used for practical assessment of the degree of contamination.

Keywords: winter road maintenance; road salts effects; needles; sodium and chlorine ions

4.1 Introduction

Road traffic is nowadays very intense and it is very important to ensure its safe and smooth operation. In winter, the maintenance is much more demanding because the road workers have to clear away the fallen snow, frost, or ice (Hofman et al. 2012). Winter road maintenance has significant benefits of improving road safety and reducing traffic delay. Min et al. (2016) argues that winter road maintenance can also be beneficial because reducing vehicular air emissions and fuel consumptions. The significant growth of road transportation in Europe begun in the early 60s of the 20th century (Fischel 2001). At that time, materials such as sand or chloride-based chemical substances were being used for winter road maintenance for the first time (Hofman et al. 2012). The application of chemical substances for the road winter maintenance brings about considerable negative effects on the environment; the trees growing near the roads are most at risk because they are in the areas flooded by the dissolved chemical solutions which contain large amounts of salts (Blomqvist, Johansson 1999; Černohlávková et al. 2008; Hofman et al. 2012).

One of the most easily observable effects of the application of de-icing road salt is the deteriorating health condition of vegetation growing in the area near the roads. The vegetation growing along the roads is becoming an important indicator that shows a high use of road salting (Langen, Prutzman 2006).

The consumption of salting materials varies in the Czech Republic, depending on the character of winter, it is usually in the range of 150 – 300 kt per year, which is comparable to the amount used in other European countries (Kramberger, Žerovnik 2008; Forczek et al. 2011). Sodium chloride is the most commonly used de-icing material for the winter road maintenance. The applied sodium chloride is mobilised by melting snow or ice and rainfall, which leads to its entering the soil environment, surface water, geological environment, and groundwater (Howard, Beck 1993; Kramberger, Žerovnik 2008). In an aquatic environment, sodium chloride dissociates into sodium cations (Na^+) and chlorine anions (Cl^-). In the soil environment, the sodium cations subsequently bind to other negative ions and displace divalent cations, mostly calcium (Ca^{2+}) and magnesium (Mg^{2+}). The chloride anions are further transported into water in unchanged form, due to its low reactivity. Sodium chloride washed off the roads causes the increased salinity in both surface- and groundwater for months after its application (Thunqvist 2004).

The increasing amount of sodium and chlorine ions in the soil environment affects the soil structure, substance dispersion, permeability, and osmotic potential; thus, leading to deterioration of quality and the loss of stability of the soil. The unstable soil properties lead to stress conditions for soil macro-organisms and the vegetation (Černohlávková et al. 2008). The vegetation near the roads is exposed to the negative effects of the salts in two ways. The aboveground plant tissues are directly exposed to the salt solution, which is sprayed by passing vehicles. The indirect influence is caused by absorption of the salt solutions into the soil near the roads which affects the soil chemistry, the dynamics of soil processes and its structure, and thus negatively affect the vegetation through the root system (Semorádová 2003).

The damage to the vegetation can be seen in necrosis and wilt of leaves and needle growth slowdown, necrosis of the root system, wilting, yellowing of the leaves, reduced plant and leaves size, seed viability may be reduced and their germination may be delayed. Road salts affecting soil may reduce the water uptake of trees and its transpiration, which may result in weakened photosynthesis and consequently reduced height and thickness of the tree. The needles of conifers may become red or brown. Salt solutions may also cause premature falling of needles as the plant is getting rid of the excessive concentration of chlorine ions; moreover, the condition of the tree deteriorates and the growth slows down (Kayama et al. 2003).

High levels of salts in the soil reduce the availability of various nutrients for plants. The key elements whose content is reduced when the sodium ions level is high are the potassium (K), magnesium (Mg) and calcium (Ca) ions. One possible indicator of salinity is the determination of the chlorine and sodium ions content in the assimilative organs of conifers.

In the Czech Republic, some studies focused on the research of the impact of salting on the soil environment (Černohlávková et al. 2008; Hofman et al. 2012). In Poland, similar study was conducted which concerned the bioindication of the effects of winter salting and its influence on the elements content (potassium, magnesium, sodium, calcium, and chlorine) in the soil environment and in the leaves of the small-leaved lime (*Tilia cordata*) (Czerniawska-Kusza et al. 2004). Chemical biomass analyses of various kinds of vegetation, such as Schreber's big red stem moss (*Pleurozium schreberi*), wavy Hair-grass (*Avenella flexuosa*), and Norway spruce (*Picea abies*), had been carried out. However, these analysed heavy metals in particular in order to determine contamination caused by anthropogenic sources in industrialised areas (Suchara et al. 2011). Kayama et al. (2003) examined the effect of de-icing salts on the health of two species of spruce, the Norway spruce (*Picea abies*) and the Sakhalin spruce (*Picea glehni*). The research proved that increased sodium and chlorine ions levels contained in soil also lead to increased level of these ions in the assimilative organs of trees. Spruce species are known for their high sensitivity to salinity in comparison with other species of trees (Larcher 1995) and for that reason the Norway spruce is the appropriate bioindicator of the influence of the road chemical winter maintenance, particularly salting materials. Fostad, Pedersen (2000) confirmed in their research that the Norway spruce was the most sensitive to the soil salinity in comparison with other analysed species of trees which were the Norway maple (*Acer platanoides),* the silver birch (*Betula pendula*) and the Scots pine (*Pinus sylvestris*). The region in the north of the Czech Republic, south of the Jizera Mountains, was chosen for this research for its abundant presence of spruce trees and because the de-icing salt materials are used for the winter road maintenance in the region.

4.2 Material and methods

4.2.1 Sampling

The samples used for this research were needle samples of first-year and second-year Norway spruce and samples of soil material collected from the vicinity of researched trees; these were analysed to determine the content of sodium, potassium, magnesium, calcium, and chlorine ions. All samples (first-year needles, second-year needles and soil samples) were collcted in the same year. The samples were collected in areas where spruce trees grow close to the roads and where the potential danger of contamination exists. A total of 32 samples of the first-year needles and 32 samples of the second-year needles from the same trees were collected together with 32 samples of soil collected from up to 5 m from the road. Some areas further from the road (at least 40 m from the road) were chosen as well for comparison; from these areas 12 samples of the first-year assimilation organs, the same number of the second-year needles and 12 samples of soil material were collected. The soil samples were collected up to the distance of 1.5 m from the individual Norway spruce tree from which the assimilation organs had been collected. The sample consist of about 100 g of soil collected at a depth of 0 – 25 cm, which was later dried at room temperature. After drying, the samples were sieved and milled. To acquire the Norway spruce assimilation organs, the whole first- and second-year branches were cut, not just the needles. Every single tree chosen for the analysis was also assessed visually; the assessed criteria were the tree health condition and its contamination potential (Semorádová 2003). For each spruce tree, the first- and the second-year branches were collected and put separately in paper bags. The samples were dried at room temperature and ground on a cutting mill.

4.2.2 Chemical analysis

The following procedure was used to determine the concentration of sodium, calcium, potassium, and magnesium ions:

About 0.4 g of homogenised plant material was digested in a mixture of nitric acid ultrapure and hydrogen peroxide ultrapure using Teflon vessels and a high pressure and high temperature microwave digestion system SW-4 (Beghof). Duplicate digestions of each sample were prepared in parallel. The digested samples were diluted to a final volume 50 ml with ultrapure water (Millipore).

The following procedure was used to determine the concentration of chlorine ions:

To determine the concentration of chlorine ions in the assimilation organs, first, the homogenised sample (adjusted to the size < 2 mm) was mixed with ultrapure water at a ratio of 1:10, then it was stirred and boiled. Boiling granules were added to the sample to stir it. The samples were left to cool down after about a minute of boiling. The leachate was poured into clen wessel after 30 minutes of leaching and the chlorine ions were determined.

Soil sample preparation for determination of concentrations of sodium, calcium, potassium, and magnesium ions:

A plastic container of 500 ml volume was filled with 25.0 g of dry sieved soil sample and 250 ml of ultrapure water. The whole soil sample is air-dried according to the procedure of ISO 11464: 1994 (ISO 11464: 1994 Soil quality - Pre-treatment of samples for physico-chemical analyzes). The containers were put into a shaker (Reax 20 rotary shaker) and left shaking for 24 hours at laboratory temperature and the rotation speed of 5 rpm. After the extraction, the samples were set aside for 20 minutes before being further processed. Soil samples extracted with water were centrifuged (Universal 320 R benchtop centrifuge) for 20 minutes at the rotation speed of 4000 rpm. If needed, the samples were further filtered through 0.45 μm membrane filter. The samples thus prepared were used for the analysis.

The concentrations of sodium, calcium, potassium, magnesium, and chlorine ions were determined using an ICPQQQ spectrometer (Agilen Technologies). The quality of the analytical results was checked via frequent analyses of reference materials (NIST Pine Needles 1575a, NIST Trace elements in natural water 1640a).

4.2.3 Statistical evaluation of the analyses results

Software R (R Development Core Team, 2010) was used for statistical analysis. At the beginning, the data was summarised and the basic characteristics for visualisation of element content in the spruce needles and soil were calculated. To assess the dependence of the contamination potential and the concentration of ions in the needles, the nonparametric Kruskal-Wallis test was performed. First, the data normality was tested (Shapiro-Wilk test) on the significance level $\alpha = 0.05$; H0 = the data distribution is normal. The normal data distribution was not confirmed, the H0 hypothesis was rejected. Nonparametric tests are applied for the data with abnormal distribution, for that reason the Kruskal-Wallis test was chosen. The higher class of the contamination potential supposed higher sodium and chlorine concentration in the Norway spruce needles and in the soil. Null hypothesis was established on the significance level $\alpha= 0.05$; H0 = the ions concentrations (in first- and second-year needles and soil) are independent of the contamination potential.

The Kruskal-Wallis test was used to assess the dependency of the tree health condition and the elements concentration in the first-year and the second-year needles. The tree health condition was supposed to deteriorate with a higher sodium and chlorine ions concentration in the assimilative organs. Null hypothesis was established on the significance level $\alpha= 0.05$; H0 = the ions concentrations (in first- and second-year needles and soil) are independent of tree health state.

The Wilcoxon pair test was used to compare the sodium and chlorine ions concentrations (in the assimilative organs and in the soil samples) in the proximity of the roads and in the areas further from the roads. The choice was based on the confirmation of abnormal data distribution using the Shapiro-Wilk test. The test calculation derives from pair values of two measurements – in the proximity of the road and further away. The areas further from the road are supposed to contain smaller amount of chlorine and sodium ions than the areas near the road. Null hypothesis was established on the significance level $\alpha = 0.05$; H0 = the ions concentrations of soil samples collected near the road do not differ from those of soil samples collected further from the road.

The relation of the elements concentrations (sodium, chlorine, calcium, magnesium, potassium) in the first- and the second-year needles was also assessed. The nonparametric Wilcoxon pair test based on the abnormal data distribution was chosen for this comparison as well. Null hypothesis was established on the significance level $\alpha = 0.05$; H0 = the ions concentrations values do not differ in the first- and second-year samples.

4.3 Results

The concentrations of the individual ions content in the analysed needle samples range from 0–6 mg.g^{-1} Na, 0–7 mg.g^{-1} Cl, 0–2 mg.g^{-1} Mg, 0–19 mg.g^{-1} K and 0–15 mg.g^{-1} Ca. The basic parameters of the descriptive statistic are shown in the Table 4.1.

Table 4.1: *Numeric data characteristic for individual ions of elements (Sodium, Chlorine, Magnesium, Potassium, Calcium). Concentration (mg.g-1) in first-year and second-year needles of the Norway spruce and soil samples (* the values below the limit of detection, SD – standard deviation).*

	Na (mg.g^{-1})			*Cl (mg.g^{-1})*		
	1st year	*2nd year*	*Soil*	*1st year*	*2nd year*	*Soil*
Number of samples	32	32	32	32	32	32
minimum	*	0.0250	0.0022	*	*	*
1st quartile	0.0427	0.0689	0.0108	0.2939	0.4238	0.1083
median	0.0831	0.1405	0.0185	0.6323	0.6521	0.2592
average	0.4589	0.6359	0.0311	0.8704	1.1272	0.2297
3rd quartile	0.1231	0.4482	0.0529	1.2233	1.1951	0.3263
maximum	3.7700	5.1066	0.1013	4.0688	6.3273	0.6072
SD	0.9775	1.1236	0.0270	0.8569	1.3132	0.1413
	Mg (mg.g^{-1})			*K (mg.g^{-1})*		
	1st year	*2nd year*	*Soil*	*1st year*	*2nd year*	*Soil*
Number of samples	32	32	32	32	32	32
minimum	0.0004	0.2647	0.0023	*	0.9414	0.0006
1st quartile	0.6731	0.5467	0.0037	3.9893	3.4295	0.0059
median	0.8553	0.8304	0.0051	5.5563	5.1949	0.0099
average	0.9640	0.8621	0.0065	6.2028	5.1620	0.0125
3rd quartile	1.2370	1.1102	0.0077	7.2714	6.6976	0.0155
maximum	2.0056	1.8770	0.0235	18.7791	9.1051	0.0470
SD	0.4441	1.1346	1.3139	3.3671	2.1623	0.0107

	Ca ($mg.g^{-1}$)		
	1st year	*2nd year*	*Soil*
Number of samples	32	32	32
minimum	*	1.0440	0.0029
1st quartile	2.6973	2.8666	0.0062
median	3.2632	3.9706	0.0151
average	3.9481	4.9263	0.0206
3rd quartile	4.8042	5.9738	0.0255
maximum	12.6679	14.6580	0.0804
SD	2.5121	3.1731	0.0182

The results of the elements concentration were evaluated based on four factors:

1. the contamination potential,
2. the health condition,
3. the distance from the road,
4. the age of needles (first-/second-year).

4.3.1 The relation between the concentration of elements in the needles and area contamination potential

The samples were divided into three classes per the sodium and chlorine ions concentration and the contamination potential:

1st category - lowest contamination potential, a tree with the lowest possibility of contamination,

2nd category - medium contamination potential, a transitional zone with minor contamination,

3rd category - highest contamination potential, the trees immediately next to the road.

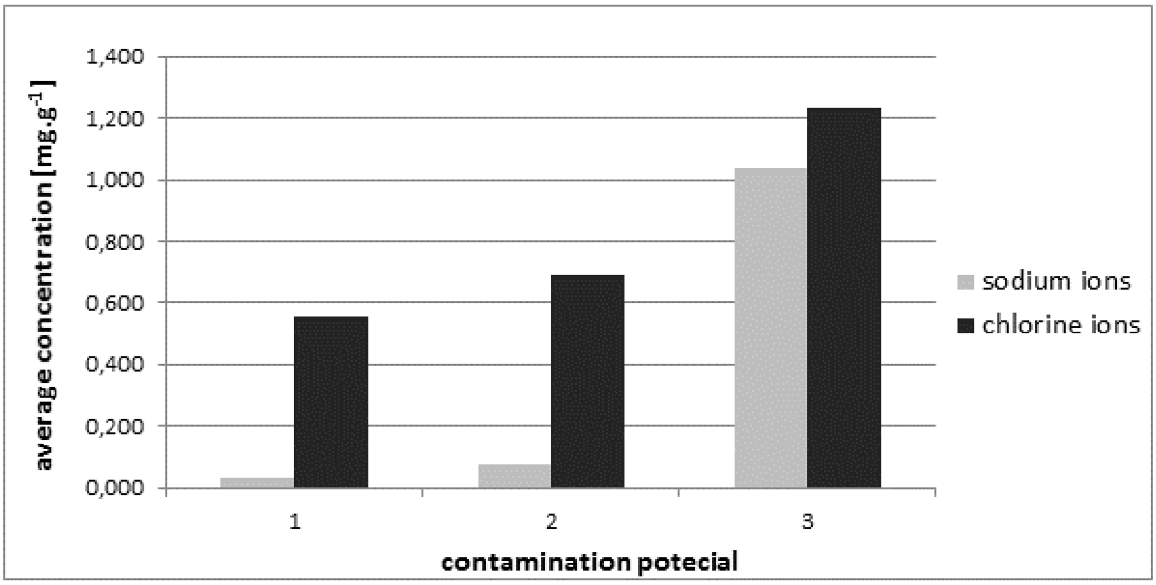

Figure 4.1: *Average chlorine and sodium ions concentration in the first-year needles in dependency on the contamination potential shows the tendency of growing concentration with the increasing contamination potential.*

The average sodium and chlorine concentration in the first- and the second-year needles shows that the concentration increases with growing contamination potential.

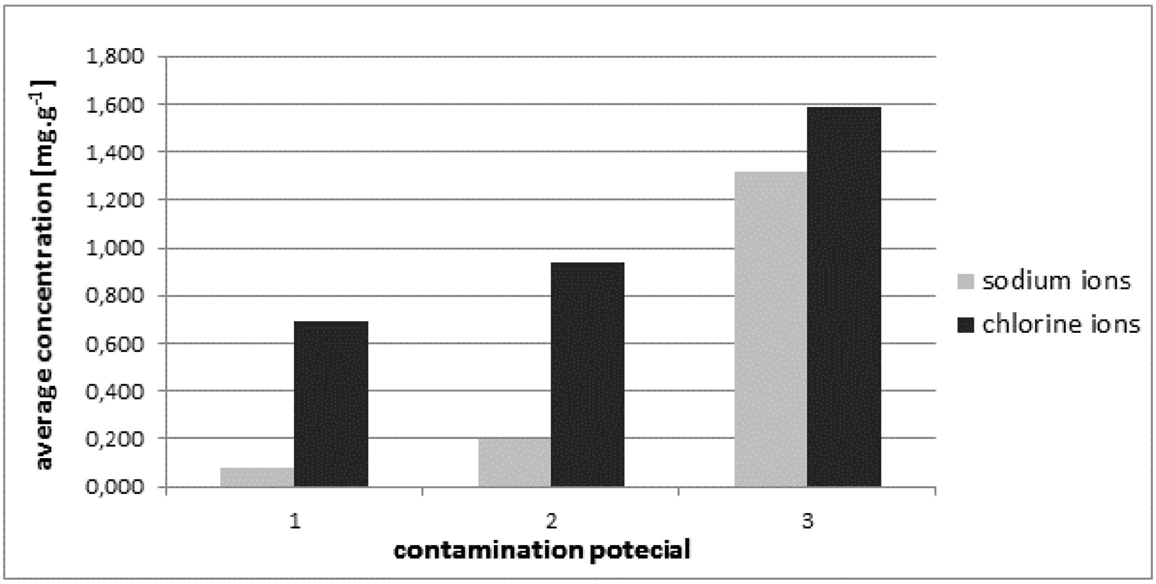

Figure 4.2: *Average chlorine and sodium ions concentration in the second-year needles in dependency on the contamination potential.*

The average sodium concentration in soil shows the slightly growing tendency at increasing contamination potential.

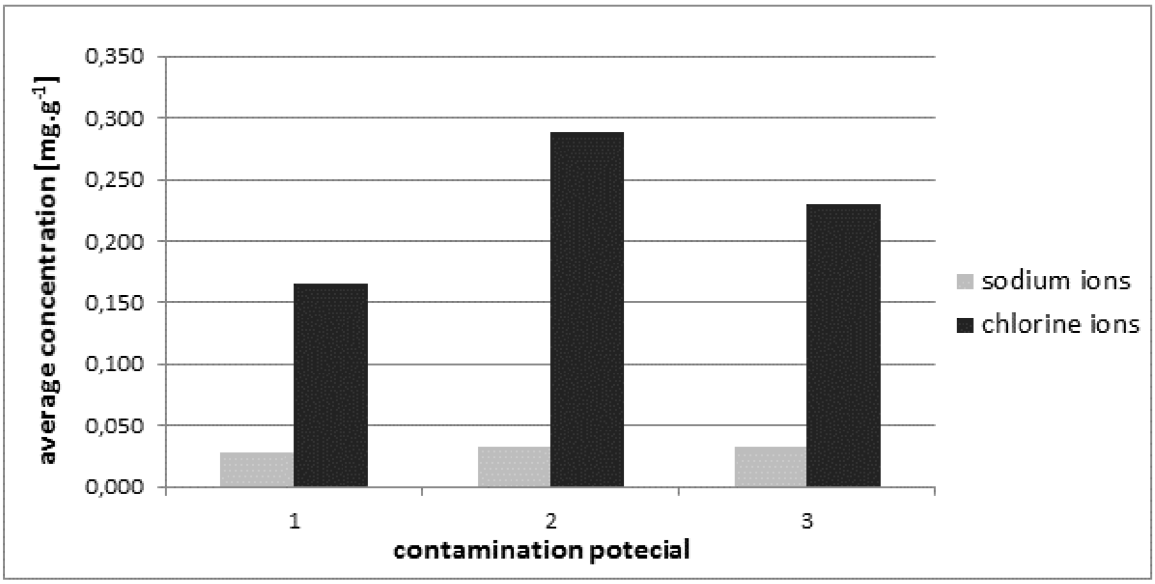

Figure 4.3: *The average concentration of chlorine and sodium in soil depending on the contamination potential.*

The testing of the significance of sodium and chlorine ions concentration differences between the particular contamination potential categories was done by the Kruskal-Wallis test. The test confirmed statistically significant dependency of the contamination potential on the sodium ions concentration in the first-year and the second-year needles. Such dependency was not confirmed for chlorine ions and for the soil samples (Table 4.2).

Table 4.2: *Dependency of the contamination potential on concentration of the elements (sodium and chlorine) in the first- and the second-year needles of the Norway spruce and in the soil samples. Results of the Kruskal-Wallis test (p-value). Values < 0.05 confirm the dependency.*

	1st year	*2nd year*	*Soil*
Na	0.000001338	0.000372	0.4236
Cl	0.06851	0.4244	0.2944

4.3.2 Relation between the elements concentration in needles and the tree health condition

The samples were divided into five categories for the evaluation of the relation between sodium and chlorine ions concentration and the tree health condition:

1st category – healthy tree,

2nd category – slightly damaged tree,

3rd category – moderately damaged tree,

4th category – damaged tree,

5th category – severely damaged tree.

The average sodium ions concentration in the first-year needles increases with deteriorating health condition of the tree. For chlorine ions, the situation is similar except for the first category where the average concentration exceeds the concentration in the second category. The average sodium ions concentration in the second-year needles also increases with deteriorating health condition of the tree. For chlorine ions, such regular growing trend is not evident. Even though the trends are apparent from the average concentration, these results must be considered tentative due to the small number of samples in each health condition category.

The testing of the significance of sodium and chlorine ions concentration differences between the health condition categories was done by the Kruskal-Wallis test. The test confirmed statistically significant dependency of the tree health condition on the sodium ions concentration in the first- and the second-year needles and on the chlorine ions concentration in the first-year needles of the Norway spruce (Table 4.3). The dependency of chlorine ions concentration in the second-year needles on the tree health condition was not confirmed (Table 4.3).

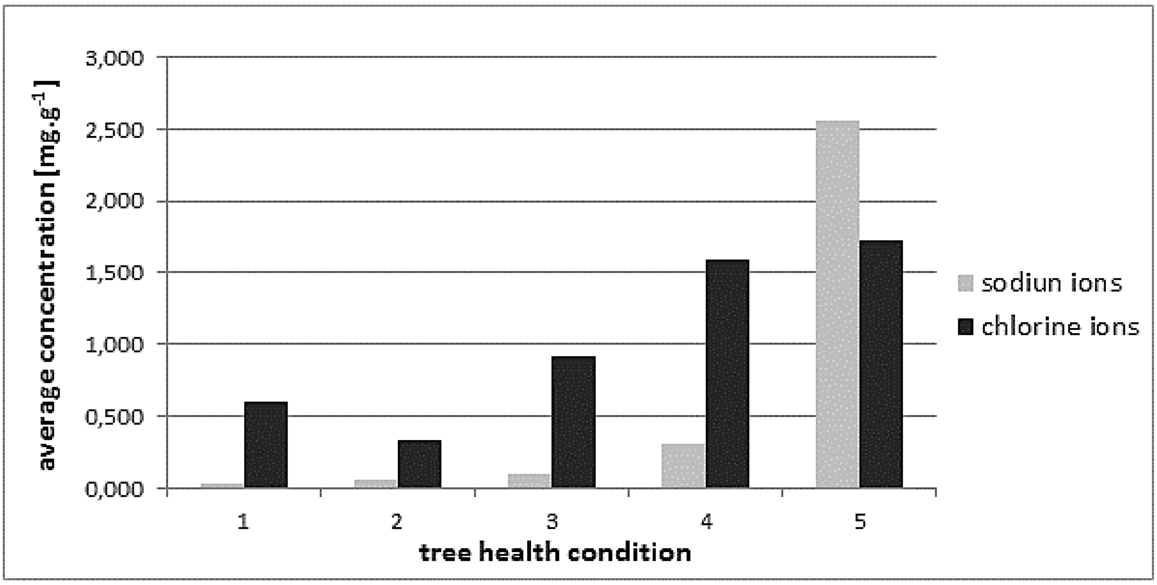

Figure 4.4: *The average sodium and chlorine concentration in the first-year needles depending on the tree health condition.*

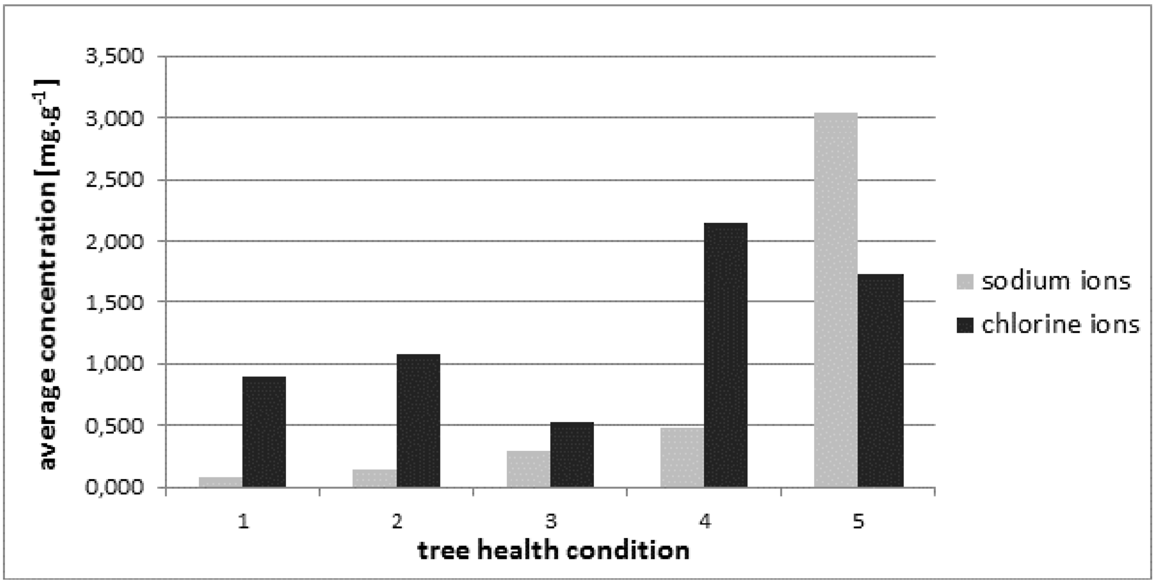

Figure 4.5: *The dependency of the average sodium and chlorine concentration in the second-year needles and the tree health condition.*

Table 4.3: *The dependency of tree health state on the concentration of the elements (sodium, chlorine) in the first- and the second-year needles of the Norway spruce. The results of the Kruskal-Wallis test (p-values). Values <0.05 confirm the dependency.*

	1st year	*2nd year*
Na	0.00001188	0.000429
Cl	0.003753	0.591

4.3.3 The comparison of the elements concentration depending on the distance from the road

The samples were divided in two categories for the evaluation of relation of sodium and chlorine ions concentration in needles of trees growing near the road and in trees growing further from the road:

1. category – samples collected from up to 5 m from the shoulder of traffic lane,

2. category – samples collected at least 40 m from the shoulder of traffic lane.

The distance was determined by two factors. The first factor is the presence of trees (selected conifer) and the second is the probability of an increased salt concentration at this distance. At 5 m distance, selected conifers are already occur, it is the immediate distance from the road where samples could be collected and the increased concentration of de-icing salts is assumed here.

The average sodium ions concentration in the first- and the second-year needles and the soil was lower for the samples collected in the areas further from the road. Chlorine ions in the first-year needles is present in a higher average concentration in the areas further from the road; for the second-year needles and the soil, the chlorine ions concentration is higher near the road.

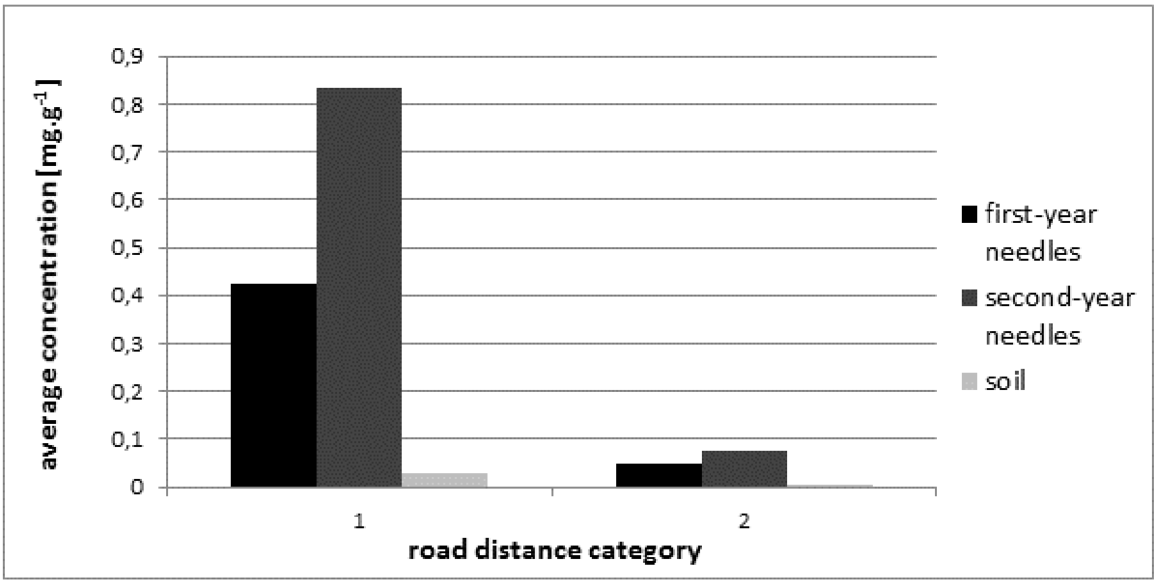

Figure 4.6: *The average sodium ions concentration in the first- and the second-year needles and the soil depending on the distance from the road (1st category - <5 m, 2nd category: > 40 m).*

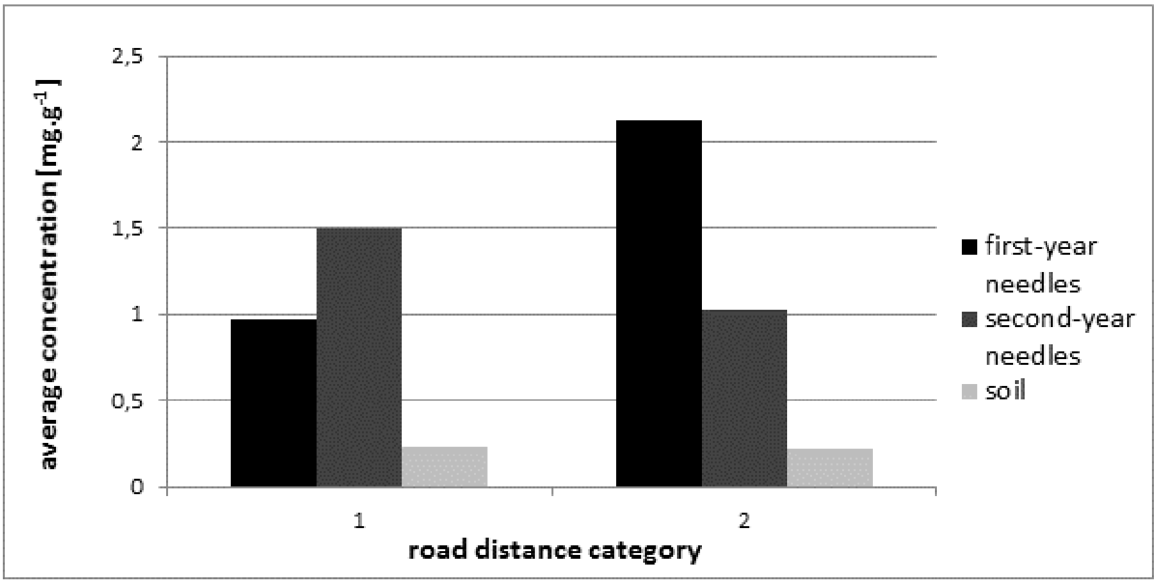

Figure 4.7: *The average chlorine ions concentration in the first- and the second-year needles and the soil depending on the distance from the road (1st category - <5 m, 2nd category: > 40 m).*

The Wilcoxon pair test was carried out to test the significance of sodium and chlorine ions concentration differences depending on the distance from the road (Table 4.4). The test confirmed the statistically significant distinction in the ions concentration between the areas near the road and more distant areas; for chlorine ions, the distinction was confirmed in the first-year needles and for sodium ions in the second-year needles and the soil (Table 4.4).

Table 4.4: *Comparison of elements (sodium, chlorine) content in areas close to and distant from the road in the first- and the second-year needles and in the soil extract. The results of the Wilcoxon pair test (p-values). The values < 0.05 confirm the significant distinction in concentrations.*

	Na			*Cl*		
	1st year	*2nd year*	*Soil*	*1st year*	*2nd year*	*Soil*
p-value	0.099	0.01855	0.01221	0.03418	0.2061	0.791

4.3.4 The comparison of the ions concentrations in the first-year and the second-year needles

The samples were divided by years to evaluate the relation between the concentration of sodium, chlorine, magnesium, potassium, and calcium ions in needles depending on the needle year.

Sodium, chlorine, and calcium ions have a higher concentration in the second-year needles, where as magnesium and potassium ions have higher concentration in the first-year needles.

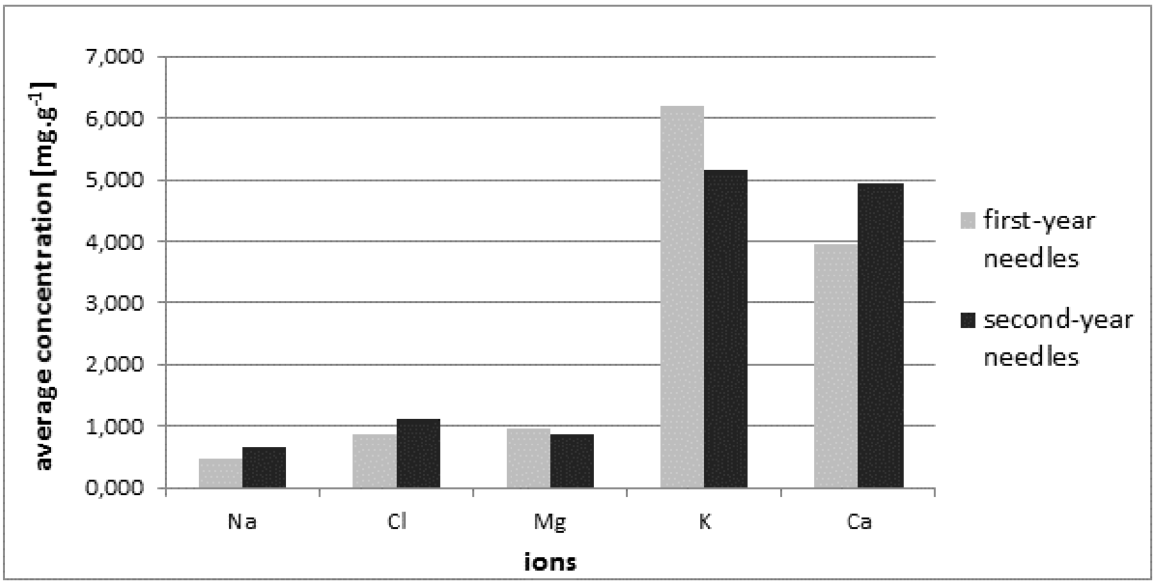

Figure 4.8: *The average concentration of each ions (sodium, chlorine, magnesium, potassium, and calcium) in the first- and the second-year needles of the Norway spruce.*

The Wilcoxon pair test was used to test the significance of differences in the concentration of sodium, magnesium, potassium, calcium, and chlorine ions, depending on the needle year (Table 4.5). The test confirmed statistically significant distinction in sodium and potassium ions concentration (Table 4.5).

Table 4.5: *The comparison of the ions contents (sodium, magnesium, potassium, calcium, and chlorine) in the first- and the second-year needles. The results of Wilcoxon pair test (p-values). The values < 0.05 confirm the significant distinction in concentrations.*

	Na	*Mg*	*K*	*Ca*	*Cl*
p-value	0.001235	0.1716	0.04754	0.1106	0.4776

4.3.5 Contamination evaluation scale

Based on the evaluation of the results and analysis of literature, a scale with framework concentration values was designed (Table 4.6), which can be used for practical evaluation of the degree of contamination. The scale was designed specifically for sodium ions content and specifically for chlorine ions content in the first- and the second-year needles of the Norway spruce (Table 4.6).

Table 4.6: *The proposed scale of sodium and chlorine ions concentrations in the first- and the second-year needles of the Norway spruce for the practical assessment of the level of contamination.*

class	*level of concentration*	*tree condition*	*Na ($mg.g^{-1}$)*		*Cl ($mg.g^{-1}$)*	
			1st year	2nd year	1st year	2nd year
1	normal	healthy	< 0,6	< 0,7	< 0,7	< 1,1
2	slightly higher	slightly damaged	0,7 - 1,9	0,8 - 2,9	0,8 - 2,0	1,2 - 2,4
3	high	damaged	> 2,0	> 3,0	> 2,1	> 2,5

4.4 Discussion

The dependency of the sodium ions concentration (both in the first-year and the second-year needles) on the contamination potential was confirmed. The average sodium ions concentration in the needles increased with growing contamination potential (Figure 4.1; 4.2). This fact also confirmed Kayama et al. (2003) in their study, where the content of sodium ions in the Norway spruce needles collected in areas further from the road with smaller contamination potential were lower than in needles of trees with higher contamination potential. This fact was not confirmed for chlorine ions, however, the average concentration values show a similar tendency of growing concentration with increasing contamination potential (Figure 4.1; 4.2). This phenomenon can be caused by high solubility and subsequent high mobility of chloride anions in the soil and in the plant body (Pavlová 2006). Therefore, it is more easily and quickly washed out from the soil than the sodium ions.

The health condition of a tree is an important indicator of contamination (Langen, Prutzman, 2006). The dependency of the tree health condition and sodium ions content in needles was confirmed (Table 4.3). The increasing average sodium ions concentration becomes apparent with the deteriorating health condition of the tree (Figure 4.4; 4.5). According to the study by Kayama et al. (2003) it was also discovered that sodium ions contents are higher in damaged trees with worse health condition. This increasing trend was confirmed for chlorine ions as well, but only in the first-year needles (Table 4.3). The second-year needles show various ions concentrations depending on the health condition of particular tree (Figure 4.5). This can also be caused by the high mobility of chloride anions (Pavlová 2006) or by the direct spraying of salt solution on the tree (Semorádová 2003; Langen, Prutzman 2006). In such cases (contamination by direct spraying) some needles can show high values of chlorine ions concentration, however, it may not be visible on the overall health state of the tree (Figure 4.5).

In the comparison of sodium and chlorine ions concentrations based on the area proximity to the road, the differences in chlorine ions concentrations in the first-year needles and sodium ions concentrations in the second-year needles were confirmed (Table 4.4). The distinct sodium ions concentrations were confirmed in the soil samples (Table 4.4). The significant difference in chlorine ions concentrations in the first-year needles between the areas near the roads and those further away point out that according to the average ions concentrations in needles there was an increased amount of chlorine ions in the more distant areas. However, Semorádová (2003) argues that even areas as far as 30 – 70 m from the road can be critical for the accumulation of salt solutions due to various factors such as steep hillside, outfalls of road draining installations and waterlogged foot of a hill. Cain et al. (2001) also states that accumulation of ions from salt-based de-icing materials can occur even at greater distances from the road as a result of many influences. The accumulation of chlorine ions in such areas can be greater due to its high mobility in the soil environment and in plants. For sodium ions, no significant differences in the first-year needles were confirmed (Table 4.4). The average sodium ions concentration in the areas further from the road shows certain decrease in its concentration in the first- and the second-year needles and in the soil (Figure 4.6).

After a comparison of the ions content (sodium, chlorine, magnesium, potassium, and calcium) in the first- and the second-year needles, a statistically significant difference in the concentrations of sodium and potassium ions was confirmed by a test (Table 4.5). The average concentrations of each element in collected samples show certain distinction of these concentrations for all the elements (Figure 4.8). Sodium, chlorine, and calcium ions show lower values in the first-year needles than in the second-year needles. The transport of calcium ions in plants is sparse and its redistribution from older needles is limited (Lhotáková 2012). The calcium concentration is lower in the first-year needles, as Kayama et al. (2003), Truparová, Kulhavý (2011) and Bouchal (2012) confirmed in their studies. The concentrations of sodium and chlorine ions are also lower in the first-year needles than in the second-year needles. The research by Kayama et al. (2003) and Suchara et al. (2011) also confirmed this tendency. The average potassium ions content in the first-year needles was higher than in the second-year needles (Figure 4.8). The potassium content in needles decreases with needle age (Truparová, Kulhavý 2011). The Bouchal (2012) study also registered higher potassium content in the first-year needles (5 – 9 $mg.g^{-1}$) than in the second-year needles (4 – 7 $mg.g^{-1}$). This trend was also confirmed by Kayama et al. (2003). The average content of magnesium was also higher in the first-year needles than in the second-year needles (Figure 4.8) which was confirmed in studies by Kayama et al. (2003) and Bouchal (2012) as well.

4.5 Conclusion

The research into the effects of winter road maintenance on selected conifer, the Norway spruce (*Picea abies*), confirmed the increased sodium and chlorine ions concentrations in trees growing in the areas with higher contamination potential. A deterioration of health condition of the Norway spruce trees depending on the increasing sodium and chlorine ions concentration in needles was also observed. This research paper describes and evaluates the negative influences these chemical elements have on the ambient vegetation and it confirms their accumulation in the assimilative organs of the trees. The Norway spruce is a suitable for bioindication of winter chemical road maintenance because of its increased sensitivity to salting and its abundance in the area of interest. Proposed scale with framework values of ions concentrations of substances in the spruce needles can be used for a practical assessment of the level of contamination and for winter maintenance control. To increase the practical utility of such bioindication, it would be beneficial to create similar scales for other species of abundantly growing trees and to verify their validity in other areas.

Kapitola 5

Impact of road salting on Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*)

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Abstract

Evaluation of the impact of transport on the surrounding environment requires an ecosystem approach: to analyze components that provide information about the distribution of concentrations of the monitored contaminants and to allow an estimate of the dynamics of movement of these substances in the environment. Trees are used for biomonitoring for wide range of contaminants, coming not only from air pollution from industry or transport but also from winter chemical road maintenance. The research paper presents the determination of sodium and chloride ions content in assimilative organs of conifers and evaluates the influence of the contamination potential on these ions contents in needles of the Scots pine (Pinus sylvestris) and Norway spruce (*Picea abies*). Scots pine is studied a useful bioindicator for different tip of trace elements, but in the case of influence of winter maintenance, there is not so deep focusing as in the case of spruce. We have used this species of conifers for their usual occurrence. To assess the differences between sensitivity of salinity of different type of needles, the results of analysis of first- and second-year needles of Scots pine needles and samples of the Norway spruce were compared. The study was conducted in two different areas (for Scots pine and Norway spruce) in the Czech Republic. Samples of soils were collected near each tree of interest. The results of ions concentrations (Na, Cl) were evaluated depending on two factors: the distance from the road and the age of the needles. For evaluation of the impact of transport on the surrounding environment also the concentrations of wide range of elements were measured. The study confirmed a higher sensitivity of Norway spruce to salinity than in Scots pine. Given the confirmed increased sensitivity of spruce stands to the effects of winter road maintenance, spruce is not an appropriate tree species for the immediate vicinity of road infrastructure. Increased NaCl accumulation in the assimilation organs of the conifer trees near the road was confirmed and scales with concentrations were established to assess the degree of contamination.

Keywords: needles; winter road maintenance; NaCl; sodium ions; chloride ions; assimilation organs

5.1. Introduction

Transport and its networks affect the form and quality of ecosystems (Bíl et al. 2019; Keken et al. 2016; Rhodes et al. 2014; Roger et al. 2011) as well as human health (Kušta et al. 2017; Trombulak, Frissell 2000; Wei et al. 2014). Ecosystems around transport infrastructure can be influenced from close by or up to thousands of metres away (Keken et al. 2019). The extent of the final influence is determined by both the type of pollutant (Zítková et al. 2018) and the structure of the surrounding habitats (Keken, Kušta 2017; Kušta et al. 2014) or the type of receptor on which the pollutant acts.

Many studies have shown the adverse effects of pollutants generated by transport on the environment, including winter maintenance products, especially salts such as sodium chloride (NaCl) (Ramakrishna, Viraraghavan 2005). The use of NaCl is one of the most common de-icing methods. According to Lundmark, Olofsson (2007) and Cunningham et al. (2008), at least 90% of the total deposition of Na + and Cl- in the soil occurs within 20 metres of roads. These salts are often used for de-icing roads, pavements and public areas, and they can gradually accumulate in the environment and affect water quality (Godwin et al. 2003), the structure and vitality of aquatic ecosystems (Sanzo, Hecnar 2006), soil quality (Dai et al. 2012; Ordonez-Barona et al. 2018) and microorganisms and fungal organisms occurring therein (Calvo-Polanco et al. 2008; Day et al. 2010; Yi et al. 2008), as well as the structure and vitality of surrounding habitats (Collins and Russell 2009; Hanslin 2011; Langen, Prutzman 2006; Sienkiewicz-Paderewska et al. 2017).

Studies also confirm that the use of salts for de-icing can affect the condition of trees (Ordonez-Barona et al. 2018; Cekstere et al. 2008; Equiza et al. 2017). Soil is normally capable of effectively maintaining its density (Page et al. 2015; Bühler et al. 2017); however, winter maintenance practices such as regular application of salts can change soil chemistry, which can alter soil's ability to create conditions for successful tree growth (Ordonez-Barona et al. 2018). The effects of de-icing salts on vegetation may include direct exposure to leaves, needles, buds, or bark of a stem or branches to sprayed water contaminated with salt, or indirect exposure through increased salt concentrations in the soil. Such exposure may cause damage to the leaves, needles, buds, or root system. Increased salinity can affect both the growth of root systems and their function (Hanslin 2011; Neumann 1995) and significantly affect the health or viability of individual trees (Graves, Gallagher 2003; Paludan-Müller et al. 2002; Jonsson 2006).

Salts that enter the soil can further seep into groundwater. The amount of infiltrated salt depends on the permeability of the soil. Compared to surface waters (Maxe 2001), groundwater has less chance of diluting an infiltrated salt solution, therefore groundwater is more vulnerable than surface water (Lundmark, Olofsson 2007; Serrano, Gaxiola 1994). Water supplies are contaminated most often, changing the characteristics of drinking water (salty taste). In addition, salts can increase the hardness, alkalinity, and total dissolved solids content of water (Scholz, Grabowiecki 2007; Søberg et al. 2016; Szota et al. 2015).

In the context of biomonitoring and monitoring the progressive development of the state of the individual components of the environment, it is necessary to use appropriate methods and samples to identify the characteristic contaminants and determine their concentrations to assess the dynamics of their movement in the environment. Suitable types of samples used for biomonitoring of the environmental burden by transport or winter maintenance include biomass from vegetation around transport infrastructure, more specifically tree leaves or needles (Kayama et al. 2003; Klink et al. 2018; Zítková et al. 2018).

This paper aims to evaluate and compare the use of Norway spruce and Scots pine biomass for biomonitoring of environmental contamination due to winter road maintenance. The aim of the study was to identify the number of ions from saline solutions in Scots pine biomass from the available data and compare them with the results of accumulation of these ions in Norway spruce (Zítková et al. 2018). In order to increase the practical usefulness of bioindication, it is also appropriate to create a scale with framework values for assessing the degree of contamination by saline solutions for Scots pine and comparing it with the scale for Norway spruce.

5.2 Material and methods

5.2.1 Sampling

The samples of first-year and second-year Norway spruce and Scots pine and samples of soil material were collected from the vicinity of researched trees. The samples were collected in September 2015 in areas where these trees grow close to the roads and where the potential danger of contamination exists. These are areas where salting is used and are not excluded from chemical winter maintenance (eg. protected areas, protection of water resources, etc.).

Scots pine needles and samples of soil were collected in area north of Prague along 1st, 2nd and 3rd class roads. Norway spruce needles and samples of soil were collected in the north of the Czech Republic in the south-eastern part of the Liberec Region also along 1st, 2nd and 3rd class roads. Traffic intensity was varied depending on the class of roads (1st, 2nd and 3rd). In the lower ones, annual average daily traffic (AADT) ranged from 1000 to 3000 in the higher from 6000 to 30 000.

Those two areas were chosen for this research for its abundant presence of these species and because the de-icing salt materials are used for the winter road maintenance here.

According to winter maintenance, roads are divided into 4 categories. The roads selected for the study are into the first two categories that require intensive maintenance. The amount of salt applied depends on local conditions (snow cover, icing, etc.). The amount of salts used for disposal here is in the range of 20 - 40 g/m2.

The application of salts on one intervention day should not exceed the amount of 60 g/m2.

A total of 32 samples of the first-year needles and 32 samples of the second-year needles from the same trees were collected together from Norway spruce with 32 samples of soil collected from up to 5 m from the roadside. Some areas further from the road (at least 40 m from the roadside) were chosen as well for comparison; from these areas 12 samples of the first-year assimilation organs, the same number of the second-year needles and 12 samples of soil material were collected.

A total of 30 samples of the first-year needles and 30 samples of the second-year needles from the same trees were collected together from Scots pine with 30 samples of soil collected from up to 5 m from the roadside. Also, in Prague areas were collected needle samples at a distance of 40 m from the roads for comparison. The distance (5 and 40 meters) was always measured perpendicularly to the roadside.

The soil samples were collected up to the distance of 1.5 m (from the stem) from individual tree which the assimilation organs had been collected. The sample consist of about 100 g of soil collected at a depth of 0 – 25 cm, which was later dried at room temperature. After drying, the samples were sieved and milled. To acquire the Norway spruce and Scots pine assimilation organs, the whole first- and second-year branches were cut, not just the needles. For each tree, the first- and the second-year branches were collected and put separately in paper bags. The samples were dried at room temperature and ground on a cutting mill.

5.2.2 Chemical analysis

Chemical analysis was performed equally for both species of conifers.

5.2.2.1 Determination the concentration of Na, Ca, K, Mg and trace elements

About 0.4 g of homogenised plant material was digested in a mixture of nitric acid ultrapure and hydrogen peroxide ultrapure using Teflon vessels and a high pressure and high temperature microwave digestion system SW-4+ (Beghof). Duplicate digestions of each sample were prepared in parallel. The digested samples were diluted to a final volume 50 ml with ultrapure water (Millipore).

5.2.2.2 Determination the concentration of chloride ions

To determine the concentration of chloride ions in the assimilation organs, first, the homogenised sample (adjusted to the size < 2 mm) was mixed with ultrapure water at a ratio of 1:10, then it was stirred and boiled. Boiling granules were added to the sample to stir it. The samples were left to cool down after about a minute of boiling. The leachate was poured into a clean vessel after 30 minutes of leaching. The chloride ions were determined by spectrophotometry using Spectroquant Prove 300 (Merck-Milipore) with selective test Spectroquant® Test for chloride determination by photometry, measuring range 2.5 – 250 mg.l-1 Cl-1. The quality of the analytical results was checked via frequent analyses of reference material (RM ION-96.4 A natural river water with certificate value of Chlorides).

5.2.2.3 Determination of concentrations of chloride ions in soil

A plastic container of 250 ml volume was filled with 10.0 g of dry sieved soil sample and 100 ml of ultrapure water. The containers were put into a shaker (Reax 20 rotary shaker) and left shaking for 24 hours at laboratory temperature and the rotation speed of 5 rpm. After the extraction, the samples were set aside for 1 hour before being further processed. Soil samples extracted with water were centrifuged (Universal 320 R benchtop centrifuge) for 20 minutes at the rotation speed of 4000 rpm. If needed, the samples were further filtered through 0.45 μm membrane filter. The samples thus prepared were used for the analysis.

5.2.2.4 Determination of concentrations of macro and trace elements in soil

Soil samples were prepared according ISO 11466 (Soil quality – Extraction of trace elements soluble in aqua regia). About 1.0 g of homogenised (sieved, milled) soil samples were digested in 10ml of aqua regia using Teflon vessels in microwave system SW-4+ (Berghof) at a temperature 200°C and pressure 30 bar. Duplicate digestions of each sample were prepared in parallel. The digested samples were diluted to a final volume 50 ml with ultrapure water (Millipore).

Concentrations of elements (except chloride) were determined with an ICPMS/MS (Agilent 8800 ICP-QQQ, Agilent Technologies, Japan). The quality of the analytical results was checked via frequent analyses of reference materials (NIST Pine Needles 1575a, NIST Trace elements in natural water 1640a, QCM Metranal 34 - soil).

5.2.3 Evaluation of the analyses results

First, the data were summarized and the basic characteristics were calculated to visualize the concentration of individual element ions in Norway spruce and Scots pine needles and in soil.

To compare the concentration of Cl, Na, Mg, Ca, and K ions, the average concentration of these ions in needles and soil samples was calculated in the category up to 5 m from the road and the concentration of ions in needles in the category 40 m from the road. The relationship of ion concentration (Cl, Na, Mg, Ca, and K) in the first and second year of needles was also assessed. For comparison, average concentrations of these ions in the first and second years of needles were calculated.

5.3 Results

In order to obtain an overview of the concentration ranges of analyzed ions of the elements (Cl, Na, Mg, Ca and K) in the evaluated set, the basic parameters of descriptive statistics are presented in the following tables (Table 5.1; 5.2). Ions concentrations in the needles of Scots pine analyzed ranged from: 0.002-0.043 $mg.g^{-1}$ for Cl; 0-2.22 $mg.g^{-1}$ for Na; 0.329-1.59 $mg.g^{-1}$ for Mg; 0.002-9.90 $mg.g^{-1}$ for Ca; and 0.006-3.58 $mg.g^{-1}$ for K (Table 5.1). Concentration ranges of contents of individual elements in analyzed samples of Norway spruce needles range from: 0.294-6.33 $mg.g^{-1}$ for Cl; 0-5.11 $mg.g^{-1}$ for Na; 0-2.01 $mg.g^{-1}$ for Mg; 0-14.7 $mg.g^{-1}$ for Ca; and 0-18.8 $mg.g^{-1}$ for K (Table 5.2).

Table 5.1: *Numerical characteristics of data for individual ions of elements (Cl, Na, Mg, Ca, and K). Concentration ($mg.g^{-1}$) in first-year and second-year needles of the Scots pine and soil samples near roads (SD – standard deviation).*

	Cl ($mg.g^{-1}$)			*Na ($mg.g^{-1}$)*		
	1st year	*2nd year*	*Soil*	*1st year*	*2nd year*	*Soil*
Number of samples	30	30	30	30	30	30
minimum	0.002	0.004	0.009	0.020	0.000	0.069
1st quartile	0.005	0.007	0.025	0.073	0.173	0.109
median	0.009	0.009	0.054	0.273	0.541	0.170
average	0.011	0.014	0.056	0.356	0.737	0.284
3rd quartile	0.014	0.018	0.072	0.543	1.26	0.270
maximum	0.031	0.043	0.165	1.41	2.22	2.05
SD	0.008	0.010	0.036	0.327	0.646	0.368

	Mg ($mg.g^{-1}$)			*Ca ($mg.g^{-1}$)*		
	1st year	*2nd year*	*Soil*	*1st year*	*2nd year*	*Soil*
Number of samples	30	30	30	30	30	30
minimum	0.612	0.329	0.427	1.36	0.002	0.633
1st quartile	0.831	0.868	0.905	2.32	4.05	2.92
median	1.10	1.08	1.61	3.29	5.29	6.61
average	1.03	1.01	1.59	3.10	5.21	11.2
3rd quartile	1.19	1.18	1.83	3.70	6.44	12.3
maximum	1.59	1.54	6.10	5.06	9.90	61.7
SD	0.241	0.275	1.08	1.02	2.00	13.9

	K ($mg.g^{-1}$)		
	1st year	*2nd year*	*Soil*
Number of samples	30	30	30
minimum	1.64	0.006	0.641
1st quartile	2.05	1.61	1.49
median	2.18	1.84	3.14
average	2.28	1.81	3.50
3rd quartile	2.47	2.00	5.25
maximum	3.58	2.66	8.07
SD	0.384	0.484	2.06

Table 5.2: *Numeric data characteristic for individual ions of elements (Cl, Na, Mg, Ca, and K). Concentration (mg.g^{-1}) in first-year and second-year needles of the Norway spruce and soil samples near roads (* the values below the limit of detection, SD – standard deviation).*

	Cl (mg.g^{-1})			*Na (mg.g^{-1})*		
	1st year	*2nd year*	*Soil*	*1st year*	*2nd year*	*Soil*
Number of samples	32	32	32	32	32	32
minimum	*	*	*	*	0.025	0.002
1st quartile	0.294	0.424	0.108	0.043	0.069	0.011
median	0.632	0.652	0.259	0.083	0.141	0.019
average	0.870	1.13	0.230	0.459	0.636	0.031
3rd quartile	1.22	1.20	0.326	0.123	0.448	0.053
maximum	4.07	6.33	0.607	3.77	5.11	0.101
SD	0.857	1.31	0.141	0.978	1.12	0.027
	Mg (mg.g^{-1})			Ca (mg.g^{-1})		
	1st year	*2nd year*	*Soil*	*1st year*	*2nd year*	*Soil*
Number of samples	32	32	32	32	32	32
minimum	*	0.265	0.002	*	1.04	0.003
1st quartile	0.673	0.547	0.004	2.70	2.87	0.006
median	0.855	0.830	0.005	3.26	3.97	0.015
average	0.964	0.862	0.007	3.95	4.93	0.021
3rd quartile	1.24	1.11	0.008	4.80	5.97	0.026
maximum	2.01	1.88	0.024	12.7	14.7	0.080
SD	0.444	1.13	1.31	2.51	3.17	0.018

	K $(mg.g^{-1})$		
	1st year	*2nd year*	*Soil*
Number of samples	32	32	32
minimum	*	0.941	0.001
1st quartile	3.99	3.43	0.006
median	5.56	5.19	0.010
average	6.20	5.16	0.013
3rd quartile	7.27	6.70	0.016
maximum	18.8	9.11	0.047
SD	3.37	2.16	0.011

The expended measurement uncertainties are 10% for all elements and are calculated for each actual measurement from two parallel pairs of measurement results of the same sample, or reference material (from digestion to analysis) as 2*RSD of these replicates. From a long-term point of view, the uncertainties for these selected elements are always in the maximum range of + -10% (Figure 5.1; 5.2; 5.3; 5.4; 5.5; 5.6). The results of element ion concentrations were evaluated according to two factors: i) distance from the road and ii) age of the needles.

5.3.1 Comparison of element ion concentration depending on distance from the road

To evaluate the relationship of Na and Cl ions concentrations in needles in individual trees near the road and individual trees more distant from the road, the samples were divided into two categories:

Category 1 – samples taken within 5 m of the road,

Category 2 – control samples taken at least 40 m from the road.

A basic summary of the results for Scots pine is given in the graphs (Figure 5.1; 5.2); for Norway spruce (Figure 5.3; 5.4).

Average concentrations in the first and second years of needles were lower in the more remote locations than in the closer ones (Figure 5.1). The same was true for soil samples, where lower concentrations occurred in Category 2 locations (Figure 5.1).

Concentrations of chloride ions in the second year needles and in soils also showed lower concentrations in more remote locations; however, in the first year it was the opposite and the concentration of chloride ions was higher in samples from more remote locations (Figure 5.2).

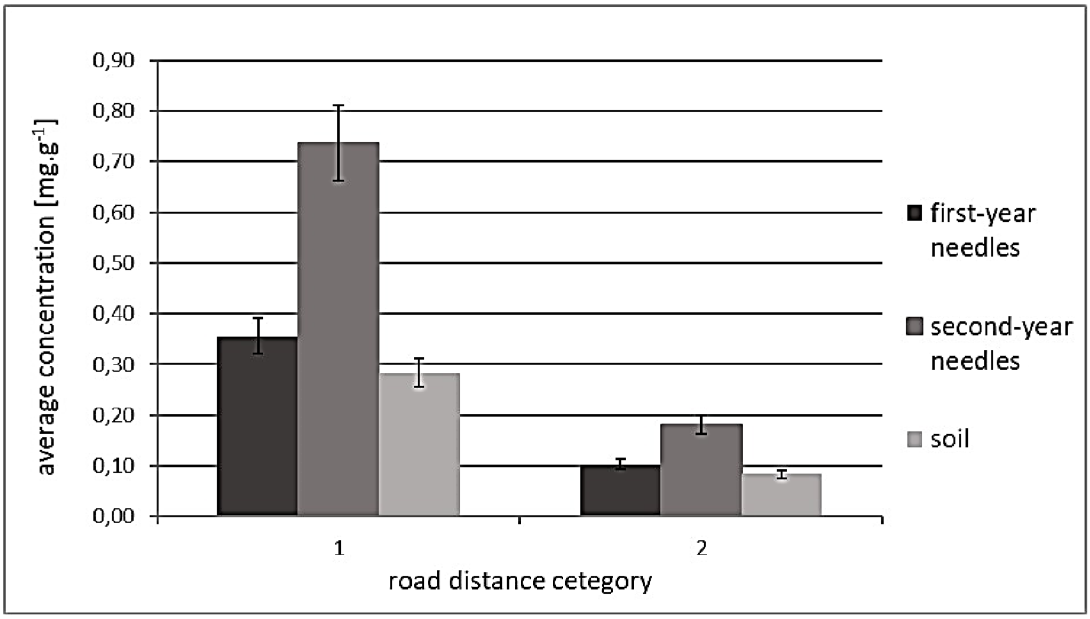

Figure 5.1: *Sodium ions concentrations in needles of Scots pine depending on the distance from the road.*

Average concentrations of sodium ions in the first and second years of Scots pine needles and soil depending on distance from the roadside (1st category: <5 m, 2nd category: > 40 m).

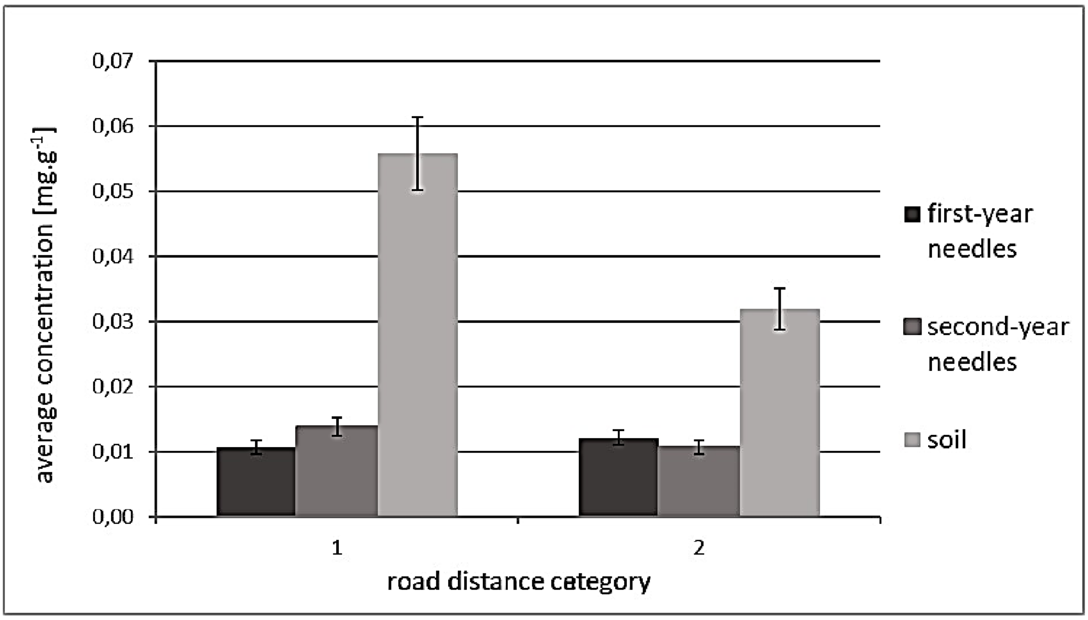

Figure 5.2: *Chloride ions concentrations in needles of Scots pine depending on the distance from the road.*

Average concentrations of chloride ions in the first and second years of Scots pine needles and soil depending on distance from the roadside (1st category: <5 m, 2nd category: >40 m).

Average ion concentrations in the first and second years of Norway spruce needles and soil were lower in sodium in more remote locations (Figure 5.3). Chloride in the first year of needles shows a higher average concentration value in more remote locations; in the second-year needles and in soil the concentration of chloride is higher near the road (Figure 5.4).

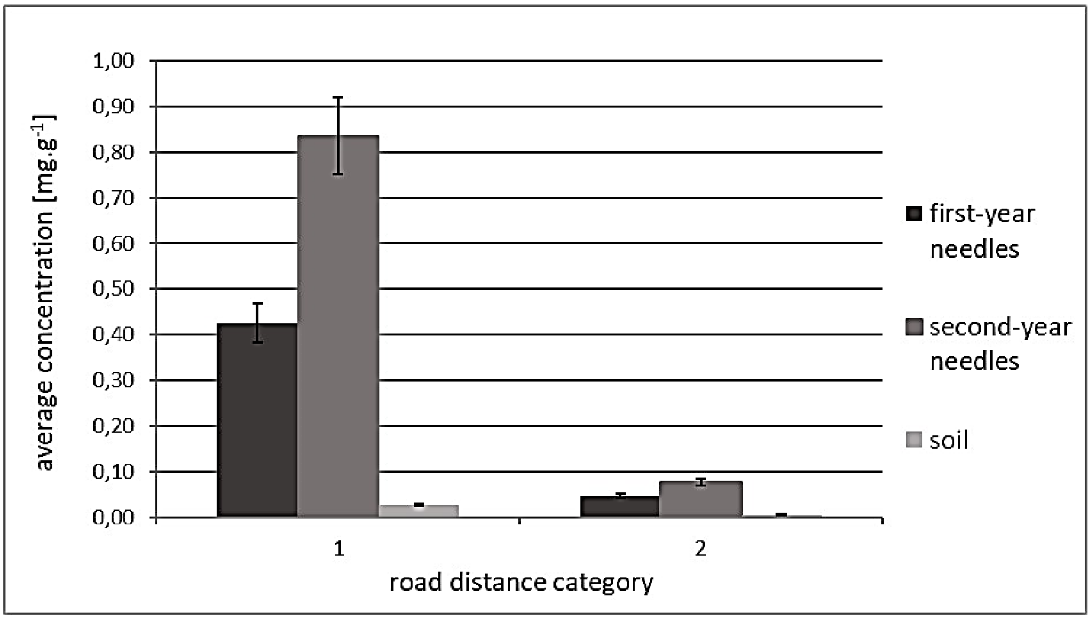

Figure 5.3: *Sodium ions concentrations in needles of Norway spruce depending on the distance from the road.*

The average sodium ion concentrations in the first- and the second-year needles of Norway spruce and the soil depending on the distance from the roadside (1st category - <5 m, 2nd category: > 40 m).

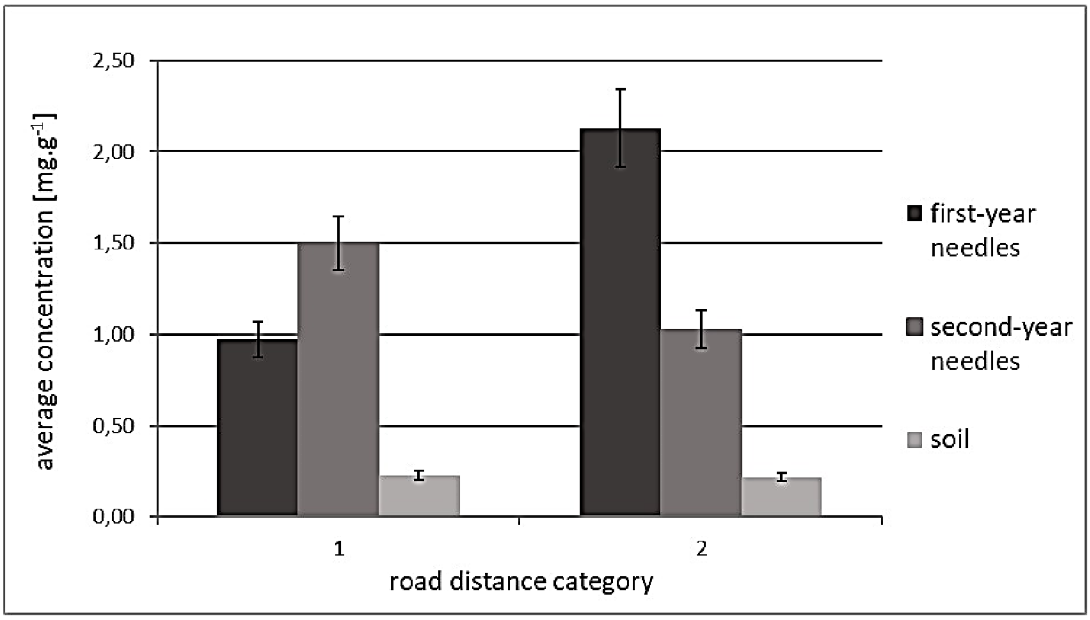

Figure 5.4: *Chloride ions concentrations in needles of Norway spruce depending on the distance from the road.*

The average chloride ions concentrations in the first- and the second-year needles of Norway spruce and the soil depending on the distance from the roadside (1st category - <5 m, 2nd category: > 40 m).

5.3.2 Comparison of element ion concentrations depending on the age of the needles

To evaluate the relationship of Na, Cl, Mg, K, and Ca ion concentration in Scots pine and Norway spruce needles depending on the year of needles, the samples were divided into first and second years.

The average concentration of individual element ions in both years of Scots pine needles shows the difference in these concentrations. Chloride, sodium and calcium show higher concentrations in the second year of needles, while potassium shows a higher concentration in the first year. For magnesium, these concentrations are approximately the same (Figure 5.5).

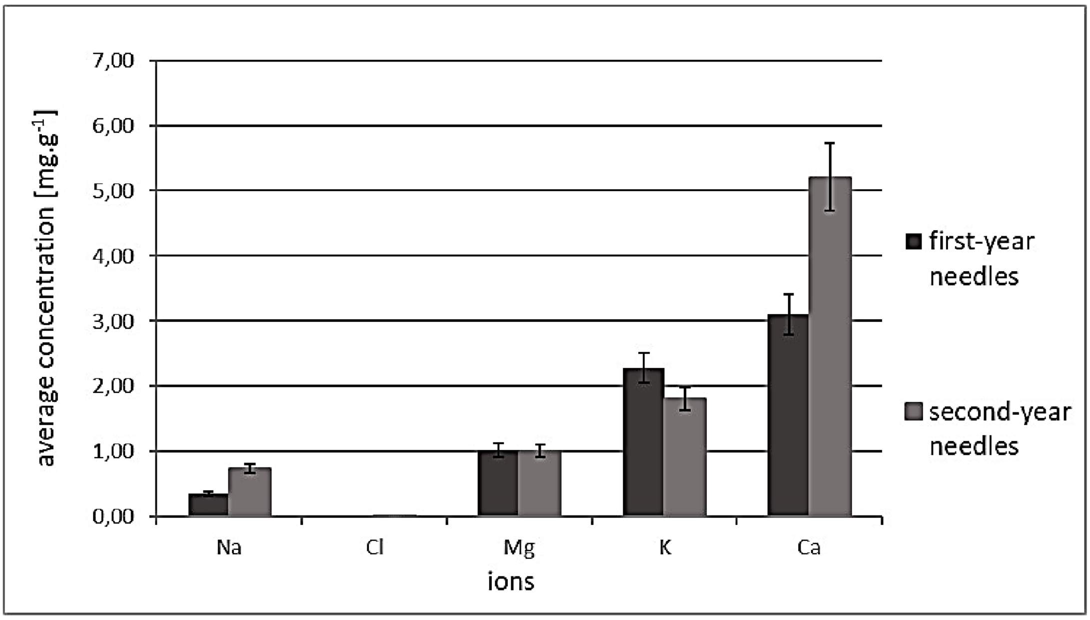

Figure 5.5: *Concentrations of Na, Cl, Mg, K, and Ca in needles of Scots pine.*

Average concentrations of Na, Cl, Mg, K, and Ca in first- and second-year needles of Scots pine at a distance of <5 m from the roadside.

In Norway spruce, the concentrations of all ions in the first- and second-year needles are similar to those of Scots pine. In sodium, chloride and calcium, the concentrations in the second year of needles are higher. Magnesium and potassium show higher average concentrations in the first year (Figure 5.6).

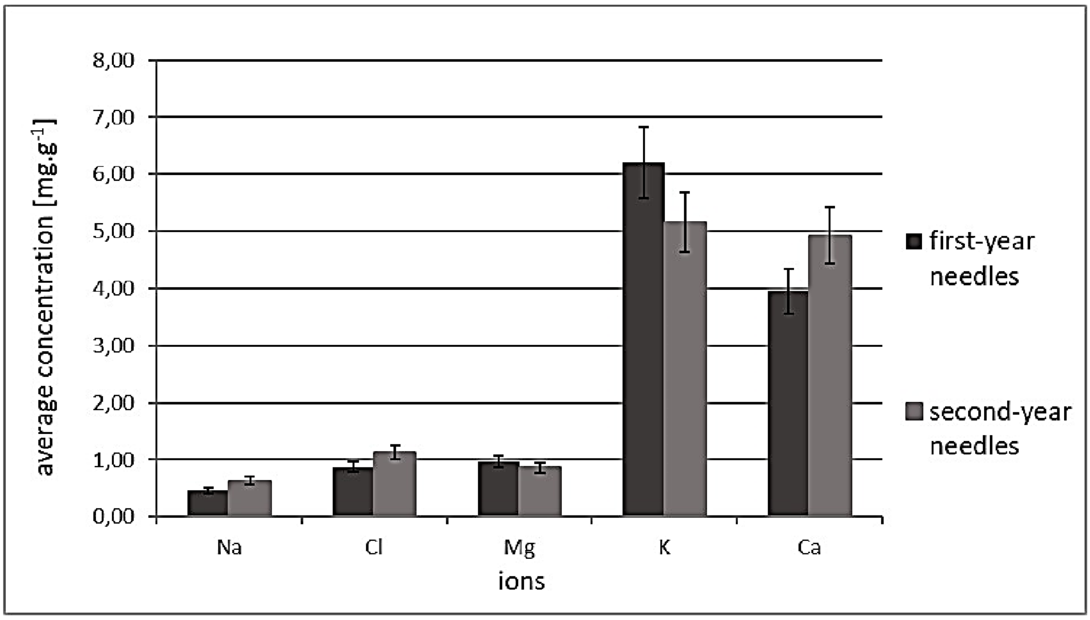

Figure 5.6: *Concentrations of Na, Cl, Mg, K, and Ca in needles of Norway spruce.*

Average concentrations of Na, Cl, Mg, K, and Ca in the first- and second-year needles of Norway spruce at a distance <5 m from the roadside.

5.3.3 Scale for contamination assessment

Finally, based on the results and evaluation of the literature data, a scale with frame values of Na and Cl ions concentrations was proposed for possible practical use in assessing the degree of contamination. The scale was created separately for Na content and for Cl content in the first and second years of Scots pine needles (Table 5.3) and compared with the scale for Norway spruce (Table 5.4).

Table 5.3: *Proposed scale of Na and Cl ion concentrations in first and second years of Scots pine needles for practical assessment of the degree of contamination.*

class	*level of concentration*	*Na (mg.g^{-1})*		*Cl (mg.g^{-1})*	
		1st year	*2nd year*	*1st year*	*2nd year*
1	normal	< 0.4	< 0.8	< 0.010	< 0.013
2	slightly higher	0.5 – 0.7	0.9 – 1.3	0.011 – 0.015	0.014 – 0.020
3	high	> 0.8	> 1.4	> 0.016	> 0.021

Table 5.4: *Proposed scale of Na and Cl concentrations in first and second years of Norway spruce needles for practical assessment of the degree of contamination (Zítková et al. 2018).*

class	*level of concentration*	*Na (mg.g^{-1})*		*Cl (mg.g^{-1})*	
		1st year	*2nd year*	*1st year*	*2nd year*
1	normal	< 0.6	< 0.7	< 0.7	< 1.1
2	slightly higher	0.7 – 1.9	0.8 – 2.9	0.8 – 2.0	1.2 – 2.4
3	high	> 2.0	> 3.0	> 2.1	> 2.5

5.4 Discussion

Analysis of Scots pine needles confirmed higher concentrations of Na ions in locations adjacent to roads in both the first and second years (Figure 5.1). Norway spruce was also confirmed to have a higher average concentration of Na ions in needles at places with a higher potential for contamination (Figure 5.3), i.e., near roads, than in more remote locations (Zítková et al. 2018). According to Kayama et al. (2003), Norway spruce needles at locations more distant from roads also showed lower concentrations of Na ions. Chloride anions show a higher concentration in Scots pine near the road in the second year and in the soil (Figure 5.2); however, they are much more mobile and therefore their increased concentrations may also occur at more distant locations where they are washed out more rapidly than Na. Cain et al. (2001), Semorádová (2003) and Zítková et al. (2018) point to higher concentrations of Cl ions at more distant locations from roads (Figure 5.4). Semorádová (2003) shows that the accumulation of chloride ions also depends on other factors (steep slopes, drain device outlets from roads, terrain changes, soil structure, etc.), which may be the reason for different concentrations of mobile chloride ions in the environment.

When comparing the content of ions (Cl, Na, Mg, Ca, and K) in the first and second year of Scots pine needles taken near the road (Figure 5.5), there are some differences in concentrations for all elements. Na, Cl, and Ca ions show lower values in the first year of needles than in the second year. The Norway spruce needles also confirm the higher concentration of Ca ions in the second year of needles (Figure 5.6). Lower levels of Ca ions in the first year are also shown in studies by Kayama et al. (2003), Truparová, Kulhavý (2011), Bouchal (2012) and Zítková et al. (2018). This phenomenon is explained by Lhotáková (2012): the transport of Ca ions in the plant body is more limited than the transport of other elements, and the subsequent redistribution of this element to younger needles is limited.

Na and Cl also show lower concentrations in the first year of Scots pine needles. This trend is also confirmed in the studies by Kayama et al. (2003) and Suchara et al. (2011). The same tendency can be observed in the study by Zítková et al. (2018). In Norway spruce needles (Figure 5.6), the ions of elements (Na, Cl and Ca) show higher average concentrations than pine; however, they show the same tendency in lower accumulation of these ions in earlier years.

For Mg and K, the average ions concentration in pine needles (Figure 5.5) and Norway spruce (Figure 5.6) was higher in the first year of needles than in the second. In general, these ions are more readily bound than, for example, Ca ions, and therefore move more easily (Czerniawska-Kusza et al. 2004). Higher concentrations in the first year were also found in Kayama et al. (2003) and Bouchal (2012). According to Fostad, Pedersen (2000), NaCl exposure causes an increase in the concentration of K ions in plant assimilation organs. Townsend (1980) describes the same tendency. For Norway spruce, however, the values of K ions were significantly higher than for Scots pine, which might be explained by the high sensitivity of spruce to increased exposure to saline solutions.

The accumulation of Na ions in the assimilation organs is lower than the accumulation of Cl ions, as confirmed by Lumis et al. (1976) and Townsend (1980). This was not confirmed in Scots pine (Figure 5.5), where Cl ions showed lower assimilations. However, Cl ions showed higher concentrations than Na ions in Norway spruce (Figure 5.6). The concentration of both ions in the assimilation organs varies significantly between species (Fostad, Pedersen 2000). The highest concentration and needle damage are confirmed in Norway spruce (Fostad, Pedersen 2000; Zítková et al. 2018). Lower concentrations can be observed in Scots pine (Figure 5.5) or Norway maple and silver birch species (Fostad, Pedersen 2000).

The sensitivity of Norway spruce to salinity has been shown in several studies (Dragsted 1979; Semorádová, Materna 1982; Fostad, Pedersen 2000; Suchara et al. 2011; Zítková et al. 2018). Despite the fact, that Scots pine does not have as high sensitivity to salinity as Norway spruce, the accumulation of ions from the de-icing mixtures in the assimilation organs can also be observed and can therefore be used to indicate de-icing salt contamination. Based on the results and research, a scale was created for the first and second years of Scots pine (Table 5.3), which can be compared with a similar scale created for assessing the degree of contamination of spruce stands along roads (Table 5.4). The scale for spruce stands shows higher values than the scale for Scots pine.

5.5 Conclusion

The study of accumulation of de-icing salt ions used for winter road maintenance confirmed higher concentrations of Na and Cl ions in Scots pine assimilation organs in the locations immediately adjacent to roads. The study evaluates the negative effects of de-icing salts and its accumulation in needles. The results of Scots pine needle analyses were compared with the results of the study of winter maintenance bioindication on Norway spruce. According to the comparison, an increased sensitivity of Norway spruce to salinization can be confirmed; however, Scots pine also shows increased concentrations in locations near roads. For a possible comparison with the scale for Norway spruce, proposed in a previous study, a scale with concentration values was created based on the results for Na and Cl ions concentrations in Scots pine to assess the degree of contamination. For greater practical use, it would be advisable to validate this in other areas as well or analyze other widespread species and create similar scales.

5.5.1 Application and practice

The management of a biotopes which are in the vicinity of the road infrastructure is very specific. In case of forest stands they are often same age and monocultural character, which are increasingly inhibited by the effects of climate change such as decreasing the grand total rainfall and its fluctuations during individual months, increasing the temperature, or the associated intensifying of dissemination the spread of non-native species. The change resulting by salinization may thus contribute to exceeding the acceptable level of negative impact on these stands and these biotopes may be at a higher risk of mix of negative effects in the future than they can cope with. This will then lead to their lose.

For these reasons, it is necessary to restored or reconstructed of existing road infrastructure in the context of its surrounding environment in such a way that the ecosystems affected by transport are adapted as much as possible to the potential climate change as well as to the traffic and maintenance.

Given the confirmed increased sensitivity of spruce stands to both abiotic and biotic agents, their high exposure and sensitivity to future climate change and the current high sensitivity to the effects of winter road maintenance, spruce is not an appropriate tree species for the immediate vicinity of road infrastructure. Even with regard to safe and continuous transportation, for the biotopes which surround roads should be plant by trees with lower sensitivity to all negative effect.

Kapitola 6

Applying principles of EIA Post-project analysis in the context of suburban infrastructure development

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Abstract

Residential, commercial, and infrastructural construction is a worldwide phenomenon that is monitored and evaluated in various details in different countries in terms of environmental impact. The prediction verification approach in the sense of principles of post-project analysis (PPA) within the EIA process for a residential complex was performed in this study. Re-analyses for selected environmental factors were done, the results of which were compared with reference values measured, modelled, or predicted during the EIA process. Hydro chemical changes and noise levels were selected as the most important factors. The results of the comparison of individual predictions and measurements of noise levels indicate the accuracy of former EIA outcomes. However, it is possible to identify an ever-increasing rate of noise level loading, which is caused by an overall cumulative effect, due to which the predicted values will most probably be exceeded in upcoming years. The results of the comparison of hydro chemical parameters show certain changes after the implementation of the project for some measured factors, such as water saturation by oxygen or pH. In some parts of the monitored water profile, significantly higher values of chlorine ions, sulphates, or surfactants were measured. Results show that the prediction and conclusions regarding selected parameters of EIA evaluation were accurate for the construction phase and the first year's use of the residential complex; however, they could not precisely identify medium to long-term cumulative effects. Similar studies in the sense of EIA PPA principles focuses on urban development are an opportunity for improving predictions within the EIA process and from the lessons gain more sustainable development could be achieved.

Keywords: EIA follow-up; sustainability development; ex-post evaluation; human environment interaction; urbanization; cities

6.1 Introduction

Residential, commercial, or infrastructural construction development is a worldwide phenomenon. Economic development, both nationally and transnationally, is considered as not sustainable in the long-term. For this reason, environmental policies have been developed, the aim of which is primarily the sustainable development of society (Moldan 1992).

The Environmental Impact Assessment (EIA) process is applied in every country of the World (Bond et al. 2020). This tool was developed 50 years ago to consider the environmental consequences of development before approval decisions were made (Morrison-Saunders, Arts 2004a; Keken et al. 2022). Its gradual development and improvement will be a crucial factor in preventing, reducing, or compensating for the risks associated with significant global changes (so-called global megatrends) which the world faces in the 21st century. The effects of these local, but especially global, changes are also collectively referred to as the Anthropocene (Steffen et al. 2015; Retief et al. 2016).

Post-project analysis within the EIA process (EIA-PPA) can be understood as a process of monitoring and evaluating the real environmental impact (Wood 2003; Pölönen et al. 2010; Jalava et al. 2015) for projects that were evaluated in the EIA process during planning and permission (Partidario, Fischer 2004; Marshall et al. 2005; Morrison-Saunders et al. 2007).

6.1.1 General tasks of the study

Residential, commercial, or infrastructural construction is a worldwide phenomenon that is monitored and evaluated at various detail in different countries in terms of environmental impact. Construction is carried out similarly around the world, so this study may be internationally relevant to practitioners in the field of impact prediction and impact assessment specialization. This study aimed to evaluate the real impact on the environment in the field of noise pollution and hydro chemical change of an implemented residential project using a mutual comparison of predicted and real impacts. The article presents what the EIA predictive accuracy was and to what extent the EIA conclusions contributed to achieving greater sustainability.

6.1.2 History and evolution of post-project analysis within EIA process

Although the implementation of EIA-PPA is not often required by the legislative framework (nor under European Directive 2014/52/EU on the assessment of the effects of certain public and private projects on the environment), its principles and basic parameters of application have been shaped for a long time: i) first definitions were provided by e.g. Bisset (1980), Tomlinson, Atkinson (1987), Wilson (1998), Arts, Nooteboom (1999); ii) the significance and rationale for EIA-PPA has been formulated by e.g. Bisset (1980), Sadler (1988), Dipper et al. (1998), Arts et al. (2001); iii) the methodology approaches for EIA-PPA has been published by e.g. Bailey et al. (1992), Wilson (1998), Baker, Wood (1999); iv) evaluation of technical aspects of EIA-PPA, such as the accuracy of impact predictions, were published by e.g. Sadler (1987), Bisset, Tomlinson (1988), Lee (1998); and v) the linkages between the results of EIA-PPA and environmental management have been published by e.g. Glasson (1994), Marshall (2001), Morrison-Saunders, Arts (2005).

6.1.3 EIA post-project analysis in the 21. Century

EIA Follow-up can be conceptualized depending on different levels (Morrison-Saunders et al. 2021): micro level (individual project – the effectiveness of the extent to which the EIA process has contributed to preventing, eliminating, reducing, or compensating for environmental risks); macro level (EIA system – the experience of the extent to which the EIA process has the power to influence subsequent authorization processes, as well as the overall decision-making process, i.e. how much the EIA process affected the final design and authorization of the project); and the meta level (EIA concept itself – the usefulness and sustainability of the extent to which the EIA process has contributed to a higher level of sustainability). According to Zhao et al. (2012), EIA-PPA consists of monitoring and evaluating the impact of projects on the environment after their implementation, and it falls under the type of evaluation that deals with impact analysis. It compares predicted expectations with the real impact and becomes a key tool for testing EIA predictive power, or its accuracy (Braniš, Christpoulos 2005; O'Faircheallaigh 2007). EIA-PPA allows for a formal and factual review of the EIA process, its resulting recommendations, and permitted conditions (Alan et al. 1998; Arts et al. 2001; Retief et al. 2016, Loomis, Dziedzic 2018; Pinto et al. 2019; Keken et al. 2022). Post-project analysis is necessary to determine the results of EIA. Incorporating feedback into the process allows us to learn from experience (Morrison-Saunders et al. 2007; Morrison-Saunders et al. 2021).

6.1.4 Linkages between EIA and EIA Follow-up

EIA implementation, the variability of the assessed activities, and the details of evaluation are constantly discussed factors worldwide. Some countries (such as the United Kingdom, Finland, Denmark, the Netherlands, Lithuania, Estonia, and Australia) have conducted detailed studies on the effectiveness of the EIA process and defined issues to be addressed (Simpson 2001; Ahammed, Nixon 2006; Christensen 2006; Pölönen 2006; Kruopiene et al. 2008; Heinma, Poder 2010; Pölönen et al. 2010; Runhaar et al. 2013). The EIA process has been examined primarily from the legal, procedural, and fiscal point of view and, simultaneously, regarding the quality of individual output (Sadler 1996; Hickie, Wade 1998; Marsden 1998; Baker, Wood 1999; Rees 1999; Baker, McLelland 2003; Cashmore et al. 2004; Bina 2007; Retief 2007;

Zhu, Ru 2008; Keken et al. 2022). Other studies have also dealt with the quality of EIA documents, the effectiveness of their process implementation (Bailey 1997; Baker, Wood 1999; Pinho et al. 2006), and the role of EIA in development planning (Sadler 1996; Hickie, Wade 1998; Hacking, Guthrie 2008; Kolhoff et al. 2013); however, little attention has been paid to whether the EIA process is effective, efficient, and useful in what it really needs to achieve, namely to protect the environment, achieve a higher level of sustainability, and help achieve higher awareness, higher participation rates, and an overall balance in decision-making (Arts et al. 2012).

6.1.5 Human environment interaction in case of infrastructure development

Due to the constant growth of the world's population, achieving sustainable urban development and functioning is becoming a global challenge (Newman, Jennings 2008; Wu 2014). For example, in China, the proportion of urbanized population increased from 19.92% in 1978 to 49.95% in 2010, causing many problems in terms of traffic organization, social inequalities, reduced and threatened biodiversity, and deteriorating water and air quality (Ke et al. 2014). It is estimated that in 2014, 56% of the world's population was living in an urban environment and the assumption for 2050 is an increase in the number of people living in cities to 66% (United Nations 2015). Existing cities are responsible for significant depletion of natural resources and significant loss of agricultural land (FAO 2011). The adverse impact of urbanization on the environment is mainly caused by the density of centralized infrastructure elements and heavy traffic (McKinney 2002; EPA 2016). The urban environment has different biophysical characteristics compared to the open landscape, such as increased and accelerated surface runoff, hydrological characteristics (piping, regulation, and straightening of watercourses), changes in surface infiltration properties, reduced biodiversity, rising temperatures and development of urban heat island (Gill et al. 2007;

Zhang et al. 2009; Fletcher et al. 2013). All of these issues limit sustainable urban development and the question remains how to develop urban environments in a sustainable way (Ke et al. 2014).

6.2 Materials and methods

6.2.1 Study location

The residential complex studied (Milíčovský háj) is located on the south-eastern edge of Prague, the capital of the Czech Republic (Figure 6.1). A significant part of the affected land has been ecologically burdened in the past. Before construction of the residential complex, there was a construction yard for construction of a neighbouring panel housing estate, which included sheet metal halls, paint warehouses, solid fuel boiler room (including asbestos load), landfill, and a waste sorting room (Figure 6.2). The total area was approximately 65,502 m2. A total of 36 three- to five-storey apartment buildings were built with a planned capacity of 750 apartments, for which there were 742 underground garage parking places and 103 surface parking places. The planned population was about 1750, with a maximum of 2204 inhibitions. Construction began in 2010 and was completed in 2016.

6.2.2 Data collection and analysis

The mission of the work is applying to principles of post-project analysis therefore we followed comparison of predicted and real impacts. In the first phase, the documents prepared during the EIA were analysed: Notification, Conclusion of the Screening and Scoping Procedure, Environmental Impact Assessment Report (EIS Reporting), Expert Report (EIS Review), comments from all stakeholders on these documents, and the conclusion on the significant effects of the project on the environment (Conclusion on EIA). This first phase was important for obtain of categorization and quantification of predicted impacts. A partial result of the analysis was the identification of selected factors/impacts of the project on the environment, which were selected for detailed monitoring and mutual comparison: (i) noise level; and (ii) changes in hydro chemical parameters. The current state of these parameters was identified by repeated new measurements (noise) and sampling (hydro chemical parameters).

6.2.2.1 Noise level and traffic intensity

Based on the Study of Noise pollution from road traffic and construction activities for the project of the residential complex "Milíčovský háj" (Novák, 2007), the same noise measurement (PNM1) site was selected as for the elaboration of the Environmental Impact Assessment Report (Figure 6.1) (predicted values). In addition, a site PNM2 was selected which was in a newly built street. A total of 7 measurements and 1 prediction were taken at PNM1, with 4 measurements at PNM2 (Table 6.1; 6.2). Simultaneously, during the measurements, traffic intensity in the affected street profiles was also determined. Measurements were always taken at night, between 22:00 and 06:00 (LAeq,8h), thus eliminating the inclusion of noise from the construction site, and the study could focus purely on change caused by the existence of residential complex.

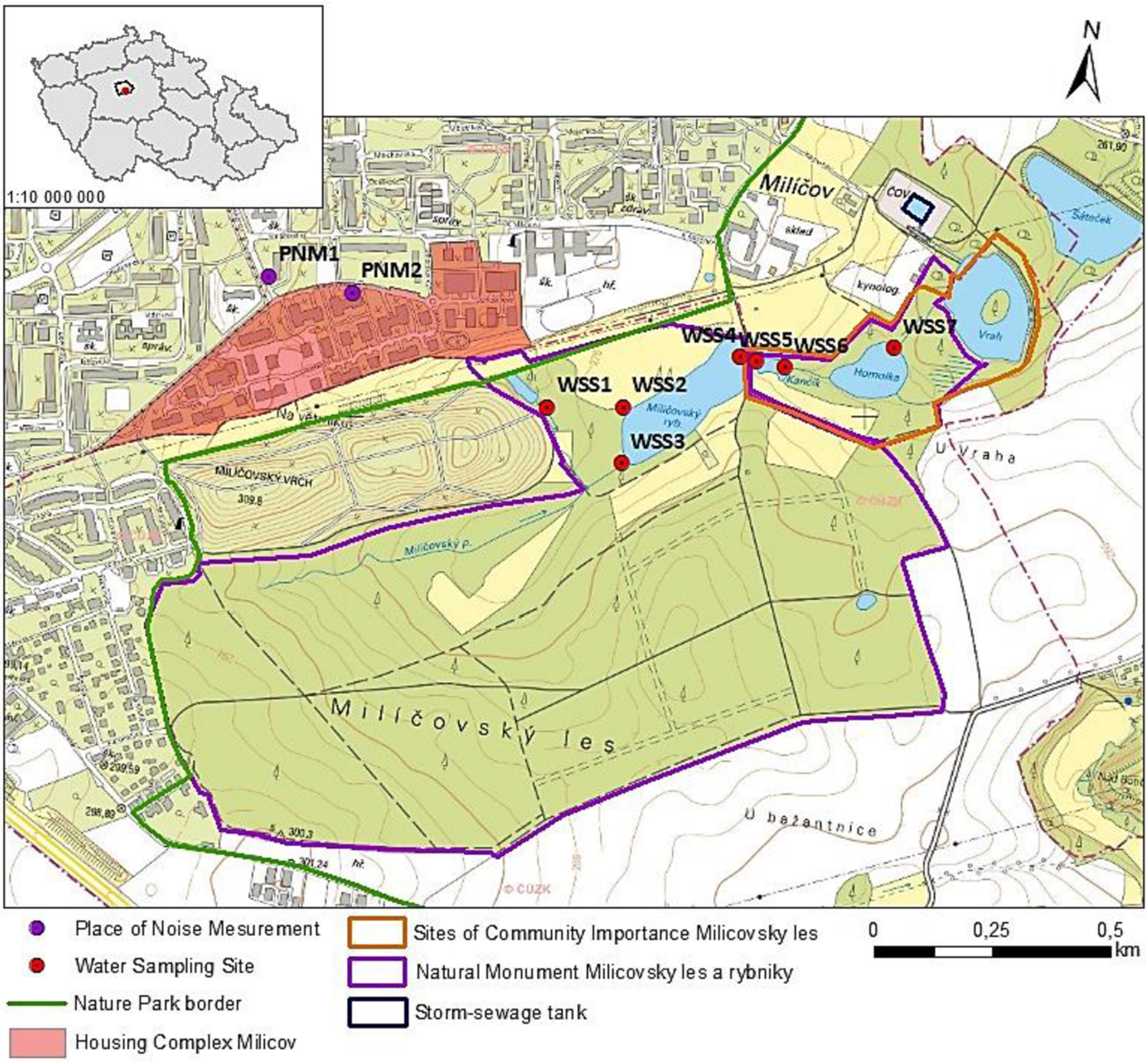

Figure 6.1: *Study location and wider linkages.*

6.2.2.2 Hydro chemical conditions

According to the Hydro chemical Study Milíčovský les (Šupíková 2007), the monitored chemical parameters of surface water quality were selected according to the most probable contaminants that could enter the pond system. A total of 3 samplings were performed (one during the elaboration of the Environmental Impact Assessment Report, and two after the project was completed).

The following chemical parameters were monitored at all sampling points:

- Chemical pollution indicators: Anionic surfactants, Non-polar extractive substance (C10 – C40); BTEX, PAH, MTBE;
- Water chemistry parameters: Cl-, SO42-;
- Heavy metals: Al, Pb, Ni, Zn, Fe;
- Parameters measured in-situ: pH, oxidation reduction potential, amount of dissolved oxygen; and water saturation by oxygen.

Surface water quality was assessed at 7 water sampling sites (WSS) (Figure 6.1). During the resampling of hydro chemical parameters, there was not enough water for sampling at WSS2 for both dates and not enough water for sampling at WSS3 on the second date (i.e. data are not available for these time periods).

6.2.3 Methodological approach of sampling and measuring

Noise measuring and water sampling occurred in both phases of the study (pre- and post-assessment) according to the same rules, with a uniform methodological approach to guarantee maximum compatibility and relevance of data. The methodology of water sampling is based on the internal regulations of the SOP and was specified for the conditions of the project evaluation. Analyses concerning hydro chemical conditions were provided in the laboratories of the Czech University of Life Sciences Prague. Noise measurements in both phases of the study (pre- and post-assessment) were performed by the same accredited testing laboratory, Akustika Praha, s.r.o. The methodological procedure was in full compliance with ČSN ISO 1996-2 "Acoustics – Description, measurement and evaluation of environmental noise – Part 2: Determination of sound pressure levels" and the Methodological instructions for measuring and evaluating noise in the nonworking environment, issued by the Ministry of Health of the Czech Republic.

6.2.4 Content and scope of performed EIA process

The evaluation started with the submission of a Notification to Competent Authority. Based on Conclusion from Screening and Scoping Procedures, the project of the residential complex should have been subject to a full-scale EIA process. The Competent Authority requested the preparation of an Environmental Impact Assessment Report with a focus on: (i) site drainage; (ii) evaluation of the transport service of the area and capacity assessment of the surrounding communication network; (iii) effects on protected areas situated at the vicinity of the given territory; and (iv) effects on public health. The conclusion of the assessment stated that the project is in accordance with the use defined in the valid zoning plan and project implementation would cause an increase in traffic load and thus deterioration of the noise situation in residential buildings along access roads. It was predicted that the increase in noise load would be a maximum of 3 dB. The runoff conditions of rainwater and the catchment area of Milíčovský stream with the Milíčov ponds and wetland system will also be change. The conclusion of the assessment stated that Milíčovský les a rybníky Natural Monument and Milíčovský les SCI will not be affected by the implementation and operation of the assessed project. Overall, the assessed project could therefore be considered as acceptable in terms of environmental and public health impacts.

6.3 Results

Part of the land affected by the construction of the residential complex was already ecologically burdened before the start of construction work; there was an old ecological burden, see Chapter 6.3.1. (Figure 6.2, 2003 and 2006). The construction of the project contributed to the elimination of this burden, and thus to the elimination of the risks that were associated with it and endangered individual components of the environment.

6.3.1 Noise level and traffic intensity

Measurement of noise level pressure during the construction and operation phase of the project show the accuracy of the EIA predictions. It can be stated that the rate of predicted noise load was partially overestimated according to the actual measurement (the real measured values of noise levels during construction and the first years of use were lower than the predicted values). However, it is also necessary to focus on the ever-increasing rate of noise level load (see individual measurements in Table 6.1), which can be attributed to the overall cumulative effect, due to which the real situation begins to approach the predicted values and will probably exceed them (Table 6.1; 6.2). For both sites for noise measurement, a significant increase in traffic intensity can be identify (Table 6.1; 6.2).

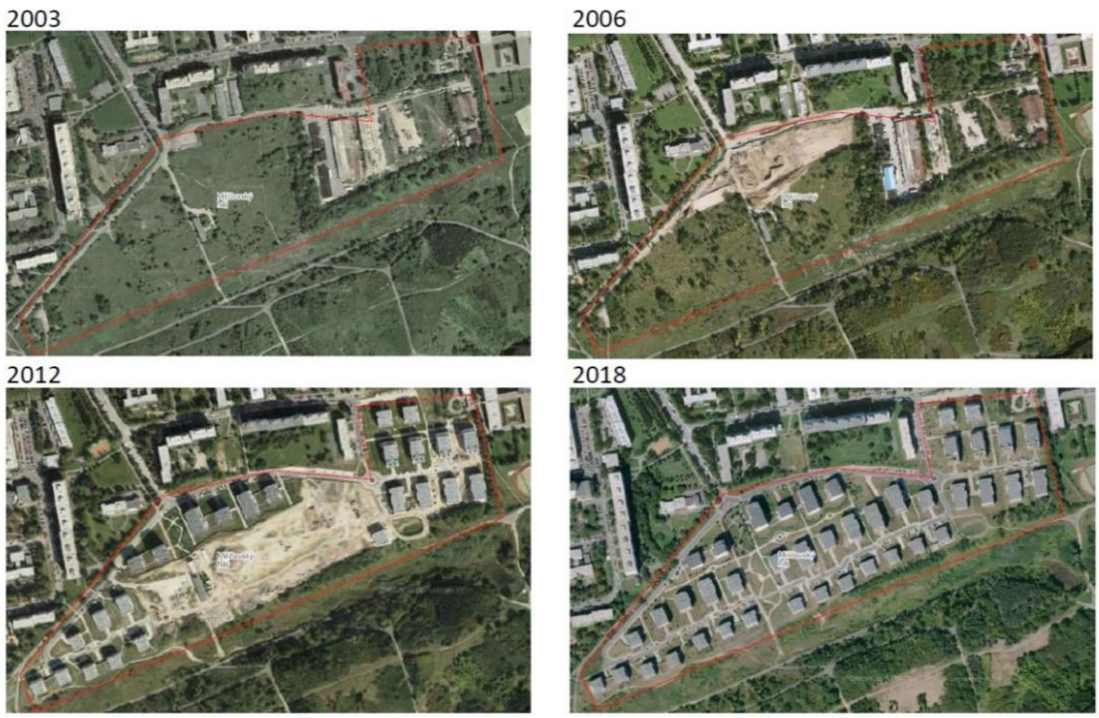

Figure 6.2: *Study location – temporal development of the condition of the site between 2003–2018 (red line).*

Table 6.1: *Results of noise measurement and traffic intensity calculation at site PNM1.*

	Date	*Noise level 22:00 – 06:00 $L_{Aeq,8h}$ ± u (dB)*	*Difference to first measurement ΔL (dB)*	*Accounted traffic volume*				
B	28. - 29. 06. 2007	47 ± 1.8	-	17	0	0	0	0
P	28. - 29. 06. 2007	48 ± 1.8	+1	33	0	0	0	0
C	26. - 27. 06. 2012	43.6 ± 1.8	-3.4	58	0	0	0	1
C	25. - 26. 09. 2012	44.0 ± 1.8	-3	52	0	0	17	0
C	19. - 20. 06. 2013	44.1 ± 1.8	-2.9	115	0	0	5	0
C	03. - 04. 09. 2014	43.5 ± 1.8	-3.5	96	0	0	3	0
A	22. - 23. 11. 2016	45.2 ± 1.8	-1.8	174	0	0	8	0
A	04. - 05. 09. 2019	46.6 ± 1.8	-0.4	138	0	0	7	4

B – measurement before construction; P – prediction of the impact; C – measurement during construction; A – measurement after construction during use of the buildings.

Table 6.2: *Results of noise measurement and traffic intensity calculation at site PNM2.*

	Date	*Noise level 22:00 – 06:00 $L_{Aeq,8h}$ ± u (dB)*	*Difference to the first measurement ΔL (dB)*	*Accounted traffic volume*				
B P	This is a street that was created by construction, which means that no measurements or control calculations were taken here within the EIA.							
C	19. - 20. 06. 2013	42.1 ± 1.8	-	36	0	0	5	0
C	03. - 04. 09. 2014	41.6 ± 1.8	-0.5	44	0	0	4	0
A	22. - 23. 11. 2016	46.7 ± 1.8	+4.6	79	0	0	8	0
A	04. - 05. 09. 2019	46.6 ± 1.8	+4.5	88	0	0	7	2

B – measurement before construction; P – prediction of the impact; C – measurement during construction; A – measurement after construction during the use of the buildings.

6.3.2 Hydro chemical conditions

The results of individual measurements for three time periods are presented in Table 6.3 (04/2007 (B), 05/2019 (A1), and 10/2019 (A2)).

Table 6.3: *Results of in-situ measurement of selected hydro chemical parameters.*

Water sampling sites (WSS)		*Date of sampling*	*pH*	*Oxidation reduction potential Eh (mV)*	*Dissolved O_2 (mg/L)*	*O_2 saturation (%)*
1	B	04/2007	7.400	270.800	3.680	38.000
	A_1	05/2019	7.340	192.000	2.970	29.000
	A_2	10/2019	7.170	138.000	1.050	9.200
2	B	04/2007	7.380	332.200	7.670	68.700
	A_1	05/2019	N/S	N/S	N/S	N/S
	A_2	10/2019	N/S	N/S	N/S	N/S
3	B	04/2007	7.400	208.000	5.630	48.300
	A_1	05/2019	7.360	-20.000	1.510	13.800
	A_2	10/2019	N/S	N/S	N/S	N/S
4	B	04/2007	7.860	291.000	9.810	94.000
	A_1	05/2019	8.460	51.000	8.910	86.100
	A_2	10/2019	8.400	99.000	11.200	99.700
5	B	04/2007	7.670	277.500	8.010	73.400
	A_1	05/2019	8.690	17.000	12.120	115.700
	A_2	10/2019	7.740	38.000	7.810	74.100
6	B	04/2007	7.880	313.600	7.830	71.000
	A_1	05/2019	9.600	59.000	9.970	95.800
	A_2	10/2019	7.490	-13.000	3.500	31.700
7	B	04/2007	7.940	170.880	6.940	67.200
	A_1	05/2019	8.870	75.000	11.010	108.200
	A_2	10/2019	7.830	169.000	7.310	68.800

B – measurement before construction; A – measurement after construction during use of the buildings; N/S – Not sampled.

Oxygen saturation has a diverse tendency, both along the observed profile of the pond system and at different times. However, very low oxygen saturation is observed in many places. The lowest values were measured at WSS1 (newly built pond within the compensation in relation to the environment) and, after project implementation, they had a declining trend at other time periods. At the same site, a gradual decrease in pH values can be seen (Table 6.3).

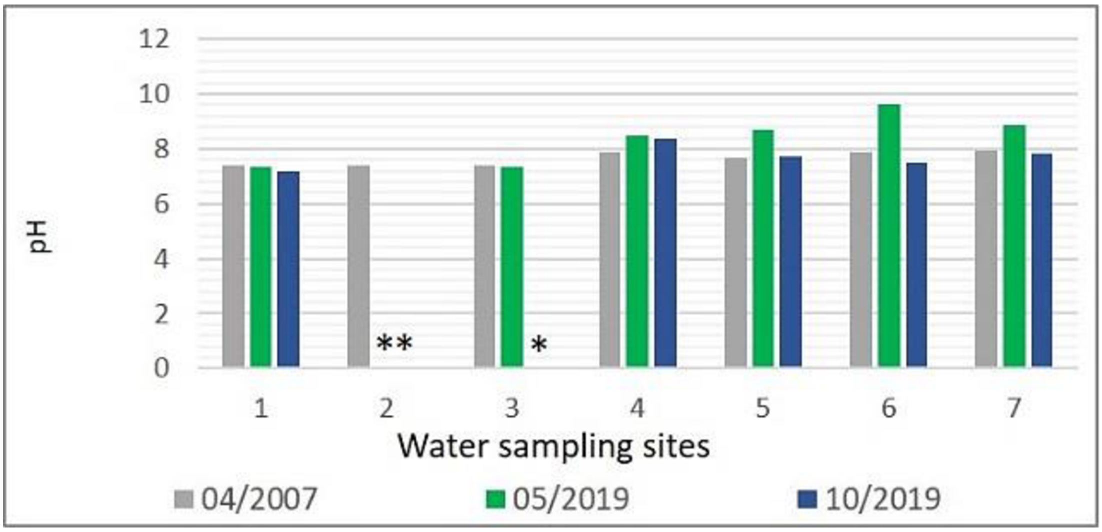

Figure 6.3: *pH along the monitored profile of the pond system (April 2007, May 2019, and October 2019) (* not sampled).*

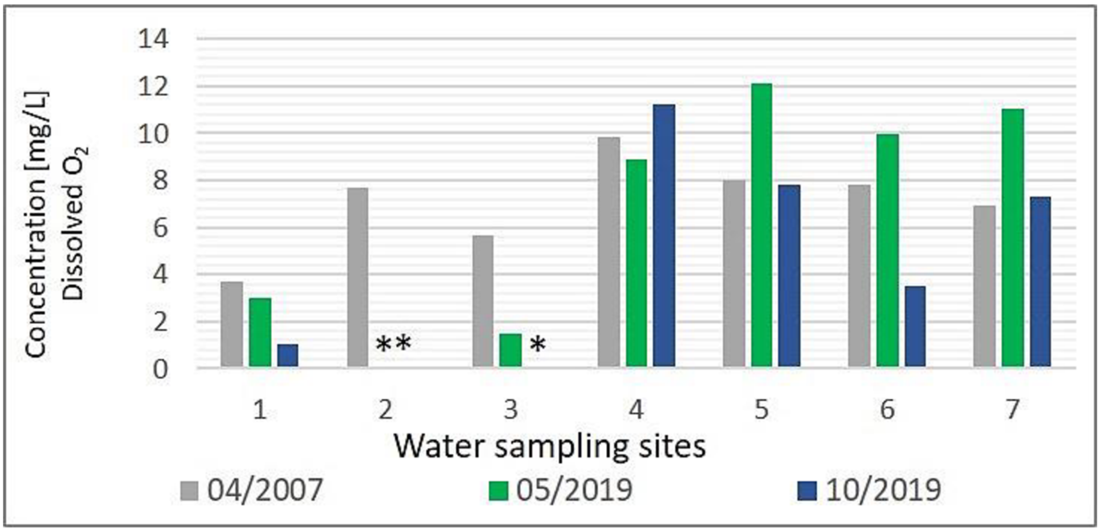

Figure 6.4: *Dissolved oxygen content in water along the observed profile of the pond system (April 2007, May 2019, and October 2019) (* not sampled).*

Values of oxygen saturation also correspond to the values of dissolved oxygen (Figure 6.4), which have a similar tendency. The lowest values were measured at WSS1. However, lower values can also be observed in other sites (e.g., WSS3). pH values in the first period (04/2007) ranged from 7.38 to 7.94, while the tendency of increasing values can be observed in the direction of the monitored profile of the pond system (downstream) (Figure 6.3). The results of individual concentrations of metals

(Al, Fe, Ni, Pb, Zn) and other parameters determining water chemistry in all three time periods are summarized in Table 6.4.

Table 6.4: *Results of hydrochemical sampling of water quality – heavy metals and water chemistry parameters.*

Water sampling sites (WSS)		Date of sampling	Al (mg/L)	Fe (mg/L)	Ni (mg/L)	Pb (mg/L)	Zn (mg/L)	SO_4^{2-} (mg/L)	Cl^- (mg/L)
1	B	04/2007	0.081	0.510	0.006	<0.1	<0.01	345.000	53.300
	A_1	05/2019	<0.10	0.03111	0.00365	0.00001	0.00928	168.675	120.110
	A_2	10/2019	<0.10	0.14082	0.00506	0.00042	0.00717	61.67	113.79
2	B	04/2007	0.094	0.980	0.013	0.015	<0.01	294.000	42.800
	A_1	05/2019	N/S	N/S	N/S	N/S	N/S	N/S	N/S
	A_2	10/2019	N/S	N/S	N/S	N/S	N/S	N/S	N/S
3	B	04/2007	0.088	0.330	0.011	<0.1	<0.01	182.000	42.100
	A_1	05/2019	<0.10	0.84558	0.00623	0.00001	0.00442	134.684	46.395
	A_2	10/2019	N/S	N/S	N/S	N/S	N/S	N/S	N/S
4	B	04/2007	0.303	1.080	0.010	<0.1	0.013	191.000	37.000
	A_1	05/2019	0.44	0.02983	0.00453	0.00588	0.00330	335.469	61.747
	A_2	10/2019	0.15	0.02900	0.00318	0.00199	0.00568	444.53	53.25
5	B	04/2007	0.299	1.390	0.010	<0.1	0.033	190.000	37.400
	A_1	05/2019	<0.10	0.03495	0.00382	0.00557	0.02063	332.595	63.949
	A_2	10/2019	0.13	0.02352	0.00499	0.00002	0.08775	518.87	69.47
6	B	04/2007	0.317	1.240	0.009	<0.1	0.013	165.000	37.700
	A_1	05/2019	1.5	0.03726	0.00176	0.00510	0.00274	235.128	67.910
	A_2	10/2019	0.1	0.05795	0.00501	0.00746	0.00938	534.84	54.41
7	B	04/2007	0.040	0.240	0.006	<0.1	<0.01	168.000	35.800
	A_1	05/2019	<0.10	0.15153	0.00403	0.01124	0.00371	164.447	55.848
	A_2	10/2019	<0.10	0.01890	0.00432	0.00011	0.00406	151.08	61.25

B – measurement before construction; A – measurement after construction during use of the buildings; N/S – Not sampled.

Chloride concentration along the monitored watercourse has decreasing trend (downstream, see Table 6.4, WSS 1B to 7B) in the first period (before project implementation– April 2007). Higher values are observed at the beginning of the pond system in the tributaries (Figure 6.5). In the following two time periods (after project implementation – May and October 2019), the values of chloride concentration increased with a peak in the spring (after winter maintenance). The highest values were measured in WSS1 at approximately 120 mg/L in May 2019 and approximately 114 mg/L in October 2019 (Figure 6.5). This is the first measured site in the direction of the surface water inflow from the affected area. Sulphate concentration along the monitored watercourse has also decreased trend (downstream, see Table 6.4, WSS 1B to 7B) in the first period (before project implementation – April 2007) (Figure 6.6). The highest value was measured at the inflow of WSS1 345 mg/L. In the next two time periods (after project implementation – May and October 2019); however, there is a gradual increase along the monitored pond profile and at the end it decreases again (Figure 6.6). The highest values in the second period (May 2019) are observed at WSS4, namely about 336 mg/L, and the third period (October 2019) at WSS6, with a concentration of 535 mg/L.

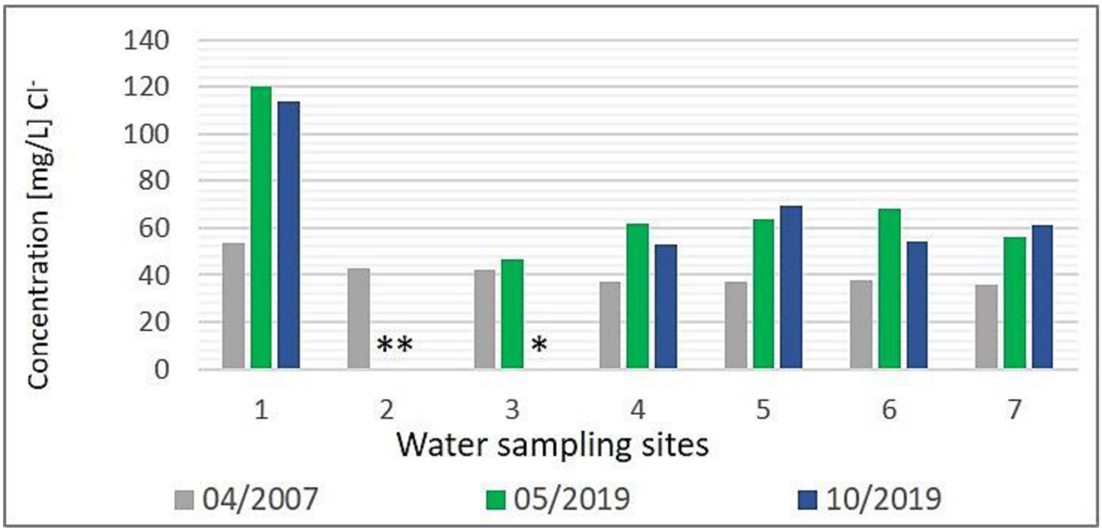

Figure 6.5*: Cl- ion concentration in water along the observed profile of the pond system (April 2007, May 2019, and October 2019) (* not sampled).*

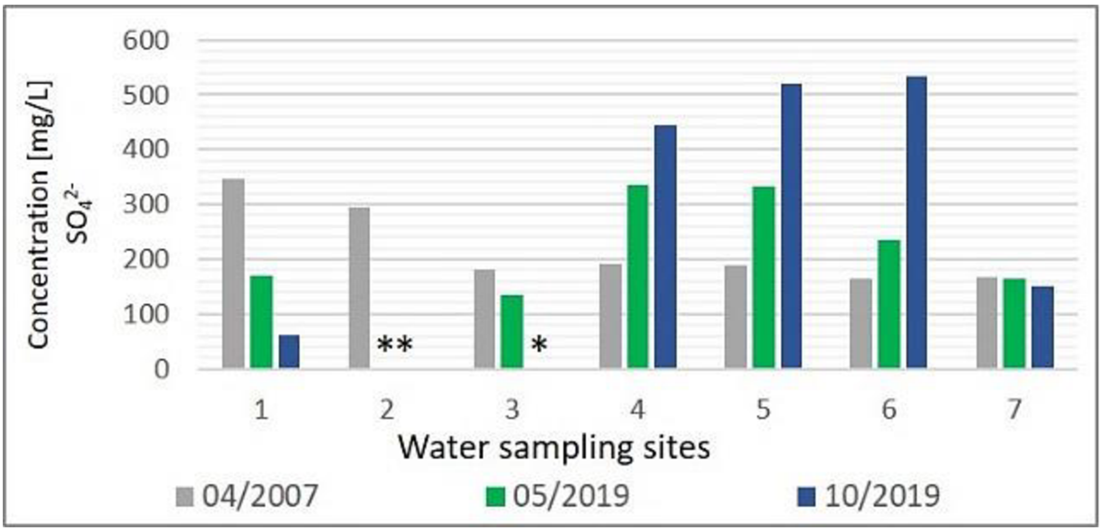

Figure 6.6: *Sulphate concentration along the monitored profile of the pond system (April 2007, May 2019, and October 2019) (* not sampled).*

The results of the concentrations of individual organic pollutants in the monitored profile of the pond system are summarized in Table 6.5 and Table 6.6. The most significant changes in concentrations are mainly observed in surfactants (Table 6.5) and PAHs (Table 6.6).

Table 6.5: *Results of hydrochemical sampling of water quality – chemical pollution indicators - A*

Water sampling sites (WSS)		Date of collection	benzene (µg/L)	toluene (µg/L)	ethylbenzene (µg/L)	xylene (µg/L)	NEL* (C10-C40) (mg/L)	surfactants (mg/L)	MTBE (µg/L)
1	B	04/2007	< 0.2	< 0.2	< 0.2	< 0.2	< 0.1	0.060	< 0.2
	A_1	05/2019	<0.1	<0.1	<0.1	<0.1	0.270	0.230	<0.1
	A_2	10/2019	<0.1	<0.1	<0.1	<0.1	<0.2	0.450	<0.1
2	B	04/2007	< 0.2	< 0.2	< 0.2	< 0.2	< 0.1	< 0.05	< 0.2
	A_1	05/2019	N/S	N/S	N/S	N/S	N/S	N/S	N/S
	A_2	10/2019	N/S	N/S	N/S	N/S	N/S	N/S	N/S
3	B	04/2007	< 0.2	< 0.2	< 0.2	< 0.2	< 0.1	< 0.05	< 0.2
	A_1	05/2019	<0.1	<0.1	<0.1	<0.1	0.160	0.360	<0.1
	A_2	10/2019	N/S	N/S	N/S	N/S	N/S	N/S	N/S
4	B	04/2007	< 0.2	< 0.2	< 0.2	< 0.2	< 0.1	< 0.05	< 0.2
	A_1	05/2019	<0.1	<0.1	<0.1	<0.1	<0.1	0.240	<0.1
	A_2	10/2019	<0.1	<0.1	<0.1	<0.1	<0.2	0.510	<0.1
5	B	04/2007	< 0.2	< 0.2	< 0.2	< 0.2	< 0.1	< 0.05	< 0.2
	A_1	05/2019	<0.1	<0.1	<0.1	<0.1	<0.1	0.280	<0.1

Water sampling sites (WSS)		Date of collection	benzene (µg/L)	toluene (µg/L)	ethylbenzene (µg/L)	xylene (µg/L)	NEL* (C10-C40) (mg/L)	surfactants (mg/L)	MTBE (µg/L)
	A_2	10/2019	<0.1	<0.1	<0.1	<0.1	<0.2	0.500	<0.1
6	B	04/2007	< 0.2	< 0.2	< 0.2	< 0.2	< 0.1	< 0.05	< 0.2
	A_1	05/2019	<0.1	<0.1	<0.1	<0.1	<0.2	0.430	<0.1
	A_2	10/2019	<0.1	<0.1	<0.1	<0.1	<0.2	0.650	<0.1
7	B	04/2007	< 0.2	< 0.2	< 0.2	< 0.2	< 0.1	< 0.05	< 0.2
	A_1	05/2019	<0.1	<0.1	<0.1	<0.1	<0.2	0.330	<0.1
	A_2	10/2019	<0.1	<0.1	<0.1	<0.1	<0.2	0.550	<0.1

*B – measurement before construction; A – measurement after construction during use of buildings, N/S - Not sampled, * Non-polar extractive substance.*

Surfactant concentrations (April 2007) were below 0.05 mg/L, except for WSS1 (Figure 6.7). In the second period (May 2019), concentration values were higher and reached the highest values at WSS3 and WSS6. In the third period (October 2019), concentrations along the observed profile had a similar tendency; however, the concentration values were even higher (Figure 6.7).

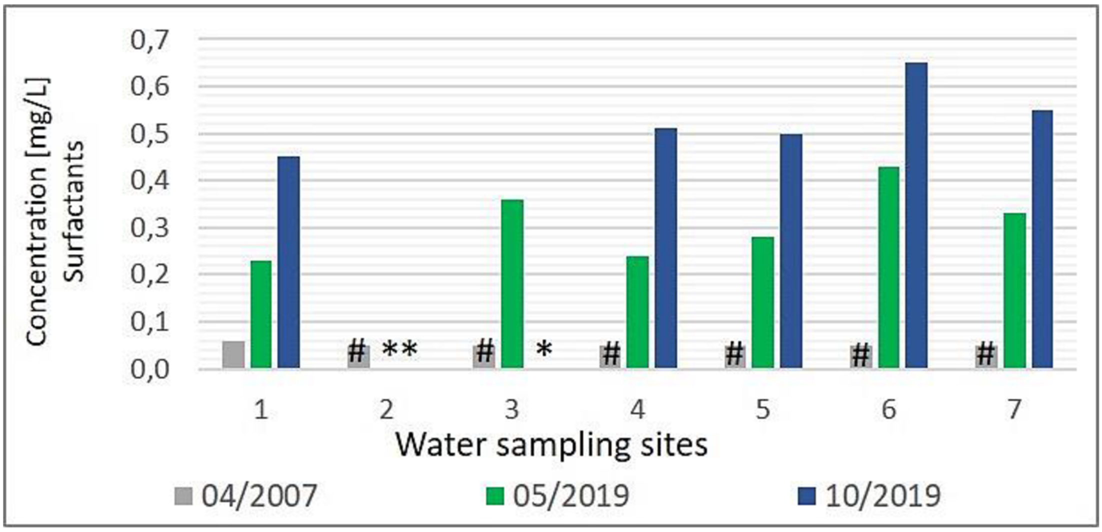

Figure 6.7: *Surfactant concentration along the observed profile of the pond system (April 2007, May 2019, and October 2019) (* not sampled, # values <0.05).*

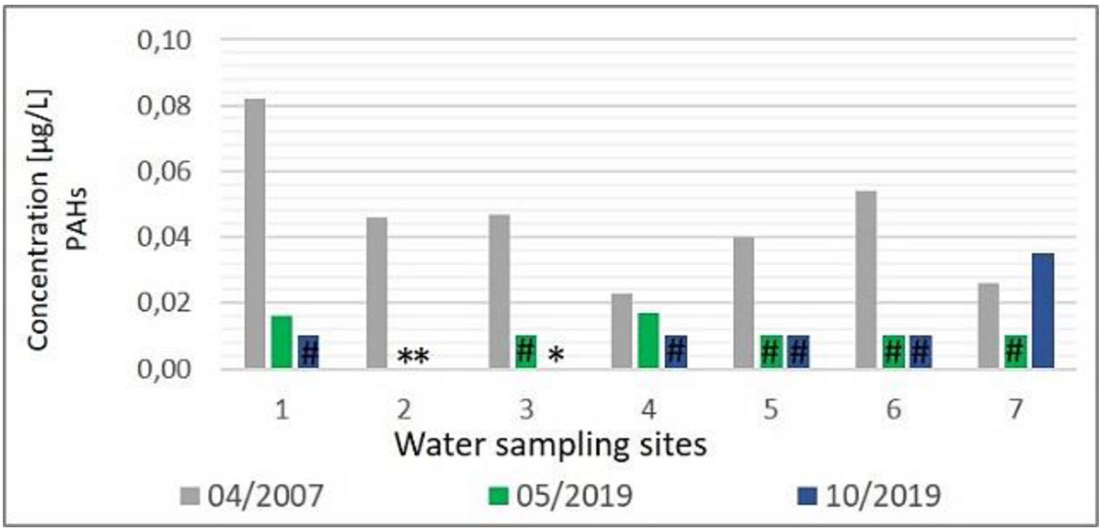

Figure 6.8: *PAH concentration along the observed profile of the pond system (April 2007, May 2019, and October 2019) (* not sampled, # values <0. 01).*

Concentrations of PAHs showed the highest values in the first period (April 2007) and reached the highest values at WSS1 and WSS6 (Figure 6.8; Table 6.6). In the second period (May 2019), the measured values for almost all WSSs were <0.01 µg/L; the highest values were reached for WSS1 and WSS4. In the third period (October 2019), PAHs concentrations in the whole monitored profile were <0.01 µg/L, except WSS7, where the value was higher and reached about 0.035 µg/L (Figure 6.8; Table 6.6).

6.4 Discussion

Much of Europe can be characterized as a constantly expanding urbanized area. Strong urbanisation process can even be observed in China (Ke et al. 2014). The direct consequence of these trends in urban and suburban areas is the loss of natural and seminatural habitats. The process of urbanization of the suburban environment in most cases contributes to the development of a number of adverse effects that reduce the quality of the environment (Tzoulas et al. 2007; UN 2018). At the same time, environmental conditions in cities are also constantly deteriorating (Gill et al. 2007;

WHO 2016). The trend in gradual degradation of certain environmental components can also be observed within our study area, both in the context of noise load and selected hydro chemical parameters. From our results we can concluded that, from a mid- to long-term perspective, the overall cumulative and synergic impact became more important and in future going to be kea for given territory.

In the context of future planning and design, it is desirable to provide ongoing feedback on implementing EIA processes through EIA-PPAs, thereby assessing their role within the search for more sustainable solutions for overall development (Wilson 1998; Wood 2000; Wood et al. 2000; Stewart-Oaten, Bence 2001; Marshall et al. 2005). The results of our analyses show that, for the construction phase and the first years of residential complex use (short-term perspective), the predictions within the EIA process were of a high level, with sufficient preventive potential; however, in the mid- to long-term horizon (after finalisation of project), the accuracy of impact prediction decreased, especially in the context of overall cumulative and synergistic effects. The development of the suburban and urban environment is dynamic, and all factors are fundamentally influenced by the context of overall development designed by zoning planning, thereby predefining the extent and intensity of environmental impact and the overall sustainability framework. Closer and more effective cooperation between zoning planning and designing and assessing planned projects could overtake these mid- to long-term cumulative and synergistic changes.

6.4.1 Context of the assessment

The results of our study clearly state that, in terms of formal requirements, the EIA was properly applied in all legal requirements. The content and scope of the documents prepared during the EIA complied with the requirements set out in the Conclusion of the Screening and Scoping Procedure, and, simultaneously, all documents were sufficiently consulted with all stakeholders, including answering their comments. From the point of view of material requirements of the EIA process, a methodological shortcoming in the assessment of hydro chemical changes is evident. During the EIA, individual parameters of the hydro chemical status were measured in the examined sites (reference status) interpreting the situation before the construction; however, there was no prediction of a change in hydro chemical parameters. For these reasons, it is currently almost impossible to identify to what extent the residential complex itself contributes to the growing cumulative effect of changes in hydro chemical parameters and to what extent the overall development of the surrounding region. Our conclusions confirm the relatively high accuracy of partial EIA analyses for noise loading, i.e., that the actual impacts measured in the project operation phase corresponded in their parameters to those predicted.

6.4.2 Post-decision and post-realisation actions

The basic principles for ensuring the sustainability of landscape and water features in urban and suburban environments are multifunctionality, interconnection, biodiversity, consideration of urban environment factors, and cooperation with local stakeholders or groups (Pauleit et al. 2011; Ely, Pitman 2014; Mell 2014; Davies et al. 2015; Wang, Banzhaf 2018). Local stakeholders or local communities must be involved in management and maintenance plans after the completion of the projects, or after their submission, so that the responsibility for any changes or gradually increasing cumulative effects passes to the users of these projects or their owners and local authorities. According to the zoning plan, land occupied by the construction of the residential complex was intended for development, and, according to the Conclusion on EIA, the proposed measures (retention reservoir and drainage ditches) should contribute to the overall stabilization of the wetland ecosystem in the protection zone of the Milíčovský les a rybníky Natural Monument.

6.4.3 Prediction verification in the sense of EIA PPA principles

According to Morrison-Saunders, Arts (2004a), Morrison-Saunders et al. (2003), one of the important parts of post-project analysis is monitoring, which is done to verify that the implemented activities are in accordance with the conditions set before implementation and whether the impacts of the project are within the range expected. Based on the results of our study, we can say that the implemented EIA process in the case of our followed parameters contributed to the reduction of risks to the environment and helped to positively influence the final project design and overall decision; nevertheless, the impact predictions in context of cumulative and synergistic effects need to improve. For example, it is possible to look in more detail at chloride concentrations, higher concentrations of which are usually attributed mainly to the effect of winter maintenance (Zítková et al. 2018; Zítková et al. 2021). The results of further studies show that chloride concentrations in water draining from streets, roads, and motorways reached 4-699 mg/L in Germany (Göbel et al. 2007), 43-110 mg/L in Slovenia (Gotvjan, Zagorc-Končan 2009), and 1.7–884 mg/L in the USA (Tucillo 2006). The values of the highest chloride concentrations before implementation of the residential complex within the area studied by us reached approximately 53 mg/L, and after implementation (during use of the residential complex) approximately 120 mg/L and 114 mg/L, respectively. The mutual comparison suggests that there are no unusual chloride concentrations in the area in question; on the contrary, they are rather low. It is also possible to consider the noise load, the values of which before implementation were 47 dB ± 1.8, while the prediction for construction and operation was 48 dB ± 1.8. The real values of the noise load ranged from 43.6 dB ± 1.8 to 46.6 dB ± 1.8. Many infrastructure projects have problems delivering sustainability commitments made earlier in the planning process (Arts, Faith-Elll 2012; Wessels et al. 2015). Implementation of similar EIA post-project analysis of suburban development can help to improve this situation.

6.5 Conclusion

The conclusions of the EIA assessment and its predictions for our followed parameters were accurate for the construction phase and the first years of use of the residential complex; however, it failed to precisely identify the medium to long-term cumulative and synergistic effects, which are and will, to some extent, reflect strategic planning (the level of urbanisation designed by zoning plan). Closer and more effective cooperation between zoning planning and designing and assessing planned projects could overtake these mid- to long-term cumulative and synergistic changes. In the future, it is necessary to strengthen complementarity between Strategic Environmental Assessment (SEA) which evaluate the environmental integrity of strategies which form the framework for future development in given territory and EIA processes which evaluate final project solution in given territory from the development point of view The sites affected by construction are not isolated from each other and the provision of EIA-PPAs represents an opportunity to improve future predictions of possible cumulative and synergistic effects and, at the same time can provide a strong dataset for proper and more sustainable design of zoning planning and development strategies.

Table 6.6: *Results of hydrochemical sampling of water quality – chemical pollution indicators - B*

Water sampling sites (WSS)		*Date of collection*	*naphthalene (μg/L)*	*phenanthrene (μg/L)*	*anthracene (μg/L)*	*fluoranthene (μg/L)*	*pyrene (μg/L)*	*benz(a) antracene (μg/L)*	*chrysene (μg/L)*	*benzo(b) fluorantene (μg/L)*	*benzo(k) fluorantene (μg/L)*	*benzo(a) pyrene (μg/L)*	*indeno(1,2,3-cd) pyrene (μg/L)*	*benzo(g,h,i) perylene (μg/L)*	*Total PAHs MoE (μg/L)*
1	B	04/2007	< 0.01	0.034	0.003	0.005	0.015	0.004	0.004	0.023	0.001	0.001	< 0.001	0.001	0.082
	A_1	05/2019	0.008	0.014	0.003	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.016
	A_2	10/2019	0.007	0.007	0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.01
2	B	04/2007	0.020	0.016	0.001	0.012	0.007	0.002	0.003	0.002	0.001	0.002	0.001	0.002	0.046
	A_1	05/2019	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S
	A_2	10/2019	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S
3	B	04/2007	< 0.01	0.013	0.001	0.012	0.006	0.004	0.004	0.003	0.002	0.003	< 0.001	0.003	0.047
	A_1	05/2019	0.011	0.006	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.01
	A_2	10/2019	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S
4	B	04/2007	< 0.01	0.012	0.001	0.006	0.001	0.002	0.001	0.001	0.001	0.001	< 0.001	0.001	0.023
	A_1	05/2019	0.01	0.011	0.003	0.003	0.003	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.017
	A_2	10/2019	0.006	0.004	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.01
5	B	04/2007	< 0.01	0.013	0.002	0.012	0.002	0.002	0.004	0.004	0.002	0.002	< 0.001	0.003	0.040
	A_1	05/2019	0.01	0.007	<0.002	<0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.01
	A_2	10/2019	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.01
6	B	04/2007	< 0.01	0.012	0.001	0.010	0.014	0.006	0.004	0.003	0.002	0.003	< 0.001	0.003	0.054
	A_1	05/2019	0.014	0.008	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.01
	A_2	10/2019	0.007	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.01
7	B	04/2007	< 0.01	0.012	0.002	0.005	0.005	0.001	0.001	0.003	0.001	0.001	< 0.001	0.001	0.026
	A_1	05/2019	0.009	0.006	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.01
	A_2	10/2019	0.007	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	0.035

B – measurement before construction; A – measurement after construction during use of the building; N/S – Not sampled.

Kapitola 7

Environmental Impact Assessment – the range of activities covered and the potential of linking to post-project auditing

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Abstract

Environmental Impact Assessment (EIA) is undoubtedly one of the world's most successful environmental policy tools for managing and controlling dynamic development schemes. The aim of our study was to evaluate the numerical and type variability of projects included in EIA. Furthermore, our study focused on identifying possible links to post-project auditing, both selective and predictive EIA power. Data on initiated EIA process were used (13,984 of issued conclusions on Screening and scoping Procedures and 1,418 of reasoned conclusion on EIA). The study identified ten types of projects by whose gradual changes in wording and limits in their description in legislation had the impact on the total number of their initiated EIA process. Based on the results, we are able to recommend which types of projects should be focused on when testing EIA selective accuracy (when Competent authority have to determine whether EIA is required or not) and which types of projects we should focus on when testing EIA predictive accuracy (in the case of projects with reasoned conclusion by the Competent authority on the significant effects of the project on the environment). To test EIA selective power, the ten types of projects we selected (their sum between 2002–2017) represent approximately 58% of all submitted project by developers to EIA (of the total 13,984). To test EIA predictive power, the five selected types of projects with the most frequently issued reasoned conclusions on EIA (their sum between 2002–2017) represent approximately 48% of all issued reasoned conclusions on EIA (of the total 1,418). For the optimal legislative setting of post-auditing, it would not be necessary to create audits for each individual project, but only for selected types of projects based on the analysis of numerical and type variability.

Keywords: EIA follow-up; EIA effectiveness; evaluation; environmental policy; sustainability; development

7.1 Introduction

Planning, development and all interactions between man and the environment (living and non-living) have been growing dynamically, globally, and de facto since the beginning of the 18th century. The increasing demands of society have been and still are reflected in growing environmental changes and risks, which has shaped the societal demand for measures (processes) that could prevent, eliminate, minimize, or compensate for environmental degradation. The concept of Environmental Impact Assessment (EIA) was first enacted in the United States in the 1970s by the so-called "NEPA" (Morrison-Saunders, Arts 2004a). At the beginning of the 21st century, the concept of EIA can be found in every country of the World (Bond et al. 2020). Environmental Impact Assessment is a process that analyses and evaluates the potential impacts that human activities can have on the environment. Main purpose is to guarantee a sustainable development that is in harmony with conservation of ecosystems, protection of human health, and with consideration of social aspects. (Wood 1993; Wathern 1994; Morrison-Saunders et al. 2001; Morrison-Saunders, Arts 2004b; Jay et al. 2007; Toro et al. 2010; Morgan 2012; Toro et al. 2013). It assumes that consequences and future developments can be predicted and formally planned (Retief et al. 2016). However, the results of the EIA will always be predictions, and the real impacts may differ from them more or less.

The implementation of EIA has been discussed worldwide and has long been one of the important topics of expert studies (Loomis, Dziedtic 2018). Its gradual development and improvement in the sense of achieving more accuracy of the predictions will be a crucial factor in preventing, reducing, or compensating of environmental risks associated with the development. Post-project analysis within the EIA process (EIA-PPA) or in other words EIA Follow-up can be understood as a process of monitoring and evaluating the real environmental impact (Wood 2003; Pölönen et al. 2010; Jalava et al. 2015) for projects that were evaluated in the EIA process and thus their potential impacts were predicted. In the context of planning and designing EIA-PPA allows for a formal and factual review of the EIA process, its resulting recommendations, and permitted conditions (Retief et al. 2016; Loomis, Dziedzic 2018; Morrison-Saunders et al. 2021; Pinto et al. 2019). It compares predicted expectations with the real impact and becomes a key tool for testing EIA predictive power, or its accuracy (Braniš, Christpoulos 2005; O'Faircheallaigh 2007). it is desirable to continuously provide feedback on implemented EIAs, assess their effectiveness (Wood 2000; Stewart-Oaten, Bence 2001; Marshall et al. 2005), and thus gain new knowledge, experience, lessons, and examples of good practice which can improve the whole concept of evaluation in future. The remaining question is, how the post-auditing should be legislatively design in the linkages to EIA process in temporal and material context.

7.1.1 EIA legislative background in Czechia

The introduction of EIA in the Czech Republic took place in the following steps:

- On 1st July 1992 the Environmental Impact Assessment (EIA) process was implemented into the Czech Republic's legal system, upon the entry into force of Czech National Council Act No. 244/1992 Coll., on environmental impact assessment. The process constitutes both an important element in the system of preventive environmental protection instruments and, simultaneously, a significant component of environmental policy.
- As of 1st January 2002, Czech National Council Act No. 244/1992 Coll., namely, its section pertaining to impact assessment of projects, was superseded by Act No. 100/2001 Coll., on environmental impact assessment and amending some related regulations.
- On 1st May 2004, the Czech Republic became a member of the European Union, so the legislative background of EIA process was harmonized with the

EU Directive on the assessment of the effects of certain public and private projects on the environment (now Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014).

- On 1st November 2017 the last relevant amended of Act No. 100/2001 Coll., to this study was provided by Act No. 326/2017 Coll.

The Czech EIA Act (No. 100/2001 Coll.) requires that development consent (or, in other words, license) for public and private projects which are likely to have significant impacts on the environment, shall be only granted after prior assessment of its “likely significant” environmental impacts. The EIA Act provided two sets of projects in Annex No. 1, Category I and II (Table 7.1 Detailed overview of initiated process “submitted project by developers” in the period 2002–2017 within individual projects for each category of projects and the year of the monitored period; in each year there is a listed number of issued conclusions on Screening and scoping Procedures for a given type of project).

Projects listed in Category I of Annex No. 1 to this Act and changes to these projects where the change in capacity or scope in itself meets the relevant threshold, if specified; these projects and changes to projects are considered as having significant effects on the environment and are always subject to an EIA “full scale EIA” (Annex 1, Category I in Czech EIA Act is similar as Annex 1 in EU Directive). Projects listed in Category II in Annex No. 1 to this Act and changed to these projects if, in terms of its own capacity or scope, the change meets the relevant threshold, if specified, or which may have a significant adverse effect on the environment, especially if the capacity and scope of the project is to be substantially increased or if its technology, management of operation or manner of use is to be substantially changed; these projects and changes to projects are subject to an EIA if so determined in the Screening and scoping Procedure (a case-by-case examination) “small scale EIA” (Annex 1, Category II in Czech EIA Act is similar as Annex 2 in EU Directive).

The objective of the Screening and scoping Procedure (a case-by-case examination) for projects and changes of projects listed in Annex 1, Category I is to further specify the information that should be included in the Environmental Impact Assessment Report in other words in EIS reporting (full scale EIA). The objective of the Screening and scoping Procedure for projects and changes of projects listed in Annex 1, Category II is to determine whether the project may have a significant environmental impact and thus it shall be subject to an EIA (small scale EIA). If the projects cannot have significant effects on the environment, the evaluation is terminated. If the projects can have significant effects on the environment, the Competent authority have to specify of the information that should be included in the Environmental Impact Assessment Report (EIS reporting) (full scale EIA). Based on the Notification (information provided by developer), comments on the Notification and the written conclusion on Screening and scoping Procedure (issued by Competent authority), the developer shall ensure the preparation of the Environmental Impact Assessment Report (EIS reporting) by an authorized person.

When the Environmental Impact Assessment Report is submitted to the Competent authority, the Competent authority shall ensure the preparation of the EIS Review (Expert Report by an independent person authorized to this effect). The expert shall prepare the EIS Review based on the Environmental Impact Assessment Report, and all received comments thereon, considering the conclusions of the public hearing (if the public hearing took place). Based on the Environmental Impact Assessment Report, the comments received thereon, public hearing (if the public hearing took place), and the EIS Review, the Competent authority shall issue a reasoned conclusion on the significant effects of the project on the environment (Conclusion on EIA) (Figure 7.1).

Through Czech Environmental Information Agency (CENIA), the Competent authorities have to publish the following at the internet (within Information System of EIA).: Notification (basic information on the characteristic of the project, state of the environment in given territory and anticipated adverse effect of project on environment provided by developer); conclusion of the Screening and scoping Procedure; Environmental Impact Assessment Report (identification and evaluation of all adverse effects on the environment); information about where and when the public hearing on a project is to be held, if ordered; EIS Review (Expert Report, independent review of quality and completeness of all information regarding to evaluation, provided by the developer); and a reasoned conclusion on the significant effects of the project on the environment (Conclusion on EIA). This ensures the accessibility of all information and all related documents on the assessment to everyone. Based on this, the public, public concerned, NGOs, affected administrative bodies, affected local governments, may submit written comments or their requirements for assessment.

7.1.2 General tasks of the study

In the Czech Republic, an EIA covers almost 120 types of projects with different details of their capacity. The analysis of the projects included in the EIA (both small scale – annex 1 category II and full scale – annex 1 category I), their numerical, and type variability is a basic prerequisite for the rational continuation and deepening of the discussion on the possibility of performing post-project auditing as a tool for development, improvement, and optimization of EIA concept. The aim of our study was to evaluate the numerical and type variability of projects the most often included in the EIA process (both small scale – annex 1 category II and full scale – annex 1 category I) between 2002 and 2017 (submitted by developers to Competent authority), and to identify possible links to post-project auditing, both selective (small scale EIA – annex 1 category II) and predictive power (accuracy) (full scale EIA – annex 1 category I).

7.2 Materials and methods

7.2.1 Dataset background

The study includes data about initiated (EIA) process (submitted by developers to Competent authority, both small scale – annex 1 category II and full scale – annex 1 category I) within the entire Czech Republic (Central Europe) from 2002 (the current law has entered into force) to 2017 (last relevant amended of law to this study was provided in this year) (see chapter 7.1.1). The data used were provided by the Czech Environmental Information Agency (CENIA, which is a subordinate organization of the Ministry of the Environment of the Czech Republic). The information provided contained data on the initiated (EIA) process, in more detail, the number of conclusions on Screening and scoping Procedures (hereinafter "Conclusions on SSP"), and the number of reasoned conclusions on the significant effects of the projects on the environment (hereinafter "Conclusions on EIA"). For each project, the following information was provided by CENIA: i) Project identification code; ii) Identification of Competent authority; iii) Localization of the project; iv) Name of the project; v) Classification of the project according Annex 1, if the project belongs to Category I or Category II; vi) Identification information about developer; vii) Date of issued Conclusions on SSP and its outcome; viii) Date of reasoned conclusions on the significant effects of the projects on the environment and its outcome (if the full scale EIA was required); and ix) Valid wording of the law (version) for assessment of given project.

The total number of Conclusions on SSP was 13,984. The total number of Conclusions on EIA was 1,418. Next, we worked with the individual amended versions of Act No. 100/2001 Coll., On Environmental Impact Assessment for the period under review (with valid wording of the Annex 1 for given years).

7.2.2 Selective and predictive accuracy of EIA in linkages to post-project auditing

The term selective accuracy is used for the projects belonging to Annex 1 - Category II in the context of Conclusions on SSP. The mission is the identification whether the project may have a significant environmental impact and whether it should be subject to an EIA or not. The result is a sorting of projects into two groups: i) EIA is required, and ii) EIA is not required. If we want to evaluate the correctness of these decisions, made by Competent authority, we are testing the selective accuracy (power) of the assessment (small scale EIA process), respectively of Screening Procedures.

The term predictive accuracy is used for the projects belonging to Annex 1 - Category I in the context of Conclusions on EIA (full scale EIA process). The EIA process is completed by the Conclusion on EIA which can be positive or negative. Negative conclusion means impossibility of realisation of the given project. Positive conclusion means consent to realisation and are supply with recommendations and binding conditions for the phase of construction and phase of operation of the given projects. If we want to evaluate the correctness of conclusions on EIA, made by Competent authority and next functionalities as accuracy of the impact predictions and efficiency of mitigation measures designed in Conclusions on EIA, we are testing the predictive accuracy (power) of EIA.

7.2.3 Data processing

All data about initiated (EIA) process (both small scale – annex 1 category II and full scale – annex 1 category I) (submitted by developers to Competent authority) were categorized in terms of: i) number of Conclusions on SSP and Conclusions on EIA in individual years; (ii) distribution of the number of Conclusions on SSP and Conclusions on EIA by region; iii) representation of individual types of projects within the Conclusions on SSP and Conclusions on EIA; and (iv) representation of different results of Conclusions on SSP and Conclusions on EIA.

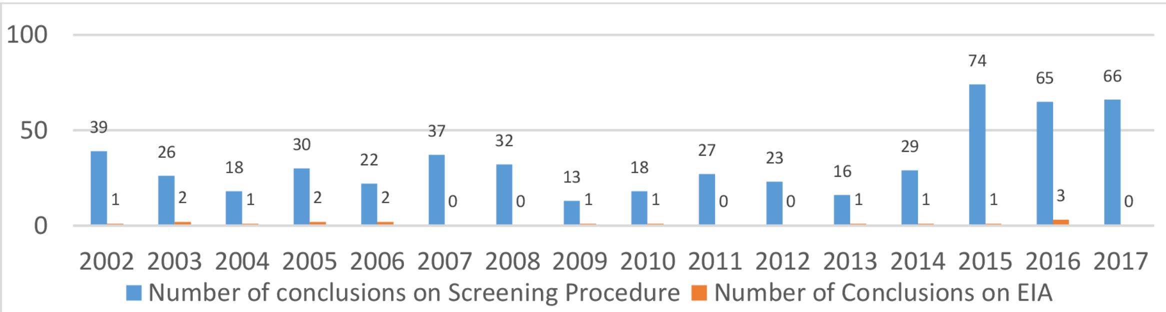
7.2.4 Data analysis

Ten types of projects were selected for which the diction of the project definition/description in legislation changed (in terms of factual content or limit values) due to legislative amendments. Simultaneously, these changes could have an impact on the absolute number of initiated (EIA) process. The ten types of projects analysed in detail include: 1. Livestock breeding of specified amount; 2. Wastewater treatment plants for a specified number of equivalent inhabitants; 3. Wind farms of specified power and hub height; 4. Surface finish of metals and plastic materials, including paint shops, of the specified treatment area; 5. Production or processing of polymers, synthetic rubbers, and elastomer-based products within a specified limit; 6. New construction, widening, and relocation of roads of all classes and local roads; 7. Facilities for the storage, treatment, or recovery of hazardous waste; 8. Storage of selected hazardous chemical substances and chemical preparations of specified capacity; 9. Warehouses or shopping complexes, including shopping centres of specified size and number of parking spaces; 10. Other infrastructure projects of specified size. The individual types of projects are listed in a general wording (without limits) so that their description is valid for all analysed versions of the law.

7.3 Results

The ten types of projects analysed represent approximately only 8% out of all types of projects listed in Annex 1 (overall almost 120 types of projects, which belong to EIA evaluation both small and full scale of evaluation) but (their overall sum of Conclusions on SSP) include approximately 58% of all issued Conclusions on SSP between 2002 and 2017 (exactly 8,092 out of a total of 13,984). Within Figure 7.2 to Figure 7.11, we present ten selected types of projects with an overview of how the number of Conclusions on SSP, (issued by Competent authority) and the number of Conclusions on EIA (issued by Competent authority) changed in individual years.

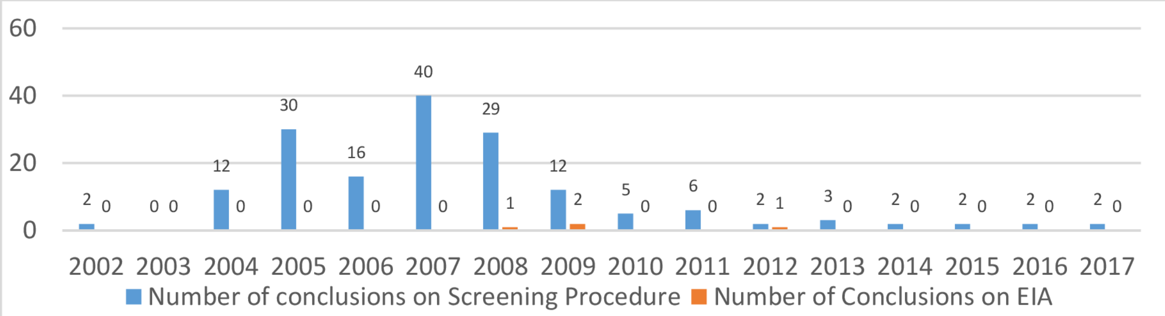
Simultaneously, changes in the description or capacity of projects (from Annex 1 EIA Act) and their time validity can be identified in the tables situated below the Figure 7.2 to Figure 7.11. Thus, the numbers of Conclusions on SSP in individual years can be linked to individual valid description/definition of the type of project in the valid version of legislation for the given time period.



Valid description of the project in legislation until 2015	**Valid description of the project in legislation between 2015–2017**
Livestock breeding with a capacity of 50 to 180 livestock units (1 livestock unit = 500 kg live weight).	Facilities for intensive livestock breeding with a capacity from 50 livestock units (1 livestock unit = 500 kg live weight)

Figure 7.2: *Number of Conclusions on SSP and Conclusions on EIA for Livestock breeding of a specified amount.*

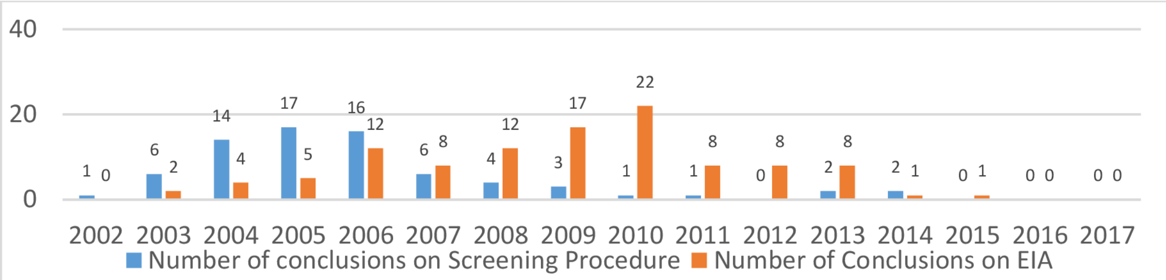
In the monitored period, the description or capacity of the type of the project was amended in 2015, which can also be identified in the number of Conclusions on SSP, which have substantially increased since that amendment. The total number of Conclusions on SSP was 535. The total number of Conclusions on EIA was 16. On average were, 33.4 Screening procedures (small scale EIA) per one Conclusion on EIA (full scale EIA) (Figure 7.2).



Valid description of the project in legislation until 2004	Valid description of the project in legislation until 2017
Wastewater treatment plants with a capacity exceeding 10,000 PE, if it does not belong to category I, and sewerage for more than 5,000 connected inhabitants.	Wastewater treatment plants with a capacity of 10,000 to 100,000 equivalent inhabitants, sewerage from 5,000 to 50,000 connected inhabitants, or industrial sewerage with a diameter of more than 500 mm.

Figure 7.3: *Number of Conclusions on SSP and Conclusions on EIA for wastewater treatment plants of specified capacity.*

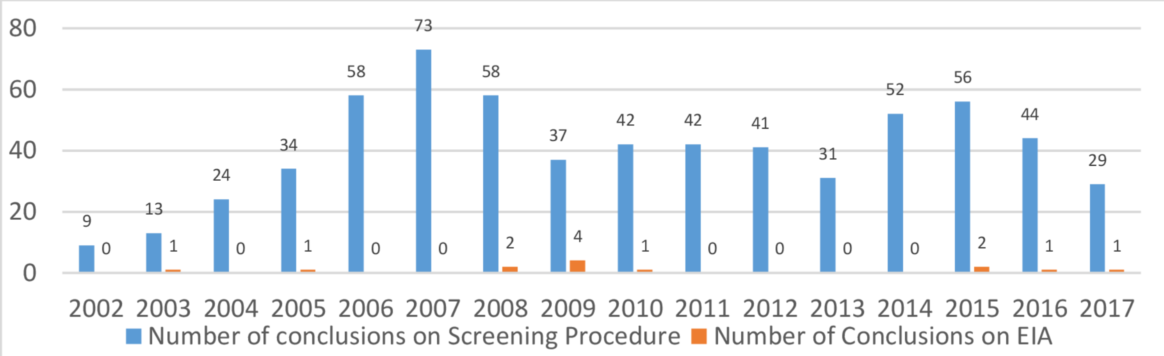
In the monitored period, the description or capacity of the type of the project was amended in 2004, which probably did not have an impact on the number of Conclusions on SSP. It can be concluded that the number of submitted project to evaluation was mostly influenced by the targeting of the subsidy policy in the area of environment and the possibility to draw funds from the EU structural funds for co-financing the construction of wastewater treatment plants after the Czech Republic's accession to the EU (1st May 2004). The total number of Conclusions on SSP was 165. The total number of Conclusions on EIA was 4. On average were, 41.3 Screening procedures (small scale EIA) per one Conclusion on EIA (full scale EIA) (Figure 7.3).



Valid description of the project in legislation until 2004	**Valid description of the project in legislation between 2004–2017**
Wind farms with a maximum output of 5 kWe.	Wind farms with a total installed power exceeding 500 kWe or with a hub height exceeding 35 m.

Figure 7.4: *Number of Conclusions on SSP and Conclusions on EIA for wind farms of specified capacity.*

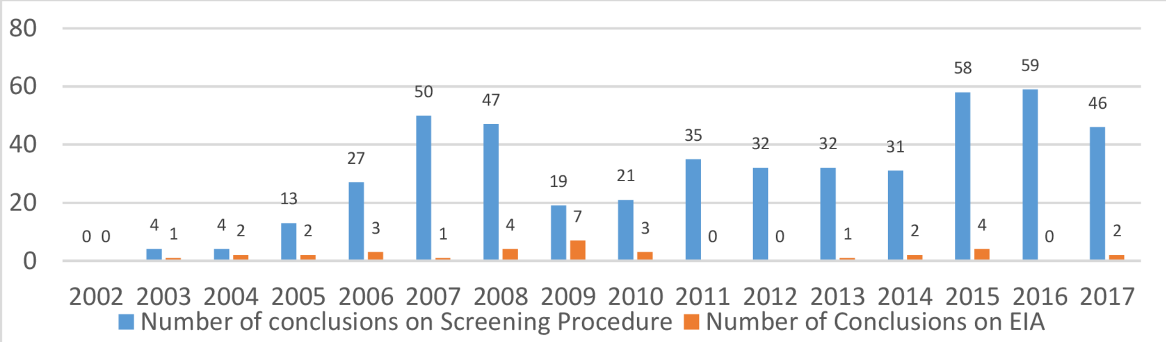
In the monitored period, the description or capacity of the type of the project was amended in 2004, which probably did not have an impact on the number of Conclusions on SSP. The targeting of the subsidy policy in the area of environment and the state-guaranteed purchase and price of energy generated by wind farms had a fundamental influence on the number of submitted project to evaluation. The total number of Conclusions on SSP was 73. The total number of Conclusions on EIA was 108 (Figure 7.4).



Valid description of the project in legislation until 2004	Valid description of the project in legislation between 2004–2017
Surface finish of metals and plastic materials by electrolytic or chemical processes from 10,000 to 500,000 m^2/year of treatment area.	Surface finish of metals and plastic materials, including paint shops, from 10,000 to 500,000 m^2/year of total treatment area.

Figure 7.5: *Number of Conclusions on SSP and Conclusions on EIA for metal surface finish of a specified area.*

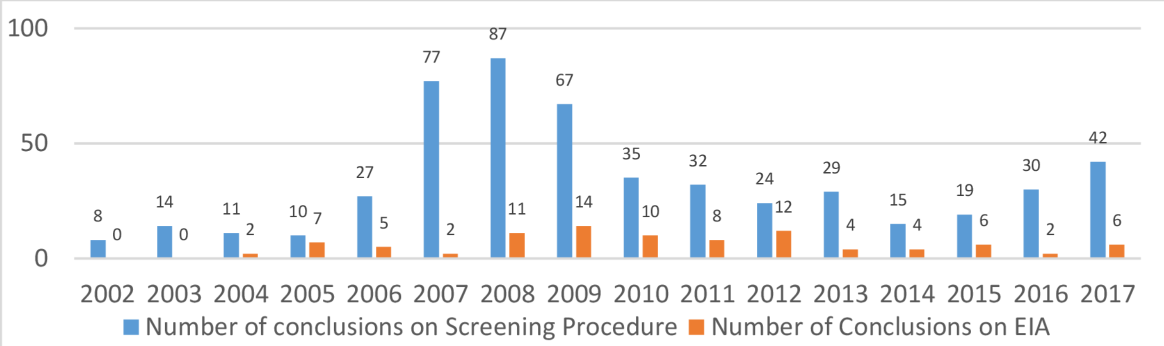
In the monitored period, the description or capacity of the type of the project was amended in 2004. The total number of Conclusions on SSP was 643. The total number of Conclusions on EIA was 13. Can be identify a high number of initiated evaluations however a relatively small number were fully assessed. On average were, 49.5 Screening procedures (small scale EIA) per one Conclusion on EIA (full scale EIA) (Figure 7.5).



Valid description of the project in legislation until 2004	Valid description of the project in legislation between 2004–2017
Production or chemical processing of polymers and synthetic rubbers, production and processing of products based on elastomers	Production or processing of polymers and synthetic rubbers, production and processing of products based on elastomers with a capacity exceeding 100 t/year.

Figure 7.6: *Number of Conclusions on SSP and Conclusions on EIA for the production or processing of polymers of specified capacity.*

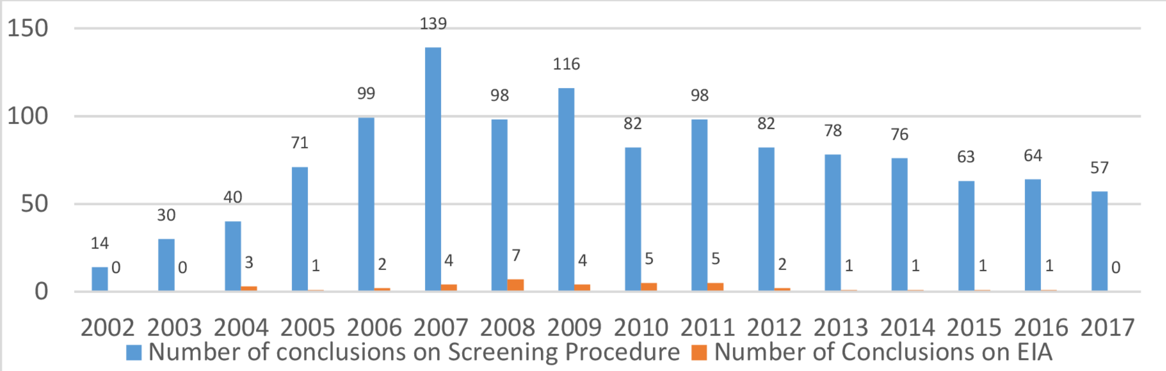
In the monitored period, the description or capacity of the type of the project was amended in 2004. Simultaneously, the trend of increasing numbers of the Conclusions on SSP for the rest of the monitored period with a fluctuating character can be observed since 2004. The total number of Conclusions on SSP was 478. The total number of Conclusions on EIA was 32. On average were, 14.9 Screening procedures (small scale EIA) per one Conclusion on EIA (full scale EIA) (Figure 7.6).



Valid description of the project in legislation until 2004	Valid description of the project in legislation between 2004–2006	Valid description of the project in legislation between 2006–2017
New construction and reconstruction of roads with a width greater than 10 m (projects not listed in category I)	New construction and reconstruction of roads with a width greater than 10 m (projects not listed in category I) or local roads with four or more lanes longer than 500 m.	New construction, extension, and relocation of roads of all classes and local 1st and 2nd class roads (projects not included in category I).

Figure 7.7: *Number of Conclusions on SSP and Conclusions on EIA for road construction and reconstruction.*

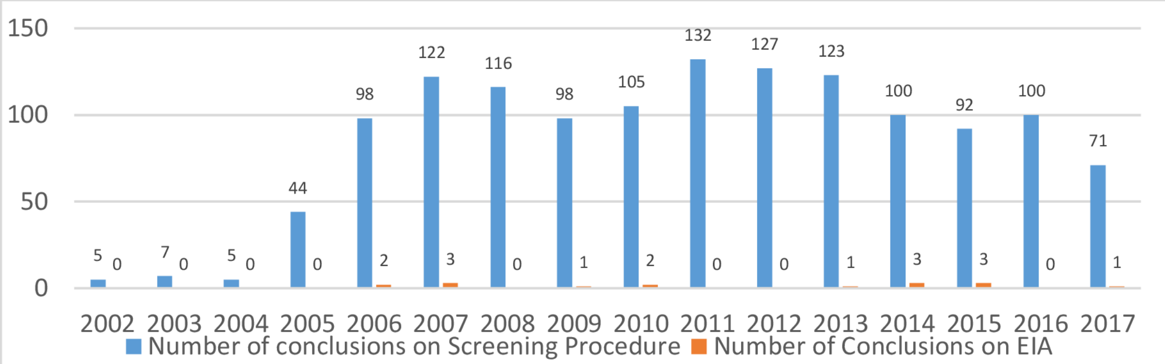
In the monitored period, the description or capacity of the type of the project was amended in 2004 and then in 2006. With the second amendment, increasing numbers of the Conclusions on SSP can be observed. Simultaneously, the number of the submitted project to evaluation could be affected by the possibility of co-financing infrastructure construction from the EU structural funds. The total number of Conclusions on SSP was 527. The total number of Conclusions on EIA was 93. Can be identify that a relatively large number of projects were fully assessed. On average were, 5.7 Screening procedures (small scale EIA) per one Conclusion on EIA (full scale EIA) (Figure 7.7).



Valid description of the project in legislation until 2004	Valid description of the project in legislation between 2004–2006	Valid description of the project in legislation between 2006–2015	Valid description of the project in legislation between 2015–2017
Other waste management facilities with a capacity of 1000 up to 30,000 t/year.	Other waste management facilities with a capacity of 1000 to 30,000 t/year; hazardous waste management with a capacity of 100 to 1000 t/year.	Facilities for the storage, treatment, or recovery of hazardous waste; facilities for physico-chemical treatment, energy recovery, or disposal of other wastes.	Facilities for the disposal or industrial use of waste (projects not included in category I).

Figure 7.8: *Number of Conclusions on SSPs and Conclusions on EIA for waste facilities of specified capacity.*

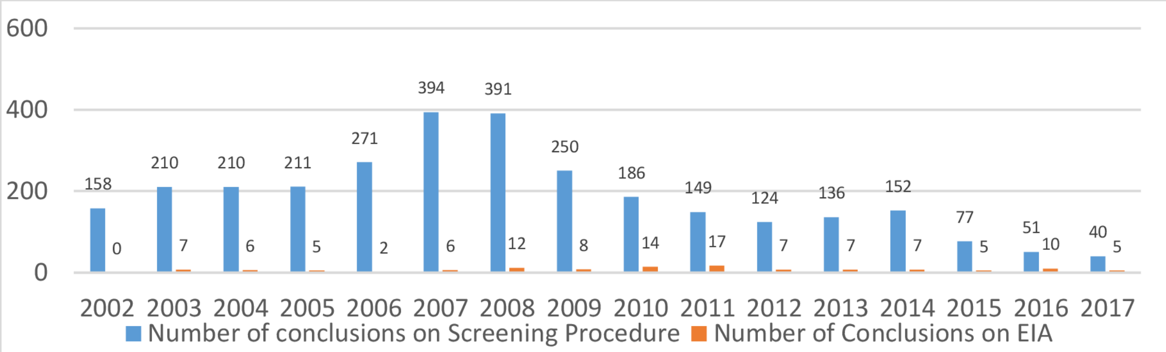
In the monitored period, the description or capacity of the type of the project was amended in 2004, and then in 2006 and 2015. Simultaneously, from 2004 a gradual increase of the number of Conclusions on SSP can be observed, which remained at relatively balanced high numbers in the remaining years. The total number of Conclusions on SSP was 1207. The total number of Conclusions on EIA was 37. On average were, 32.6 Screening procedures (small scale EIA) per one Conclusion on EIA (full scale EIA) (Figure 7.8).



Valid description of the project in legislation until 2004	**Valid description of the project in legislation between 2004–2017**
Storage of toxic substances and pesticides in quantities exceeding 1 t; liquid fertilizers, pharmaceutical products, paints, and varnishes in quantities over 100 t.	Storage of selected hazardous chemical substances and chemical preparations (highly toxic, toxic, harmful, corrosive, irritant, sensitizing, carcinogenic, mutagenic, toxic for reproduction, dangerous for the environment) and pesticides in quantities exceeding 1 t; liquid fertilizers, pharmaceutical products, paints and varnishes in quantities over 100 t.

Figure 7.9: *Number of Conclusions on SSP and Conclusions on EIA Storage of selected hazardous chemicals.*

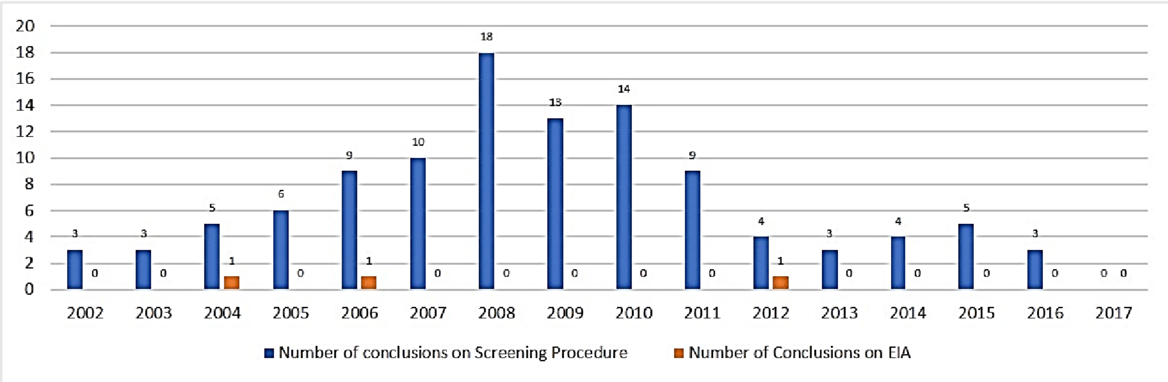
In the monitored period, the description or capacity of the type of the project was amended in 2004; simultaneously, an increase of the number of Conclusions on SSP can be observed since 2005, which remained at high numbers in the remaining years. The change in the number of submitted project to evaluation can be connected to the amendment of the description or capacity of the project in 2004. The total number of Conclusions on SSP was 1345. The total number of Conclusions on EIA was 16. Can be identify that a very small number of projects were fully assessed. On average were, 84.1 Screening procedures (small scale EIA) per one Conclusion on EIA (full scale EIA) (Figure 7.9).



Valid description of the project in legislation until 2004	Valid description of the project in legislation between 2004–2015	Valid description of the project in legislation between 2015–2017
Industrial and commercial zones, including shopping centres with a total area of more than 3,000 m^2 of built-up area; parking areas or garages with a built-up area of over 1000 m^2.	Warehouses or commercial complexes, including shopping centres, with a total area of more than 3,000 m^2 of built-up area; car parks or garages with a capacity of over 100 parking spaces in total for the entire building.	New industrial zones and development projects for industrial areas with an area of over 20 ha. Urban development projects with an area of over 5 ha. Construction of warehouse complexes with a total area of over 10,000 m^2 of built-up area. Construction of commercial complexes and shopping centres with a total area of over 6,000 m^2 of built-up area. Car parks or garages with a capacity of over 500 parking spaces in total for the entire building.

Figure 7.10: *Number of Conclusions on SSP and Conclusions on EIA for industrial, warehouse, and commercial complexes of specified capacity.*

In the monitored period, the description or capacity of the type of the project was amended in 2004 and then in 2015. This is the type of project with the highest number of Conclusions on SSP for the monitored period. The total number of Conclusions on SSP was 3010. The total number of Conclusions on EIA was 118. The differences in numbers of submitted project for evaluation in individual years (increase after 2005 and decrease since 2009) can rather be attributed to the economic situation and the global economic crisis (between 2007 and 2015) than legislation amendments. On average were, 25.5 Screening procedures (small scale EIA) per one Conclusion on EIA (full scale EIA) (Figure 7.10).



Valid description of the project in legislation until l 2004	Valid description of the project in legislation between 2004–2015	Valid description of the project in legislation between 2015–2017
Other infrastructure projects listed in the approved spatial planning documentation.	Other infrastructure projects on an area of over 5,000 m^2.	Other infrastructure projects on an area of over 2 ha.

Figure 7.11: *Number of Conclusions on SSP and Conclusions on EIA for other infrastructure projects of specified capacity.*

In the monitored period, the description or capacity of the type of the project was amended in 2004 and then in 2015. The total number of Conclusions on SSP was 109. The total number of Conclusions on EIA was 3. On average were, 36.3 Screening procedures (small scale EIA) per one Conclusion on EIA (full scale EIA) (Figure 7.11).

7.3.1 Selective and predictive power of EIA

Between 2002 and 2017, a total of 13,984 Conclusions on SSP and 1,418 Conclusions on EIA were issued by Competent authorities. Selected 5 types of projects with the highest number of issued Conclusions on EIA in individual years (out of a total of about 120 types of projects from Annex 1), represents less than five per cent from all types of projects which can be relevant for EIA process (Table 7.2). Sum of Conclusions on EIA of these five types of projects is in total 680 out of a total of 1, 418, which represents approximately 48% of all issued Conclusions on EIA) (Table

7.1). Based on this, can be identify which types of projects from Annex 1 are most often assessed in full scale EIA. Therefore, their inclusion in post-project analysis can cover the highest number of issued Conclusions on EIA within testing the predictive power of EIA, thus analysing whether the EIA process was effective, efficient, and useful (see Table 7.2), overview of the types of the projects with highest number of issued Conclusions on EIA. On the other hand, we can identify that a total of 13,984 of project was submitted by the developer to Competent authority for Screening and Scoping Procedures and only 1,418 of them was finished by Conclusion on EIA; this means that in the case of 12,566 submitted projects, the result of Screening Procedures was that EIA was not required, or the assessment was terminated for another reasons. The overall sum of Conclusions on SSP from our ten selected projects represents approximately 58% of all issued Conclusions on SSP between 2002 and 2017. Based on this, can identify which types of projects from Annex 1 are most often the subject of Screening and Scoping procedures for given years; therefore, their inclusion in post-project analysis can cover the highest number of issued Conclusions on SSP within testing the selective power of EIA, thus analysing whether the decision to carry out an EIA or not to carry out an EIA was correct.

As supplementary material we would like to show the overall overview of all types of projects submitted for Screening Procedures between 2002–2017 (see Table 7.1).

Table 7.1: *Total number of issued Conclusions on EIA in a given year and the total number of Conclusions on EIA for the 5 types of projects with the highest sum of issued Conclusions on EIA.*

Years	*2002–2009*							
	02	*03*	*04*	*05*	*06*	*07*	*08*	*09*
∑CT5/Y	10 83%	38 58%	52 54%	50 44%	41 38%	49 45%	67 48%	61 42%
∑C/Y	12	65	95	114	107	109	139	145
Years	*2010–2017*							
	10	*11*	*12*	*13*	*14*	*15*	*16*	*17*
∑CT5/Y	63 53%	46 56%	40 43%	31 42%	28 49%	40 59%	34 60%	30 48%
∑C/Y	120	101	93	74	57	68	57	62

∑CT5/Y, the total number of Conclusions on EIA issued for the five most frequently represented types of projects per year; next is given the percent ratio of the total number of Conclusions on EIA issued for the five most frequently represented types of projects from the total number of all Conclusions on EIA issued per year. ∑C/Y, the total number of all Conclusions on EIA issued per year.

7.4 Discussion

The EIA process is a globally recognized tool in the field of environmental protection and is one of the world's most successful tools for managing and controlling dynamic development schemes (Morgan 2012). Although it has existed for about 50 years, it is constantly evolving and its changes seek to respond to new challenges and global megatrends (Steffen et al. 2015; Retief et al. 2016). The gradual development, improvement, and adaptation of the EIA concept will be an essential prerequisite for reducing the risks associated with the major global changes the world is facing today (Steffen et al. 2015; Retief et al. 2016). Due to its global reach, we can find dozens of studies on the topic of its development, quality of output, or process problems. These include, for example, studies evaluating the format and quality of EIA in Finland Pölönen et al. (2010), Turkey Bilgin (2015), and Denmark Lyhne et al. (2017). Furthermore, the authors of the studies focus on the individual parts that make up the

EIA process Ulibarri (2019), or meeting the goals set by the EIA process Simpson (2018).

Whether a more general approach evaluating the whole framework of the EIA process is more desirable, or an approach that focuses only on parts of the EIA, we cannot say; however, both approaches must have a common basis in the relevance of real data obtained by post-project monitoring, both predictive and selective EIA power. The results of analyses of both these levels can more clearly present the concept of the EIA and its focus, thus contributing to a deeper understanding and increase in environmental awareness and wider integration of environmental criteria into decision-making. EIA PPA should be an essential component of Environmental Impact Assessment (EIA) if the success of EIA in improving the sustainability of a project once implemented is to be determined (Pinto et al. 2019).

7.4.1 Range of covered activities and their quantitative changes due to amendments of law

The strongest link between the change in the description or capacity of the project in Annex 1 and the total number of projects submitted by the developers for evaluation (both, small- and full-scale EIA) can be identified, for example, in the storage of selected hazardous chemicals (see Figure 7.9). Before the legislative change until 2004 the number of submitted projects for Screening Procedures reached only single figures, while after the legislation change (after 2004), the number of submitted projects for Screening Procedures was almost permanently in the hundreds. Other aspects that influenced the number of submitted projects for Screening Procedures include changes in the subsidy policy at the European, national, and regional level of planning, such as the project concerning wind farms (Figure 7.4), or infrastructure construction (Figure 7.7), differences within the economic situation of regions, and the overall international economic situation, for example the project concerning industrial zones, commercial zones, and warehouses (Figure 7.10), as well as changes in other legislative norms or changes in trends and behaviour of society (generally residential or commercial construction).

Some studies also point to the fact that the number of submitted projects for Screening Procedures may also be influenced by political lobbying. Due to the interconnectedness of state administration and self-government, there may be "pressure" on Competent Authorities to influence the final outcome of the evaluation process (McCullough 2017; Williams 2017). One of the most frequently mentioned problems in the EIA process is the quality of national legislation (El-Fadl, El-Fadl 2004; Gałaś 2015). Our study showed that the quality of the legislation is also related to its amendment conected with description of the projects and their limit values and thus, de facto, to influence the scope of the types of the projects and overall number of projects submitted for Screening Procedures.

The results of EIA audits are a necessary feedback for environmental management and the optimization of the EIA process itself (Retief 2007; Morrison-Saunders et al. 2015), especially in controversial projects attracting considerable public attention (Bisset 1984). Studies on the EIA process and its problems can provide important information, insights, and experience that can be used to optimize it (Alton, Underwood 2003; Morrison-Saunders, Retief 2012; Loomis, Dziedtic 2018). The results of our study indicate that, from the point of view of finding the optimal legislative setting of post-auditing within the EIA (for investors as well as for regulators, state administrations, and self-government units as well as public and nongovernmental organizations), there would not be an obligation to carry out audits for each individual project, which could be quite problematic and in principle rejected. Based on our findings, it is possible to identify the suitability of given projects for testing the EIA predictive power, which can be the projects for which Conclusions on EIA are most often issued. Due to our approach, we can identify quite low number of types of projects which cover almost half of issued Conclusions on SSP and half of issued Conclusions on EIA. Their inclusion to post-project analysis can have the largest impact on optimisation of the whole concept.

7.4.2 Analysing of types and overall numbers of project submitted for Screening Procedures and potential scheme of linking to post-project auditing

The results of our study encourage the possibility of defining monothematic meta-post-audits within one type of project (more similar intentions could be assessed). The solution can be that the Ministry of the Environment, as the central Competent Authority in the area of EIA, can continuously assess which types of projects are most submitted for Screening Process (small scale EIA) and which types of projects are the most often include in the EIA (full scale EIA). Within the system thus defined, and in cooperation with national grant agencies, the Ministry of the Environment could announce grant calls for monothematic meta-post-audits focusing on both selective (small scale EIA) and predictive EIA power (full scale EIA) for individual types of projects currently most included in the Screening Procedures and EIA, and thus obtain much-needed and relevant data which are a basic condition for the possible development and improvement of the concept of impact assessment and thus achieving a higher degree of sustainability. It would be necessary to design monothematic meta-post-audits into two levels: i) analyse Conclusions on Screening procedures and test in more detail the EIA selective power; and ii) analyse Conclusions on EIA and test EIA predictive power.

Similar mechanisms for linking the EIA process to post-project monitoring could help overcome the main problems thus far in the context of their application. According to Braniš, Christopoulos (2005), these problems include a lack of professional, institutional, personal, and financial support for the subsequent management of the required information.

7.5 Conclusion

The EIA concept has undergone major development in the Czech Republic, with a number of changes. The most important of these have often been in response to updates made in the European Directive. However, for its further improvement and development, a broader legislative approach and the use of post-project analyses will be necessary. The results of our study show that, to provide feedback on the EIA implementation, it is appropriate to use nationwide databases interpreting the numerical and type variability of projects included in the EIA in individual years. From our results, we are able to recommend which projects should be focused on to test EIA selective accuracy and which projects should be focused on when testing EIA predictive accuracy. Simultaneously, we find that for testing EIA selective accuracy, 10 types of project out of approximately 120 (Annex 1, EIA Act) are enough to cover approximately 58% of all submitted projects (issued Conclusions on SSP), and within predictive accuracy, testing the 5 types of the projects with the highest number of issued Conclusions on EIA out of about 120 (Annex 1, EIA Act) will cover approximately 48% of all issued Conclusions on EIA.

The EIA concept has and will have its limits, whether in terms of time, human resources, financial resources, or general credibility and acceptance by all stakeholders. However, it is still evolving, and if legislators, regulators, and impact analysis professionals are able to learn from previous decisions, they can find ways to optimize the shortcomings identified worldwide and the EIA concept can become a better and more widely accepted tool of environmental protection.

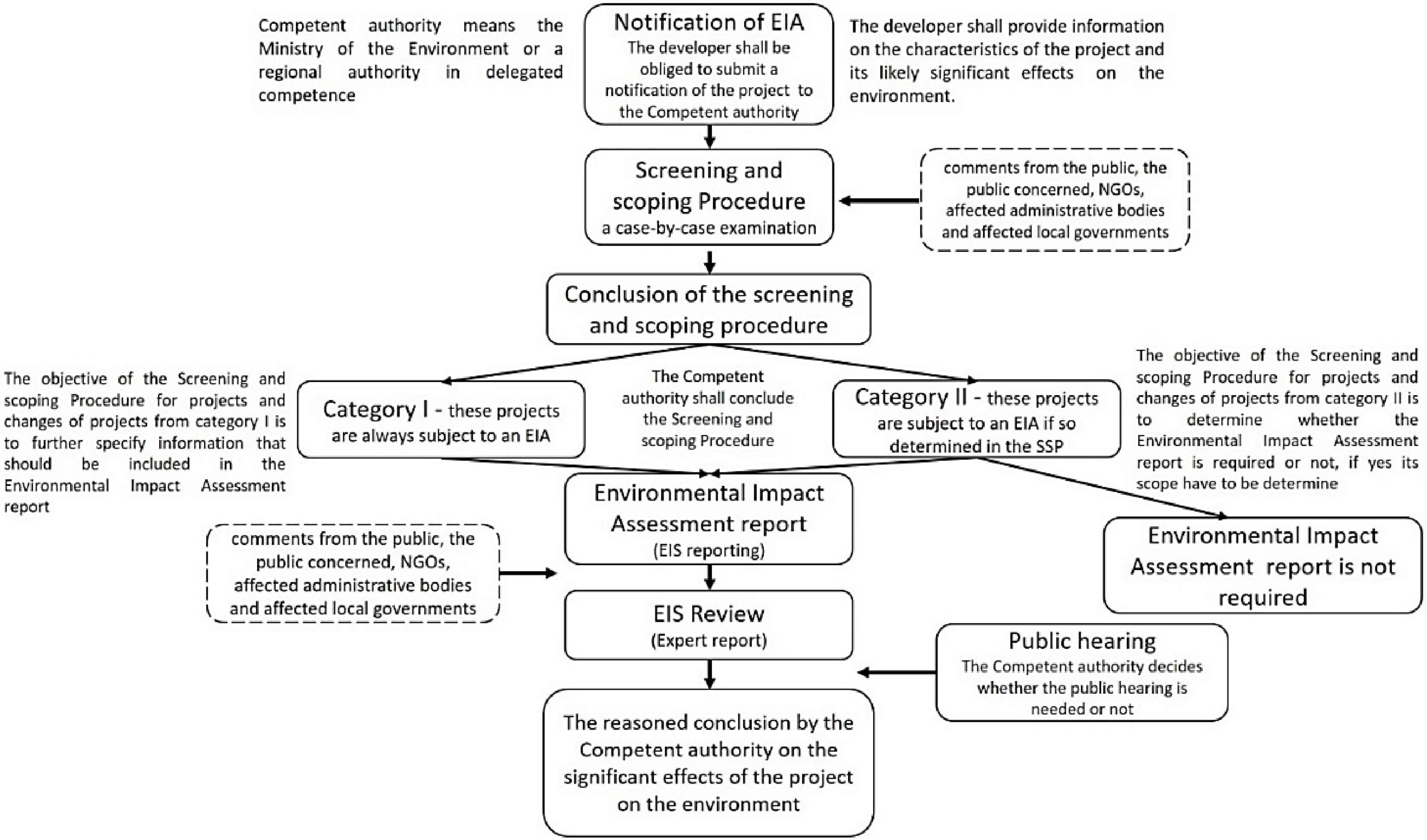


Figure 7.1: *Schematic illustration of the EIA process in the Czech Republic.*

Table 7.2: *List of five types of projects with the highest number of issued Conclusions on EIA in given years.*

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
TOP 1	(5) Livestock breeding of specified capacity [Cat. I.]	(12) Livestock breeding of specified capacity [Cat. I.]	(18) Livestock breeding of specified capacity [Cat. I.]	(16) Hazardous waste disposal facilities [Cat. I.]	(12) Wind farms of specified power and hub height [Cat. II.]	(13) Livestock breeding of specified capacity [Cat. I.]	(18) Livestock breeding of specified capacity [Cat. I.]	(17) Wind farms of specified power and hub height [Cat. II.]	(22) Wind farms of specified power and hub height [Cat. II.]	(17) Warehouse or commercial complexes, including shopping centres of specified size and number of parking spaces [Cat. II.]	(12) New construction, extension, and relocation of roads of all classes and local class I. and II. roads [Cat. II.]	(8) Wind farms of specified power and hub height [Cat. II.]	(8) Livestock breeding of specified capacity [Cat. I.]	(17) Livestock breeding of specified capacity [Cat. I.]	(11) Surface finish of metals and plastics, including paint shops of specified capacity [Cat. I.]	(8) Surface finish of metals and plastics, including paint shops of specified capacity [Cat. I.]
TOP 2	(2) Surface finish of metals and plastics, including paint shops of specified capacity [Cat. I.]	(12) Hazardous waste disposal facilities [Cat. I.]	(11) Hazardous waste disposal facilities [Cat. I.]	(11) Livestock breeding of specified capacity [Cat. I.]	(11) Livestock breeding of specified capacity [Cat. I.]	(13) Surface finish of metals and plastics, including paint shops of specified capacity [Cat. I.]	(13) Extraction of minerals and peat of specified limits [Cat. II.]	(14) Livestock breeding of specified capacity [Cat. I.]	(14) Warehouse or commercial complexes, including shopping centres of specified size and number of parking spaces [Cat. II.]	(8) Wind farms of specified power and hub height [Cat. II.]	(8) Wind farms of specified power and hub height [Cat. II.]	(7) Livestock breeding of specified capacity [Cat. I.]	(7) Warehouse or commercial complexes, including shopping centres, of specified size and number of parking spaces [Cat. II.]	(6) Surface finish of metals and plastics, including paint shops of specified capacity [Cat. I.]	(10) Warehouse or commercial complexes, including shopping centres of specified size and number of parking spaces [Cat. II.]	(7) New railway construction of specified length [Cat. I.]
TOP 3	(1) Extraction of crude petroleum and natural gas within a specified limit [Cat. I.]	(7) Warehouse or commercial complexes, including shopping centres, of specified size and number of parking spaces [Cat. II.]	(9) Extraction of minerals and peat of specified limits [Cat. II.]	(9) Extraction of minerals and peat of specified limits [Cat. II.]	(7) Extraction of minerals and peat of specified limits [Cat. II.]	(9) Extraction of minerals and peat of specified limits [Cat. II.]	(12) Extraction of minerals and peat of specified limits [Cat. II.]	(14) New construction, extension, and relocation of roads of all classes and local class I. and II. roads [Cat. II.]	(10) Extraction of minerals and peat of specified limits [Cat. II.]	(8) New construction, extension, and relocation of roads of all classes and local class I. and II. roads [Cat. II.]	(7) Livestock breeding of specified capacity [Cat. I.]	(7) Warehouse or commercial complexes, including shopping centres, of specified size and number of parking spaces [Cat. II.]	(5) Extraction of minerals and peat of specified limits [Cat. II.]	(6) Extraction of minerals and peat of specified limits [Cat. II.]	(6) Extraction of minerals and peat of specified limits [Cat. II.]	(6) New construction, extension, and relocation of roads of all classes local class I. and II. roads [Cat. II.]

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
TOP 4	(1) Hazardous waste disposal facilities [Cat. I.]	(4) Surface finish of metals and plastics, including paint shops of specified capacity [Cat. I.]	(8) Extraction of minerals and peat of specified limits [Cat. II.]	(7) Extraction of minerals and peat of specified limits [Cat. II.]	(6) Hazardous waste disposal facilities [Cat. I.]	(8) Wind farms of specified power and hub height [Cat. II.]	(12) Wind farms of specified power and hub height [Cat. II.]	(8) Warehouse or commercial complexes, including shopping centres of specified size and number of parking spaces [Cat. II.]	(10) New construction, extension, and relocation of roads of all classes and local class I. and II. roads [Cat. II.]	(7) Extraction of minerals and peat of specified limits [Cat. II.]	(7) Warehouse or commercial complexes, including shopping centres of specified size and number of parking spaces [Cat. II.]	(5) Surface finish of metals and plastics, including paint shops of specified capacity [Cat. I.]	(4) New construction, extension, and relocation of roads of all classes and local class I. and II. roads [Cat. II.]	(6) New construction, extension, and relocation of roads of all classes and local class I. and II. roads [Cat. II.]	(4) Hazardous waste disposal facilities [Cat. I.]	(5) Warehouse or commercial complexes, including shopping centres, of specified size and number of parking spaces [Cat. II.]
TOP 5	(1) Livestock breeding of specified capacity [Cat. II.]	(3) Overhead power lines of specified voltage [Cat. I.]	(6) Warehouse or commercial complexes, including shopping centres, of specified size and number of parking spaces [Cat. II.]	(7) New construction, extension, and relocation of roads of all classes and local class I. and II. roads [Cat. II.]	(5) Extraction of minerals and peat of specified limits [Cat. II.]	(6) Warehouse or commercial complexes, including shopping centres of specified size and number of parking spaces [Cat. II.]	(12 Warehouse or commercial complexes, including shopping centres of specified size and number of parking spaces [Cat. II.]	(8) Surface finish of metals and plastics, including paint shops of specified capacity [Cat. I.]	(7) Extraction of minerals and peat of specified limits [Cat. II.]	(6) Livestock breeding of specified capacity [Cat. I.]	(6) Surface finish of metals and plastics, including paint shops of specified capacity [Cat. I.]	(4) New construction, extension, and relocation of roads of all classes and local class I. and II. roads [Cat. II.]	(4) Surface finish of metals and plastics, including paint shops of specified capacity [Cat. I.]	(5) Warehouse or commercial complexes, including shopping centres of specified size and number of parking spaces [Cat. II.]	(3) Livestock breeding of specified capacity [Cat. I.]	(4) Extraction of minerals and peat of specified limits [Cat. I.]

At the beginning of the project descriptions we present the number of issued Conclusions on EIA for a given project in a given year (X) indicates the total number of Conclusions on EIA issued by Competent authority for the type of project in a given year), and at the end of the project descriptions we present information on, whether project belongs to Annex 1 Category I (full scale EIA), or Category II (small scale EIA) of EIA Act. For better orientation same type of project in individual years are indicate by same colour therefore can be easily identify how projects with the highest number of Conclusions on EIA change according to their overall sum in given year.

Kapitola 8

Diskuse a závěr

Presentovaná disertační práce obsahuje čtyři publikované studie představené v předchozích kapitolách, které jsou zaměřené na post-projektová hodnocení v rámci analýzy impaktů. První dvě publikované studie se zabývají možnou indikací dopadů zimní údržby silnic na vybraných jehličnanech, která je jedním z významných impaktů provozu silničních staveb na životní prostředí. Třetí publikovaná studie je zaměřena na dva významné impakty rezidenční výstavby a jejich hodnocení v rámci post-projektové analýzy v procesu EIA. Čtvrtá studie se věnuje početní a typové variabilitě projektů, které byly hodnoceny v rámci posuzování vlivů na životní prostředí a zjištění možných souvislostí s následnou post-projektovou analýzou.

Na jednotlivé studie bude v textu odkazováno následovně:

Studie I: Bioindication of road salting impact on Norway spruce (*Picea abies*).

Studie II: Impact of road salting on Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*).

Studie III: Applying principles of EIA Post-project analysis in the context of suburban infrastructure development.

Studie IV: Environmental Impact Assessment – the range of activities covered and the potential of linking to post-project auditing.

Následující část disertační práce obsahuje komentáře k jednotlivým výzkumným tématům, závěry a shrnutí disertační práce, stejně tak jako možnou aplikaci a využitelnost v praxi a návrh na možný další výzkum v oblasti post-projektových hodnocení. Kompletní diskuse a závěry jednotlivých studií jsou obsaženy v presentovaných publikovaných článcích v Kapitolách 4 – 7. V této kapitole tedy budou pouze shrnuty výsledky a diskuse, uvedeny komentáře autora k jednotlivým výzkumným tématům a diskuse o tom, jak byly naplněny cíle disertační práce.

8.1 Bioindikace chemické zimní údržby

Solení komunikací je jedním z významných impaktů dopravních staveb na životní prostředí. Zimní údržba je však nezbytná pro bezpečný, plynulý a spolehlivý provoz. Důležitým ukazatelem kontaminace prostředí zimní údržbou může být zdravotní stav vegetace rostoucí v okolí komunikací. Ve Studii I byl hodnocen zdravotní stav na smrku ztepilém (*Picea abies*). U jednoletých i dvouletých jehlic se potvrdila závislost obsahu iontů sodíku na zdravotním stavu stromů (Table 4.3) (Figure 4.1; 4.2), stejně tak tomu bylo i ve studii Kayama et al. (2003), kde obsahy iontů sodíku byly vyšší u jedinců vykazujících horší zdravotní stav. Tato tendence zhoršujícího se zdravotního stavu s rostoucím obsahem iontů v jehličí se potvrdila i u chlóru, avšak jen v případě prvních ročníků jehličí (Table 4.3), což může být spojeno se zvýšenou mobilitou iontů chlóru v prostředí i rostlinách a jeho rychlejším vyplavování (Pavlová 2006) či např. přímým ostřikem jehlic solným roztokem (Semorádová 2003; Langen, Prutzman 2006).

Byla hodnocena také závislost koncentrace iontů v prvních a druhých ročnících jehličí na potenciálu kontaminace. U iontů sodíku se tato závislost potvrdila (Table 4.2) – koncentrace byly vyšší v jehličí z jedinců, kteří se nacházeli na místech s vyšším potenciálem kontaminace (Figure 4.1; 4.2). tuto závislost potvrdila také studie Kayama et al. (2003). V případě iontů chlóru se tato skutečnost nepotvrdila, ale z průměrných hodnot lze pozorovat, že se zvyšujícím se obsahem koncentrací je i potenciál kontaminace vyšší (Figure 4.1; 4.2).

Při hodnocení závislosti obsahu iontů chlóru a sodíku na vzdálenosti jedince od komunikace se potvrdila závislost, která by se na první pohled mohla zdát zvláštní. Potvrdil se významný rozdíl koncentrace iontů chlóru v prvních ročnících jehličí mezi jedinci vyskytující se v těsné blízkosti u komunikace a jedinci ze vzdálenějších lokalit (Table 4.4), kde koncentrace byly vyšší u jedinců z větších vzdáleností (Figure 4.7). Semorádová (2003) však uvádí, že kritickými lokalitami pro akumulaci solných roztoků mohou být i místa vzdálená 30 - 70 m od komunikace a někdy i dále a to kvůli několika faktorům, jako jsou např. prudké svahy, vyústění odtokových zařízení ze silnic či podmáčené paty svahů. Cain et al. (2001) také uvádí, že ke kumulaci solných rozmrazovacích materiálů může docházet i ve větších vzdálenostech od silnic vzhledem k mnoha vlivům a vyšší mobilitě některých iontů.

Studie I popisuje a hodnotí negativní vlivy rozmrazovacích solí, konkrétně chloridu sodného na smrk ztepilý (*Picea abies*), který se potvrdil i jako vhodný bioindikátor tohoto impaktu vzhledem k jeho zvýšené citlivosti na zasolení. Byla pro něj proto vytvořena stupnice s rámcovými hodnotami koncentrací pro možné hodnocení stupně kontaminace prostředí v okolí komunikací (Table 4.6).

8.2 Impakt solení silnic na borovici lesní (*Pinus sylvestris*) a smrk ztepilý (*Picea abies*)

Studie II tematicky navazuje na Studii I a věnuje se vlivu solení silnic a srovnává hodnocení koncentrací v závislosti na dvou faktorech u borovice lesní (*Pinus sylvestris*) a smrku ztepilého (*Picea abies*). Koncentrace chloridu sodného řeší v závislosti na vzdálenosti jedince borovice nebo smrku od komunikace a na stáří jehličí (první a druhé ročníky). Chemické analýzy jehličí borovice lesní (*Pinus sylvestris*) potvrdily vyšší koncentrace iontů sodíku v lokalitách těsně sousedících s komunikacemi (Figure 5.1). U jehličí smrku ztepilého (*Picea abies*) byla také potvrzena vyšší koncentrace iontů sodíku u jedinců, kteří se vyskytovali v blízkosti komunikací (Figure 5.3) (Zítková et al. 2018). To bylo potvrzeno i ve studii Kayama et al. (2003).

První ročníky jehličí borovice lesní vykazují obdobný nečekaný trend, stejně jako smrk ztepilý ve Studii I a to, že vyšší koncentrace iontů chlóru se vyskytují ve vzdálenějších lokalitách od silnice (Figure 5.2; 5.4). Jak bylo řečeno, může to být zapříčiněno zvýšenou mobilitou iontů chlóru. Studie Cain et al. (2001), Semorádová (2003) a Zítková et al. (2018) také poukazují na vyšší koncentrace iontů chlóru i ve vzdálenějších lokalitách od komunikací a Semorádová (2003) uvádí, že akumulace chloridových iontů závisí i na dalších činitelích (prudké svahy, vyústění odtokových zařízení z komunikací, terénní změny, struktura půd apod.).

Při hodnocení koncentrace v závislosti na stáří jehlic byly porovnány i další ionty prvků (Mg, K a Ca), které mohou být ve vzájemném ovlivnění s koncentracemi NaCl. U borovice lesní ionty sodíku, chlóru a vápníku vykazují nižší hodnoty v prvních ročnících jehličí než v druhých (Figure 5.5). U jehličí smrku ztepilého se také potvrzuje vyšší koncentrace vápenatých iontů v druhých ročnících jehličí (Figure 5.6). Kayama et al. (2003), Truparová Kulhavý (2011), Bouchal (2012) a Zítková et al. (2018) ve svých studiích také potvrzují nižší hodnoty iontů vápníku v prvních ročnících jehličí. To může být vysvětleno tak, že transport vápenatých iontů v rostlinném těle je více omezený, než dalších prvků a následná redistribuce tohoto prvku do mladších ročníků jehličí je limitována (Lhotáková 2012).

U hořčíku a draslíku byla průměrná koncentrace iontů v jehličí borovice lesní (Figure 5.5) i smrku ztepilého (Figure 5.6) vyšší v prvních ročnících jehličí než v druhých. Dle Czerniawska-Kusza et al. (2004) jsou tyto ionty lehčeji vázané, například oproti iontům vápníku, a proto se snadněji distribuují. Vyšší koncentrace v prvních ročnících jehličí byly zjištěny i ve studiích Kayama et al. (2003) a Bouchal (2012). Dle Fostad, Pedersen (2000) expozice NaCl způsobuje zvýšení koncentrace draselných iontů v asimilačních orgánech rostlin, což popisuje i Townsend (1980). U smrku ztepilého byly hodnoty draselných iontů výrazně vyšší, než je tomu u borovice lesní, což by mohla vysvětlovat právě vysoká citlivost smrku na zvýšenou expozici NaCl.

Koncentrace iontů chlóru a sodíku v jehličí se významně liší mezi jednotlivými druhy (Fostad, Pedersen 2000). Nejvyšší koncentrace a poškození jehlic se potvrzuje u smrku ztepilého (Fostad, Pedersen 2000; Zítková et al. 2018). Nižší koncentrace můžeme pozorovat u borovice lesní (Figure 5.1; 5.2), nebo u javoru mléč (*Acer platanoides*) a břízy bělokoré (*Betula pendula*) (Fostad, Pedersen 2000). Citlivost smrku ztepilého na NaCl se ukázala v několika studiích (Dragsted 1979; Semoradová, Materna 1982; Fostad, Pedersen 2000; Suchara et al. 2011; Zítková et al. 2018). Přesto, že borovice lesní nemá tak vysokou citlivost na zasolení, stále může být vhodným druhem k možnému hodnocení stupně kontaminace prostředí kolem komunikací vzhledem ke kumulaci iontů v jejích asimilačních orgánech. Na základě výsledků byla navržena obdobná stupnice (Table 5.3) pro hodnocení impaktu solení silnic jako pro smrk ztepilý.

8.3 Principy post-projektového hodnocení v kontextu rozvoje příměstské infrastruktury

Studie III se věnuje principům post-projektového hodnocení v kontextu rezidenční výstavby. U konkrétního záměru byly studovány významné vlivy jako akustický tlak a změny chemismu vod v okolí záměru ve smyslu zajištění zpětné vazby procesu EIA. Expandující urbanizované území způsobuje ovlivňování stavu jednotlivých složek životního prostředí, veřejného zdraví i pohody obyvatel (Tzoulas et al. 2007) a přispívá tak k rozvoji řady negativních impaktů, které snižují kvalitu životního prostředí (United Nations 2018). V tomto kontextu představují preventivní povolovací procesy možnost, jak dopadům na životního prostředí předcházet, popřípadě je eliminovat, minimalizovat, či kompenzovat. Pro budoucí plánování a projektování je žádoucí průběžně zjišťovat zpětnou vazbu skrze post-projektové analýzy a tím posuzovat účinnost (Wilson 1998; Wood 2000; Wood et al. 2000;

Stewart-Oaten, Bence 2001; Marshall et al. 2005) k dosahování vyšší úrovně ochrany životního prostředí a celkové udržitelnosti.

Během procesu EIA byly měřeny jednotlivé parametry hydrochemického stavu ve zkoumaných lokalitách (referenční stav) interpretující situaci před výstavbou a poté pro srovnání a zpětnou vazbu po realizaci projektu. Detailněji se můžeme podívat například na koncentrace chloridů, jejichž vyšší koncentrace bývají přisuzované zejména vlivu zimní údržby (Zítková et al. 2018; Zítková et al. 2021). Jiné studie ukazují, že koncentrace chloridů ve splachových vodách z ulic, silnic a dálnic dosahovaly např. v Německu 4–699 $mg.l^{-1}$ (Göbel et al. 2007), ve Slovinsku 43–110 $mg.l^{-1}$ (Gotvjan, Zagorc-Končan 2009) nebo v USA 1.7–884 $mg.l^{-1}$ (Tucillo 2006). Hodnoty nejvyšších koncentrací chloridů před realizací obytného souboru v rámci námi řešeného území dosahovaly přibližně 53 $mg.l^{-1}$ a v průběhu užívání obytného souboru přibližně 120 $mg.l^{-1}$. Vzájemné srovnání naznačuje, že v námi řešeném území nedochází k neobvyklým koncentracím chloridů, naopak jsou spíše v nižších úrovních. Z hlediska požadavků procesu EIA lze poukázat na metodický nedostatek, kdy byly měřeny jednotlivé parametry hydrochemického stavu ve zkoumaných lokalitách (referenční stav) interpretující situaci před výstavbou, avšak absentovala predikce změny hydrochemických ukazatelů, která by byla vyvolaná pouze výstavbou a užíváním obytného souboru. I to je důvodem, proč je v současnosti téměř nemožné identifikovat do jaké míry se na narůstajícím kumulativním efektu změn hydrochemických parametrů podílí obytný soubor samotný a do jaké míry celkový rozvoje okolního regionu.

Měřeno bylo i akustické zatížení, jehož hodnoty před realizací odpovídaly úrovni 47 dB ± 1.8, přičemž predikce pro výstavbu a provoz byla na úrovni 48 dB ± 1.8. Reálné hodnoty akustického zatíženy se pohybovali (z fáze realizace až do 5 let užívání) v rozmezí 43.6 dB ± 1.8 až 46.6 dB ± 1.8.

Dle Morrison-Sauderse, Artse (2004a) je jednou z nejdůležitějších částí post-projektové analýzy monitoring, který je prováděn s cílem ověření, zda je realizace projektu v souladu s podmínkami, které byly stanoveny před realizací a zda jsou dopady projektu v rozmezí, které bylo předpokládáno. Studie může potvrdit relativně vysokou přesnost dílčích analýz EIA pro akustické zatížení, tedy že skutečné impakty naměřené ve fázi užívání projektu odpovídaly svými parametry těm predikovaným. Zásadní slabiny celého konceptu analýzy impaktů v kontextu infrastrukturní výstavby lze pozorovat v oblasti kumulativních a synergických vlivů.

Městská výstavba se nachází v pomyslném průsečíku spotřeby zdrojů, růstu populace, aplikace moderních technologií, kultury a ekonomiky, a proto může mít jedinečnou pozici k řešení problému udržitelnosti, které však vyžadují dlouhodobé politické úvahy a koncepce (Voß et al. 2009). Legislativní uchopení post-projektových analýz v rámci procesu EIA by umožnilo získávat reálnou a kontinuální zpětnou vazbu k předchozím rozhodnutím v rámci projektového plánování a hodnocení a poučit se tak z nedostatků pro účinnější a přesnější hodnocení projektů budoucích.

8.4 Rozsah zahrnutých aktivit v rámci posuzování vlivů na životní prostředí a možnost propojení s post-projektovou analýzou

Studie IV se zabývá rozsahem typů projektů zahrnutých do procesu posuzování vlivů na životní prostředí a možné propojení s post-projektovou analýzou. Proces EIA je celosvětově uznávaným nástrojem v oblasti ochrany životního prostředí a jedním z nejúčinnějších nástrojů řízení a kontroly rozvoje výstavby projektů (Morgan 2012). Rozvoj, zdokonalování a přizpůsobování EIA bude nezbytným předpokladem pro snížení rizik spojených s velkými globálními změnami, kterým dnešní svět čelí (Steffen et al. 2015; Retief et al. 2016). Post-projektová analýza by měla být nezbytnou součástí posuzování vlivů na životní prostředí, pokud má být zajištěna úspěšnost EIA, zlepšování udržitelnosti projektu a jeho realizace (Pinto et al. 2019).

Změnou legislativy došlo ke změnám v počtu posuzování určitých typů záměrů. Změna popisu nebo kapacity projektu v Příloze č. 1 zákona 100/2001 Sb., ovlivnila počet předložených projektů k posouzení, toto lze pozorovat například u typového záměru „skladování vybraných nebezpečných chemických látek“ (Figure 7.9). Před změnou legislativy (do roku 2004) dosahoval počet předložených projektů k posouzení pouze jednociferných čísel, zatímco po změně legislativy (po roce 2004) se počet předložených projektů pohyboval téměř trvale ve stovkách. Mezi další aspekty, které ovlivnily množství předložených projektů k posouzení patří změny v dotační politice na evropské, národní i regionální úrovni plánování, např. projekty týkající se větrných elektráren (Figure 7.4) nebo výstavby infrastruktury (Figure 7.7), rozdíly ekonomické situace regionů a celkové mezinárodní ekonomické situace, např. projekty týkající se průmyslových zón, komerčních zón a skladů (Figure 7.10), a také změny dalších legislativních norem nebo změny trendů a chování společnosti (obecně rozvoj bytové nebo komerční výstavby).

Některé studie současně poukazují na skutečnost, že počet projektů předložených k posouzení může být ovlivněn také politickým lobbingem (McCullough 2017; Williams 2017). Jeden z nejčastějších problémů, který je v rámci posuzování vlivů na životní prostředí zmiňován, je kvalita státních legislativních předpisů (El-Fadl a El-Fadl 2004; Gałaś 2015). Tato studie prokázala, že kvalita legislativy také souvisí s její novelizací spojenou s popisem projektů a jejich limitních hodnot. Tím tak může de facto ovlivnit rozsah typů projektů a celkový počet projektů předkládaných k posouzení.

Post-projektová analýza je nezbytnou zpětnou vazbou pro environmentální řízení a optimalizaci samotného procesu EIA (Retief 2007; Morrison-Saunders et al. 2015) a může poskytnout důležité informace, poznatky a zkušenosti, které lze využít k jeho optimalizaci (Alton, Underwood 2003; Morrison-Saunders, Retief 2012; Loomis, Dziedtic 2018). Pro vhodné legislativní nastavení post-projektových analýz by na základě závěrů této studie bylo vhodné identifikovat typy projektů, u kterých by bylo výhodné testovat účinnost EIA. Takovými typy projektů by byly ty, které jsou nejčastěji posuzovány ohledně dopadů na životní prostředí a je pro ně vydané závěrečné stanovisko. Díky tomuto přístupu můžeme identifikovat poměrně nízký počet typů projektů, které však pokrývají přibližně polovinu projektů, pro které byla vydána závěrečná stanoviska v rámci posuzování vlivů na životní prostředí.

8.5 Závěr

Všechny čtyři publikované studie se zaměřují na určitou formu post-projektového hodnocení v rámci analýzy vybraných impaktů na životní prostředí. Studie I a II identifikovaly významnost hodnocení chemické zimní údržby a potvrdily negativní vliv solného roztoku na rostoucí vegetaci kolem komunikací a akumulaci těchto prvků v asimilačních orgánech vybraných jehličnanů. Byla identifikována i zvýšená citlivost smrku ztepilého (*Picea abies*) k zasolení, a tedy jeho nevhodnost výsadby při obnově vegetace kolem silničních struktur. V závěru Studií I a II byly navržené rámcové stupnice (Table 5.3; 5.4) na základě výsledků koncentrací iontů sodíku a chlóru v jehličí vybraných jehličnanů. Tyto stupnice je možné využít pro budoucí post-projektová hodnocení stupně kontaminace prostředí podél komunikací solným roztokem nebo ke kontrole zimní údržby.

Studie III na konkrétním záměru rezidenční výstavby identifikovala významné impakty a porovnala výsledky nových měření s predikovanými hodnotami před výstavbou záměru. Závěry EIA posouzení byly ve svých predikcích poměrně přesné pro fázi výstavby a první roky užívání rezidenčního objektu, avšak nedokázaly dostatečně citlivě identifikovat střednědobé až dlouhodobé kumulativní efekty. Výsledky studie ukazují i na aplikovatelnost post-projektové analýzy jako nástroje zpětné vazby pro úroveň plánování a hodnocení. Post-projektová analýza představuje možnost, jak zdokonalovat budoucí predikce možných kumulativních a synergických impaktů a ověřila přínos její aplikace a potřebu určitého legislativního uchopení a širší integrace. Dílčí post-projektové analýzy jednotlivých infrastrukturních staveb by mohly vytvářet celek evaluace strategického plánování a rozhodování a poskytovat tak k implementovaným strategickým dokumentům, respektive k jejich rozvojovým cílům, dostatečné množství relevantních, měřitelných a věcných indikátorů o jejich reálném dopadu na životní prostředí, podle kterých by šlo přesněji nastavovat rámce budoucího využití území. I Studie IV ověřila významnost a přínos post-projektové analýzy a budoucí nezbytnosti jejího širšího legislativního pojetí a využívání, pokud se má proces posuzování vlivů na životní prostředí zdokonalovat a rozvíjet. Výsledky studie ukazují, že pro zajištění zpětné vazby procesu EIA je vhodné využít celostátní databázi projektů posouzených v rámci procesu EIA. Na základě výsledků lze říci, na které typy projektů se zaměřit pro budoucí post-projektová hodnocení.

Post-projektová analýza je obecně nástrojem jehož aplikací získáváme zpětnou vazbu nezbytnou k hodnocení ať už procesu, činnosti, projektu či konkrétního postupu a na základě jejích výsledků možnost dané procesy zlepšovat a přizpůsobovat současným potřebám a případně navrhnout možné postupy pro budoucí post-projektová hodnocení. Analýzy a jejich výsledky Studií I – IV identifikovaly významnost a ověřily nezbytnost post-projektových analýz, jako užitečného nástroje ke zlepšení efektivnosti procesů v oblasti ochrany životního prostředí.

8.7 Budoucí výzkum

Post-projektové analýzy jsou široce využívaným environmentálním nástrojem k hodnocení procesů, projektů, postupů apod. a získání zpětné vazby. Ve čtyřech publikovaných studiích této disertační práce byla určitá forma post-projektového hodnocení aplikovaná v každé z nich a lze s jistotou říci, že byla ověřena nezbytnost tohoto hodnocení a jeho implementace i do budoucna.

Ze závěru Studie I a Studie II byly vytvořené rámcové stupnice, které je možné využít pro indikaci stupně kontaminace solným roztokem v prostředí kolem komunikací. Tyto stupnice jsou vytvořené pro smrk ztepilý (*Picea abies*) a borovici lesní (*Pinus sylvestris*). Do budoucna by bylo vhodné ověřit tyto výsledky i v jiných lokalitách a dle metodiky vytvořit stupnice i pro jiné hojně se vyskytující druhy dřevin.

Nezbytnost post-projektového hodnocení v rámci procesu EIA je stále široce diskutovaným tématem napříč všemi státy. Studie III i IV ukazují nezbytnost tyto analýzy aplikovat. Spolehlivé a průkazné výsledky post-projektových analýz tak mohou přispět k rozvoji diskuse o možnostech jejího legislativního ukotvení a širší integrace. Aplikace post-projektových analýz je nezbytná, jak ukazuje i Studie III a její provádění i na dalších projektech je možné vzhledem k dostupnosti potřebných dokumentů a analýz z procesu EIA, které jsou veřejné přístupné. Jak ukázala studie IV pro optimální legislativní nastavení a provádění post-projektových analýz by nebylo nutné vytvářet tato hodnocení pro každý jednotlivý projekt, ale pouze pro vybrané typy projektů, které mají nejvyšší zastoupení (10 typů projektů z celkem cca 120 pokrývá přibližně 48 % veškerých projektů, které byly hodnoceny v rámci procesu EIA a bylo pro ně vydané závěrečné stanovisko). Do budoucna je vhodné aplikovat post-projektovou analýzu na tyto typy projektů a získat tak zpětnou vazbu a další relevantní data pro její implementaci jako důležitého nástroje ochrany životního prostředí.

Kapitola 9

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Kapitola 10

Curriculum Vitae

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Bioindication of road salting impact on Norway spruce (Picea abies) (2018). **Zítková J.**, Hegrová J., Anděl P. Transportation Research Part D. Transport and Environment 59, 58 – 67.

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